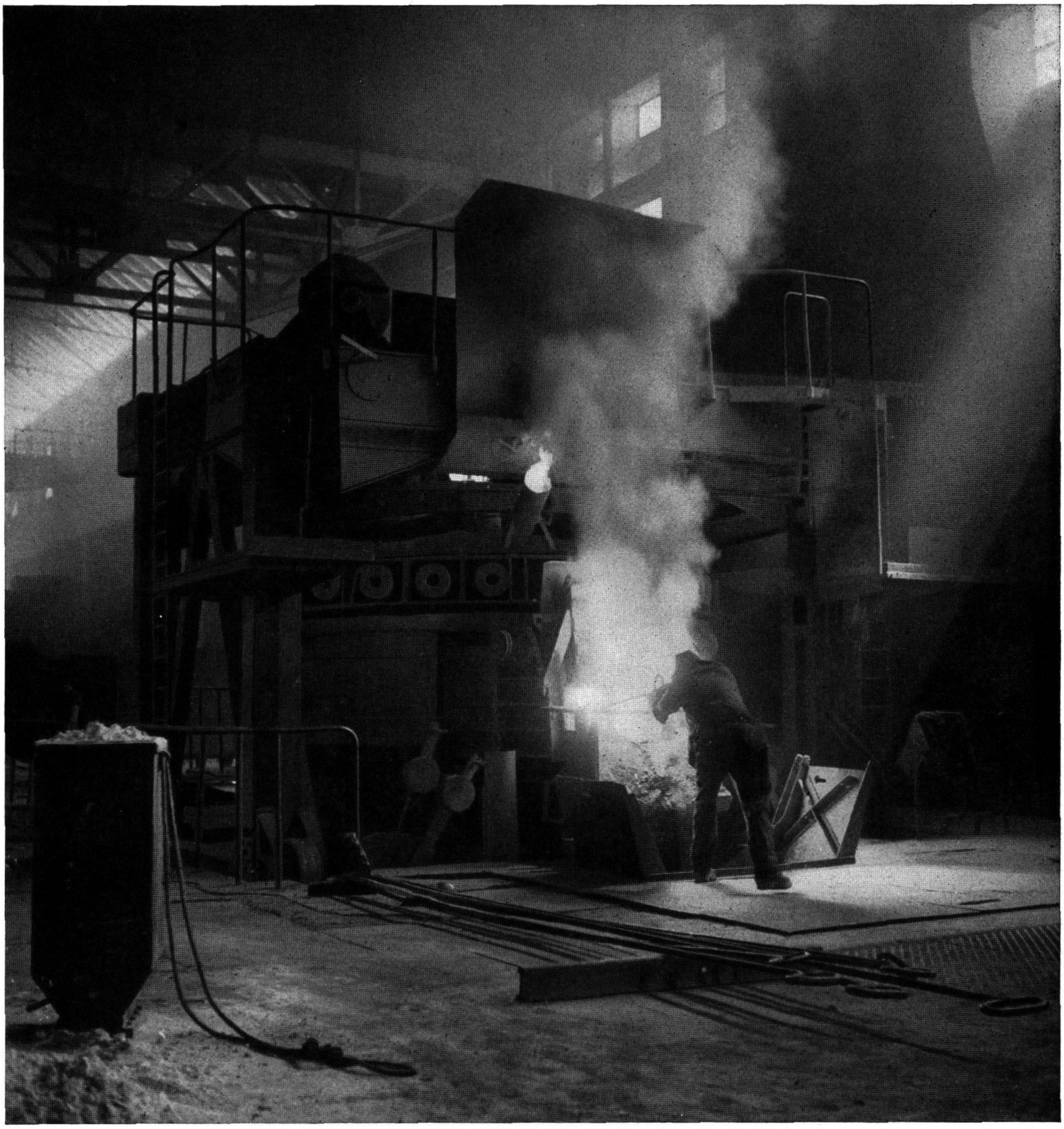
THE BROWN BOVERI REVIEW



From scrap to high-quality steel in the arc furnace.

Special electrothermal number

BROWN BOVERI

BUILD

ELECTRIC MELTING FURNACES

FOR STEEL, GRAY CAST IRON, AND METAL ALLOYS

Electric annealing and hardening furnaces for all steel products

Electric reheating furnaces for pressing or rolling processes

Electric furnaces for bright annealing by various systems

Electric furnaces for nitride hardening

Electric furnaces for the ceramics industry and in particular large tunnel furnaces

Electric cremation furnaces

ELECTRICALLY-HEATED FURNACES OFFER IMPORTANT ADVANTAGES OVER FUEL-FIRED FURNACES

THE BROWN BOVERI REVIEW

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INTRODUCTION.

THE possibilities offered by electricity as a source of heat were recognized even in the earliest days of electrical engineering. As electrical machinery gradually developed and as increasingly big quantities of energy became available, we find the first large electric furnaces being put up in industrial plants. The first types of industrial importance were melting furnaces using carbon electrodes. These were used to produce calcium carbide, ferro alloys, and aluminium. These products caused revolutionary changes in industrial life in general and the metal industry in particular. The 1900—1910 period was marked, in this field, by the appearance of the electric steel furnaces.

The necessity of finding substitutes for materials which were no longer available, a feature of the last World War, led to the discovery and development of stainless steels and non-oxidizing steels up to temperatures of 1000° C. Only a few years later, we find a steel suitable for use as a heat conductor being put on the market, in the form of the classic chrome-nickel steel, the appearance of which opened the way to the development of annealing furnaces. The American automobile industry was the first to recognize the outstanding advantages offered by the electric furnace for annealing and hardening and, as early as 1922, was electrifying furnace plants used for these processes.

For a long time, the highest temperature practicable for metals used as heating conductors was 1000° C and it was only in the course of the last decade that the intensive development of chromium-iron-aluminium combinations allowed of further progress being achieved in this direction, the limit temperature being raised to 1300° C. Maximum temperatures of the 1500° C range are still the sphere of ceramic semi-conductive products on a silicon-carbide basis, the field of application of which, however, is limited.

The advantages inherent to electric furnaces explain why they have met with such success. The change-over from fuel firing to electric heating often brings better operating conditions. Soot, dust and troublesome exhaust gases are entirely eliminated. The better heat insulation which is a feature of electric furnaces prevents excessive heat losses by radiation. This makes operating the electric furnace an easier, cleaner and quieter job. The industrial processes carried out in electrically-heated furnaces usually result in higher quality products, less scrap, and a saving in material as a result of less oxidation. The improvement in quality is most marked when exact attainment and uniform maintenance of temperature are called for. Thus, in estimating the performance of an electric furnace the cost of heating alone is not the only factor to be considered and all the characteristics and advantages attached to heating by electricity must be taken into account.

This special number contains articles on the application of electricity to the production of heat. The object aimed at is to give a general idea of where developments stand to-day and of the manifold applications found for electrically generated heat. The fruitful developments are continuing and interesting improvements are being brought out continually. We intend to publish articles from time to time to keep our readers posted on these. In the meantime we trust that the present number will give a good general idea of the importance attained to-day by electrically generated heat in numerous branches of industry.

(MS 849) *O. Morger. (Mo.)*

THE DEVELOPMENT OF BROWN BOVERI ELECTRIC STEEL FURNACES.

Decimal index 621.365.2

The first patents on the utilization of electrical energy for melting purposes were granted in England, as early as 1878. Thirty years passed, however, before the principles laid down in the said patents were given practical application for industrial purposes and it was not until the war years, 1914—18, that we find electricity being used on a large scale for the melting of steel. Brown Boveri have been active in this field since that period and have put a series of new electric steel-furnaces on the market which incorporate all the developments realized in the fields of electrical engineering and furnace construction.

It was only at the beginning of the present century that it became possible to fulfil the desires of metallurgists as regards the melting of ores and refining of steels by electricity. The pioneers in the field of electric steel furnace design, Héroult, Girod, and Stassano filed patents in 1899, 1910, and 1912 for their particular furnace designs. All three men based their inventions on principles the correctness of which had yet to be confirmed by practical experience. Each system had its advantages and disadvantages which were, in part at least, either greatly over- or under-estimated. The chief defect imputed to furnaces built to the Héroult and Girod systems was carburization of the charge by the electrodes, while, on the other hand, these inventors claimed for their respective furnaces thorough mixing in the melted metal bath and, at least, partial heating up from the inside outwards of the material by the heat generated through the current passing through the liquid metal. The Stassano principle was closely allied, from the metallurgical point of view, to the Siemens-Martin process; it avoided, at least theoretically, carburization of the charge and strove after thorough mixing by oscillations imparted to the melting hearth. The steadily burning arc between the electrodes which is established after a few minutes in the Stassano furnace, made far less demands on the supply system than other furnaces in which the arc is set up between the electrodes and the charge itself and which are characterized by great instability.

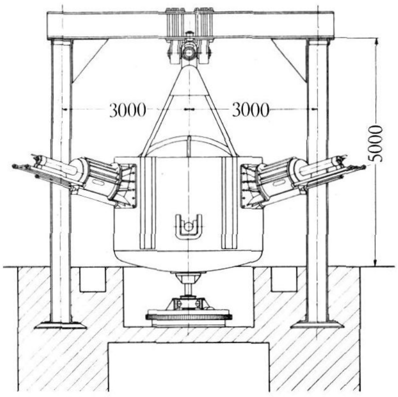

Fig. 1. — **Steel melting furnace of the Stassano type with furnace tank for tilting.**
This was the furnace design with which Brown Boveri entered the field of electric steel melting furnace construction in the years 1916—18.

At the beginning of the World War 1914—18, the Stassano furnace had already been highly developed both from a metallurgical and electrical point of view. For this reason, Brown Boveri made a contract with Stassano to acquire his patent rights and then built some furnace plants both in Switzerland and elsewhere according to the Stassano designs (Fig. 1). If to-day the problem of the refractory lining for electric melting furnaces is still a knotty problem for all steel workers it was also so in the first years of development and especially for the Stassano furnaces. Apart from the constructive difficulties encountered, relatively frequent breakages of the inclined electrodes, supported at one end only, had to be reckoned with, for the mechanical strength of electrodes of the period was far lower than that which is usual to-day. For this reason the number of Stassano furnaces built was relatively small.

The scarcity of materials which characterized the 1918—20 period called for substitutes for the reduced

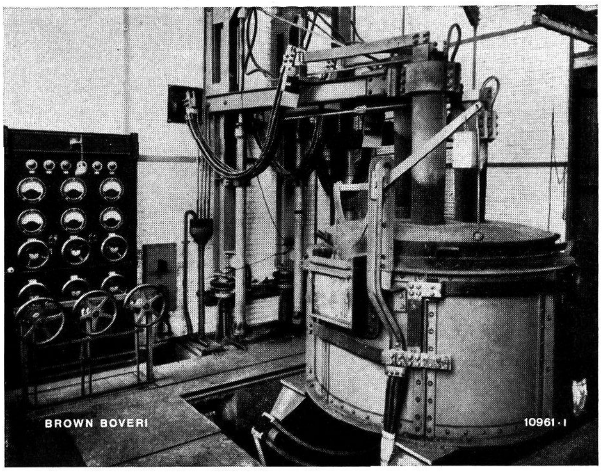

Fig. 2. — First melting furnace built by Brown Boveri for making synthetic cast iron from steel turnings by Dr. Robert Steiger's process.

The electrodes in the cover of the furnace were made of amorphous carbon and had to be lifted out before the furnace was tilted. Electro-hydraulic control of the electrodes on the Brown Boveri system is used here.

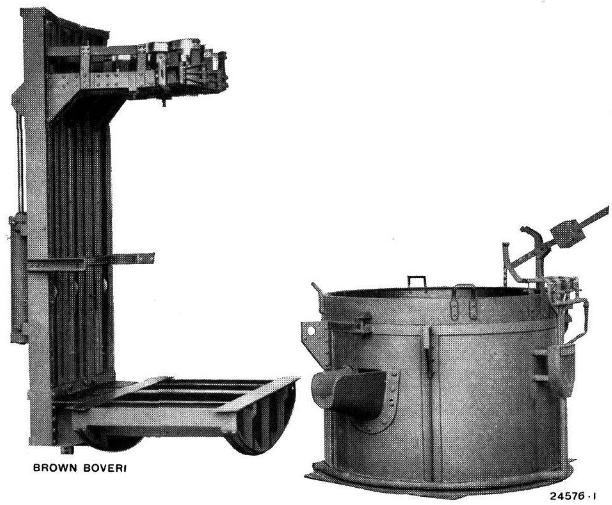

Fig. 3. — Electric steel melting furnace of the Héroult type. The electrodes are tipped with the furnace when pouring.

Workshop photograph of constructional parts of the year 1928. The sharp separation of the mechanical equipment and melting hearth proper, applied already at that period, is clearly shown. The simple hydraulic moving mechanism for the electrodes is also shown.

pig-iron imports. In various carbide works pig-iron was produced by carburizing steel turnings in electric furnaces. These were then subjected to a second melting process in cupola furnaces in the foundries. Dr. Robert Steiger invented a method of casting synthetically melted iron directly into moulds. This called for electrodes immersed vertically in the mixture of material, similarly to the arrangement in Héroult or Girod furnaces. The first plant of this type built by us was put into operation in 1918, in Messrs. J. J. Rieter & Co. A. G.'s works at Winterthur (Switzerland), Fig. 2. A newly developed system of electrode control was applied here; this is the electro-hydraulic control, a quite new departure as regards the automatic regulation of the electrodes in steel furnaces. With this design the transition from the Stassano to the Héroult system became an accomplished fact and the subsequent development of electric steel furnaces followed the latter system. On account of the quality of the electrodes available at that time, which were made of amorphous carbon, no attempt was made to tip the electrodes with the furnace, because to do so would have subjected the electrodes to a bending stress liable to cause breakage. Thus it was necessary to raise the electrodes right out of the furnace when pouring. The supporting frames for the electrodes were secured on the wall of the building in such a manner that they could be swung round and free access gained to the furnace proper. A characteristic of this furnace was the possibility of switching over one phase of the main electrodes in the cover on to a ring of poles on the floor of the furnace. The lead to the latter was wound round the furnace body in order to attain, on

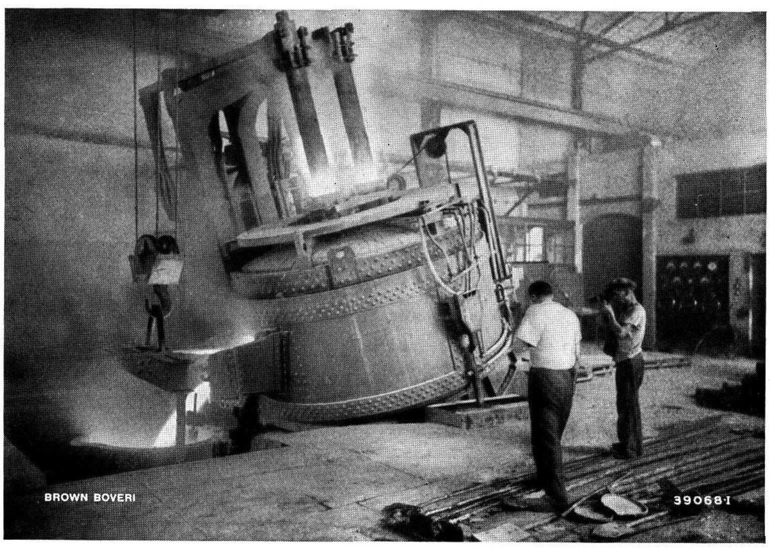

Fig. 4. — Steel melting furnace of 6 t capacity of the design shown in Fig. 3, during pouring.

This was a standard design for a long period and many such furnaces were built.

the one hand, an equalization of load in the three-phase system by increasing the inductive resistance of the phase in question, and, on the other, to counteract, by the action of the field formed, the tendency of the arc to blow over to the refractory lining. The advantages attained with this device were however more than

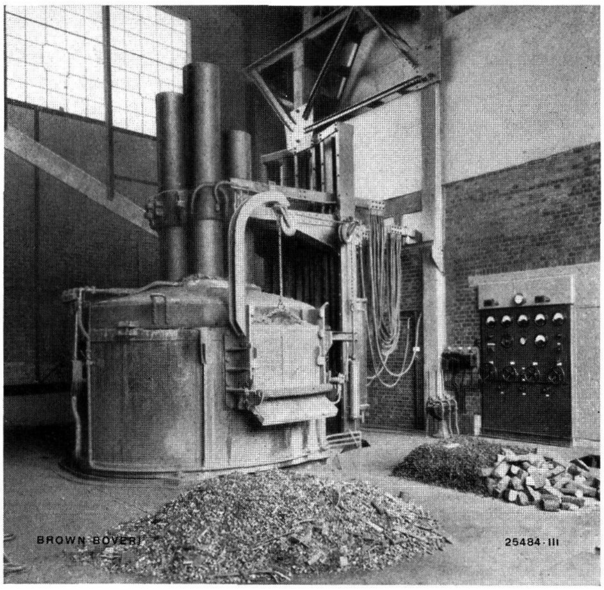

Fig. 5. — 6 t furnace for manufacturing synthetic cast iron, equipped with Söderberg electrodes, 1929 design.

counterbalanced by disadvantages, which cannot be gone into here, so that it was eliminated from all the following furnace designs.

A furnace of 5 t capacity was erected in our own foundry in Baden, likewise for the manufacture of synthetic cast iron. It followed the lines of the unit delivered to Messrs. Rieter and mentioned above. The possibility of swinging out the electrodes allowed of charging the furnace with small scrap material through the electrode apertures with a special device and this working process can be considered as the forerunner of the charging methods in favour to-day.

The improvements in the manufacture of graphite electrodes made it possible to tilt them with the furnace when pouring. This was a decided step forward both in the design and operation of electric steel furnaces. The application of our electro-hydraulic system of electrode control, which had given such satisfactory results in numerous plants, facilitated the construction of the moving gear of the electrodes and bestowed on the furnace a degree of operating reliability which had never been attained before. The hydraulic drive was also adopted for the tipping mechanism of the furnace proper and despite all theoretical objections we have never encountered a single case of *serious* trouble which could be imputed to it, or damage due to freezing, over a period of close on 25 years.

Experience proves that no furnace shell retains its original external shape however rigidly it is armoured. Thus all designs in which the electrode bushings are secured to the furnace tank must inevitably be subjected to displacements of the guiding parts which is very disadvantageous to smooth working of the electrode regulation. Brown Boveri has taken this factor into account by considering the body of the furnace on the one hand and the cradle frame with electrode mechanism on the other as separate parts. This also allows of replacing the body of the furnace and thus shortening shut-down periods. The use of graphite electrodes simplified the design of electrode holders which could now be built without water jackets, which had been indispensable up till then (Figs. 3 and 4).

A considerable number of steel furnaces were built on the design principles just described; these were of capacities of 0·5 to 35 t and results have proved them to come up to expectations.

The introduction of Söderberg electrodes entailed a change in the design of the electrode holders. It became necessary again to resort to water jackets for the electrode clamping jaws, the latter had to be enlarged and the whole electrode supporting frame reinforced in order to carry the heavier electrodes (Figs. 5 and 6).

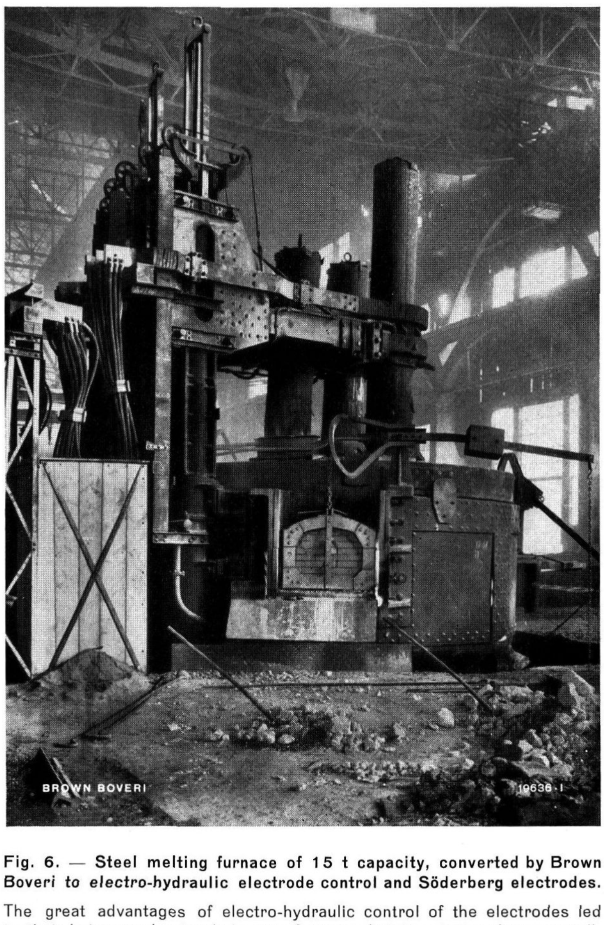

Fig. 6. — Steel melting furnace of 15 t capacity, converted by Brown Boveri to electro-hydraulic electrode control and Söderberg electrodes.

The great advantages of electro-hydraulic control of the electrodes led to their being used not only in new furnaces but in existing plants as well.

The factor of utilization of an electric steel furnace plant for charging through the furnace door is very low and the utilization of the electric energy supplied from the power stations lower still. Of the total time required to handle a charge, from beginning to end of the process, 15 to 25 % must be reckoned for charging and emptying and 5 to 10 % for repairing the hearth. During the melting time proper not more than 50 % of the electric power available is turned to useful account. Shutting down periods for renovating the melting furnace lower the factor of utilization still further. The latter can be considerably improved, however, by shortening the charging times. Charging through the top, by means of a suitable charging device, can be carried out in five minutes and in this way at least ninety minutes can be saved on the charging time in the case of a 10 t furnace. To this end, the dome of the furnace must be lifted and replaced quickly. This can be done either by running out the melting hearth and leaving the cover with electrodes in position or by running out the frame carrying the electrodes with the cover suspended to it, the hearth remaining in position. In furnaces up to 8 t capacity the first method gives relatively simple designs. In big furnaces the weights to be moved are lower when the second method is adopted. Brown Boveri, therefore, build furnaces of the smaller sizes with movable furnace body and bigger ones with movable portal. Fig. 7 shows a furnace of 12 t and Fig. 8 one of 30 t capacity with movable portal. Electric motors are used to raise the cover and run out the portal, control being from a central control desk.

The uncovering of the melting hearth for the rapid charging of the furnace lengthens the useful life of a melting plant, not only through the shortening of the charging times proper, but because shutting down periods to renovate the melting hearth are less frequent. The greater accessibility attained through the cover being removable makes repair work easier, thus giving the lining a longer life.

While the melting time for a complete furnace charge depends very little on the height of the furnace, the time required for manual charging increases more than proportionally to the weight of the charge. The greatest advantages of basket charging are obtained with big furnaces. It was thought at first that the utilization of this method of charging had reached its lowest useful limit in furnaces of about 5 tons capacity, because of the greater outlay entailed for interest and amortization on the plant. However, scrap metal is getting increasingly voluminous and makes the problem of charging small furnaces increasingly difficult, while basket charging has given very satisfactory results in big furnaces, so that to-day basket charging is being used with furnaces of 3 t and even lower capacities. As, however, the running out of the furnace as also of the portal, electrodes, and cover of small furnaces considerably complicates design, Brown Boveri have adopted a device giving a combined raising and turning movement of the cover.

This new furnace (Fig. 9) deviates in many points from ordinary designs and is chiefly characterized by the whole supporting framework of the electrodes and cover being raised by a piston in a fixed cylinder and swinging round its verticle axis. The whole supporting framework for the electrodes rests on the edge of the melting furnace during the melting process and is tilted with the furnace both when tapping off the slag and pouring. To charge the furnace the piston or the cylinder mounted beside the furnace engages

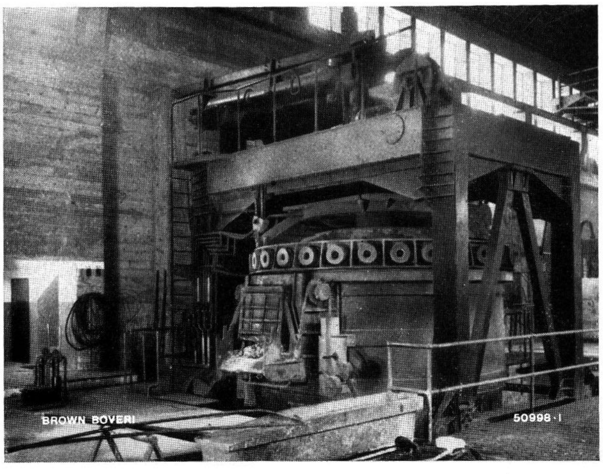

Fig. 7. — Steel melting furnace of 12 t capacity built for basket charging with furnace cover which can be run out. Furnace in plant.

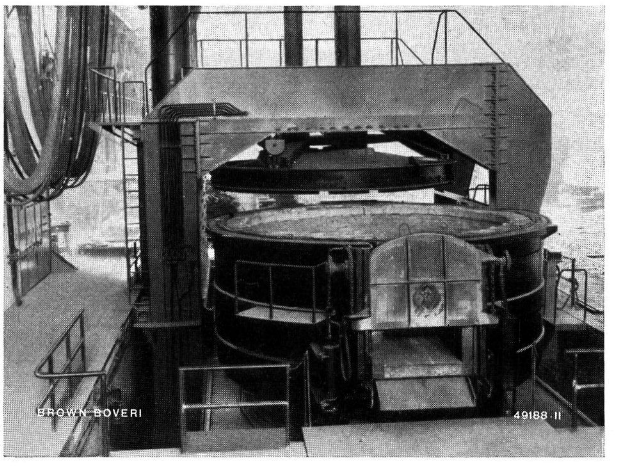

Fig. 8. — Steel melting furnace of 30 t capacity with cover run out to allow of charging.

These furnaces with mechanized charging have a better factor of utilization and have taken the place of manually charged furnaces for big units.

in the supporting frame of the electrodes and cover in its upward movement and after raising them a certain distance swings them round, thus uncovering the furnace proper. Thus the furnace is freed of any complicated moving mechanism and its operating reliability increased. A great advantage is that there are

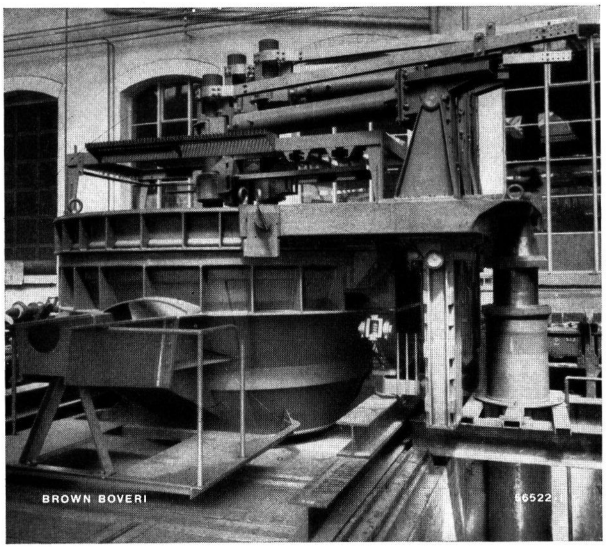

Fig. 9. — 3 t steel melting furnace for basket charging with conical hearth and cover which can be swung off.

The smallest basket-charged electric steel furnace built by Brown Boveri. This is an especially advantageous design for furnaces of 3 to 6 t capacity.

no constructional parts of the running out mechanism either in front of or behind the furnace. The experience with the first units of 3 t and 5 t capacity under construction will show whether this principle can also be applied advantageously to furnaces of a bigger capacity range.

At the beginning of this article, mention was made of the difficulties encountered with the refractory lining of the furnace. No fundamental improvements have been made in this respect during the last 25 years, and the lining problem is as pressing as ever. Thanks to the possibilities offered by being able to carry out repairs from above, the life of the hearth has been considerably lengthened, but this does not apply to the walls above the slag line. In order to be able to repair this part of the lining, it was necessary to incline the walls sufficiently to prevent the repair material applied from falling off. This led to the design of conical hearths, a measure which increased the surface of the cover, but not the external surface of the melting tank. It is true that the losses by radiation from the cover are greater, but those from the melting tank are smaller because it is possible to maintain the lining at constant maximum thickness by repairs after each charge. Therefore this furnace design is not inferior to earlier ones as regards heat economy. The shutting down hitherto necessary for renovations to the hearth and the direct and indirect expenses inherent thereto are now practically eliminated. A further and very important advantage is the increasing of the available charging space of the furnace which allows of taking a full charge even when bulky scrap is being handled. Additional charging, an operation which took up much time and meant big heat losses, is avoided to a great extent.

The conical shape of the hearth also allows of making simpler foundations combined with a collecting trough for the event of furnace leakages. In this way the other parts of the furnace are protected from damage.

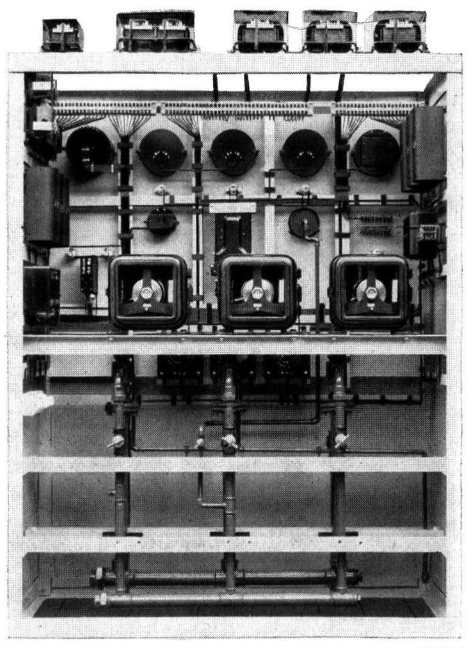

Fig. 10. — Rear view of switchboard with built-in apparatus for electro-hydraulic electrode regulation.

This regulating system has proved its worth in hundreds of plants.

All the accessory parts of the electric furnace, such as switchgear, regulating gear and transformers have been improved at the same time as the furnace proper (Figs. 10 and 11). The electro-hydraulic system of electrode regulation now operates on an impedance instead of on a pure current basis, a change which has had most beneficial results on the manufacture of soft steels. The immersion of even one

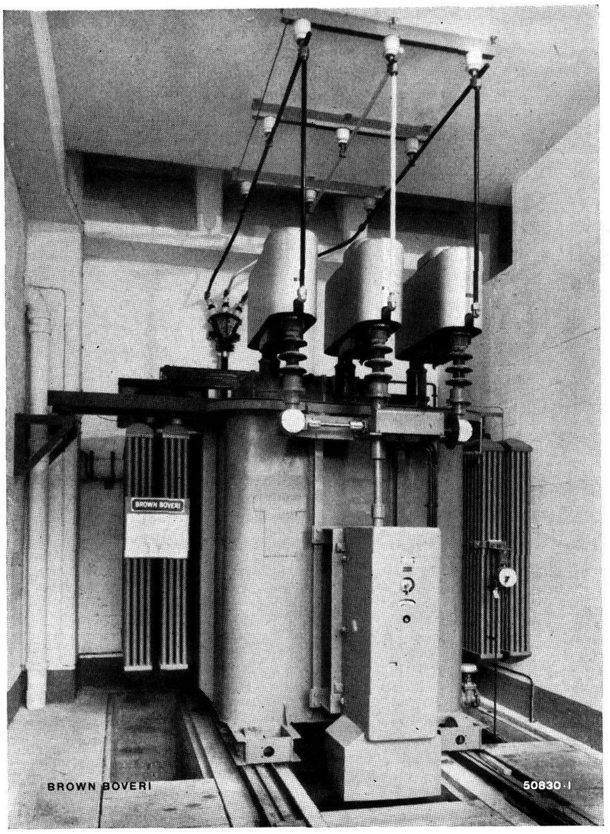

Fig. 11. — Three-phase furnace transformer with natural cooling. Output 3250 kVA, voltage ratio 3700/190—75 V.

A three-phase on-load tap-changing switch is used on the high-voltage side for changing over connections, combined with a star-delta switch. This avoids the need of cutting out the furnace frequently with consequent undesirable repercussions on the supply system.

electrode in the bath is now impossible and breakages of electrodes are avoided by the downward movement of the electrode being immediately arrested the moment the point of the electrode gets into slight conductive contact with the charge. This system of electrode regulation allows of maintaining the arc within the stable range and eliminates to a considerable extent the undesirable fluctuations in the supply system caused by arc flickering.

The number of voltage taps on the furnace transformer has been increased in recent years, and tap changing under load has been introduced on the bigger furnaces. Here Brown Boveri were able to use their excellent design of high-voltage tap-changing switch and this can be used, at the same time, for changing over from star to delta transformer connection. The advantage of on-load tap-changing is of great importance both to the steel works and to the supply system. The high-voltage tap-changing switch with its numerous steps permit of selecting the most suitable voltage for steady working with each different load. Formerly, it was necessary to cut out the furnace whenever a change in connections had to be made; this being no longer the case, the undesirable repercussions produced by electric-furnace plants on the supply system are reduced to a minimum.

(MS 847) *G. Keller. (Mo.)*

ELECTRICALLY GENERATED HEAT FOR DRYING FOUNDRY MOULDS.

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Generally speaking, drying can be carried out by fresh air, hot air, or superheated steam, under normal pressure or in a vacuum. As far as foundry moulds are concerned, only hot air and the hot-steam process are of interest from an economical point of view. This article goes into the economic advantages of electric heating and gives a description of the fundamental types of electric drying furnaces now on the market, which are, indeed, remarkable both for the variety of duties they can perform and for the new applications which have been found for them.

ALTHOUGH considerable pioneering work has been done in the course of the last 20 years, it was only recently that heat generated by electricity was applied on a larger scale to the drying of foundry moulds. If the recent trend towards electric heating took place under the pressure of actual circumstances, characterized by an increasing scarcity of fuel, there can be no doubt that the very satisfactory results obtained with electric melting furnaces played a part in drawing the attention of foundry men to the possibility of using more "white coal" in their branch of industry. In workshop service like that of a foundry and especially in moulding halls where so much was done by skilled hands, there was always sufficient labour available for looking after the heating side. Thus, from the point of view of simplification of the work, there was no very pressing need to introduce electrically heated devices for drying foundry moulds.

In estimating the profitableness of electrical drying sets, there are specific advantages for casting to be considered, apart from the well-known ones, such as higher efficiency, no supervision of the heating, elimination of a chimney and also of the stock of fuel and accumulation of ashes. Among these advantages it should be noted that the moulds no longer get burned due to faulty regulation of temperature, the drying air is free of ashes (less repair and re-drying work), better supervision of ventilation of the moulds (less scrapping of spoiled castings).

The advantageous metering tariffs available during night hours, generally lead to the drying furnaces being operated intermittently. Further, the furnace is only switched in when there are enough moulds to fill the furnace drying chamber satisfactorily; this requires several days when work is light in the foundry. For these reasons, the heat capacity of electric drying furnaces must be as low as possible in order to reduce the losses inherent to heating up the furnace; this condition is easier to realize with an electrically heated unit than in one designed for fuel firing. This also explains why fuel-fired furnaces converted to electric heating seldom give satisfaction and must be classed as faulty designs which are liable to create the erroneous impression that electrically heated furnaces are wasteful of power. Our practical experience has led us to refuse to carry out the conversion of fuel-fired furnaces to electric heating. The greater outlay entailed in buying a new furnace designed exclusively for electric heating is soon balanced by the savings effected on the metering bill.

The objection which has often been raised, namely that electric apparatus is not suitable to dust-charged atmospheres is no longer valid to-day since great progress has been made in plant and apparatus design and construction. This objection is, indeed, refuted by the success which hitherto attended the application of electricity to foundries.

The first tests in the field of electric drying carried out by Brown Boveri in their own foundry go back to the year 1918. In order to refute the general conception that electrical power was too expensive for use in simple drying processes, numerous comparative practical tests in the drying of built up moulds were carried out at that period. Fig. 1 shows the practical results.

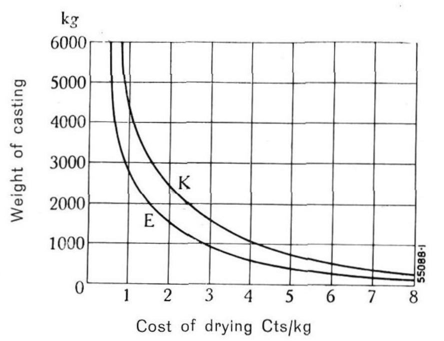


Fig. 1. — The cost of drying moulds for gray cast-iron when electric heating and coke heating is used.

K. Heating by coke (cost of coke Fr. 7. 50 per 100 kg, including 15 % for attendance).

E. Electric heating (tariff 3 Cts per kWh).

These curves were recorded during the drying of built up moulds and show clearly that the drying costs of one and the same mould are lower when electric heating is used.

The encouraging result led us to devote more attention to the development of electric drying furnaces.

In close collaboration with foundry circles, we finally brought out two types of drying furnace, Figs. 2 and 3, which met all practical requirements. The type shown in Fig. 3 generally meets all needs. The design shown in Fig. 2 is characterized by being explosion proof and is only used where explosive mixtures of gases can be produced by the special composition of the oil-bonded core; this type of furnace is, therefore,

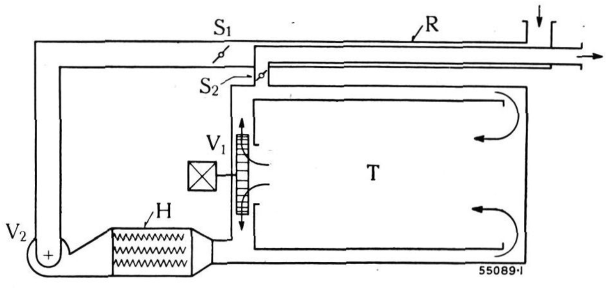


Fig. 2. — Diagrammatic layout for drying according to the hot-air process.

This arrangement is to be recommended when there is a danger of explosive gas mixtures forming (for example some kinds of oil-bonded cores).

H. Heating element. T. Drying chamber.
R. Heat exchanger. V_1. Circulation fan.
S_1, S_2. Choke valves. V_2. Ventilator for fresh air.

also used in drying varnishes. The explosion-proof quality is obtained by locating the heating resistances outside the drying chamber in the flow of fresh air.

As compared to hot-steam drying in which the moisture content of the sand in the mould is driven out by superheated steam at atmospheric pressure which is generated from the mould itself, hot-air drying for cores and moulds containing moisture is an uneconomical process because of the amount of air required as carrier of moisture and heat; in the former process no heat carrier is needed. As in the hot-steam method there is only a circulation in the drying chamber itself, when valve S 1 (Fig. 3) is closed, the air present at the beginning is rapidly expelled as the temperature

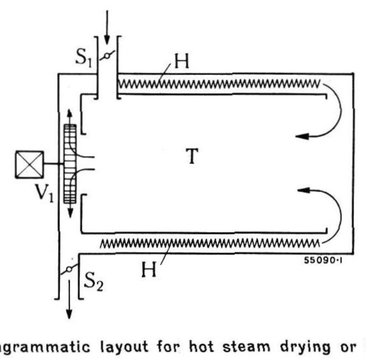


Fig. 3. — Diagrammatic layout for hot steam drying or hot-air drying.

In hot steam drying choke valve S_1 remains closed. This design is suitable for drying sand moulds or oil-bonded cores.

H. Heating element. T. Drying chamber.
S_1, S_2. Choke valves. V_1. Circulation fan.

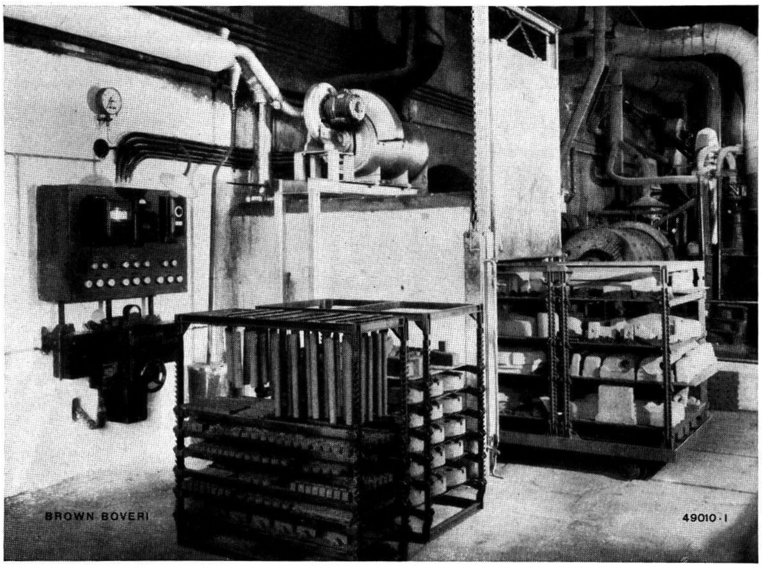


Fig. 4. — Drying furnace of the hot-air system for oil-bonded cores (60 kW, 1·75 cm^3 capacity, weight of useful charge about 800 kg. Duration of drying process about $2^1/_2$ hours).

Thanks to the successful results obtained, a bigger furnace of the same type with 3·8 m^3 capacity has been installed in the same plant. This furnace is charged by means of charging trolleys with specially designed charging frames.

rises, by the action of the vapours which form from the moisture in the pieces to be dried.

The superiority of the hot-steam drying process is made clear by the fact that in the hot-air process 3·3 kWh is the lowest expenditure of energy to be expected per kg of water content of the sand of the mould while with hot steam drying under identical chamber and charge conditions 2·5 kWh suffices. In big units and when the drying chamber is working to capacity, the energy consumption per kg of water evaporated can even be brought down to 2 kWh.

The furnace shown in Fig. 4 is of 1·75 m^3 capacity and has been in use for 4 years in Messrs. Sulzer Bros. foundry in Bulach (Switzerland). It is used for drying oil-bonded cores on the hot-air principle. A furnace of 3·8 m^3 capacity was put up in the same plant at the beginning of 1942; it works on the same principle, which proves the satisfactory performance of this type of furnace.

Among the numerous drying furnaces of different sizes, installed during recent years, special mention should be made of a big unit delivered to Messrs. J. J. Rieter & Cie., Winterthur (Switzerland) last year (Fig. 5). It works on the hot-steam principle. The major part of the electrical apparatus of this drying set, including the transformer, is located below floor level. The switchboard panel, with temperature regulator and measuring instruments is above floor level, as seen in Fig. 5. All furnaces for drying moulds are provided with entirely automatic temperature regulation; the furnace is cut out automatically after a charge is dried so that there need be no supervision during the drying process.

As the figures already given for energy consumption are only valid when the drying chamber is fully utilized, it is of fundamental importance for the economical operation of these plants that the dimensions of the drying chamber should suit the mould frames most frequently encountered and that the furnace should only be used, if possible, when the number of moulds allows of filling the drying chamber. Sand moulds which are bigger than standard ones and only encountered infrequently should be dried on site as is done with built up moulds. Even to-day, this latter method of drying moulds is generally very wasteful, open coke fires and blowers being used to blow the fuel gases through the mould to be dried. The wastefulness of this method of drying is not only to be sought in the poor utilization of the coke fuel but to as great an extent in the ineffective drying process itself, the firing gases flowing over the inner walls of the moulds producing too rapid drying of the

Fig. 5. — Drying furnace for big moulds (450 kW capacity, 48 m^3 useful weight of charge, 40 t average according to the shape of the moulds, duration of drying process about 10 hours.

The chimney, firing and ash-removing gears, as well as a chamber for holding fuel are eliminated, so that the electrically heated drying furnace can be located on the most advantageous site in the foundry, the space round the furnace remaining quite free.

surface. This surface then insulates the interior of the mould against heat and prolongs the drying of the deeper layers of sand, the heat content of the firing gases being only partially utilized while the time for the drying process is prolonged.

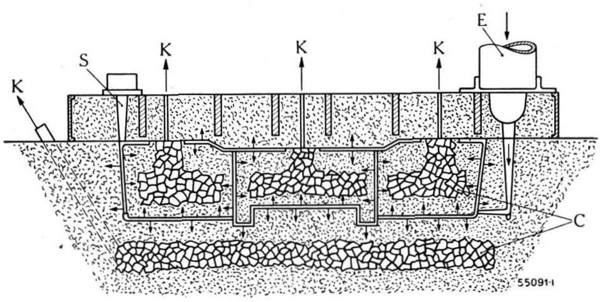


Fig. 6. — Section through a mould.

C. Layer of coke. E. Pouring head. K. Air vents. S. Gas vent.

Drying is accomplished by introducing compressed hot air, free of ashes, at point E, all other openings being closed. Cores which contain moisture can remain in the mould and be dried at the same time.

The considerations just set out led to utilizing the permeability of the mould sand to gases during drying and to the injection of the hot air (Fig. 6) under pressure through the inlet aperture into the mould, the gas vents being closed, so that the hot air must follow the flow of the mould gas, i. e. and escape through the pores of the sand and ventilating holes. This produces homogeneous drying of the mould, even of the corners, as well as a more direct elimination of moisture from the inside towards the outside. According to the degree of dryness desired, the drying process can be stopped at a determined instant. It is thus possible to regulate the drying process so that only the amount of water strictly necessary is eliminated from the sand, without influencing in any way the casting qualities of the mould. In this process, the air escapes in saturated state and with the best possible utilization of its heat content, because the external sand layers and the moulding frame are only brought up to a relatively low temperature; further, this process has the remarkable advantage that defects in the mould ventilation are easily detected by damp areas appearing on the dried mould and defective castings can be avoided by taking the necessary measures in time. There is a natural regulation of the temperature because the gas permeability is low at the beginning of the drying process and gets greater as the moisture of the sand decreases, so that the temperature of the hot air is higher at the beginning of the process than at the end. This does not lead to the mould getting too hot, because the moisture is greatest at the beginning and, therefore, the high temperature is not transmitted to the sand.

Although there is no recuperation of heat in this new drying process, as is the case with the hot-air process (Fig. 2), the consumption of energy is so low (Fig. 1) that electric heating is more advantageous than coke firing even at high metering tariffs. By simply making the moulds conform to this new drying method, as, for example, by making thinner sand partitions between mould surfaces and coke bed, we obtain a shorter drying time along with a lower outlay for the moulds.

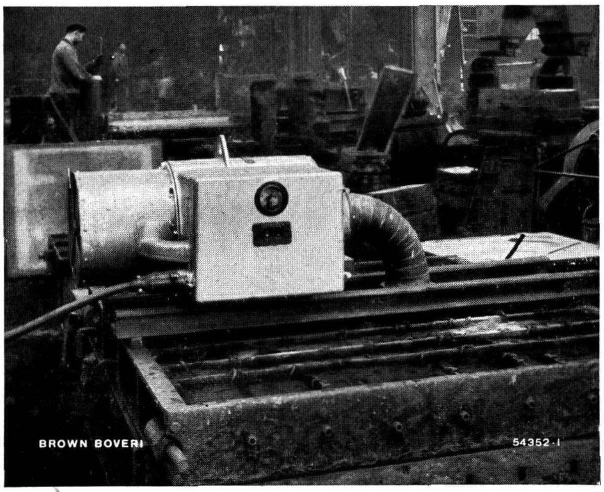


Fig. 7. — Portable drying set for a power input of 35 kW.

Suitable for drying small moulds with high gas permeability or for drying parts which have been subsequently repaired.

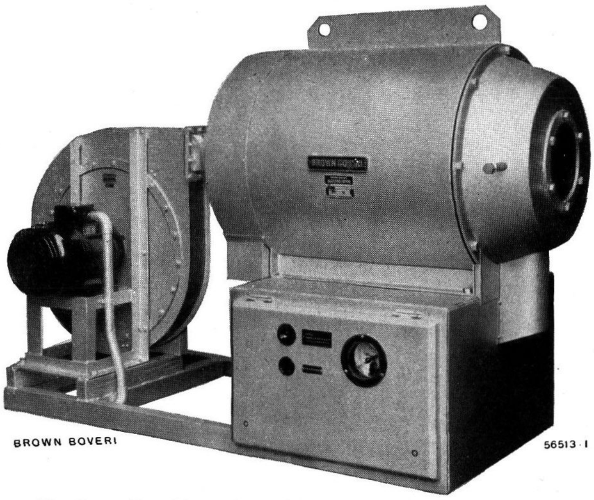


Fig. 8. — Portable drying set for a power input of 70 kW.

Thanks to the high static blower pressure this set meets all foundry requirements. A change-over switch allows of the preliminary drying of the closed mould by means of unheated fresh air.

Figs. 7 and 8 show the two newly-developed portable plants for drying out closed moulds. These drying equipments, which are always ready for service, require no supervision. All safety and switching apparatus form a totally-enclosed unit along with the air heater. If the maximum allowable drying temperature is exceeded, the heating is switched off automatically and an alarm sounded.

Generally speaking, the 70 kW sets are the most suitable for foundries, on account of their being very strong, easily moved about, and having a powerful blower with great reserve of pressure. 2—4 units of this kind allow of drying out sufficiently quickly big mould frames and built-up moulds. The 35 kW type is suitable for moulds with high gas permeability of the sand; they also do good service in drying subsequent repair work.

These portable electric dryers are designed with a view to introducing the new drying process to foundry practice, because to-day, when there is a scarcity of electric power and of fuels it is right to do everything to utilize the sources of heat available while giving preference to that form of energy which is the most economically advantageous.

(MS 832) *K. Frauenfelder. (Mo.)*

HOT GALVANIZING IN ELECTRICALLY HEATED ZINC BATHS.

Decimal index 621.369.6 : 669.586.5

Hot galvanising of iron parts plays an important part as a protection against corrosion. This article describes some electrically-heated zinc baths and their advantages as compared to coal-heated or oil-heated baths. Thanks to the automatic regulation of temperature and to uniform heating, the life of the tank is considerably lengthened and the operating reliability of the plant much increased. The economic advantages of electric heating are demonstrated with the help of a curve showing the consumption of electrical energy for various charges.

THE latest investigations into the problem of corrosion show that it is economically advisable to use some lasting form of protection from the beginning, when dealing with iron parts which are exposed to corrosion through contact with the air, with water or through being sunk in the earth. The process of rusting is generally recognized as being an electrolytic phenomenon. Especially in the case of rolled iron, the layer of oxide, as well as the scale from the rolling process, form an electrolytic element with the iron itself so that corrosion is set up when electrolytes are present. Among the numerous processes introduced to combat corrosion, metallic coatings hold an outstanding position because they offer a guarantee of great durability. According to the use to which the pieces are to be put, a coating of nickel, chromium, cadmium, copper, tin, zinc, lead or of precious metals can be applied. Of all these metals, the one most commonly used is zinc owing to its relatively low

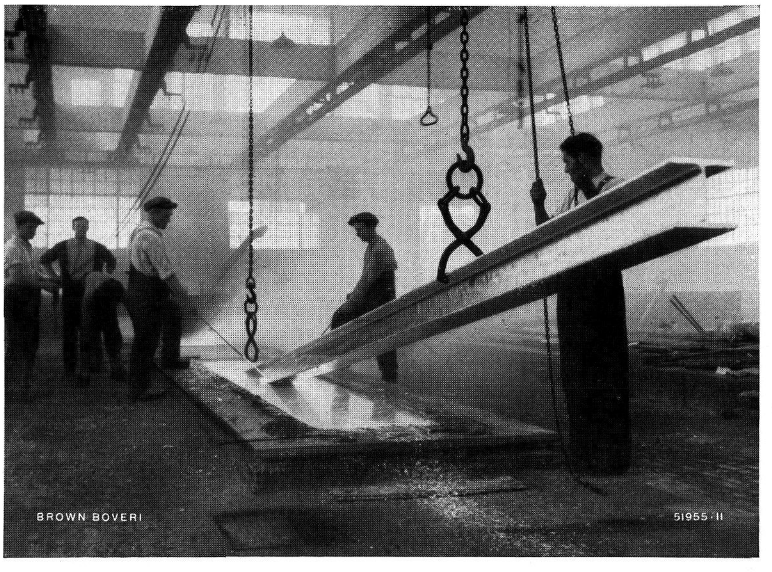


Fig. 1. — Electrically-heated zinc bath for the hot galvanizing of 14 m long rolled section iron bars and pipes.

Maximum power input 180 kW. Capacity of bath about 27,000 kg of molten zinc.

Electric heating combined with automatic temperature regulation allows of obtaining uniform heating of the whole tank. High-grade galvanizing is attained with a minimum consumption of zinc.

price and the excellent protection it provides against corrosion. Notably it is the only metal used for protective coatings which has a lower electrolytic potential than that of the iron it is protecting. Even if the protective coating gets damaged, the zinc and not the material under it is attacked while, on the other hand, if nickel or chromium coatings get pocked or scratched, marked localized corrosion of the iron is set up. Zinc ores are fairly common in Europe so that there is no scarcity of this metal even under the present abnormal conditions.

In the galvanizing process, as has already been mentioned, a thin coating of metal is applied which adheres strongly to the surface of the piece to be protected. The following processes are used to this end:—

(a) *Hot galvanizing.* — The object to be galvanized is dipped in a molten zinc bath, at a temperature of 450—460 °C.

(b) *Electro-galvanizing.* — Under the influence of direct current, a coating of metallic zinc is deposited on the object to be galvanized, which is placed in a zinc sulphate bath at room temperature and acts as cathode.

(c) *Sherardizing and cowperizing.* — The object to be galvanized is constantly rotated and heated in a drum, along with zinc dust; the zinc diffuses into the surface of the iron and thus forms the protective coating desired.

(d) *Spraying process.* — Fluid zinc is finely pulverized by means of compressed air and sprayed on to the object to be galvanized; in this way a metal coating of any desired thickness can be applied.

The choice of process used depends chiefly on the requirements laid down and the use to which the galvanized parts are to be put. Processes (b) and (d) are used, for example, where exact measurements are to be adhered to and no thermal deformations of the pieces treated can be tolerated. Sherardizing according to (c) is used for small pieces, especially cast iron. Hot galvanizing is used for constructional parts of iron, to be mounted in the open air, also for hollow bodies as well as for metal sheeting and for wires; of all the surface treatments it is the most extensively used.

I. HOT GALVANIZING.

The objects to be galvanised are first pickled in muriatic or sulphuric acid of determined concentration, this removes the scale from the iron, which is a consequence of the rolling process, as well as traces of rust which may be present and prepares as clean a metallic surface as possible for the galvanizing process. Pickling generally takes several hours and is a cold process (at room temperature). After this the pieces are dried and then immersed in the molten zinc. A layer of flux which is usually ammonium chloride, is laid on the surface of the zinc bath. The ammonium chloride combines with the melted zinc to form zinc chloride and this creates especially favourable conditions for diffusing the fluid zinc into the surface of the iron. According to the size and weight of the piece being treated, the duration of immersion lasts from about 1 to 20 minutes. 500—800 grammes of zinc are deposited on every square metre of surface. If the zinc coating is subjected to damp air or rain, a layer of zinc hydroxide and zinc carbonate forms on the surface which itself prevents further oxidation and thus, corrosion of the iron underneath. Fig. 2 shows the diagrammatic section through the surface of a galvanized iron piece which has been subjected to the influence of a damp atmosphere for a long period of time.

As regards the durability of the hot galvanized coating, the results of many years of investigation show that climatic conditions play a part here and that the air in industrial plants is especially injurious. For galvanized electric towers a life of 25 years is reckoned with under normal conditions.

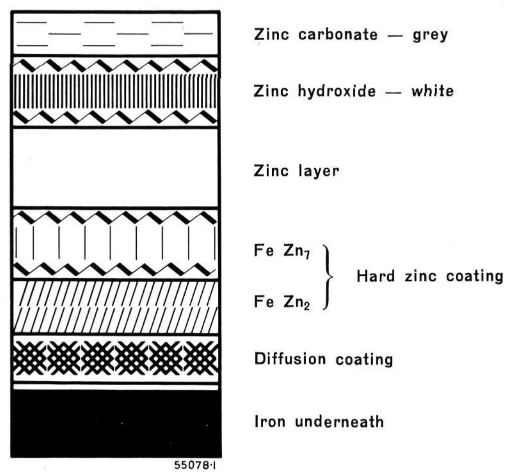


Fig. 2. — Diagrammatic section through the surface of galvanized iron exposed to atmospheric influences for a long period.

The different protective coatings which result from good galvanizing are shown clearly. The zinc surface has formed basic zinc carbonate through combining with the carbonic acid in the air; this protects the lower layer of zinc from further attack.

II. DESIGNS OF THE GALVANIZING BATH.

Bath tanks made of soft non-alloyed steel of a wall thickness of 30—50 mm, with as low a silicon content as possible, are used to hold the molten zinc. Good results have been obtained, in the case of welded tanks, by using steel of low carbon and manganese content.

Up to about 10 years ago, practically all the zinc bath tanks were heated by coal or oil. These operated with relatively big heat losses, especially because of the gases escaping up the chimney at a temperature of about 600° C. On the other hand, it is difficult to obtain uniform heating of the melting tank. In order to prevent the hot flame at a temperature of up to 1300° C coming into direct contact with the outer wall of the tank, the said walls had to be protected by a layer of bricks of fire clay. Despite this, it was impossible to prevent certain areas of the melting tank — especially during stoppages of operation — from getting overheated, which favoured the formation of a spongy iron-zinc mass or hard zinc which results in the tank wearing out quickly. It may happen that the tank bursts at some such exposed spot and that the molten zinc runs out. An accident of this nature not only means expensive repairs, but the putting out of commission of the plant for a considerable length of time. Scientific investigation showed that the hard zinc formation is mainly dependent on the temperature. It has been found that the iron has a 3·2 times greater solubility at 500° C and a 12·5 times greater solubility at 550° C than it has at 460° C. It is, therefore, of great importance that the temperature of the zinc bath should be very carefully supervised and that the tank be uniformly heated.

Apart from the prevention of the formation of hard zinc, there are other reasons for supervising the temperature closely. When the temperature of the bath is too low, the coating of zinc on the pieces being treated, is irregular and too thick. More zinc is used than is necessary. Further, the adherence of the zinc layer is poor and it flakes off easily when the galvanized piece is worked up or used. On the other hand, if the temperature is too high, the zinc coating is rough and unpleasing. Further, the surface of the molten zinc oxidizes more strongly which means an additional loss of zinc. After weighing up the disadvantages inherent to fuel firing just enumerated, it will be obvious that electric heating offers great advantages.

Electrically heated zinc melting tanks allow of uniform heating of the tank so that the whole surface is fully utilized for the heat transmission at minimum temperatures. Automatic temperature regulation prevents the admissible temperature limit being exceeded. The bath temperature of 450 to 460° C is maintained exactly and automatically, independently of the number of articles passing through the bath. In this way, the parts being galvanized get a uniform coating of the requisite thickness. Electrically-heated galvanizing baths thus work with a lower consumption of zinc and less formation of hard zinc. It is also obvious that the melting tank itself will have a longer life due to less wear, thanks to the uniform and lower temperatures of the walls. This has a favourable influence on the cost of the process. All these advantages explain why the electrification of galvanizing baths has made such great strides in recent years.

Fig. 1 shows an electrically-heated galvanizing plant which can hold 27,000 kg of molten zinc. The power input is 180 kW. Supply is at 500 V, three-phase current. The heating resistances are located on the 4 side walls of the tank and are so mounted that they radiate heat freely and that the heat is transmitted uniformly to the zinc in the bath. In the length of the bath, there are 2 entirely independent regulating groups of resistances which, in turn, are subdivided into control groups. Thermo-elements are used to measure the temperature outside the tank. The temperature of the zinc bath can be adjusted very simply

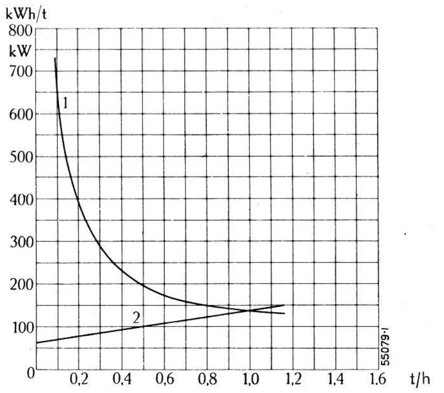


Fig. 3. — Energy consumption of an electric galvanizing bath in function of amount of material treated in bath.

Power input 160 kW. Capacity 43,000 kg of zinc.

Abscissae: Amount of iron in tons to be galvanized passed through per hour.

Ordinates: 1. Energy consumption in kWh per ton of galvanized iron.
2. Power for heating required in kW.

A power regulator adjusted to service conditions allows of precise automatic maintenance of the temperature of the bath. Operation is simpler and reliability is greater than in fuel-fired baths. This is advantageous from the economical point of view.

by means of the temperature regulator and is maintained automatically at the value set to. When the amount of heat supplied to the bath is too big, i. e. when the temperature of the bath begins to exceed the adjusted value, contactors open automatically and the heat input is reduced accordingly. It is impossible for any part of the bath itself or of the tank to get overheated.

Fire-clay brickwork forms the outer wall round the tank and holds the heating elements. In order to reduce to a minimum heat losses to the foundations, a layer of heat-insulating stones is placed behind the fire clay bricks. During stoppages in operations, the surface of the bath is covered over with zinc ashes and heat-insulating covers in order to preserve the heat stored in the baths.

Fig. 3 shows the energy consumption of a medium-sized galvanizing bath in function of the amount of iron to be galvanized passing through the bath. Curve 1 shows that the specific energy consumption drops as the amount of iron increases. This is because the losses by radiation for a given bath surface remain practically constant and that only about 70 kWh are taken from the bath by the immersion of one ton of cold iron parts into it. As when the surfaces of the bath are bright, there are greater losses by radiation, the works manager has every interest in reducing the bright surface to the necessary minimum. The practically linear character of curve 2 illustrates the necessary heating input for different amounts of material passed through the bath and with about 50% covering of the bath surface with zinc ash or a layer of ammonium chloride.

The above mentioned solubility of iron in hot zinc subjects the tank of electrically-heated galvanising baths, as well, to a certain amount of wear which, however, is considerably less than what it is in fuel-fired plants. Material defects in the tank sometimes cause small leakages after a short time, which then grow rapidly until there is a considerable outflow of molten zinc into the brickwork of the furnace. In order to detect small leaks in the tank, gutters are provided in the brickwork floor of the tank. Two contacts insulated from one another are located at the lowest point of these gutters and these actuate an alarm signal as soon as they are short-circuited by the liquid metal. The bath can then be emptied immediately, to prevent further and more serious damage.

Electric operation with its automatic temperature regulating equipment, which has proved most reliable, has certainly simplified the duties of operators considerably. From the point of view of the power-supply company, the electrically-heated galvanising bath is an advantageous power consumer because in most plants of this kind work is carried on in several shifts; the advantage to the power supply company is still more marked because the bath can be switched out, without any great loss of heat, for a period of 1 to 2 hours during the peak-load period of the day. As, in these plants, we are generally dealing with relatively big blocks of electric power, the supply system is favourably affected by the purely ohmic load which the resistance heating represents.

It is, therefore, not astonishing to find fuel-fired plants being converted to electricity whenever electric power can be supplied at reasonable tariffs. In Switzerland, for example, there are now 10 electrically-heated plants giving satisfactory service.

(MS 831) *H. E. Meuche. (Mo.)*

ELECTRIC NITRIDING PLANT OF BROWN BOVERI DESIGN.

Decimal index 621.369.6:621.785.53

Hardening by the nitriding process requires a simple charging system for the parts to be nitrided, a pot which is quite gas-tight, homogeneous temperature and a simple method of supervising the process. All these demands are met by the Brown Boveri nitriding plants.

HARDENING by nitriding is a thermo-chemical process which has as object the hardening of the surface without any quenching. Hardening is caused, here, by nascent nitrogen penetrating the surface of the metal and forming metal nitrides which are exceptionally hard in the case of certain kinds of steel alloys. The low temperature of the treatment, as compared to that necessary for case hardening, and which is below that at which iron is transformed, allows of hardening with practically no deformation of the piece treated.

The degree of surface hardening attained is very high and reaches 1100—1200 Vickers hardness units (69—70 Rockwell C hardness units). At the same time, the mechanical strength of the core, imparted to it by whatever preliminary heat treatment the piece has undergone, is essentially unaffected.

The pieces to be hardened, of special steel, are heated in a gas-tight pot at about 500° C in a stream of ammonia gas, during a determined time (between 20 and 120 hours according to the depth it is desired to give to the nitriding process). Cooling of the pot is carried out slowly in a cooling pit or in the open air, until the charge reaches about 70° C at which temperature there is no longer danger of the nitrided parts being oxidized when exposed to air.

Machine parts are treated by this method when they must be protected from any deformation during hardening and when it is desired to impart to them great resistance to friction wear. Hardening by nitriding is not suitable where the pieces are to be subjected to shocks or have to carry high specific loads. Automobile and aeroplane manufacture, machine tool and gauge manufacture make an increasing demand for parts of high superficial hardness and great precision, properties only attainable by hardening by the nitriding process. As example we may mention crank shafts, cam shafts, cylinder liners for automobiles and aeroplanes, slides, pinions, spindles, certain gear wheels as well as gauges.

Brown Boveri have developed an electric nitriding plant for this important treatment of steel; it allows

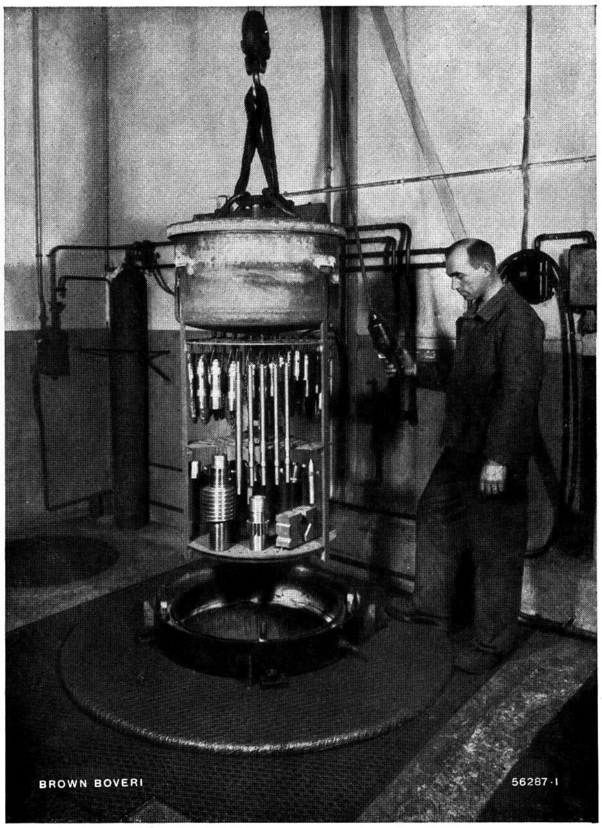


Fig. 1. — Lowering the charge into the nitriding pot.
Machine parts of any shape are easy to accommodate in a vertical nitriding pot.

of carrying out the treatment both practically and cheaply. — It is composed of a vertical electric furnace, with the requisite control and regulating apparatus, a nitriding pot and an ammonia-gas plant. The furnace, electrically heated, is very effectively heat insulated in order to keep the heat losses as low as possible during the nitriding process, which consumes the largest amount of electric power of the whole operation.

The electrical apparatus for the automatic regulation of the temperature is simple and reliable. The temperature inside the pot is maintained constant by switching in or cutting out the whole or part of the power input. There is a safety device which causes the plant to be cut out when the temperature in the pot is higher than the value adjusted on the regulator, which may occur on account of some defect.

The special design of the nitriding pot allows of easy charging of the parts to be treated (Fig. 1). The parts are placed on plates and these are hooked to suspension bars and are thus suspended from the thermally insulated cover. A lifting gear allows of lifting the cover and charge and lowering it into the pot which is already in the furnace. The seal between pot and cover is outside the furnace and water-cooled. Thus, the seal is not subjected to a high temperature and ensures a totally gas-proof sealing of the pot. In the big units, a fan to generate thorough circulation of the ammonia gas inside the pot is combined with the cover; in this way all parts to be nitrided get a homogeneous surface hardening; further the forced circulation produces quicker and stronger nitriding.

Thanks to the vertical arrangement of the pot it was possible to place the furnace and cooling pit below the surface of the shop floor, as shown in Fig. 2; in this way space was saved. If there are 2 or 3 nitriding pots available, it is possible to carry on non-stop operations.

The ammonia-gas supply plant consists of ammonia gas bottles and different apparatus for drying the gas, for controlling the consumption of ammonia and for supervising the degree of dissociation of the ammonia gas as it leaves the nitriding pot. The last measurement is important as it gives an indication of the quality of the nitriding process carried out. At its exit from the pot, the gas mixture is led to an absorption tank with water circulation. The ammonia gas still present dissolves in water while nitrogen and hydrogen escape to atmosphere outside the workshop. After the nitriding pot has been

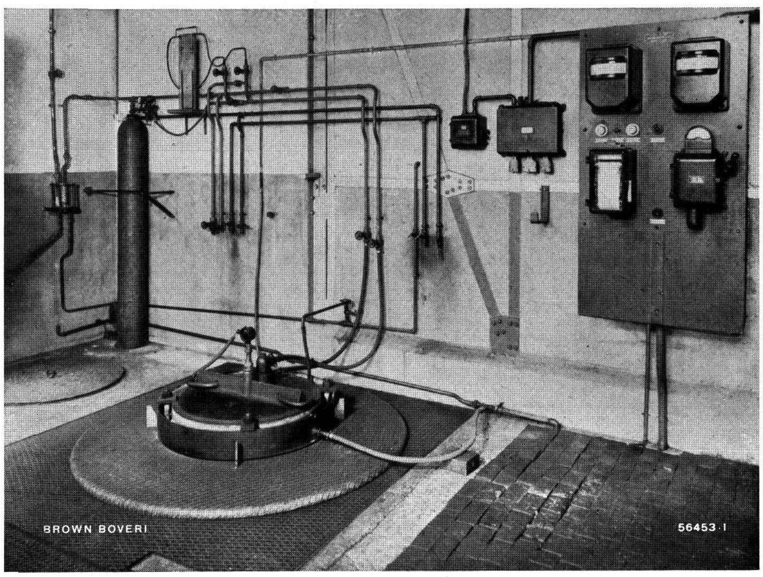


Fig. 2. — Electric nitriding furnace plant for vertical charging.
Power input: 30 kW
Charging space: 610 mm diameter
800 mm height
Easy to supervise, takes up little space.

cooled down, which requires about 4 to 6 hours, the ammonia gas still remaining in it is removed by a draught of air or by suction by means of an ejector. This prevents ammonia gas spreading through the workshop. The ammonia solution, on its delivery from the absorption tank, is led to a container, where the ammonia can be recuperated.

Up till to-day, we have delivered 15 nitriding plants in Switzerland built to the design described here which is a striking testimony of the qualities of Brown Boveri nitriding plants. Further this large number of plants allowed us to gather much experience in the field of hardening by the nitriding process.

(MS 834) *R. Lambert. (Mo.)*

CHARCOAL-GAS PRODUCERS FOR GENERATING THE PROTECTIVE ATMOSPHERE USED IN ELECTRIC BRIGHT ANNEALING PLANTS.

Decimal index 662.765.1.032:621.785.344

The gases from charcoal-gas producers form very effective, cheap and easily produced protective atmospheres. In order to attain ideal bright annealing without either decarburization or carburization the CO content of the gas must suit the composition of the alloy. Thanks to fundamentally new regulating devices, the two gas producers described here can be used for the bright annealing of most steels and alloys.

I. THE IMPORTANT PART PLAYED BY THE PROTECTIVE ATMOSPHERE IN BRIGHT ANNEALING.

THE exceptional importance of bright annealing in the metal industry is generally recognized to-day. Let us recall that under the term bright annealing, in general, a thermal treatment is to be understood in which the metal parts to be annealed must be prevented from coming into contact with oxidizing gases, so that they may retain their homogeneous, bright surface, free of any traces of oxidation. In order to fulfil these conditions, it is obvious that the cooling down process must also be carried out without oxidizing gases coming into contact with the metal parts, at least until the latter have dropped to a sufficiently low temperature to exclude the possibility of oxidation.

Oxidation of the surface is not the only chemical influence to which a metal is subjected when heated up to a high temperature. According to the composition of the surrounding atmosphere, decarburization, carburization, absorption of nitrogen and other transformations may be brought about. The two last named changes are only desirable when brought about intentionally in order to impart to the metal determined physical properties, as is done, for example, in case-hardening and nitriding. They are harmful phenomena when they accompany the ordinary annealing process. If, on the one hand, it is necessary to avoid oxidation in order to prevent loss of metal through scaling and outlay for pickling, on the other hand, it must be remembered that even a slight decarburization of tool steels complicates their manufacture considerably, on account of the subsequent tests which must be carried out and of having to remove the upper layer. A possible carburization of soft steels may render further work on them more difficult if not impossible.

In war time, when the scarcity of metals and their increase in price make themselves felt and when it is necessary to reduce losses of material to a minimum, the problem of bright annealing has become of great interest, especially as regards electric furnaces with oxidizing atmospheres.

One means of getting perfect bright annealing, is thermal treatment in a vacuum. This process, however, is costly and can only be used for small pieces made of very expensive alloys. Another process, based on the same principle, which is appreciated chiefly for its simplicity and which has been used extensively, is the Brown Boveri Grünewald bright annealing process. Here, the material to be annealed, which generally consists of rings of wire, or coils of strip, is placed in a specially designed annealing pot. The oil and grease adhering to the metal to be annealed vaporizes under the effect of heating and this before the metal has attained the temperature of oxidation; the vapours which form, expel a part of the air from the annealing pot and combine with whatever oxygen remains. Before cooling down the charge, the valve on the cover of the pot is closed in order to prevent the ingress of fresh air.

The majority of steels and copper can be bright annealed by means of the Brown Boveri-Grünewald process. It has, however, been shown that it is often difficult to get a pure bright annealing result when dealing with steels having a high carbon content, without also getting a slight superficial decarburization. Further, the increasing number of bright annealing furnace plants working on the continuous-process principle, the special design of which makes it impossible to close them as tightly as the Grünewald pot, have made it absolutely necessary to use a protective atmosphere.

A suitable protective gas must have a stable composition and the gas producer must be of rugged design and reliable in operation, as it generally has to work without attendance.

Numerous gases have been suggested as protective atmosphere. Nitrogen and town gas, for example, are seldom used while others such as cracked ammonia and hydrogen are so dear that they must be reserved for the bright annealing of high-priced, stainless steels of high chromium content, and render very good service in this field. Fig. 1 shows a plant working with cracked ammonia. Propane as well as town gas are generally only used after partial combustion; they have the disadvantage of being relatively expensive and not obtainable everywhere. Most of these protective atmospheres require expensive plants to generate and dry them.

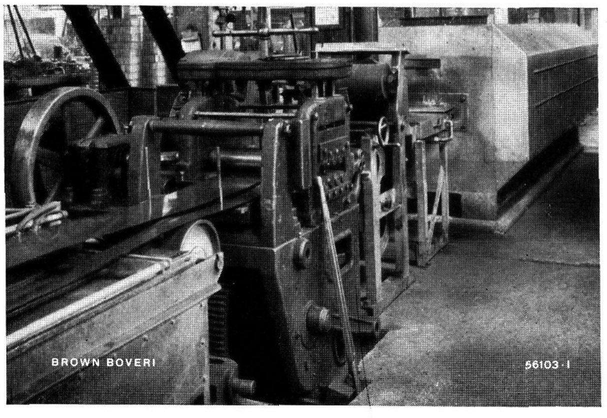


Fig. 1. — Electrically-heated furnace for the continuous bright annealing of strips of stainless chrome-nickel steel under a protective atmosphere.
The difficult problem of bright annealing stainless steels finds a perfect solution in this furnace. The protective atmosphere is composed of a mixture of hydrogen and nitrogen obtained by the cracking of ammonia.

II. DESIGN OF BROWN BOVERI PROTECTIVE ATMOSPHERE PRODUCERS.

Brown Boveri have developed a simple and mechanically strong producer for generating protective atmospheres. It works with charcoal. Here the work of the Swedish engineer Elfström on the iron-carbon-oxygen system and on the influence of the gazeous mixture of CO (carbon monoxide) and CO_2 (carbon dioxide) on iron and carbon steels could be turned to useful account. Elfström studied the conditions of chemical equilibrium of the following reactions:—

$$CO_2 + C = 2\,CO$$
$$CO_2 + FeC = 2\,CO + Fe$$
$$CO_2 + Fe = FeO + CO$$

Here he came to the three following fundamental conclusions:—

1. When a piece of iron or carbon steel is heated up to a determined temperature in gaseous mixtures of different proportions of CO and CO_2, it is always possible to determine a minimum CO content of the mixture above which it is possible to get bright annealing; this critical value of the CO content rises as the annealing temperature rises.
2. When the same test is made with a carbon steel, the C content of which is known, there is a determined CO content of the gas mixture below which surface decarburization or carburization occurs. This critical CO content grows as the annealing temperature rises and also as the C content of the steel increases. Further, it is always bigger than the critical CO content according to 1, to obtain annealing free of oxidation. From this it results that it is more difficult to prevent surface decarburization than it is to attain bright annealing.
3. If a mixture of CO and CO_2 is heated up to a determined temperature in the presence of carbon, the composition of the gas mixture changes in function of the temperature; the CO content of the gas mixture increases as the temperature of the carbon increases.

The practical solution of the problem consists in generating a mixture of CO and CO_2 in a gas producer and leading this gas mixture through an electrically heated container filled with charcoal and called a carburetter. The temperature in the carburetter is maintained constant automatically and depends on the CO content it is desired to obtain. The presence of atmospheric nitrogen simply alters

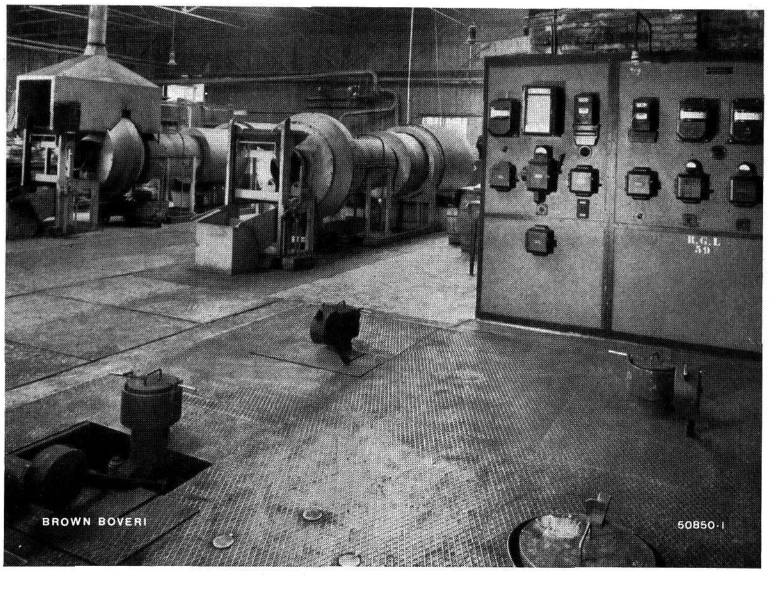


Fig. 2. — Electric drum furnace plant for the bright annealing of small clad-steel parts, with the protective gas generating plant combined with it.
There are three independent electrically-heated carburettors in which the gas generated in a single producer is brought up to the CO content most advantageous for each of these furnaces.

the percentage content of the CO and CO_2 but is of no other importance. The gas mixture produced in the manner explained above and the composition of which is maintained constant is led through the annealing chamber of the furnace. Fig. 2 shows a layout of this type with a gas producer and three carburettors which serves to supply three furnaces in which different alloys are treated.

Experience showed that it was advantageous to build the gas producer and the carburettor in one apparatus, the duty of the carburettor now being simply to enlarge the reaction zone. In this combined apparatus (Fig. 3), the combustion air enters below the producer (1) and passes through a fire grid where the combustion is completed. The gas mixture thus formed now flows through the charcoal maintained at a determined temperature in the carburettor (2), the cylinder jacket of which is electrically heated from the outside. As a result of the reducing effect of the charcoal at glow temperature a more or less big fraction of the CO_2 is reduced to CO, according to the temperature. The gas mixture is drawn by suction from the upper part of the apparatus and flows through a container (5) provided with baffle plates which is of relatively big section; here it cools down giving up moisture and dust. Finally the protective atmosphere is led to the point of consumption through a duct ventilator.

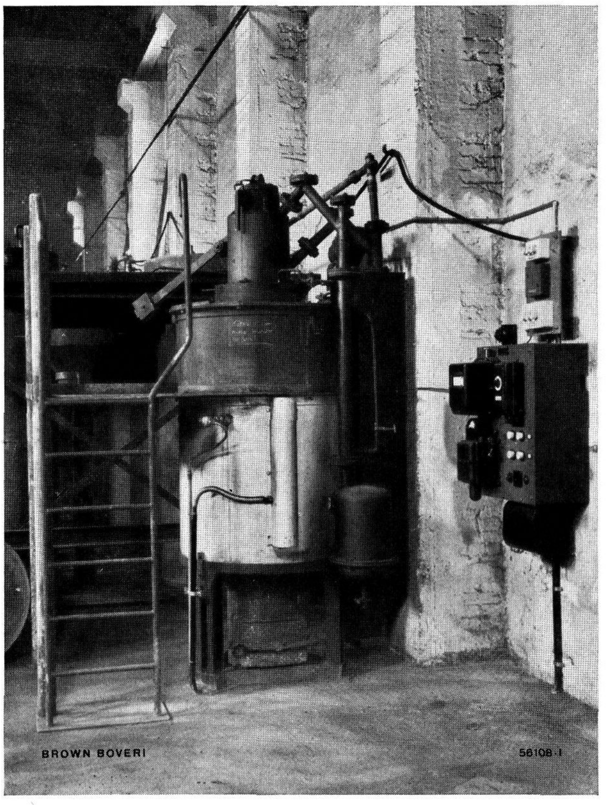


Fig. 4. — Gas producer with electrically-heated carburettor in a Brown Boveri Grünewald plant.

By the addition of this gas producing plant to the Grünewald bright annealing furnaces it has become possible to bright anneal even steels with a high carbon content without decarburization.

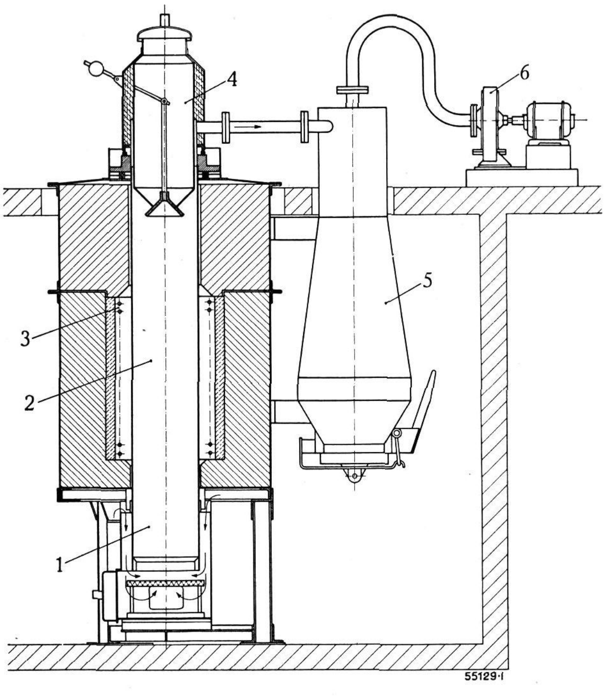


Fig. 3. — Diagram of the protective atmosphere gas producer with an electrically-heated carburettor.

1. Gas producer.
2. Carburettor.
3. Heating resistances.
4. Charcoal charging receptacle.
5. Dust and water separator.
6. Fan.

The combination of the gas generator with the electrically-heated carburettor leads to a desirable simplification of the plant producing the protective atmosphere.

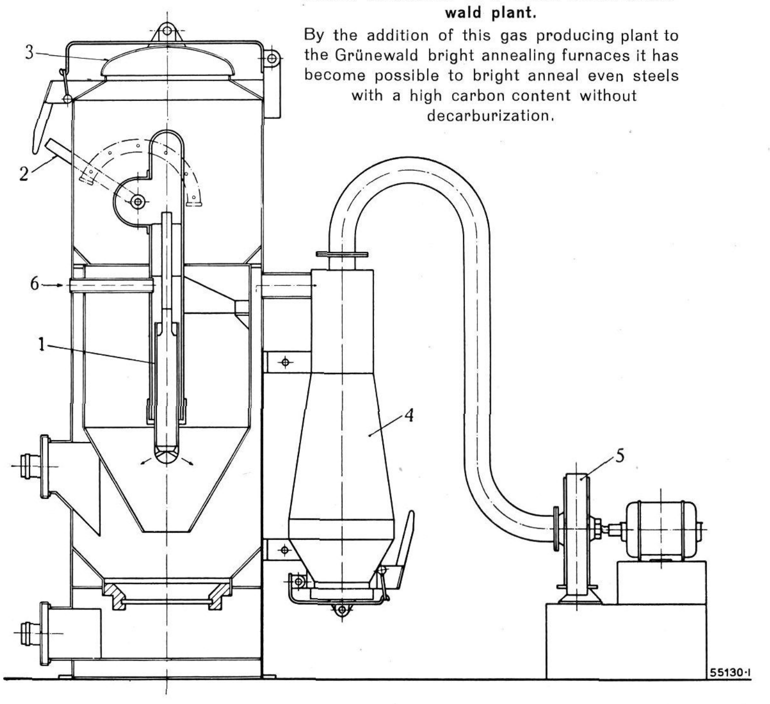


Fig. 5. — Diagram of a producer for protective atmosphere with gasification downwards and regulation of the composition of the gas through displacement of the fresh-air nozzle.

1. Fresh-air nozzle.
2. Lever for displacing fresh-air nozzle.
3. Cover.
4. Dust separator.
5. Fan.
6. Inlet of fresh air.

A modification of the height of the combustion zone produces variation of the composition of the gas in this type of gas producer. This exceptionally simple gas producer is especially suitable for making protective atmospheres for steels of low carbon content.

The temperature in the carburettor is maintained constant automatically by means of a temperature regulator connected to a thermo-element, this being accomplished by the switching in and cutting out of resistances. The charcoal charging receptacle (4) is placed above the gas producer; it is equipped with a gas-tight cover and closed off from the coal chamber by a throat stopper which is manipulated from the outside by a lever. This arrangement allows of replenishing the charcoal charge without interrupting operations.

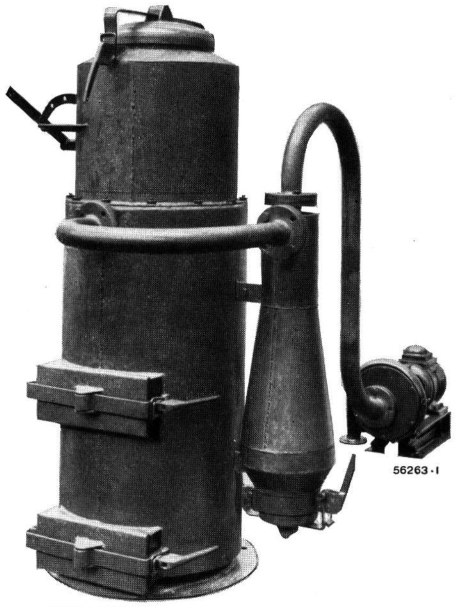


Fig. 6. — Producer for protective atmosphere with adjustable nozzle.
This producer built to the principle of the one shown in Fig. 5 is intended for an electric furnace plant for the bright annealing of steel sleeves, without any traces of carburization.

By the placing of a fan after the gas producer we always get suction pressure in the chamber of the producer which prevents the escape of poisonous CO gas during charging. Fig. 4 shows a combined gas producer of the type described.

Experience shows that the CO content of the protective atmosphere generated in a gas producer of this kind can be varied between 20 and 30 % in accordance with the value adjusted on the temperature regulator of the carburettor. It should also be mentioned that a CO content of about 35 % corresponds to a mixed gas composed of N_2 and CO and free of CO_2 (Fig. 7). It is thus possible to attain such high CO content that it is possible to achieve bright annealing without any decarburization, even with the highest carbon content in the steel.

For the bright annealing of steels having a low carbon content or of other alloys which are less sensitive to surface decarburization, it is unnecessary to use a protective atmosphere with a high CO content. To treat metals of this kind, much simpler and cheaper gas producers can be used than the one just described. This simple type, Figs. 5 and 6, has no electrically-heated carburettor and regulation of the composition of the gas is carried out by modifying the height of the combustion zone. It works with gasification directed downwards which allows of doing away with a throat stopper on the feed. Fresh air is injected through an axial telescopic nozzle (1) directed downwards and the position of which can be regulated by a lever from the outside. This is the chief characteristic of this gas producer. By lowering or raising the fresh-air nozzle, the CO content of the protective gas is modified by alteration of the zone of combustion between nozzle and grid. This permits of adjusting the composition of the gas to the characteristics of the alloy treated, over a range of 0 to about 20 % CO. Further, this gas producer has the same accessories (fan, dust separator) as the combined gas producer.

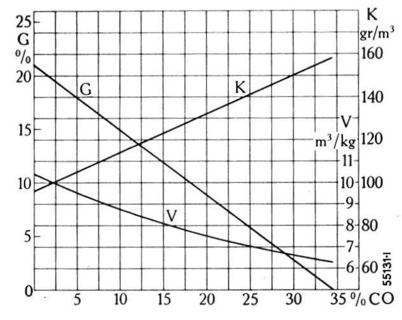


Fig. 7. — Consumption of charcoal and volume of protective atmosphere generated in function of the CO content.

V. Volume of protective atmosphere generated in m³ (50° C, 730 mm Hg) per kg of dry charcoal (ash content 5 %).

K. Consumption of charcoal in grammes per m³ of protective atmosphere.

G. CO_2 content of protective atmosphere in %.

The charcoal consumption of our protective-atmosphere producer of standard size amounts to 1—2 kg/h. Running costs are extremely low.

The gas producers described are built, at present, in two sizes with a protective-atmosphere production of 5—10 m³/h and 15—25 m³/h. The consumption of charcoal is extremely low and fluctuates, according to the CO content of the protective atmosphere, between 100 and 160 grm/m³ (Fig. 7).

These charcoal gas producers are very economical in operation and work with fuels which can be obtained everywhere. They will render excellent service in all metal-working shops for the bright annealing of carbon steels, most special steels, copper, bronze etc. Stainless steel, chromium-nickel steels and steels of high chromium content only must have hydrogen gas or nitrogen gas as protective atmosphere.

(MS 835) *R. Stahl. (Mo.)*

ELECTRICALLY-GENERATED HEAT IN THE SERVICE OF THE FOOD SUPPLY OF THE COUNTRY.

Decimal index 621.369.2:633.2

The conservation of fodder is a new field of application for electrically generated heat. Being fully aware of the vital importance, under present-day conditions, of making better use of the fodder our country can produce itself, as well as of finding a new application for the electric power generated in Swiss power stations, Brown Boveri developed a grass-drying machine which combines a very thorough drying of grass and the expenditure of a minimum of electrical energy. In a final summing up of the economic advantages of plants of this type it is shown that the artificial drying of grass is not solely an emergency measure to allow our country to affront present economic difficulties, but that it has reached a stage where it can be utilized advantageously when peace-time economic conditions return.

As the war extended, Switzerland was gradually cut off from the sources from which she normally drew a great number of supplies and was forced into the difficult position of having to get her daily bread from the products of the home soil. Now, in the case of a country dependent up till to-day, to a large extent, on imports of food and fodder, this was no easy problem to cope with, indeed it is one that can only be solved by the harnessing of every available force to this one end.

It would not have been considered possible, in pre-war days, to feed the Swiss people from the fruits of the soil of the country. To-day, thanks to the remarkable plan of cultivation which we owe to Dr. Wahlen, we have become aware that it is possible to do so. In increasing the amount of land put under cultivation to that extent required by the above mentioned plan it is obvious that the available area of purely grazing regions must suffer severely despite the fact that many heretofore uncultivated regions have been broken up, as well, and made arable. Obviously, the amount of fodder produced by the pasture lands must drop and, along with it, the quantity of milk, meat, and eggs which the country produced under peace-time conditions.

A certain drop in these products cannot be avoided in this all-embracing transformation to self-supporting conditions and must be accepted as one of the factors of the plan of cultivation, which were taken into account beforehand. The drop in the quantity of milk, meat and eggs could indeed be borne if another factor of far greater importance had not to be reckoned with:— the stoppage in the import of foreign concentrated fodder. Switzerland imported before the war annually 60—100 million francs worth of concentrated fodder, which is no longer obtainable to-day or, at least, only so in very small quantities. The conjunction of the two factors, smaller production of home fodder due to the aforesaid plan of cultivation, and stoppage of concentrated fodder imports suffice to imperil the supplies of milk and meat we count on.

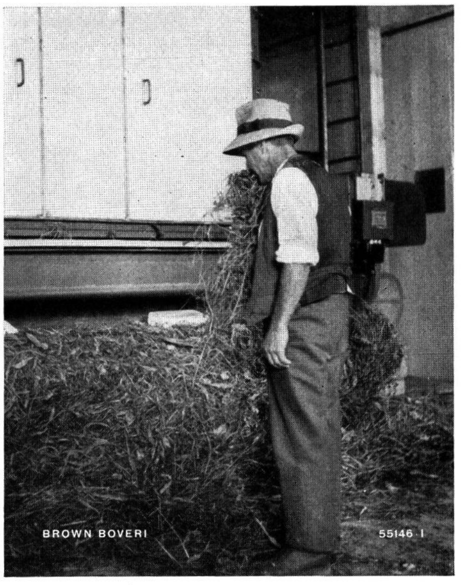


Fig. 1. — Dried grass.

A farmer puts the dried grass to the test with a critical nose. The verdict: Satisfaction at obtaining such high-class concentrated fodder from his own land.

Here, it is essential that ways be found to make better use of the fodder produced at home and this to an extent which will compensate for the lack of foreign concentrated fodder imports.

Along with the plan of cultivation embarked on for the soil we must pursue a plan of better utilization of available fodder sources.

Experimental work carried out during recent years into the problem of the conservation of fodder indicated clearly that much could be done to improve the methods previously in use and practical results attained very recently confirm this entirely.

In recognition of the position, Swiss industrial enterprises spared neither labour nor money on experimental work with the object of improving fodder conservation methods both from the technical and the economic side and, especially, those processes utilized for the artificial drying of fodder, so as to assist agriculture to meet the fodder problem.

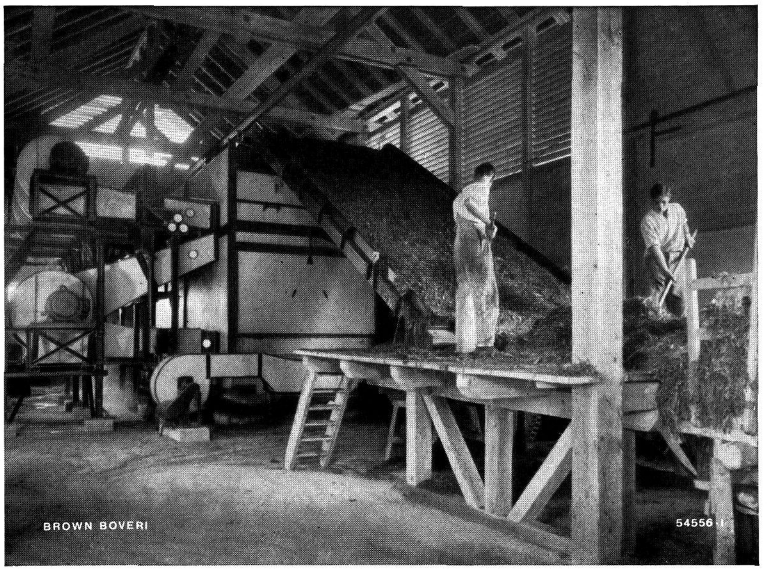


Fig. 2. — Brown Boveri grass dryer with heat recuperation seen from the fresh grass feeding side (Madiswil Agricultural Cooperative Society).

Water evaporated per hour 800 kg, corresponding to a production of 200—450 kg/h of dried grass, according to the water content of the fresh grass. Thanks to the heat recuperation, the consumption of energy is remarkably small, amounting to only 0·64 kWh per kg of water evaporated.

Brown Boveri took up the task of improving the artificial drying process and carrying it out with a smaller expenditure of electrical energy. After much preliminary experimental work, a method was evolved allowing of recuperating the heat of evaporation, which is otherwise lost. The development work accomplished and the fundamental principle of recuperation applied in this process have been made public.[1]

The fundamental principle of this method of recuperation is that the water eliminated under the form of vapour is not allowed to escape to atmosphere, as has always been the case so far, but is condensed in a heat exchanger so that the heat of evaporation it contains is utilized again to assist the drying process. The efficacity of this system of heat recuperation is proved by the fact that 30 to 40 % of the water eliminated from the fodder being dried is removed in the first drying stage and that the heat necessary for this stage is drawn from recuperation.

On the basis of the encouraging results obtained from experimental work, three big grass-drying apparatus built to the following conditions were ordered from our firm by the Swiss Federal Department for Public Economy to be delivered for the drying season 1941:—

Evaporation of water per hour 800 kg corresponding to a production of dry grass of 230 kg per hour assuming a water content of 80 % in the fresh cut grass.

A consumption of energy per kg of evaporated water of 600 kcal $\pm$ 8 % was guaranteed.

The apparatus is built on the principle of multi-belt driers. The fodder passes through the drying compartments being carried on a series of endless conveying belts of the sieve type through which air can pass and which are made of steel-wire meshing; these belts are placed one above the other and driven by strong chains on each side; the grass lying on the belts is subjected to a strong draught of air which passes through the steel meshes of the belts.

It is not necessary to give a detailed description of the design of the dryer and we would refer the reader to the publications given in foot-note 1. We

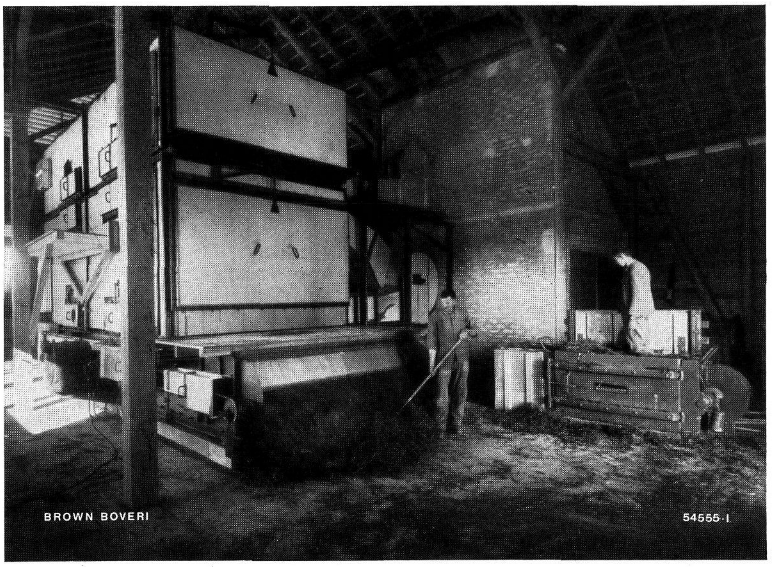


Fig. 3. — Brown Boveri grass dryer with heat recuperation, seen from dry grass delivery end and showing the bale press. Plant of the Niederhünigen-Stalden Agricultural Cooperative Society at Konolfingen.

Attendance of the plant is remarkably simple thanks to the built-in automatic temperature regulating apparatus.

[1] Bull. SEV Nr. 3/1941, "Die wirtschaftliche Grastrocknung unter Ausnützung der überschüssigen Sommerenergie".

The Brown Boveri Review 1941, Nr. 4/5, "The electric drying of grass, a present-day war-time economic problem in Switzerland".

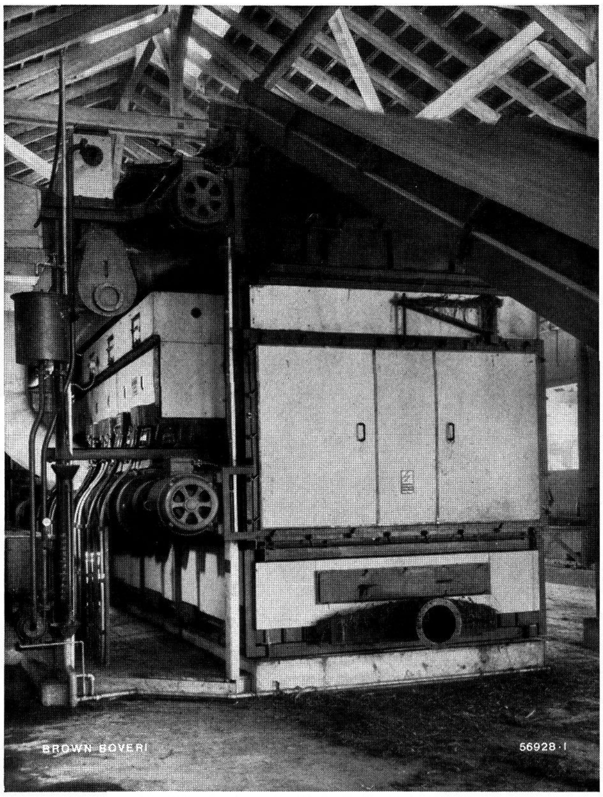


Fig. 4. — Grass dryer with heat recuperation, model 1942. Grass charging end with elevating conveyer belt. Plant of the Kiesen Grass Drying Cooperative Society.

The new design is characterized by the space-saving arrangement of the fans and heating elements, the space required across the dryer having been reduced by about 2·5 m compared with the 1941 model.

would only stress the great advantages inherent to conveyance of the grass on belts as this means that the fodder being dried is not subjected to any sudden movements likely to cut it up into smaller pieces. Experience shows, indeed, that there is no other drying process being used today in which the original form of the grass stalks and of the leaves is as well conserved as in the belt dryer. This is one reason why there is so little waste of material as compared, for example, to driers in which the matter dried is subjected to constant movement during the process. This factor is of especial importance when it is remembered that the most valuable food substances are contained in the delicate leaves which are easily damaged in drying.

Brown Boveri have built the following three plants:—

First plant for the Freiämter-Mosterei, Muri, put into operation middle June, 1941.

Second plant for the Niederhünigen-Stalden Agricultural Cooperative Society at Konolfingen, put into operation middle July, 1941.

Third plant for the Madiswil Agricultural Cooperative Society, Madiswil, put into operation middle August, 1941.

Fig. 2 shows the Madiswil grass-drying plant from the fresh-grass supply side. Fig. 3 shows the dry-grass delivery side of the Konolfingen plant with the bale press which belongs to it. It should be said, here, that four new grass dryers have been ordered this year. The first of these was put to work in June, in the Kiesen plant near Thoune.

Although these three machines have run for a relatively short time only, they have produced a very considerable amount of dry grass. The productive capacity of these machines is shown most strikingly by the figures given in a report published by the Swiss Federal Department for Public Economy, Section for Agriculture, on all the grass-drying plants put up last year, in which it is stated that of the 712 tons of dry grass delivered by 9 grass-drying plants in 7000 running hours, 322 t were delivered by the 3 Brown Boveri dryers alone in a total of 1600 operating hours.

In the Madiswil plant the average energy consumption per kg of evaporated water, measured over a long running period of 74 hours, was only 591 kcal and was, thus, below the guaranteed figure.

The experience of various manufacturers of grass-drying apparatus, in the course of last year, shows that drying apparatus without the recuperation feature also operated with considerably lower energy con-

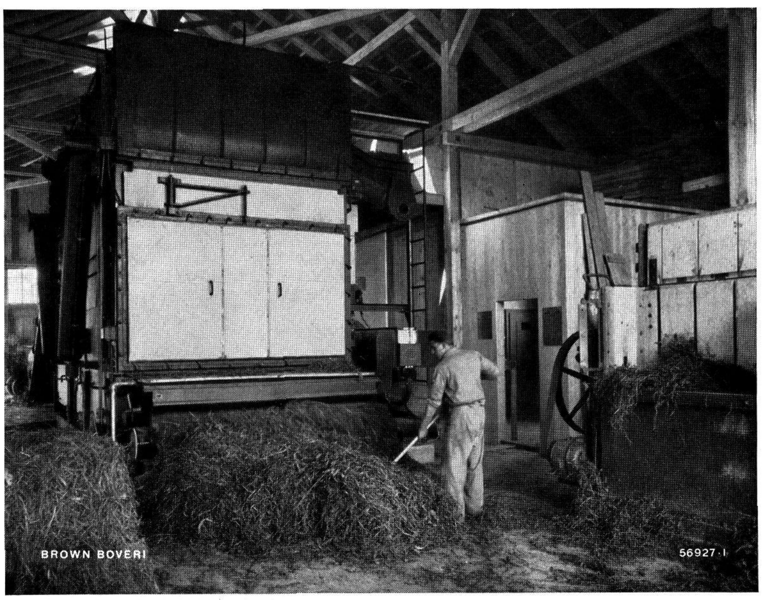


Fig. 5. — Grass dryer with heat recuperation, model 1942. Dried-grass discharge end, showing also appertaining bale press. Plant of the Kiesen Grass Drying Cooperative Society.

The baling press can hardly deal with the discharged dried grass fast enough.

sumption figures than those obtained with earlier designs using fuel firing; this is a result of electric heating being used. The consumption of an efficient dryer without the heat-recuperation feature was, nevertheless, about 35 % higher than that of our machine with the heat-recuperating feature, referred to identical amounts of water evaporated. This bigger consumption of electrical energy not only means increased running costs for the drying plant, but is an unfavourable factor to-day, from the point of view of distribution and utilization of the electric power available, of which there has been a marked shortage.

If, for example, a dryer to evaporate 800 kg per hour of water is called on to run for 2000 hours per year, the annual consumption of energy referred to the same amount of water evaporated, is 1·0 million kWh for a dryer incorporating the recuperation feature and 1·35 million kWh for one without it. The saving effected by heat recuperation is thus 350,000 kWh per year for one single dryer. This amount of energy is sufficient to manufacture about 400 tons of cast steel from iron scrap, for example, or to treat electrically about 120 tons of Swiss iron ore. These figures are sufficiently striking to show what an important part heat recuperation plays under present-day conditions.

The curves shown in Fig. 6 show the influence of the water content of the fresh grass to be dried; they give the amount of water to be evaporated for producing 100 kg of dry grass and the production of dry grass per hour in function of the water content of the fresh grass.

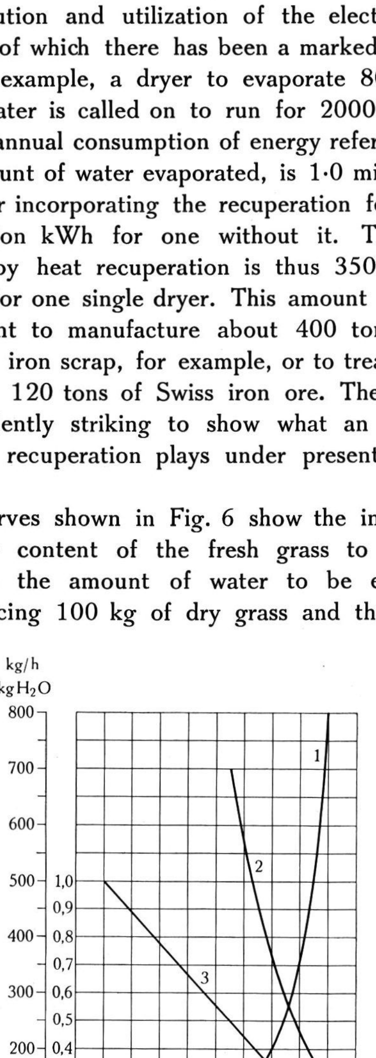


Fig. 6. — Quantity of water to be evaporated per 100 kg of dried grass produced, production of dried grass per hour and weight ratio of dried grass to fresh grass, in function of the water content of the fresh grass.

By letting the cut grass lie on the field in the sun, the economic operation of the dryer is improved. There are limits, however, to the time the cut grass should be left lying about as it loses its nourishing substances in this way.

1. Quantity of water to be evaporated per 100 kg of dried grass.
2. Production of dried grass in kg per hour.
3. Weight ratio:— dried grass/fresh grass.

The advantageous influence of a low water content on the drying costs must not be carried too far by natural drying of the cut grass lying on the field, because the nutritive substances contained in grass left lying in the fields begin to diminish which naturally affects adversely the quality of the concentrated fodder delivered by the machine.

Finally the question of the economic side of artificial grass drying must be considered. It should be stressed here that in this case, as in so many others, the factor of the best possible utilization of the plant is of great importance. In other words, the plant should be run for as many hours per year as possible. To this end, it is necessary to set up a plan for the utilization of the plant by the farmers and to have a responsible person on site to see that the said plan is adhered to and also to supervise the whole running of the plant. The experience gained during last year shows that with the help of efficient organization it is quite possible to reach a minimum of 1500 running hours per year and, as will be shown, this suffices for a profitable exploitation of the plant. The cost of a complete grass drying plant built to the data given at the beginning of this article is about Fr. 200,000. This price includes, apart from the machine proper, the outlay for the building, the erection, all electrical installations, further the auxiliaries such as the bale press, beating mill and conveying devices.

Based on the financing plan drawn up by the Section for Agriculture of the Swiss Federal Department for Public Economy and on the provisional price per kWh fixed at 1·6 centimes we get the costs given in Fig. 7 for 100 kg of dry grass, in function of the water content of the fresh grass.

Apart from the fixed sums for writing off the cost of the plant and for interest on the capital invested, these costs include:—

Charges for repairs, upkeep, wages, pressing. Further they include the cost of current and also the value of the grass delivered on the site of the dryer. This item is composed of the value of the uncut grass and the cost of cutting it and conveying it to the dryer. According to the distance it has to travel these costs reach an average of Fr. 10 per 100 kg of dried grass.

Fig. 8 gives the cost of the drying process alone without the value of the grass delivered at the drying plant, in function of the number of running hours per year. The character of these curves shows clearly the influence of the number of running hours of the plant per year. As will be seen, the operating charges rise rapidly below 1500 hours and the latter figure must, therefore, be considered as, approximately, an economic minimum.

Now comes the question of whether these expenses can be borne by the farmer.

To-day, Fr. 50 to Fr. 55 per 100 kg are being paid for concentrated fodder composed of oil cake and seeds and only very small and quite insufficient amounts of it are obtainable at all, from abroad. Maximum prices of Fr. 41 to Fr. 43 per 100 kg have been fixed by the Swiss Federal authorities for the grade of barley used for fodder as well as for wheat fodder and oats fodder, which can be considered as a part substitute for concentrated fodder; earlier, up to Fr. 50 per 100 kg had been paid for these fodders. The price of mixtures of fodder meal is at least Fr. 45 per 100 kg. If these prices are compared to the costs of dried grass which are Fr. 21 to Fr. 25, and in which at least Fr. 10 for the farmer's own labour are included, it is obvious that under present-day conditions there can be no shadow of doubt regarding the economic advantages offered by artificial grass drying.

If now this comparison is made for peace-time conditions, we get the following picture:—

According to the data of the Institute for Domestic Animal Fodder attached to the Federal Institute of Technology (E. T. H.) in Zürich 1 kg of dried grass will produce an increase in milk of 1·4 to 2 litres. If the value of dried grass under pre-war conditions is estimated on the basis of the lower figure of 1·4 litre milk increase, and if the litre of milk is back to its pre-war value of 20 centimes, and taking Fr. 9 per 100 kg as the price of the hay which is economized, calculations give Fr. 32·50 as the peace-time value of 100 kg of dry grass. This price is still considerably above the cost of production already calculated so that, on this basis, there is a fair profit to be made by grass-drying plants in normal times.

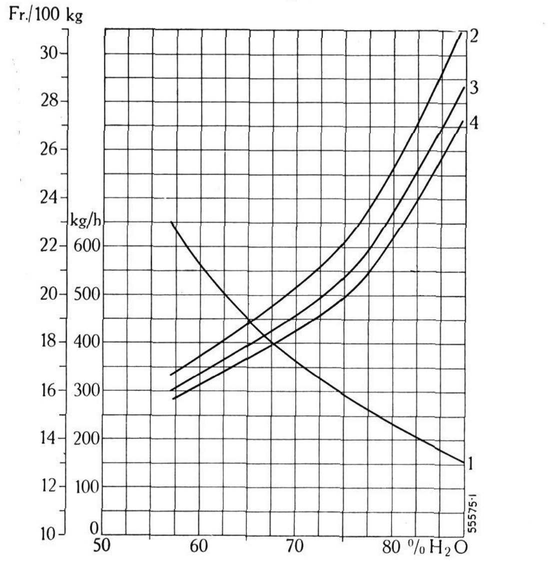


Fig. 7. — Cost of dried grass per 100 kg per hour in function of the water content of the fresh grass.

The cost of drying drops rapidly as the water content becomes smaller as a result of letting the cut grass lie on the field.

1. *Production of dried grass per hour.*
2. Cost of dried grass based on 1500 operating hours per year.
3. Cost of dried grass based on 2000 operating hours per year.
4. Cost of dried grass based on 2500 operating hours per year.

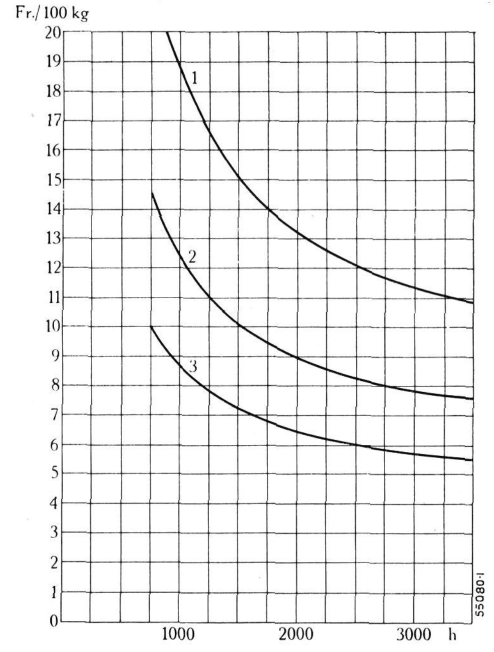


Fig. 8. — Cost of the drying process, including that of pressing into bales, per 100 kg of dried grass, in function of the number of operating hours per year.

The heat recuperating system developed by Brown Boveri leads to especially low costs for drying the grass and will allow of continuing the process with profit when peace-time conditions are re-established.

1. Cost of drying with 80 % water in fresh grass.
2. Cost of drying with 70 % water in fresh grass.
3. Cost of drying with 60 % water in fresh grass.

If account is taken of the fact that, after the war is ended, it will be years until pre-war conditions are re-established, it is fairly certain that by that time the cost of the grass-drying plants will have been written off, so that from then onwards dry grass will be able to compete advantageously with foreign concentrated fodder. This should be all the easier as the latest experience on milk production and observations on the suitability of dried grass for cattle show that it is far superior to foreign concentrated fodders.

The creation of a type of indigenous concentrated fodder in the form of dry grass is, thus, not only an emergency measure to bridge over a difficult period as regards supplies, it is a promising factor in the furthering of the economic independence of Switzerland.

(MS 837) *G. Brunner. (Mo.)*

A SMALL ELECTRIC DRYER FOR GRASS, FRUIT, OR VEGETABLES.

Decimal index 621.369.2 : 63

The small electric dryer described hereafter enables sufficient concentrated fodder for a herd of ten to twenty cows to be produced by the farmer himself. It has been developed especially for farms not within easy reach of a large central dryer. The same apparatus can also be used to dry fruit or vegetables. The resulting product is of extremely high quality.

As stated in the preceding article essential conditions for the installation of large dryers are operation on a cooperative basis and an adequate power supply. The latter requirement, however, cannot always be fulfilled. Out-of-the-way farms, which are often particularly suited to the production of high-quality concentrated fodder, are a case in point. The small electric dryer with a rating of 10 kW, for direct connection to a 380 V supply, has been especially developed for this application. In contradistinction to the large apparatus the small dryer, complete with built-on apparatus box, is transportable.

Fig. 1 depicts in diagrammatic form the construction of the apparatus, which conforms to the most recently evolved principles of drying practice, and, like its larger prototype, is designed for heat recuperation. The drying process takes place in two stages, i. e., in the preliminary and main dryers. The cover of the main dryer acts as heat exchanger, for the vapours emanating from the grass or the like condense on the inside and the heat liberated is transferred to the ventilating air of the preliminary dryer streaming over the outside. The condensate runs down into a groove and seals off the cover, and as a result also the main dryer, from the atmosphere, finally flowing off into the open. In the main dryer hot air is continually circulated in a closed circuit, while the preliminary dryer is supplied with fresh air which is heated by the return flow of the hot air in the main dryer. This intense preliminary drying enables the drying process to be carried out uniformly at low temperatures with short drying times, thus conserving the nutritious substances and vitamines. The reasons

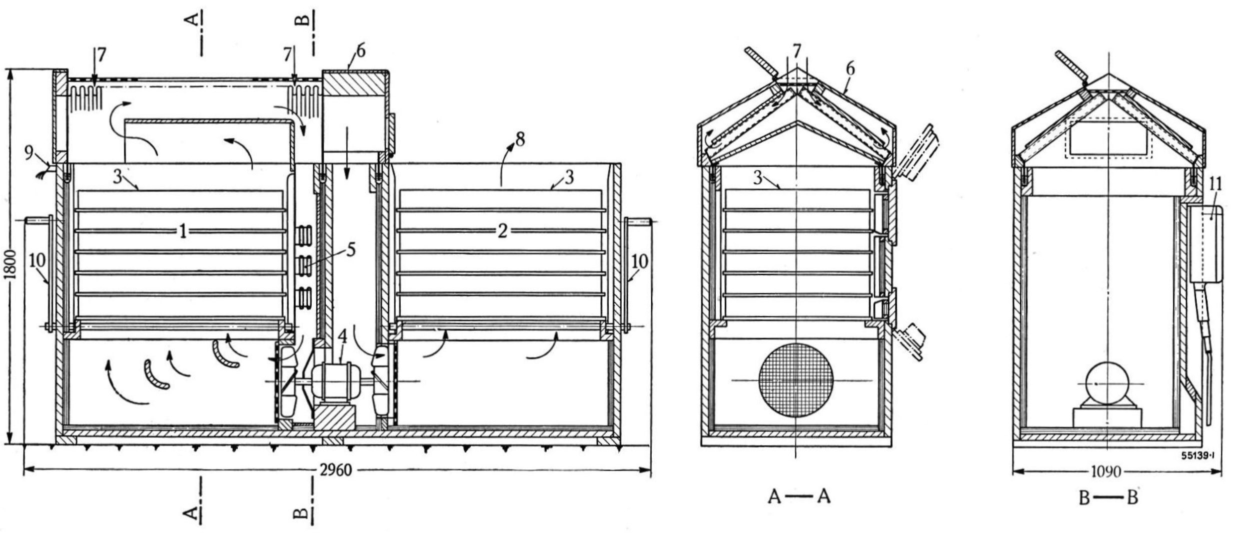


Fig. 1. — Diagram of small electric dryer for grass, fruit, or vegetables.

The cover of the main dryer forms a heat exchanger. The recuperated heat enables 50 % of the initial quantity of water in the grass or the like to be evaporated in the preliminary dryer.

1. Main dryer.
2. Preliminary dryer.
3. Trays.
4. Motor with two fans for circulation of air in main and preliminary dryers.
5. Heating resistors.
6. Cover of main dryer.
7. Fresh air inlet.
8. Air outlet.
9. Condensate drain.
10. Tray lifting device.
11. Apparatus box.

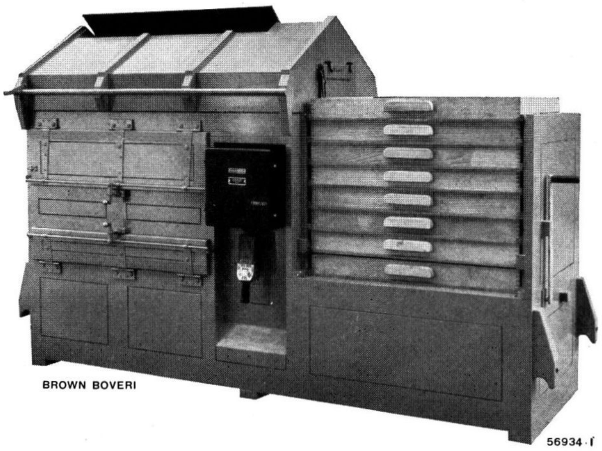


Fig. 2. — Small electric dryer for grass, fruit, or vegetables (transportable).

With a maximum input of 10 kW this apparatus delivers 50—90 kg of dried products per day of eighteen hours. It is highly suitable both for individual farms and cooperative drying plants.

for the loss of nutritive value in green material when left lying exposed to light and air are not yet definitely known and scientific investigations are at present in progress with a view to clearing up this question.

In the small dryer young green grass or clover (the latter is particularly suitable for the preparation of concentrated fodder by reason of its high albumen content) is piled up loosely on conveniently handled trays in quantities of 6—7 kg per m^2 of tray surface. The apparatus is so simple in operation that it can be left to the care of a youth. As will be clear from Fig. 2 a special lifting device is provided to raise the upper trays while the lower one is being removed. For grass drying the total tray surface is $7 \cdot 3$ m^2, but for fruit or vegetables this can be increased to approximately 14 m^2 by interposition of further trays. The apparatus has to be attended to every 60 to 100 minutes according to the goods being dried, the whole tray-changing operation taking from ten to fifteen minutes. When drying grass, therefore, about three hours daily will be needed for the attendance of the apparatus.

The daily production of the dryer in eighteen-hour service is of the order of 50 kg for green grass with a water content of 80 % or 90 kg with 70 % of water. Production is affected to an enormous extent by the water content, a reduction of 10 % in the original value resulting in an increase in production of about 75 %. This factor naturally also has an important bearing on the cost of production.

Assuming electrical energy is available at 3 Cts per kWh (Swiss currency) the production of one kilogram of dried grass will cost approximately 25 and 38 Cts, respectively, for water contents of 70 and 80 %. These values are based on a capital return of four per cent., amortization within a period of five years, an annual working period of approximately 1500 hours (100 days per annum), and the usual rates for green grass and wages.

The apparatus can also be used to advantage for the drying of fruit and vegetables. Fruit can be steamed directly in the main dryer, the condensation of the vapours being reduced for the purpose by appropriately setting the damper. An automatic regulating device prevents the temperature rising to a value liable to impair the quality of the dried product. The most suitable drying temperature for the various sorts of fruit and vegetables can be simply adjusted on a thermostat.

Several such dryers have been put into service on various farms since the middle of May this year. These include the Rossberg Farm, near Kemptthal, of the Agricultural Section of the Swiss Federal Institute of Technology, Zurich, the farm of the Brugg Agricultural School at Wildegg, and the Strickhof Agricultural School at Zurich. A further apparatus is operating on the Kiley Alp in the Bernese Oberland at an altitude of 1600 m above sea level, and supplies concentrated fodder to a large farm in the valley.

Results obtained to date prove that the small dryer produces concentrated fodder and dried fruit and vegetables of high quality, thus making a valuable contribution to the provisionment of the country.

(MS 895) *H. E. Meuche. (E. G. W.)*

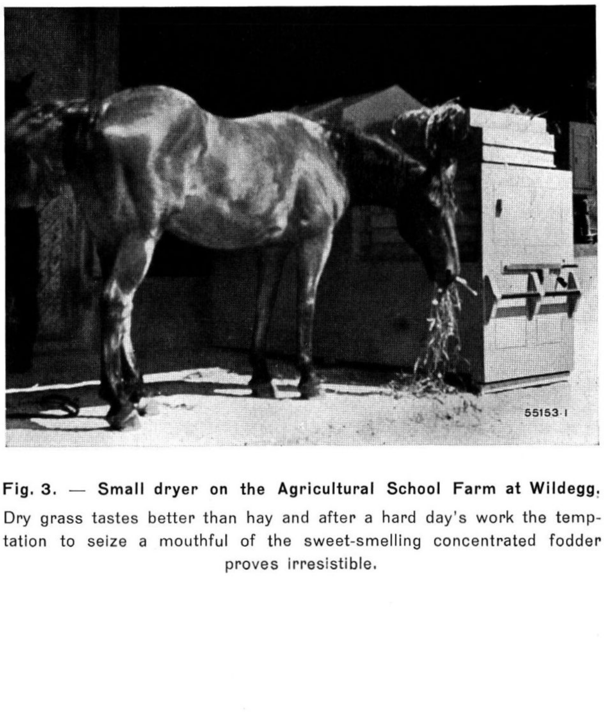


Fig. 3. — Small dryer on the Agricultural School Farm at Wildegg.

Dry grass tastes better than hay and after a hard day's work the temptation to seize a mouthful of the sweet-smelling concentrated fodder proves irresistible.

ELECTRIC TUNNEL-KILN DESIGNS.

Decimal index 621.365.413

Electric tunnel kilns are nearly always built with heat recuperation. The heat-recuperation system chosen determines the design of the tunnel kiln. From this point of view, a number of types are described in this article which also show show the various firing requirements are satisfied.

ALTHOUGH the external lines of all tunnel kilns are rather monotonous in their similarity, the interior equipment shows manifold variations. This is due, chiefly, to the firing process applied which must be strictly adhered to but which varies from one kiln to another, according to the material of which the wares being fired are made. Further, it often happens that one and the same firing programme can be satisfied by different thermal processes. The choice of the most desirable system is made on the basis of economic considerations.

In order to attain an economically satisfactory power-consumption figure with tunnel kilns, it is absolutely necessary to resort to heat recuperation. In cases in which the heat of recuperation cannot be transmitted directly or entirely to the wares to be fired going through the kiln, the waste heat is drawn off from the cooling zone in the form of hot air and made use of in another phase of the manufacturing process. Generally, drying plants for the preliminary drying of the wares to be fired offer sufficient opportunities for turning this hot air to good account.

The first big electric tunnel kilns were of the double tunnel type, with trucks bearing the wares travelling in opposite directions and in which recuperation was attained by producing a flow of heat

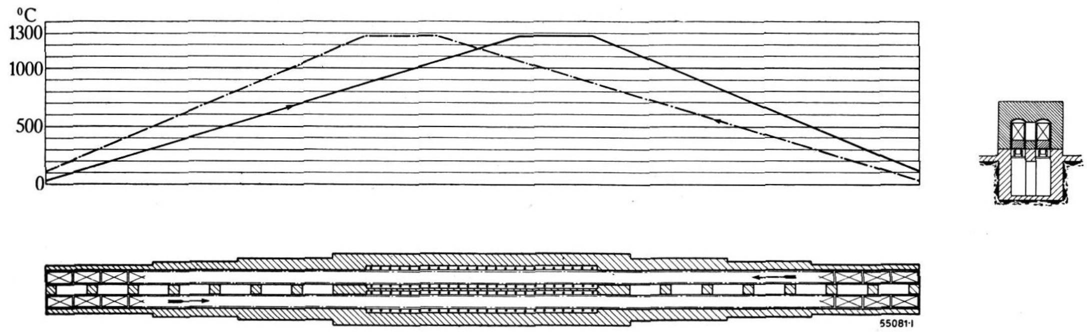


Fig. 1. — Temperature characteristics and diagram of an electrically-heated double tunnel kiln with transversal recuperation of heat.

In tunnel kilns of this type it is only possible to fire the same kind of wares in both tunnels, or the wares must be fired according to the same temperature curve; this is a consequence of the interdependence of the temperature characteristics of the tunnels.

transversally to the tunnel. The two tunnels are in direct communication with the exception of a certain length in the middle in which the high-temperature zone is located. The transversal flow of heat in the preliminary heating zone and in the cooling zone is produced by the relatively slight temperature drop which exists, transversally, from one tunnel to the other. This type of kiln can only be used for certain kinds of ceramic wares and certain operating conditions. Fig. 1 shows the temperature curves of a double-tunnel kiln of this type. It will be observed that the temperature curves are similar in both tunnels, when considered from the inlet end to the delivery end. From the middle towards both ends we get symmetrical temperature curves. They show that

In all firing processes taking place in an oxidizing atmosphere — and this applies to most of them — the variety of kiln systems to choose from is greater than when a reducing atmosphere zone is necessary. In the first case, the atmosphere in the kiln can be stationary or in movement, which leads to a variety of types. In the second case, *only* the solution with stationary atmosphere is allowable, because the reducing agent is not contained in the source of heat as is the case for fuel-fired kilns, but must be introduced separately, i. e., apart from the calories generated by electricity. It is obvious that efforts are made to economize on the amount of this foreign material, all the more so as it may have an injurious effect on the heating elements.

the branch of temperature rise lasts longer than that of temperature drop. In the transversal sense the cooling branch has higher temperatures than the corresponding ones: the heating branch of the second tunnel, in which the wares move in the opposite direction. On account of the symmetry of the temperature curves, this kind of double tunnel kiln can only be utilized when the same kind of wares, or at least wares to be fired according to the same temperature curve are treated in both tunnels. In the case of wares to be subjected to one firing process a relatively big basis of production must be available. If the wares are to be twice fired it rarely happens that the temperature curves for biscuit firing and glost-firing are identical. A further restriction in the field of the utility of the open double kiln with transversal recuperation of heat is the condition that the atmospheres in both tunnels must not exert an injurious influence on one another. The firing process generates many vapours, especially those from lead and tin oxide glazing, which, if not effectively carried off, may even damage the wares from which they emanate and do far more harm to the ceramic wares passing through the neighbouring tunnel, which are going through a quite different firing phase. Fig. 2 shows a double-tunnel kiln of the design in question.

Electric double-tunnel kilns for firing hard porcelain are in a class by themselves. A preliminary firing process is carried out to strengthen the thin walls of the pieces which are not yet glazed in order that they may withstand the glazing process proper. It takes place at 900—950° C while the high-temperature firing takes place at 1400° C and is subjected to a reducing atmosphere from about 1000—1300° C. The heating period requires about $^2/_3$ of the total firing time. For both firing processes the wares must be suitably supported on account of their very variable mechanical strength. As a result of this, double the gross weight is passed through the kiln in the high-temperature firing zone, per unit of time, than in the preliminary firing zone.

Although certain former suppositions — inequality of the temperature curves — made it seem likely that double tunnel kilns with transversal recuperation would not be suitable for the conditions in question, there is available a solution of the problem of really classical simplicity. As the requirements of the preliminary firing process are far smaller as regards space and gross firing weight as well as firing temperature than in the case of the high-temperature firing process, the exhaust heat given off by the wares having gone through the high-temperature firing process suffices entirely to cover the heat requirements for

Fig. 2. — Double-tunnel kiln for sanitary fire clay and vitreous china. Operating temperature 1280° C.

Mounting of the wares to be fired on the truck with a minimum of auxiliary and supporting material.

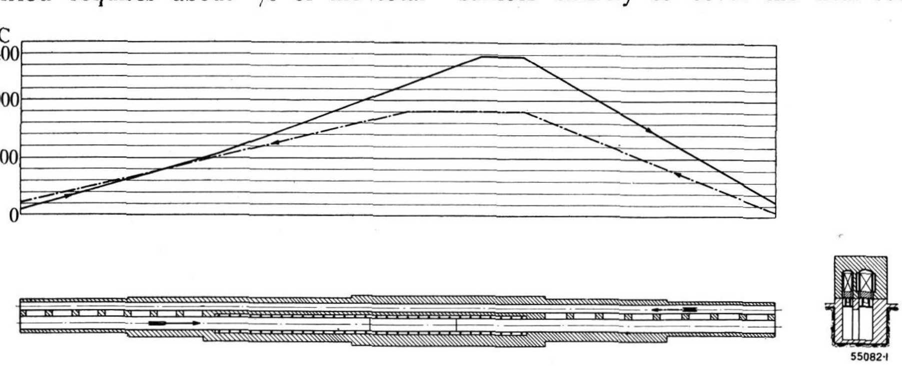


Fig. 3. — Temperature characteristics and diagram of a double-tunnel kiln for the preliminary and high-temperature firing of hard porcelain.

The very big differences between the weights and firing temperatures of wares subjected to preliminary and high-temperature firing allow of carrying out the former without additional heat.

heating the wares subjected to the preliminary firing process. The conditions will be made clear by the temperature curves of a double-tunnel porcelain kiln of this kind (Fig. 3).

A kiln was developed according to this principle, in collaboration with the Langenthal Porcelain Works (Switzerland) and put into operation in 1937 as the first big tunnel kiln in the world. Since then, two similar kilns have been built. All three units are of the same dimensions and designed for a net production of 2500 — 2800 kg of porcelain in 24 hours. They are 80—90 m long and each consumes 600 kW. 4·5 kWh of electrical energy are required per kg of fired porcelain, assuming standard charging conditions and weight ratios between porcelain and saggars. This current consumption figure includes the heat consumption for preliminary firing. The last of the three plants mentioned was also ordered by the Langenthal Works which is the best proof of the technical and economic qualities of this type of kiln. It is characteristic of the present-day difficulties Switzerland is experiencing in procuring fuel that all waste heat from the kiln no matter whether lost by radiation or in the cooling water is recuperated as far as possible by an extensive system of fans and air ducts, and is used again for drying purposes and for heating rooms. The whole works area working in conjunction with this kiln gets the heat it needs exclusively from the kiln. Fig. 4 shows the first tunnel kiln in Langenthal. The illustration is of the delivery end of the high-temperature firing tunnel.

Based on the heat-exchange processes in fuel-fired tunnel kilns, a system has been conceived which has far greater qualities of adaptability to different kinds of firing and amount of wares handled than is offered by the double-tunnel kilns just described. In fuel-fired tunnel kilns with open firing, fresh air is led through the cooling zone in counter sense to that of ware conveyance, and serves as oxygen carrier for the combustion gases. In the cooling zone this air is heated by radiation from the wares passing towards the delivery end. Coming from the firing zone, the combustion gases flow on in the same direction, that is towards the feed end of the tunnel and are led from here to the chimney. In the preliminary heating zone the combustion gases meet and heat the wares being conveyed in the opposite direction. This kind of heat recuperation has now been applied in a simple form to electric tunnel kilns. A flow of

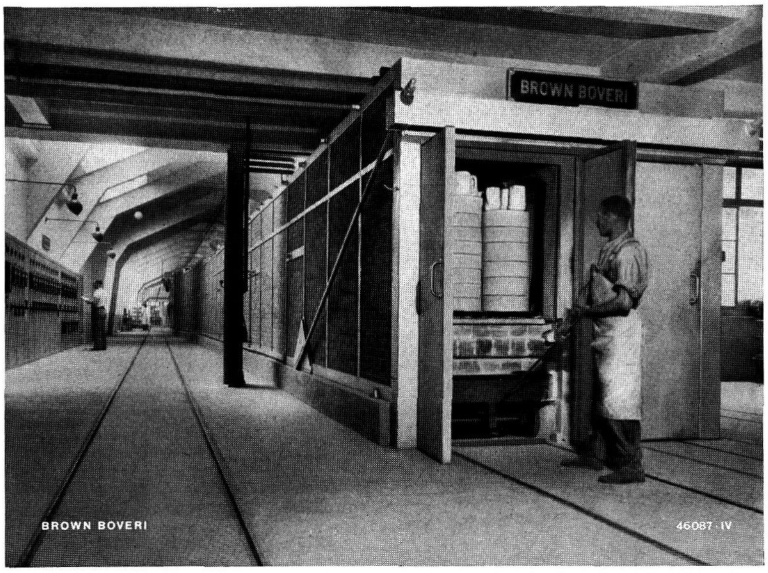
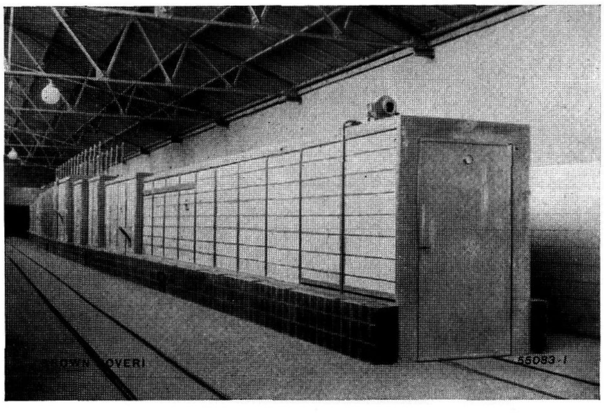


Fig. 4. — First double-tunnel kiln for preliminary and high-temperature firing of 2500—2800 kg of hard porcelain per day, in the Langenthal Porcelain Works (Switzerland).
The modern tunnel kiln is characterized by ease of supervision of the plant and cleanliness.



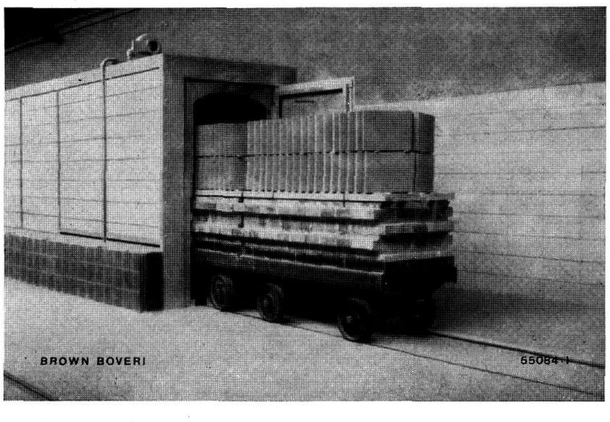


Fig. 5. — Electrically-heated single-tunnel kiln for heating ceramic building material.
The kiln is 45 m long. It works on the heat-recuperation principle by flow of air in the longitudinal sense. The same kiln is used alternately for biscuit firing and glost firing.

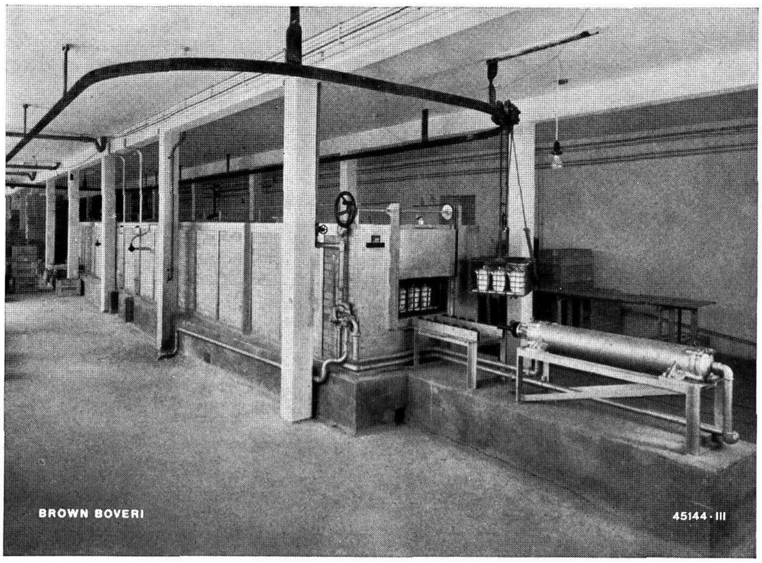


Fig. 6. — Single-tunnel kiln for the firing of decorative colours on porcelain.

Here we have a light conveying equipment instead of heavy trucks for the wares to be fired. In this way, the electrical energy required for producing 2400 kg in 24 hours is brought down to 0·22 kWh per kg of porcelain.

air artificially produced by fans is blown through the length of the tunnel in counter direction to that of the conveyance of the wares. As a result of the far stronger current as compared to purely convection currents of air which are set up by transversal recuperation, we get better efficiencies. The intensity of the air flow is however limited, as all eddying of dust particles has to be prevented. By applying longitudinal currents and, thus, of heat recuperation in longitudinal sense, it is no longer necessary to have a double tunnel in order to recuperate the heat. Indeed the double tunnel is only used where the volume of production makes it the more advantageous solution and when, in a two-firing process, the two firings must be simultaneous. In double-tunnel kilns of this kind, each tunnel works quite independently of the other and the double tunnel design is only adopted because it means a saving in building material. In the double-tunnel design as compared to the design with two single tunnels two external walls are eliminated, as well as their iron parts and, at the same time, the insulation of the middle partition is smaller than that of an outer wall. Both in the case of single-tunnel and double-tunnel kilns the temperature curve can be chosen as is considered most desirable, according to requirements, the rising branch of the curve or the falling one can be made longer or shorter. There is no restriction as regards certain conditions of symmetry as in the first type of double-tunnel kiln described. The flow of air for recuperating heat fulfils all conditions for effective ventilation of the tunnel, which is a factor of the greatest importance for certain ceramic materials undergoing preliminary firing and for all lead and tin oxide glost firing in which vapours are given off.

Fig. 5 shows a single-tunnel kiln plant for the biscuit and glost firing of ceramic building material. A special feature of this plant is that it does not take electric power from a supply system, but has a separate Diesel generator station. The management of this ceramic plant appreciated the advantages of electric heating so highly that it preferred transforming fuel into electrical energy. In 1929, the first electrically-heated tunnel kiln was ordered from Brown Boveri. This was a small unit for the firing of decorative colours on porcelain at a temperature of about 900 ° C, which was also delivered to the Langenthal porcelain works. Although it was a fairly high power consumer, owing to there being no heat recuperation, it operated to the entire satisfaction of the purchaser from the time it was put in. Two small plants for the same purpose delivered to the Norden Porcelain Works, Copenhagen (Fig. 6) and to the Norwegian porcelain works Porsgrund, respec-

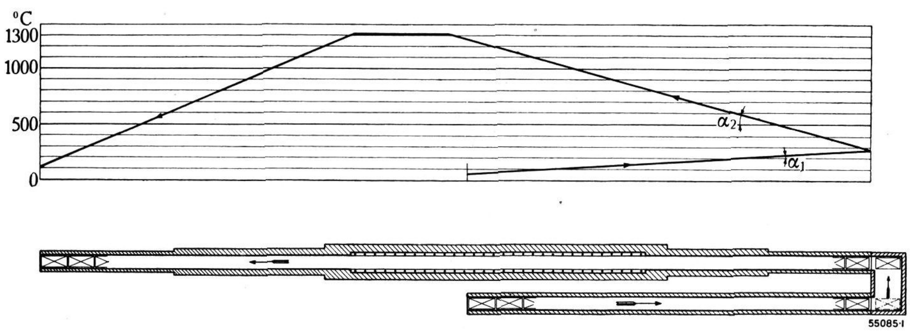


Fig. 7. — Temperature characteristic and diagram of a subdivided single-tunnel kiln for firing floor tiles of stone-ware.

The subdivision of the kiln allows of attaining a much smaller temperature gradient in the first firing zone than in the succeeding ones. Hot exhaust gas from the main tunnel is used to heat the first-stage kiln.

tively, have both got heat recuperation by a flow of air through the tunnel and work with the really exceptionally low energy consumption figure of 0·22 kWh per kilo of net porcelain. This figure is lower than the theoretical value corresponding to the heat content of the wares at firing temperatures. These plants are not built as tunnel kilns with trucks, but have metallic conveying baskets which are propelled on a roller track through the kiln by hydraulic pistons.

A very interesting design of single-tunnel kiln is applied in a kiln for firing floor tiles made of fire clay. These tiles must remain quite flat during firing and also be uniform in colour. The first requirement can only be satisfied by taking special measures for a careful heating-up process and the second one by very homogeneous temperatures. The temperature gradient must only have a relatively slight upward trend when heating up to 300 ^{0} C, but beyond this temperature can rise much more rapidly. As, in tunnel kilns, in general, there is no heating and, therefore, no temperature regulation below the 500 ^{0} C limit, the requisite modification to be imposed on the temperature characteristic cannot be attained by the usual methods. It is especially difficult to bring about a change in gradient like this in single-tunnel kilns with a heat recuperating flow of air. The desired object was attained by entirely dividing the tunnel into two longitudinal parts, the preliminary heating zone being rotated by 180 ^{0} because of space restrictions. Fig. 7 shows the diagram of a kiln of this kind. The preliminary-heating tunnel is not an independent part as it is heated by air from the main tunnel. A plant of this kind for an annual production of 15 million floor tiles is being built for a Swiss ceramics works.

The manifold uses to which the tunnel kiln can be put in the ceramics industry could be demonstrated by many other examples. Of the 15 electrically-heated tunnel kilns which Brown Boveri have built so far, only three have been replicas of existing designs. In all the other plants, the kilns have been of quite different types designed to meet the requirements of each particular case, which is a proof of the adaptability of the electrically-heated tunnel kiln to meet a great variety of requirements.

(MS 839) *O. Morger. (Mo.)*

THE ELECTRIC KILN IN THE CERAMICS INDUSTRY.

Decimal index 621.365.4 : 666.3

This article is a survey of the manifold applications of heat generated by electricity for firing ceramic wares. Taking plants already operating as examples, the article shows how perfectly the electric kiln meets the most divergent needs and allows of a more profitable operation of the plant. Years of practice prove the reliability of the electric kilns developed by Brown Boveri to meet the requirements of the ceramic industry.

THANKS to its continuous development and great adaptability, the electric kiln has won an important place for itself in the ceramics industry in the course of the last decade. It has been introduced with great success in a large number of ceramic works. In the ceramics industry, firing is that part of the entire manufacturing process which called for a maximum of reliability and skill on the part of the operators, because of the peculiarities inseparable from kiln heating by means of ordinary fuels. Thus, the ceramic manufacturer was very well served when it became possible to regulate mechanically this delicate part of the process and eliminate many uncertainties inherent to fuel firing, a development due to the introduction of electric heating in the place of fuel firing.

The field of application open to electric heating was surprisingly enlarged thanks to the successful collaboration of ceramic manufactures and electric furnace builders. Electric furnaces were designed and built to meet the requirements both as regards volume of production and type of wares to be fired. One of the chief aims was to make the best possible use of the heat generated by electricity and, when possible, to have an effective recuperating system so as to make use of the heat stored in the fired wares.

The atmosphere inside electric kilns is a pure and generally oxidizing one because there is no fuel, and thus is favourable to perfect glost firing and uniform colour effects. A really ideal uniformity in kiln temperature is attained thanks to the moderate differences in temperature between the heating elements and the interior of the kiln and the many alternatives open to the designer as regards subdivision and location of the heating elements. There is an automatic temperature regulating device which enforces the temperature characteristic it is desired to impart to the kiln during the firing process. A considerable saving in those auxiliary parts which are inseparable from firing, such as saggars and supports for the wares, is effected in many cases, thanks to a suitable kiln being available for the process.

In the following paragraphs, some electric kiln plants are described which have worked exceptionally satisfactorily for a period of several years. The advantages attained with electric kilns have indeed been so very satisfactory that many ceramic works placed repeat orders with us shortly after the first kiln had been put into operation.

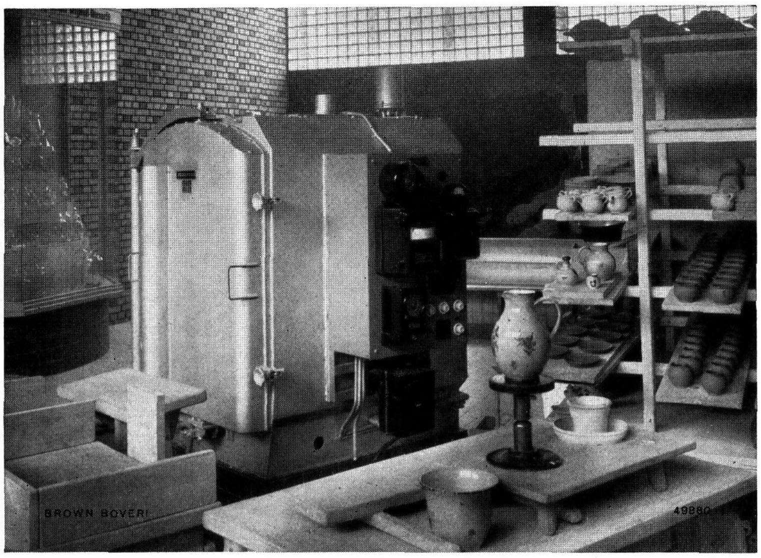


Fig. 1. — Electric chamber kiln for firing and glazing crockery and art pottery.
Maximum temperature 1050° C.
A programme regulator supervises the firing process so that it takes place exactly in accordance with the firing curve desired.

In so far as no chemical reaction originating from the glost firing or from sulphuric gases from the clay affect the heating elements, they will stand up to over 600 firings at the usual firing temperatures of 960°—980° C. There are adjustable vents in the floor and roof to allow water vapour and vapour from glost firing to escape during the heating-up process; they also allow of rapid cooling down of the wares. As a rule, the wares fired are cooled down in about 24 hours to the temperature at which they can be taken out of the kiln, so that a kiln can be switched in every second night. Two chamber kilns working in cyclic sequence and each of 0·75 m^3 capacity are able to deliver about 5 m^3 of fired wares per week at a yearly consumption of electric energy of 80,000 to 90,000 kWh. The chamber kiln shown in Fig. 2 is especially suitable for pottery wares and art pottery works, where several kilns work in cyclic sequence. The chamber kiln of Fig. 3 is also worthy of note; it is for firing hard porcelain at 1410° C. It is used as a test kiln beside tunnel kilns in big ceramic works and can also be used for special firing of art porcelain wares. On account of its high operating temperature, its heating elements are silicon carbide rods. A reducing atmosphere can be produced by special devices.

The electric truck type kiln has proved very satisfactory for firing ordinary crockery. The wares are loaded

Figs. 1 and 2 show electric chamber kilns for maximum temperatures of 1000 and 1050° C, respectively, for firing and glost firing art pottery and for colour firing on porcelain or glass wares. These kilns do not operate continuously. The firing process is generally carried out at night when low electric metering tariffs are available. The furnace has automatic temperature regulation with a time switch so that the firing process is automatic and demands no supervision. Thus, for example, the kiln is switched in at 9 p. m. and after about nine hours, which it takes to heat it up to the maximum firing temperature, and to attain a uniform temperature in the muffle, it is cut out at 6 a. m. Special kinds of firing or the firing of thick-walled wares is carried out according to a relatively flat temperature curve which is supervised by a temperature regulator with additional firing-programme regulator (Fig. 1). For potteries and art pottery works the chamber kiln with a firing chamber capacity of 0·5 to 0·75 m^3 has given excellent results and been practically standardized. It offers an optimum as regards easy and rapid charging and usually allows of carrying out the firing process within the low metering tariff period of the day.

The heating elements are composed of heat-resisting metal alloys lodged in fireclay stones so that they cannot be touched while radiating heat freely. This favours the length of life of the elements.

Fig. 2. — Four electric chamber kilns each of 0·5 m^3 firing chamber capacity, used for firing and glazing art pottery at 1000° C.

Each set of two kilns works in cyclic sequence making use of cheap night power. The switching apparatus common to each pair of kilns is switched over alternately to the kiln charged with wares. Thus, even medium-sized works can be operated on the continuous-process system.

on the truck outside the kiln, as shown in Fig. 4, and are then subjected to the heat radiating freely from the heating elements which are lodged in all four walls of the kiln. Experience shows that a clay of high chalk content, as used for most crockery, can be subjected to relatively rapid temperature fluctuations in the range of 0—400 ° C without harmful results. This allows of operating a truck kiln in a 24-hour firing cycle, approximately as follows:— At about 6 p. m. the truck charged with raw glazed wares is run into the kiln, which has cooled down to 350 ° C, here the wares are heated up to about 200 ° C in the course of the next two or three hours. The heat stored in the walls of the kiln serves, here, as source of radiating heat. After about three hours, the kiln is switched on to the supply again and the wares heated up to 980 ° C according to the determined firing curve. As a rule, the firing process is terminated at 6 a. m. at which hour the heating is cut off automatically and the kiln cooled down until the next charge is run in. The plant shown in Fig. 4 has a daily production of 2·4 m^3 and an energy consumption of about 750 kWh per firing process.

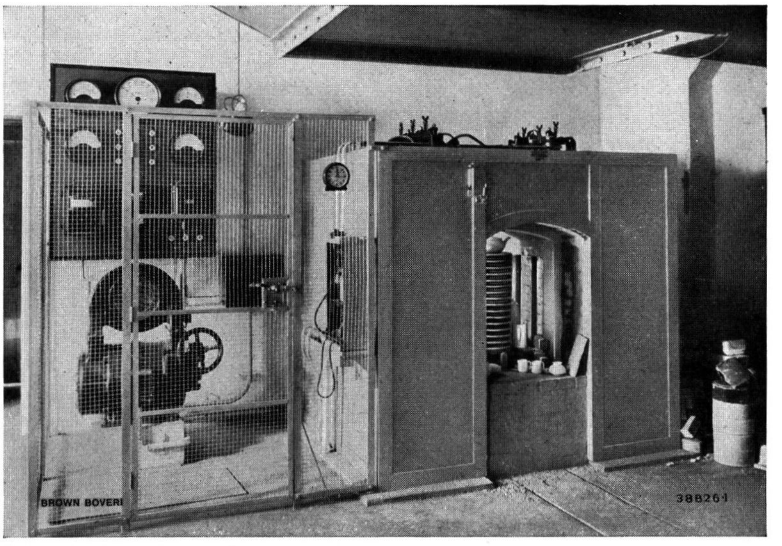


Fig. 3. — Electric chamber kiln for 1410° C used for firing porcelain.

Put up for testing purposes beside a big tunnel kiln and also used for firing artistic ceramic work, this kiln is a much appreciated firing apparatus.

The electric continuous tubular or duct type kiln shown in Fig. 5 is used for the glost firing of wall tiles. Apart from the relatively low plant cost and simple attendance, the chief advantage lies in the exceptionally low electric energy consumption of this kiln. The separate tiles are pushed through the firing ducts one after the other from the feed end and subjected uniformly to the desired firing temperature. In this way, the wares being fired are treated without supporting parts. In most works, wall tiles are still fired in multi-storied frames which are subjected to much wear and must also be heated up to the highest firing temperature. The duration of firing in electric tubular kilns is 6 to 8 hours, while it is 50 to 60 hours in ordinary round and tunnel-type kilns. When the heating elements are properly laid out and the power properly distributed the desired temperature is maintained constant automatically in each duct. The cooling down of the tiles takes place in the kiln with a corresponding gain by heat recuperation so that the finished glazed tiles are delivered at the end of the furnace at about 100 ° C. The electric multi-tubular kiln shown in Fig. 5 has 48 pusher-type ducts and can fire 6900 tiles measuring 150×150×10 mm. For 1000 °C firing temperature the energy consumption is about 22 kWh per 100 kg of wares.

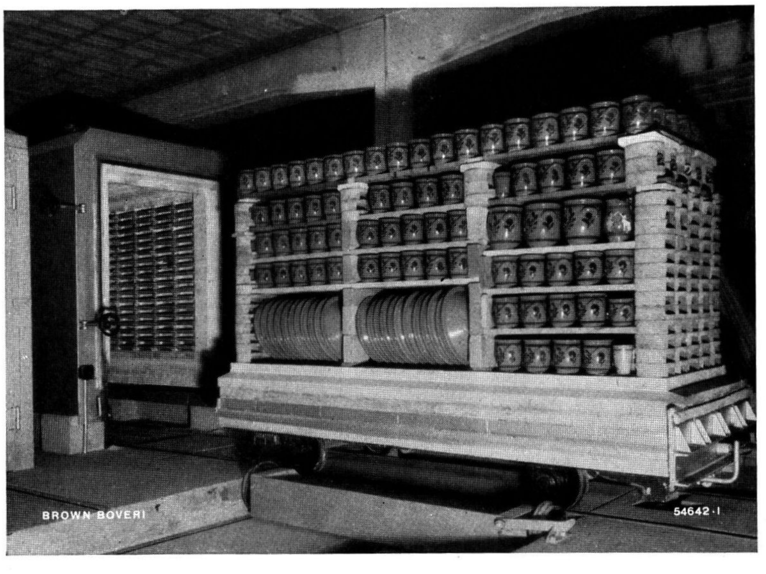


Fig. 4. — Electric truck kiln for firing crockery.

Maximum temperature 1100° C. Firing chamber capacity 2·4 m^3.

By using two charging trucks and by operating in 24-hour cycles, this kiln has a weekly output of 17 m^3. This type of kiln is an interesting innovation and has already been introduced successfully in different plants.

The principle of the tubular or duct kiln is not new in itself and many such furnaces are being run in various parts of the world, using oil or wood for heating. The disadvantage of fuel-fired kilns are, chiefly, the difficulty of regulating the temperature in the various ducts, a defect which has been overcome by electric heating. The practical advantage of electric heating is a drop in the quantity of imperfect wares produced and less material scrapped.

As regards mass production of ceramic wares, there has always been a desire to have some kind of continuous firing process and important firms have put up continuous process tunnel kilns to this end. There

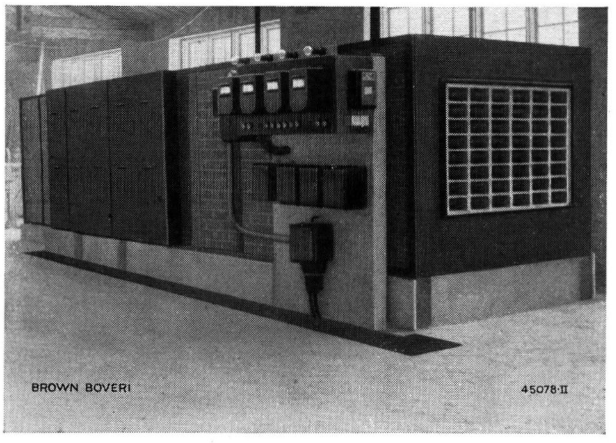


Fig. 5. — Electric tubular kiln for glazing wall tiles.
Maximum temperature 1050° C.
The advantages of this kind of kiln are low cost of plant, small power consumption, and elimination of saggars and other supports.

are numerous tunnel kilns for ceramic firing now in operation. In 1931, Brown Boveri took up the study of the electrical heating of tunnel kilns. From exhaustive studies and tests carried out on small kilns, sufficient data was collected, so that, in 1933, an electric tunnel furnace, 40 m long, for a firing temperature of 1300° C was built and put to work; it is used for firing stone ware. The experience gained with this kiln confirmed the hopes of ceramic circles as regards results and advantages inherent to electric heating and opened up a promising field of expansion for the electric tunnel kiln. For firing sanitary stone ware and vitreous china as well as for earthenware, porcelain and steatite a further 10 big tunnel furnaces up to 110 m long have been built.

The most interesting and also the most complicated electric tunnel kiln of this kind is the big unit for the biscuit and glost firing of hard porcelain.

After five years experience with the first tunnel kiln the Porzellanfabrik Langenthal (Switzerland) ordered a second one for the same power but with the latest improvements. Fig. 8 shows the big tunnel kiln II at the moment a glost-firing truck is entering the kiln, the wares on which will be fired at about 900° C. The firing tunnel on the right, the doors of which are closed, is used for biscuit firing at temperatures up to 1410° C. The system of tubes, which is also shown, is for carrying off waste heat to be used for drying.

The electric heating elements are lodged in the firing zone of the biscuit firing tunnel. These elements form a big number of regulating groups controlled independently. All the heating elements are so built that they can be replaced without cutting out the kiln. For the temperature zones up to 1200° C, the heating elements are high-grade metallic resistance alloys. For the higher temperatures ceramic semi-conductive rods are used. They have the property of getting increasingly resistant the longer the kiln is used. For this reason, the heat input to these resistances is regulated automatically to the desired value with the help of regulating transformers with progressive regulation (Fig. 6). There are thermo-elements to measure the temperatures in the different zones and recording measurement devices to give the temperature characteristic. By a suitable system of connections of the control devices the temperatures in the different regulated zones are kept automatically constant, so that it is possible to have a temperature curve in the firing ducts which follows the temperature characteristic it is desired to obtain with great precision.

The kiln atmospheres requisite for biscuit firing can be supervised in every respect in electric tunnel kilns and can be made to suit the firing programme applied. The oxidizing atmospheres are attained without artificial aid as there is no fuel used here. The limiting and the maintenance of reducing atmospheres, however, is a more difficult matter and this is necessary in firing porcelain at 1000 to 1300° C. Mechanical limiting devices, which can be adjusted as required, placed at the beginning and end of the reduction zone prevent the reduction gases escaping along the length of the

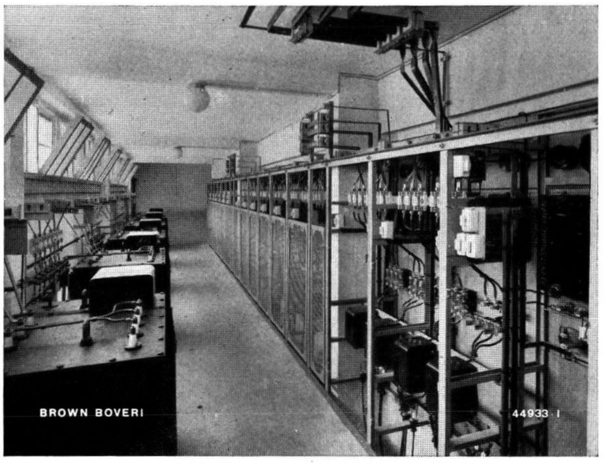


Fig. 6. — Low-voltage regulating transformers and rear view of switchboard for a big electric tunnel kiln for hard porcelain.
The control gear is mounted on a common panel so as to be easy to supervise. Its ready accessibility helps to increase the reliability of the whole plant.

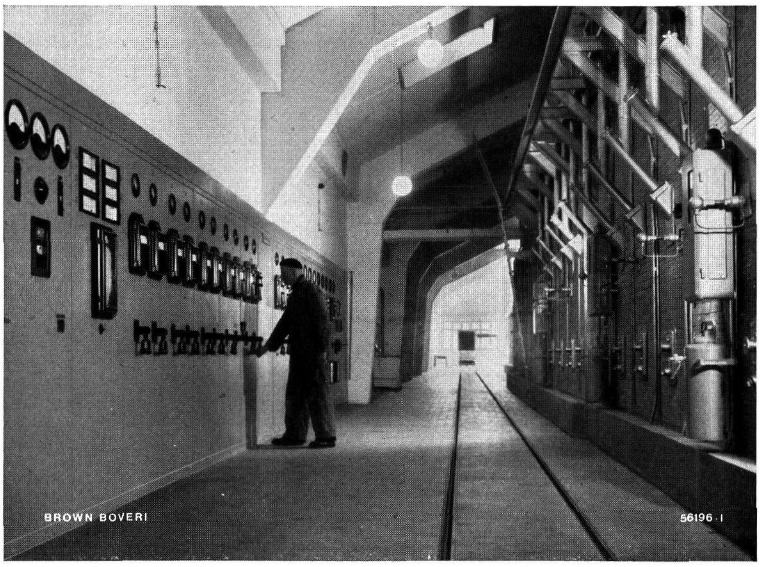


Fig. 7. — Big electric tunnel kiln for hard porcelain.

The numerous instruments on the operating panel facilitate supervision of the whole complicated firing process.

kiln and thus provide the satisfactory technical solution sought for. The reduction gases are generated very simply by introducing regulated quantities of small blocks of wood into the kiln. These gasify and thus

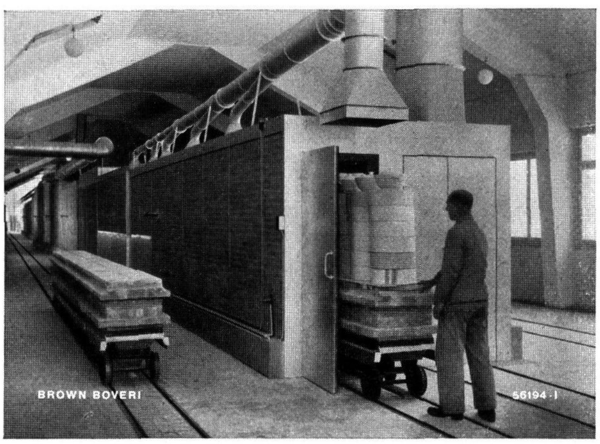


Fig. 8. — Electric double tunnel kiln for glost and biscuit firing of hard porcelain.

Operating temperature 1410° C.
Length of kiln 90 m.

Light saggars are used in electric tunnel kilns and as there are no flaky ashes the top saggars are not required. Building up the saggars on the truck is carried out in the well-lit kiln hall and the slow work associated with round kiln operations is avoided (see Fig. 9).

generate the proper reducing atmosphere. There are recording devices which allow of constant control of all conditions necessary for carrying out the reducing process properly (Fig. 7). The consumption of fuel for generating the reducing atmosphere is small and plays hardly any part in the overall operating costs of the kiln.

Experience shows that the firing grates of fuel-fired kilns have to be overhauled periodically, as well as the brick-work which comes into contact with the flames. This overhauling work is reduced to a minimum in electric kilns thanks to the relatively low temperatures of the walls and also because there are no flaky ashes. On the other hand, operating costs are influenced by the upkeep of the heating elements which are naturally subjected to wear in the higher temperature zones. The savings effected by the longer life of the saggars in electric kilns counterbalance the outlay for renewal of heating elements. Thanks to the progressive character of the heat distribution along the tunnel in electric kilns the saggars last 5 to 15 times longer than they do in coal-fired kilns. The making of new saggars is a relatively big factor in estimating the operating charges of a kiln and big savings are effected by the reduced wear of the saggars.

In order to compare the economic qualities of electric and fuel-fired kilns, the cost of heating is

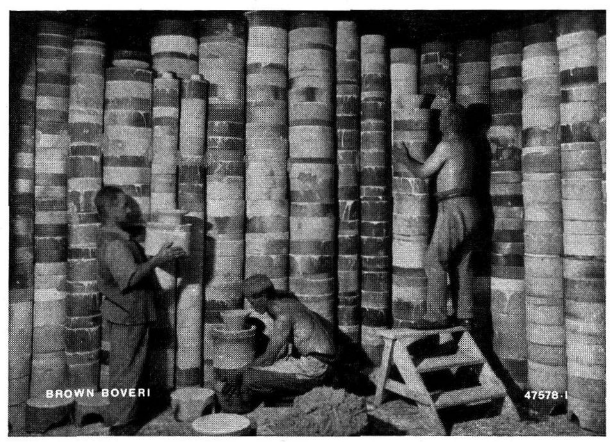


Fig. 9. — Mounting the saggars in a coal-fired round kiln for burning porcelain.

This firing method, still common to-day, necessitates the piling up of the heavy saggars into high stacks, thus resulting in serious loss of time. In the case of electric kilns this strenuous work, which has to be carried out in the hot kiln, is greatly facilitated by reason of the lower stacks and the lighter saggars.

not by any means the only factor to be considered, and this is especially true of the ceramics industry. When all the advantages inherent to electric kilns in the ceramics industry are taken into account, it is easy to understand why the electric kiln has reached such a pre-eminent position in this industry.

(MS 838) *H. E. Meuche. (Mo.)*

ELECTRIC LEERS FOR ANNEALING GLASS.

Decimal index 621.369.6 : 666.1.038.2

The thermal treatment of glass-ware to remove internal tensions demands the fulfilment of certain conditions, the exact observance of which has a great influence on the fragility of the wares and the amount of material which has to be scrapped. The electric leers described here fulfil these conditions to a very satisfactory degree.

THE cooling down of objects made of glass is not a uniform process because thin parts are no longer incandescent when the manufacturing process ends, while the thicker parts will be at varying degrees of incandescence. If a glass article of this kind is left to cool down further under the influence of air, it generally bursts into a number of pieces, as a result of the inner tensions it is subjected to. If the shape of the object is very favourable to uniform cooling, it may cool down entirely without bursting. Nevertheless it will remain very brittle on account of the inner tensions which have not been eliminated, and a slight shock suffices to break it into numerous pieces or even to reduce it to a fine powder. This phenomenon is turned to industrial advantage in the manufacture of Sekurit (a splinter-proof) glass.

A slow plastic deformation of the hot glass is necessary in order to equalize the internal tensions. There is a determined limit temperature for each glass composition below which no plastic deformation takes place. It is, therefore, of vital importance that, when cooling down, the glass object should pass through this critical temperature zone in a state in which the inner tensions have been eliminated as far as is possible.

In the thermal treatment of glass objects, there are four phases to be distinguished.

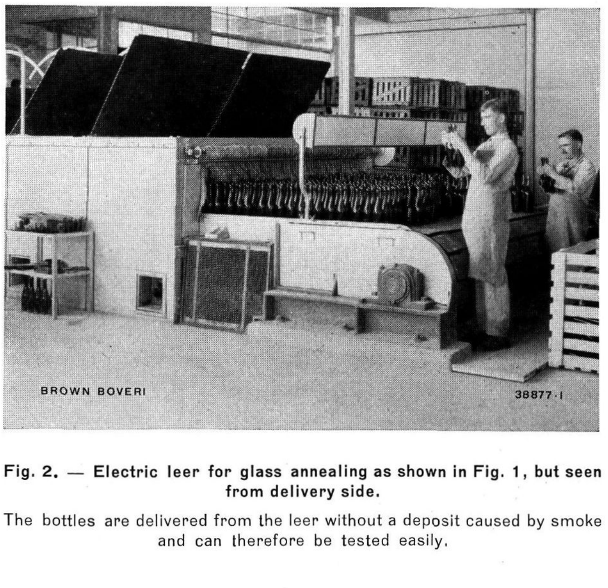


Fig. 2. — Electric leer for glass annealing as shown in Fig. 1, but seen from delivery side.

The bottles are delivered from the leer without a deposit caused by smoke and can therefore be tested easily.

1. Equalization of the temperatures.
2. Gradual equalization of the inner tensions under temperatures which are the same for the whole piece.
3. Uniform cooling of the whole article down to the limit temperature of plastic deformation. Owing to the low heat conductivity of glass, the cooling process must be a very slow one.
4. Final cooling down to the temperature of the hand. This latter cooling stage can be carried out somewhat more rapidly because the inner tensions due to differences in temperature vanish entirely when the cooling process is terminated. If, however, the last cooling stage is too abrupt, the inner tensions can attain magnitudes which cause the article to burst.

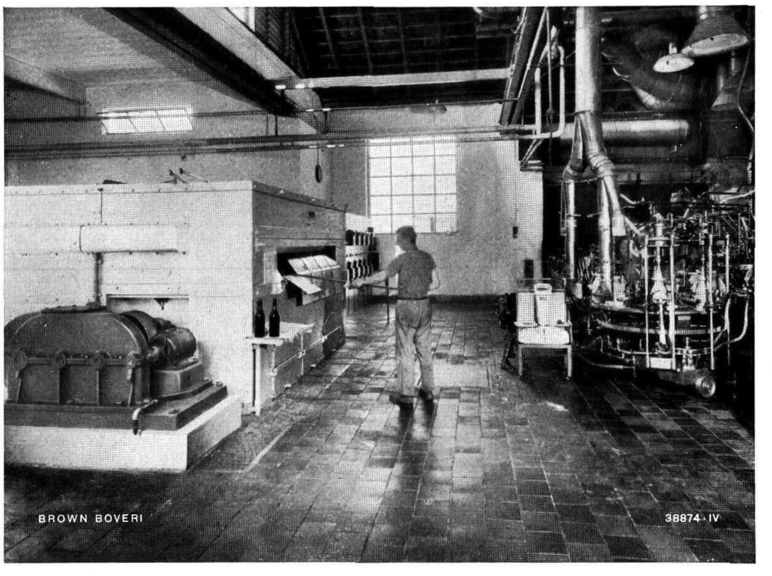


Fig. 1. — Electric leer for glass annealing with conveying belt. Seen from charging side with the bottle machine beside it.

Electric heating of glass-annealing leers allows of maintaining exactly the best cooling temperature curve. This means better quality products and less material scrapped.

The production of a glass melting furnace is continuous and considerable, amounting to 1000 kg/h. The thermal treatment requires 5 to 8 hours. The leers required for this process are, therefore, fairly big. As the glass wares are placed in the leer in hot state, they do not absorb much heat. It is, however, necessary that a determined temperature curve during the treatment be adhered to as exactly as possible. This condition makes electricity a very suitable heating agent and, for many years, electrically-heated leers have been used in numerous glass works although gas from the generators of the melting furnaces is available for heating.

In the following paragraphs, we give a short description of two plants which have been put up in a Swiss glass works at an interval of 8 years one from the other.

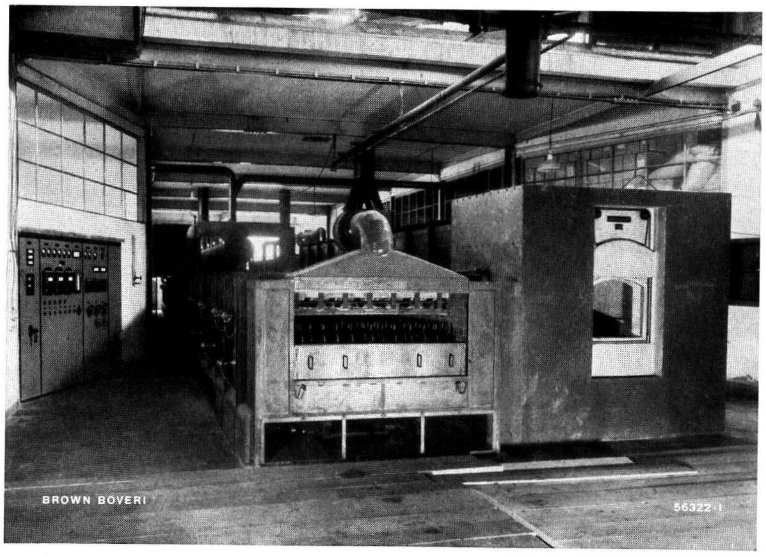


Fig. 3. — Two electrically-heated glass-annealing leers with intermeshed, alternate movement of two conveying grids, seen from charging side.
No energy expended to heat the conveying gear as the different sections of the grid remain at constant temperature. Minimum of electric power consumption.

Fig. 1 shows the feed side of the first of these leers in which glass bottles are treated. The bottles manufactured by machinery are conveyed mechanically to the leer in a hot state, the supply-side opening of which is provided with swing doors.

The conveyance of the bottles through the leer is performed by a travelling grid belt made of perforated metal sheeting, which is 2·5 m wide and 29 m long. It is maintained in constant motion by variable speed d.c. motors. Fig. 2 shows this grid-belt at the delivery end of the leer where the bottles, cooled down, are taken out and tested.

In order to maintain the proper distribution of temperature in the leer, there are heating resistances built into it, the total power input capacity of which attains 100 kW. The average power input varies between 70 and 80 kW for a standard charge of 1000—1500 bottles, that is to say for 700 to 900 kg of glass ware.

The switchboard panel visible in the background of the first illustration contains the automatic temperature regulator for the various groups of heating resistances. The temperature distribution in the cooling zone of the leer is chiefly effected by regulating a number of hot-air outlets. Part of this hot air is blown under the travelling grid-belt on its return travel which allows of recuperating a considerable part of the heat required to heat the grid.

This leer has been working for 8 years for about 10 consecutive months per year. During all this time, no defect occurred which was serious enough to make it necessary to put the leer out of action.

Despite these satisfactory results, a new type of conveying gear was used in two new leers, with the object of attaining the lowest possible power consumption. This system comprises two grids which are intermeshed and perform small cyclic alternative movements, first one and then the other taking over the advance of the incandescent wares. In this way, each section of the grid remains at a given temperature and the amount of heat required for continuously reheating the conveying belt is no longer required.

One of these two leers, which are placed beside one another (Figs. 3 and 4), is used for annealing bottles and small glass flasks of the most varied kinds, while the other one is used for big glass containers. The widths of the grids are 1·5 m and 1 m, respectively, the length being 29 m in both cases. The electric power input is 65 kW and 45 kW respectively.

Fig. 4. — The two glass-annealing leers shown in Fig. 3, seen from the glass delivery side.

In the leer used for bottles, hot air is tapped from the cooling zone and led to below the grid at the feed end of the leer so that the bottles set down are subjected to a current of hot air before they are slowly conveyed into the interior of the annealing chamber.

The leer for big glass containers has an anti-chamber with sand floor in which the containers are first deposited before being taken further and placed on the moving grid. Under this chamber there is a second one to keep the tools, which are necessary for moving the wares, at a suitably high temperature.

The two new leers are to be supplied from one single melting furnace which, unfortunately, has not yet been put into operation owing to the present scarcity of coal. It is expected that the new leers will show a reduction in consumption of electric power of 20 to 25 % per kg of wares treated, as compared to the consumption of the earlier plant.

(MS 836) *P. Schlenker. (Mo.)*

BEHAVIOUR OF NON-SCALING STEELS AT HIGH TEMPERATURES.

Decimal index 669.018.82

In furnace construction the question of materials deserves particular attention due to the exacting conditions obtaining. Apart from being resistant to furnace gases, a non-scaling steel should also be sufficiently heat resistant and tenacious. The influence of oxygen, carbon, nitrogen, and sulphur on special chrome-nickel steels is briefly shown by means of a number of examples. An exact knowledge of structural and mechanical changes in materials is essential for the successful construction of furnaces.

IN the construction of high-temperature furnaces the question of materials is far more important than in most other branches of electrical engineering. This is chiefly due to the fact that the various processes, such as reduction in strength, structural changes, oxidation, diffusion, etc., which at low temperatures take place extremely slowly and are often of little importance, increase very rapidly in intensity with rising temperature and affect the life of the component to a decisive extent. The heavy intensification of the reactions gives the resulting material changes quite a special character.

The main points to be observed when selecting materials can be grouped approximately as follows: —

Resistance to oxidation and to corrosion by any gases which may be present.

Heat resistance sufficiently high to withstand operating stresses and ensure stability over a long period, i. e., no embrittlement.

Technological fitness for manufacture, e. g., good bending and welding properties.

The necessary non-scaling property, i. e., resistance to oxidation, can, in certain special cases, be imparted to the steel by surface treatment, e. g., by calorizing. This consists essentially in producing on the surface a highly aluminous coating which finally forms a dense protective film of aluminium oxide. Both its life and its resistance to high temperatures are restricted, however, for the thickness of the aluminium coating is limited. Permanent non-scaling properties can only be obtained by alloying the material with suitable elements, the best of which is chromium. This has become an indispensable alloying element for all furnace metallic structural materials. Its effect can be augmented by adding silicon and aluminium. Each temperature entails a certain percentage of alloying element to maintain non-scaling properties, the proportion of chromium attaining its upper limit at approximately 30 % for 1200° C. No matter what percentage of, for instance, nickel can compensate for too little chromium, as shown by the example in Fig. 1. The alloy in question here has a composition of 80 % Ni, 5 % Cr, and 15 % Fe, and with a temperature of only 850° C lost nearly 60 % of its strength through intense inter-crystalline oxidation after a relatively short working period.

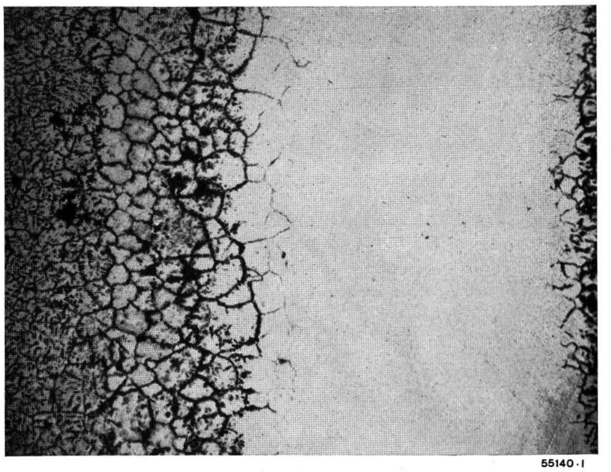


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Fig. 1 — Effect of oxygen on steel with inadequate chromium content. Heavy inter-crystalline oxidation (cross-section, unetched). (Magnification × 25)

Apart from oxygen, other gases can attack steel. A case in point is the deleterious effect of sulphurous

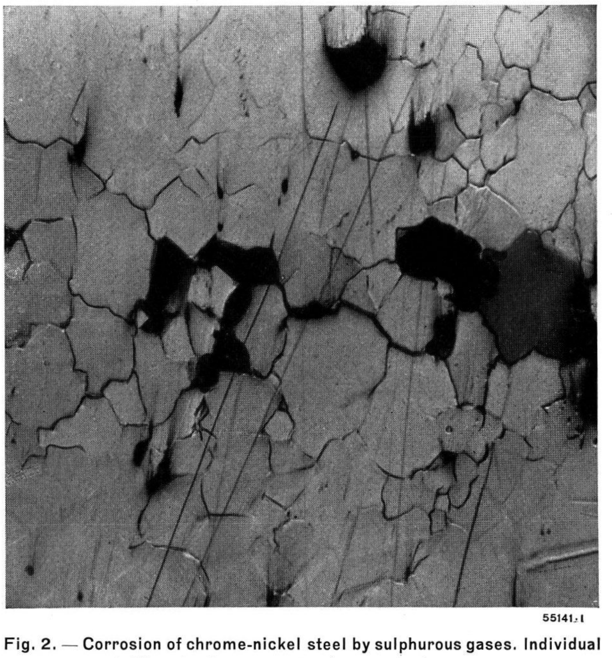

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Fig. 2. — Corrosion of chrome-nickel steel by sulphurous gases. Individual crystallites broken away (surface ground specimen). (Magnification × 100)

furnace gases on alloys containing a high percentage of nickel, where inter-crystalline destruction takes place to a great depth, often without external visible loss of material. Fig. 2 shows an instance of this. Chromium steels with only a small percentage of nickel or no nickel inclusions whatsoever are resistant to these gases however.

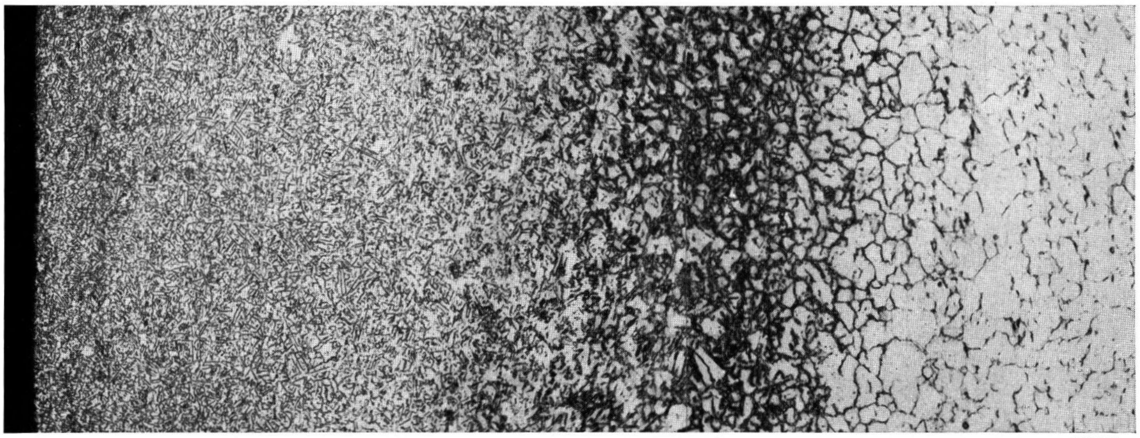

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Fig. 3. — Effect of hydrocarbon gases: Carburization advancing from left and carbide formation, in cross-section. (Magnification × 100)

The carburization of steel in a reducing carbon atmosphere is of particular importance. The chrome carbides formed absorb so much chromium from the steel that the non-scaling property of the latter drops below the resistance limit. At the same time the material may become brittle. An interesting example of carburization is shown in Figs. 3 and 4. An externally heated vessel, constructed from 3·5 mm plate, contained a carburizing gas, the outside being surrounded by air. Carburization set in on the inside and gradually permeated the entire plate. Fig. 3 depicts the carbide formation advancing from left to right in a section through the plate. When the carburizing process finally reached the outside of the plate, the latter began to scale heavily in the air, while the inside, in contact with the reducing hydrocarbon gases, remained entirely unaffected. This is particularly marked in the case of the welds (Fig. 4), the inside (left-hand view) still having highly pronounced contours, while the outside (right-hand view) is far less sharply defined, due to scaling.

Nitrogen also reacts with steel at very high temperatures, diffusing into the steel structure to a considerable depth and forming nitrides. The structural features, however, are different from those encountered in the nitriding process for hardening low-alloyed structural steels. Given certain conditions the steel may be greatly impaired. On the one hand, the chromium content of the matrix may be reduced, while on the other the increase in volume due to the nitration appears to cause violent local stresses in the structure. From a metallographical point of view the different nitrides formed by the various alloys are very interesting. In the case of a steel with 0·05 % C, 18 % Cr, 8 % Ni, and 0·43 % N_2 a pronounced nitrogen perlite (Fig. 5) was produced which was hardly to be distinguished from a carbon perlite of ordinary mild steel. Here, too, the structure was found to have become broken up, while cracks had also formed. In a steel with higher percentages of alloying elements, i. e., 0·02 % C, 22 % Cr, 20 % Ni, and 0·29 % N_2, grain boundary nitrides and nitride needles, as shown in Fig. 6, were produced. These, however, appear to affect the strength of the material to a far less extent.

55143·Ia 55143·Ib

Fig. 4. — Effect of carburization: On the inside (left) highly pronounced contours, not oxidized; on the outside (right) less sharply defined contours due to scaling.
(Magnification × 1)

The above notes do not nearly exhaust or describe all of the reciprocal effects possible between furnace atmosphere and furnace structural steels. There still remain the consequences of steam, pressure, and catalytic effect of solid foreign matter, such as lime and carbon, on oxidation, but these are beyond the scope of this article.

The branch of metallurgy chiefly occupied with this field in recent years has succeeded in finding a remedy for all of the foregoing effects and failings, either by varying alloying constituents, adding alloying elements, or suitably pre-treating the material. Improved operating performance, however, must not be obtained at the cost of technological properties. Sheet metal

Fig. 5. — Effect of nitrogen: Nitrogen perlite in an austenitic steel with 18 % Cr and 8 % Ni.
(Magnification × 100)

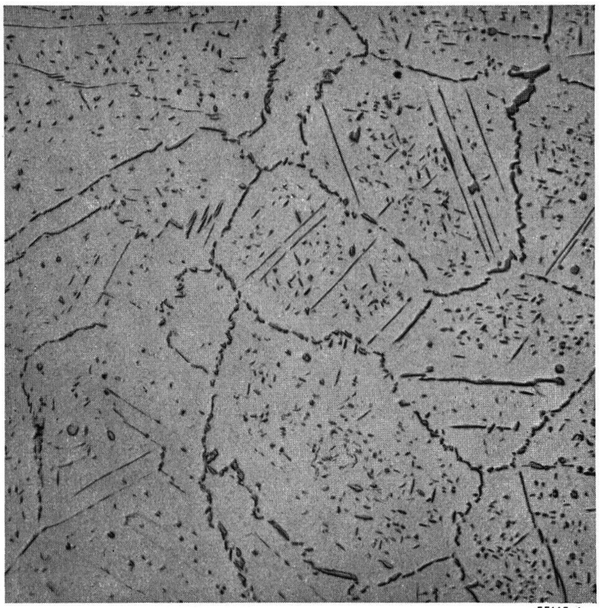


Fig. 6. — Effect of nitrogen: Nitride needles and grain boundary nitrides in an austenitic steel with 22 % Cr and 20 % Ni.
(Magnification × 100)

for linings or pots must still have good bending, and possibly also, beading properties, while a high degree of weldability is likewise now imperative for practically all furnace constructions. In the case of certain castings (alloy castings containing a high percentage of silicon) the machinability may prove a deciding factor.

The mechanical strength of nickel-free, pure chrome steels at elevated temperatures (creep strength) is extremely low. It can be substantially increased, however, by the addition of nickel, although not less than 8 % is usually necessary. The chief thing is to obtain another type of structure, i. e., the austenite, having much higher creep strengths (or resistance to deformation at elevated temperatures) than the ferrite of the chrome steel. Although nickel — sometimes together with tungsten — has proved particularly suitable, manganese and nitrogen can also be used for the same purpose, thus enabling large quantities of nickel to be economized when this element is difficult to obtain. Like the resistance against chemicals the strength also decreases extremely rapidly with increasing temperature. The result is distortion (bending, extension) and cracking. When continuously heated, certain steels are subject to structural changes, such as carbide precipitation, grain growth, and other instability phenomena. In conjunction with these a certain embrittlement zone may be produced, the temperature range within which it occurs being governed by the composition of the steel and the treatment to which it has previously been subjected.

This enumeration of the changes possible in metallic furnace material under special conditions may create the impression that the furnace designer is faced with practically insurmountable difficulties. That such is not the case, is proved by the ever-increasing number of electric furnaces to be found in trouble-free operation in all branches of industry from year to year. In the foregoing an effort has been made to show how multifareous are the demands made on these materials and how thoroughly the operating conditions must be studied to prevent impairment of non-scaling steels. The means are available, but to exploit them and apply them correctly a thorough knowledge of the individual materials is essential. Only collaboration between furnace operating staff, designer, and metallurgist can ensure an absolutely reliable design.

(MS 896) *H. Zschokke. (E. G. W.)*

THE UTILIZATION OF ELECTRICITY IN CREMATION FURNACES.

Decimal index 614.62

The electrical heating of cremation furnaces meets more an desthetical and hygienic than a purely technical need. Apart from fulfilling all idealistic requirements the modern electrical cremation furnace permits of very economical operation.

HEAT generated by electricity in place of fuel can, speaking generally, be considered as a technical advance. However, the demands made on electrical heating when applied to cremation furnaces are chiefly of an aesthetic nature, which, in this case, outweighs the economic side of the question.

These demands can be summarized in the four following conditions:—

1. Cremation must be carried out solely by superheated air and not by the introduction of incandescent gases into the furnaces.
2. Cremation must be as rapid as possible, it must be complete and carried out with as little smoke as possible.
3. Up till the moment at which the ashes are removed, cremation must take place without manual intervention.
4. All written and unwritten laws of aestheticism and hygiene must be strictly observed from the beginning to the end of the cremation process.

It is chiefly the first of the four conditions just enumerated which was not entirely fulfilled up till today by even the latest types of fuel-heated cremation furnace. The electric cremation furnace satisfies these demands entirely, which explains why the initiative towards introducing electric cremation furnaces originated from the advocates of cremation and not from industrial circles.

A rapid historical survey shows that the first patents on electrically-heated cremation furnaces were taken out in the United States. At that time, the designs were based chiefly on purely electro-technical and economic considerations, and for this reason never found a practical application. The Cremation Association (Feuerbestattungs-Genossenschaft) of Biel (Switzerland) took the initiative of building an electrically-heated cremation furnace in 1928/29 and a contract was drawn up between the said Association and Brown Boveri in 1932 covering the building of this furnace. Thus, the first electrically-heated cremation furnace in the world was put into service at Biel in the year 1933.

The problem to be solved was defined by the four general fundamental conditions which have been enumerated and also by the space available in the furnace hall which was already built.

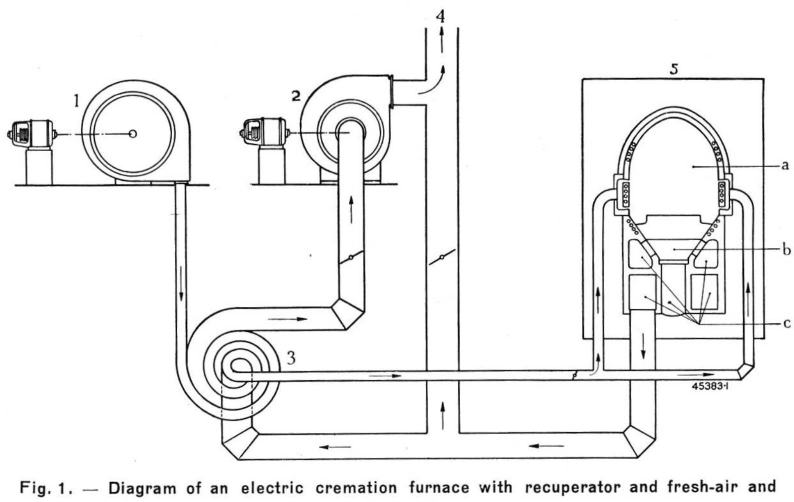


Fig. 1. — Diagram of an electric cremation furnace with recuperator and fresh-air and smoke-gas fans.

1. Fresh-air fan.
2. Exhaust-gas fan.
3. Spiral-type recuperator.
4. Connection to chimney.
5. Diagrammatic section of cremation furnace.
   a. Combustion chamber.
   b. Chamber for collecting ashes.
   c. Second-stage combustion ducts.

Investigations and calculations showed that to fulfil all demands satisfactorily, it would be necessary to build an entirely new type of furnace.

The furnace is designed on the lines of a grid furnace because this offers certain technical advantages and allows of complete incineration of the body. The fundamental design is shown in the diagrammatic drawing (Fig. 1), which gives a section view. The combustion chamber is 1 m wide, 1 m high and 2·4 m long and subdivided, by grids placed perpendicularly to the longitudinal axis, into an incinerating chamber above and a chamber for collecting the ashes below. On both sides of the latter and underneath it there are smoke-combustion ducts in which the smoke is consumed. Thus, the chamber for collecting the ashes has ducts on three sides of it which are at a high temperature and maintain the ashes at glow heat, so that they are burnt white before being taken out. The narrow spacing of the main grid prevents bigger parts which have not been consumed from falling through. Small parts, especially charcoal, which are not entirely consumed in the chamber for collecting the ashes can be drawn into a second-stage trough-shaped combustion grid where their transformation to ashes is consummated. A fire-clay plate serves to separate this second-stage combustion grid from the chamber for collecting the ashes so that while the ashes of a first cremation are being cooled a second cremation can take place in the main combustion chamber, without the ashes getting mixed.

The combustion air is injected laterally over the grid while the gases from the combustion are drawn downwards between the grids into the chamber for collecting the ashes. The gases then pass to the lateral ducts under this chamber, then to the recuperator and are evacuated through the chimney. Jets of hot air injected through nozzles at determined points of the smoke-combustion ducts prevent the formation of smoke.

The great differences between bodies to be cremated as regards parts which are inflammable (and give off heat) and those which must be evaporated (which consume heat) call for corresponding measures as regards adjustment of the quantities of air to be introduced primarily to the main combustion chamber and, secondly, to the smoke combustion ducts. Good preheating of the combustion air is advantageous in preventing the formation of smoke and also in allowing utilization of the heat produced by incineration. This preliminary heating of the air is carried out in a metal recuperator with spiral channels (Fig. 1). The gases exhausted from the furnace pass through the interior spiral channel from the middle outwards, while the fresh air passes through the outer channels from the outside towards the inside. The cooling down of the smoke gases and heating up of the combustion air are shown in the heat diagram (Fig. 2). The complete temperature diagram of a cremation, given in Fig. 3, shows this as well. The very satisfactory exchange of heat which attains 40,000 kcal/h in an apparatus of only 0·25 m^3 useful capacity is achieved thanks to the high velocities imparted to the gases and the air. In order to overcome the pressure drop in the recuperator, the static pressure of the fresh-air fan and smoke-gas fan is chosen of suitable strength.

The recuperator can also be done away with altogether, which of course, simplifies the whole plant.

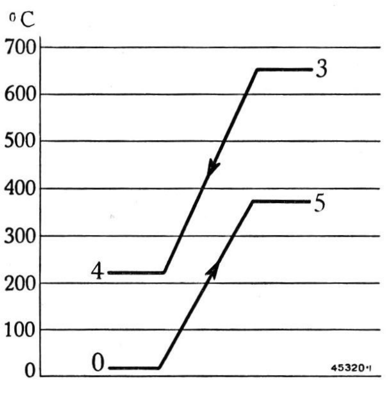


Fig. 2. — Heat diagram of a recuperator of spiral type. 3—4 temperature characteristic of smoke gas. 0—5 temperature characteristic of fresh air.

The metallic spiral-type recuperator results in instantaneous exchange of heat thanks to its inherent low heat capacity and excellent heat conduction qualities.

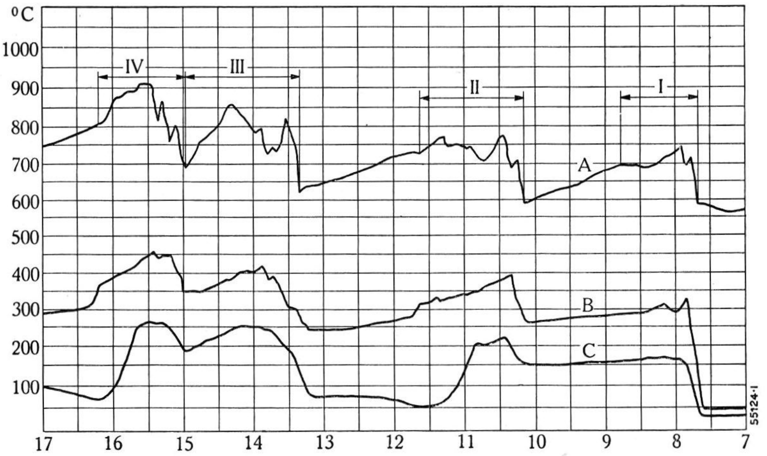


Fig. 3. — Complete temperature diagram recorded on four successive cremations carried out in the St. Gallen crematorium.

A. Temperature in combustion chamber.
B. Temperature of smoke gases at inlet of the recuperator.
C. Temperature of preheated fresh air at inlet of furnace.
I, II, III, IV. Duration of different cremations.

According to the factor of utilization of an electrically-heated cremation furnace the amount of electrical energy consumed to heat the furnace may be a factor of little or capital importance. Cremation furnaces which are little used are, therefore, built for low heat accumulation while those in constant use are built for high heat accumulation. In the first case the losses by radiation are practically of no importance while in the second case the losses due to heat accumulation can be disregarded.

Fig. 4 shows the heating up and cooling down curves of a furnace of massive design with good heat insulation. To heat it up from 20 to 620°, it is necessary to expend 650 kWh. Practically, this amount of energy

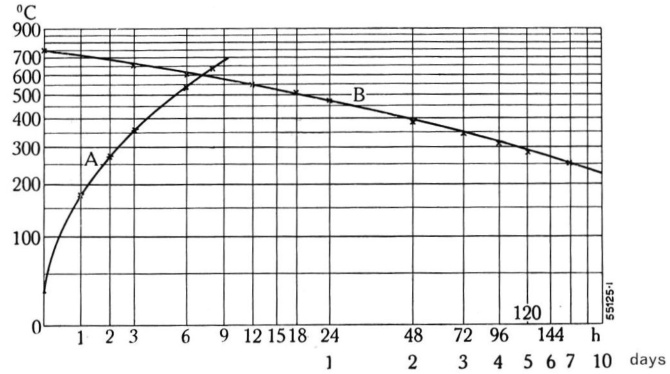


Fig. 4. — Heating-up and cooling-down curves recorded on the electric cremation furnace in the St. Gallen crematorium.
A. Heating-up curve with a power consumption of 65 kW.
B. Cooling-down curve with smoke-gas valves closed.

TABLE I.

BIEL CREMATORIUM.

Operating data recorded with the electric cremation furnace.

Year	1933 [1]	1934	1935	1936	1937	1938	1939	1940	1941
kWh high metering tariff	1953	15,691	14,015	4,067	8,433	7,587	12,955	11,034	12,547
kWh low metering tariff	4431	22,680	27,396	11,647	25,034	25,562	25,828	26,498	22,012
Total kWh	6384	38,371	41,411	15,714	33,467	33,149	38,783	37,532	34,559
Number of cremations	18	137	152	82	182	168	217	230	205
kWh per cremation	354	280	272	191	184	198	178·7	169·4	168·5
Cremations per month	10	12·3	12·6	15·3	15	13·8	18·1	19·2	18·1
Cost of energy per cremation Fr.	15.10	14.45	13.85	7.92	7.67	8.48	7.14	7.20	7.43

[1]) Operating time 2 months; results affected by test measurements.

TABLE II.

BERNE CREMATORIUM.

Operating results recorded with the electric cremation furnace.

	1941										1942	
	March	April	May	June	July	August	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.
kWh high-metering tariff	1000[1])	920	640	860	500	270	270	160	160	330	70	180
kWh low-metering tariff	195	580	1450	1800	1610	1360	1150	910	940	430	550	400
kWh for fans	234	196	145	155	139	151	170	160	143	181	215	169
Number of cremations	69	54	42	40	42	45	55	55	52	58	67	60
kWh heating energy per cremation	17·32	27·80	49·70	66·50	50·23	36·20	25·92	19·45	21·14	13·08	9·26	9·66
kWh motor energy per cremation	3·38	3·62	3·45	3·87	3·31	3·38	3·09	2·91	2·75	3·10	3·21	2·81
Total kWh per cremation	20·70	31·42	53·15	70·37	53·54	39·58	29·01	22·36	23·89	16·18	12·47	12·47
Cost of energy per cremation in Fr.	1.55	2.05	2.72	3.64	2.69	2.02	1.53	1.33	1.36	1.23	0.95	0.96

Date of putting into operation: 27th February, 1941. [1]) Energy consumption affected by test measurements.

need never be expended, except at the first heating up assuming that there is a minimum of 30 cremations per month, because the furnace never cools off altogether between cremations as the curve shows. Table I contains operating data on the Biel cremation furnace since it was put into service in 1933. The steady drop in electrical energy consumption per cremation is due to constructive improvements introduced during the first few years and to the fact that the operators became more skilled in attending the new type of furnace. Of course, the increase in the number of cremations, according to curve A of Fig. 5, plays a part here. Table II gives the results of the first operating months of the electric cremation furnace in Berne, which also reveal the effect of the greater number of cremations and of skilled attendance.

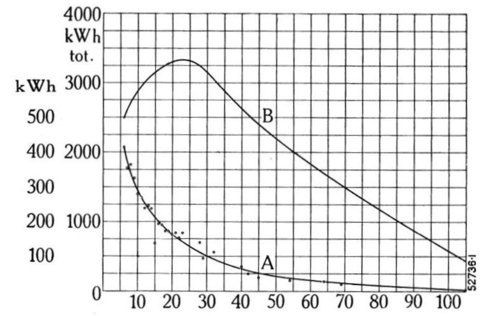


Fig. 5. — Average energy consumption per cremation (A) and the total amount of energy consumed (B) per month in function of the number of cremations per month.

When there are more than 25 cremations per month, both the consumption of energy per cremation and the total amount of energy consumed per month drop considerably.

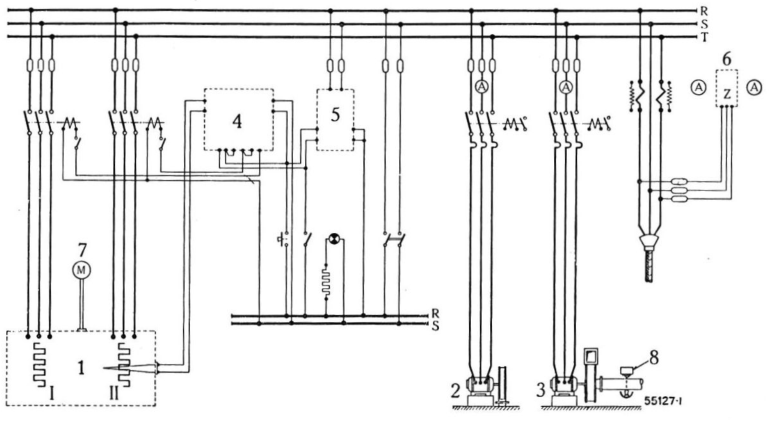


Fig. 6. — Fundamental diagram of connections of an electric cremation furnace plant.

I and II. Heating element groups in the combustion chamber.

1. Cremation furnace.
2. Fan for compressed air.
3. Fan for smoke gases.
4. Temperature regulator.
5. Automatic time switch.
6. Meter.
7. Manometer.
8. Smoke-gas indicating instrument.

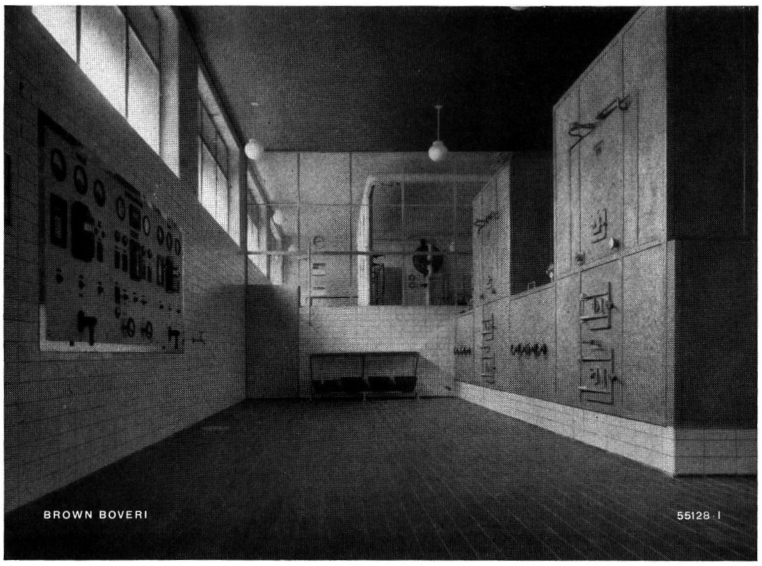


Fig. 7. — Stockholm crematorium. Back view of the two cremation furnaces. Switch-board panel on the left.

The furnaces have a housing of aluminium sheeting to harmonize with the rest of the crematorium.

The electrical equipment for a cremation furnace heated by electricity comprises, chiefly, the heating resistances which are lodged in the muffle walls of the main combustion ducts and, therefore, are not visible. These resistances have a capacity of 60 kW and can be connected directly to any electric supply system up to 380 V. The electrical apparatus proper is concentrated on a switchboard panel which also contains the handwheels by means of which the combustion air is regulated. Fig. 6 shows the fundamental diagram of connections of an electric cremation furnace.

The heating up of the furnace can be carried out without supervision, thanks to a time switch, while a temperature regulator supervises and regulates the temperature automatically during this process. Usually no electrical energy is supplied to the furnace during the cremation proper, because the surplus of heat from the process of incineration as compared to the amount

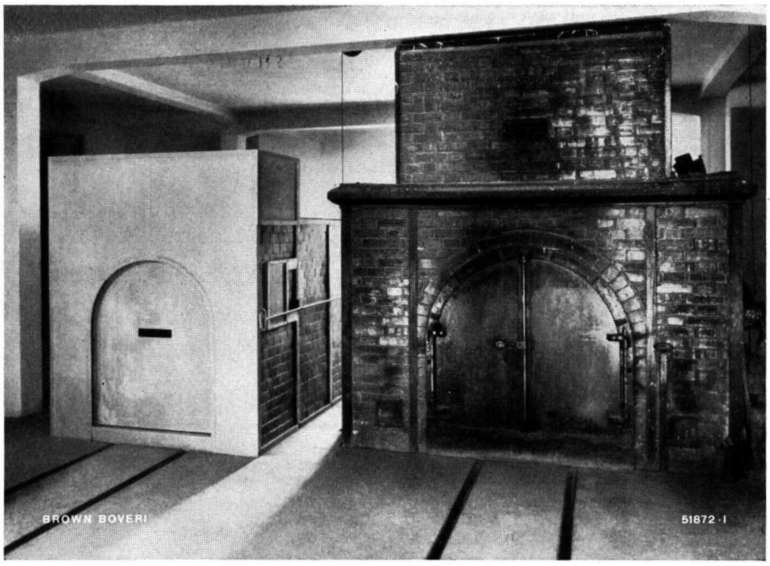


Fig. 8. — Lucerne crematorium. On left electric cremation furnace of Brown Boveri type and on right old coke-fired crematorium furnace.

The smaller dimensions of the electric crematorium furnace make the hall seem more roomy.

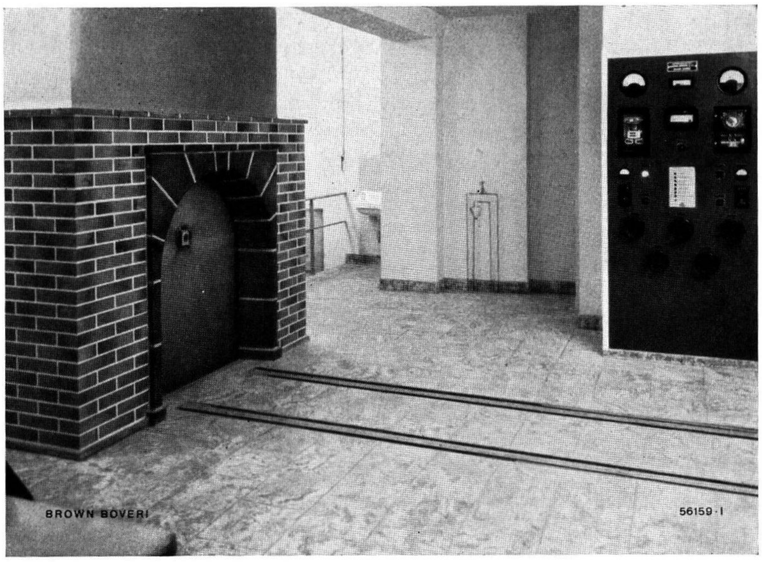


Fig. 9. — St. Gallen crematorium.

The furnace is provided with a covering of hard baked tiles which suits the architecture of the hall while also enhancing the heat-insulating qualities of the furnace itself.

of heat utilized is generally so considerable that all furnace losses are covered by it. As Fig. 3 shows, the temperature rises rapidly after the coffin is introduced and can attain 1100^0 C. The final temperature after entire incineration is usually higher than that at the introduction of the coffin, if it is not brought down by special measures. All the technical processes inherent to the incineration can be followed by reading the smoke indicator, the pressure gauge on the suction side of the furnace and the temperature-indicating instrument, on the indications of which the amount of primary and secondary air admitted can be regulated.

In order to satisfy the fundamental conditions laid down at the beginning of this article, attention must be given to the external appearance of the furnace. In order to harmonize with the style of cremation hall itself and its architectural features, the furnace is either given a smooth metal housing or walled in with glazed tiles or rough hard-baked tiles. All the 24 electrically heated cremation furnaces now operating or being built to our design thus look different although built to the same constructional principles. Figs. 7, 8, and 9 show three typical plants the appearance of each being made to suit the desires of the architect so that they harmonize with their surroundings.

To summarize, we may say that the electric cremation furnace meets all idealistic demands. The smokeless incineration in pure air is assured and the passing of the body to a state of ashes carried out by a natural process of combustion. Economically speaking an electrically-heated cremation furnace is superior to one fired by fuel under all circumstances.

(MS 833) *G. Keller. (Mo.)*

BRIEF BUT INTERESTING

The development of the water-jet electric boiler.

AFTER having given up the building of electric boilers for several years, Brown Boveri took up this branch of electrical engineering again in the year 1933. The following programme of construction was drawn up which was based on the experience gained with our own earlier boiler designs and with those of other makers:—

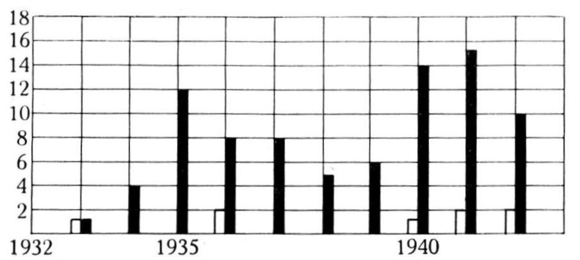
1. No insulators or built-in ceramic parts immersed in water, as these parts dissolve in concentrated boiler water and are liable to crack under heat stressing, this chiefly under the effect of boiler scale.
2. No excessive increase in the current density and amount of steam generated on the electrodes, in order to prevent sparking on the electrodes and their consequent wearing out.
3. Long water tracks of small section for the current to pass through to allow of applying high voltages; further, there is then no danger of a flash-over between electrodes due to high conductivity of the water (concentration) as may occur with immersed electrodes.
4. Big vaporizing surfaces.
5. Progressive control from no load to full load.

	Minimum value	Maximum value
Power input	300 kW	10,000 kW
Voltage	3000 V	16,500 V (line)
Steam pressure, gauge . .	1·5 kg/cm²	29 kg/cm²
Quantity of steam generated	420 kg/h	17,000 kg/h

The major part of the boilers was installed in Switzerland and the figures show what an important place the electric boiler has won for itself in this country, as a consumer of excess power.

The aim of the electrical economic policy in Switzerland is to utilize every source of water power available throughout the year. The electric boiler and the heat pump are destined to become useful agents, in carrying out the aim in question.

As to the much discussed methods of storing summer energy for use in winter it should be said here that it is carried out most simply, and according to Spoerli's proposal[2], by generating heat by electric power in summer and by utilizing during the winter, the coal economized in this way.



☐ Hot-water plants. ▮ Steam plants.

Fig. 1. — Number of boiler plants for producing steam and hot water.

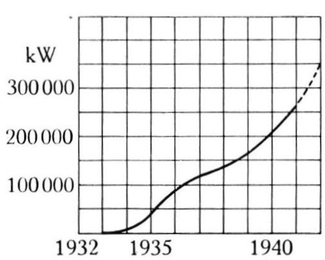


Fig. 2. — Total power input in kW.

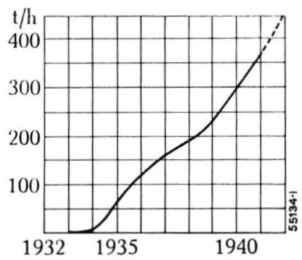


Fig. 3. — Total quantity of steam generated in the boilers in t/h.

Electric boilers for high and low voltages are a considerable and always increasing help in economizing fuel oil and coal. These boilers are reliable in service and simple in design and are used advantageously in works as well as industrial plants.

The articles enumerated in the foot-note give information on how all these requirements were satisfactorily met by the design of the water-jet electric boiler.[1]

Figs. 1 to 3 showing the development of the water-jet boiler, from 1933 up till to-day, demonstrate clearly that all requirements have been satisfactorily fulfilled and that clients are appreciating this type of boiler at its true worth.

The table gives the minimum and maximum figures for power input, voltage, steam pressure and steam delivery during the period in question.

[1] E. Soldati: The Brown Boveri water-jet high-voltage electric boiler; see The Brown Boveri Review 1935, pages 71—76.
E. Soldati: The Brown Boveri low-voltage electric boiler; see The Brown Boveri Review 1936, pages 263—267.
A. Strub: Measurements carried out on the Brown Boveri electric boiler in the Zuckerfabrik & Raffinerie Aarberg (Switzerland); see The Brown Boveri Review 1937, pages 167—168.
E. Soldati: Hot-water electric-boiler plant belonging to the Société des Bains et Eaux d'Henniez S. A., Henniez (Switzerland); see The Brown Boveri Review 1938, pages 68—70.
E. Soldati: Electric boilers; see The Brown Boveri Review 1938, pages 231—236.
A. Strub: Brown Boveri high-voltage electric steam boilers for high pressures and automatic regulation; see The Brown Boveri Review 1940, pages 139—141.

The amount of coal economized depends, of course, on the amount of electric energy available; for the past year 1940/41 it is calculated that about 126,000 t of coal were economized.

(MS 879) *Dr. h. c. Ad. Meyer. (Mo.)*

An unpretentious generator of large quantities of heat.

ENORMOUS quantities of energy are handled in modern high-voltage electric boilers in a minimum of space and with a lower expenditure of material than is possible with any other type of power convertor. This is made clear by Fig. 1 showing a 10,000 kW boiler which generates 14 t of steam per hour at a pressure of 12 kg/cm² and consumes all the power produced by an average-sized hydro-electric power station.

This conversion of energy is carried out practically without losses. Even the energy consumed by the water-circulation pump lodged in the boiler itself is delivered to the boiler water in the form of heat if we disregard

[2] A Spoerli: Speicherung von Sommer-Ueberschussenergie für den Wärmebedarf im Winter; see Bulletin S. E. V. 1940, pages 564—567.

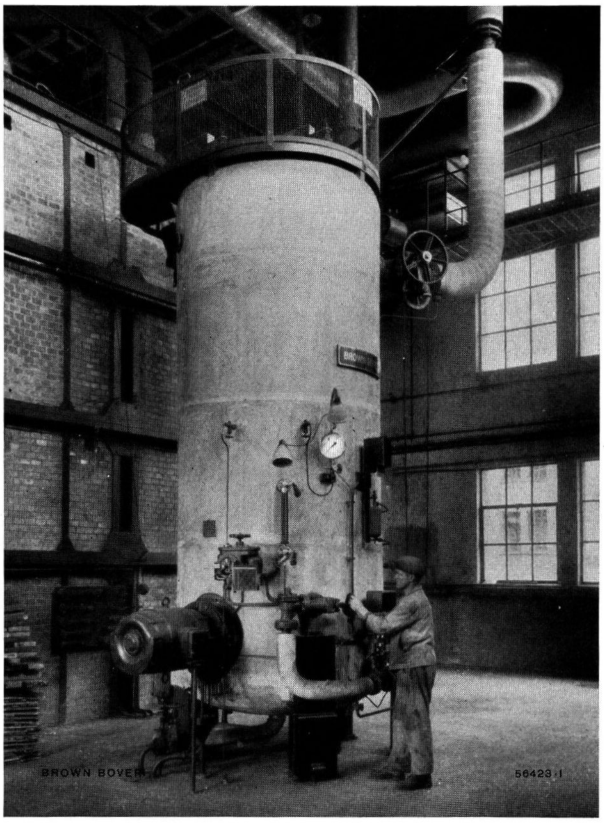


Fig. 1. — Water-jet electric steam boiler, 10,000 kW, 13,000 V, three-phase, 50 cycles, 12 kg/cm² gauge pressure, steam delivery 14,600 kg/h, installed in a Swiss paper mill.

With regard to its big output, the boiler is small and for this reason can be put under pressure rapidly. The load can be progressively regulated between 0 and 10,000 kW independently of the upper limit of water conductivity. There are no ceramic parts immersed in water.

the very low losses of the motor itself. As the power required to drive the pump is approximately equal to the losses through heat radiation from the boiler, the latter can be kept under pressure by the power of the pump alone when it is cut off from the electric supply and on condition that all valves are closed; this, at least for certain sizes of boiler and assuming effective insulation of the latter. Here, the electrical energy of the pump motor is first converted into mechanical energy and converted again to hydraulically lost heat, under which form it is delivered to the boiler water.

(MS 866) *A. Strub. (Mo.)*

How can the energy of electric boilers available at inconvenient times be made use of without putting up expensive new plant?

In the majority of cases, the electric boiler is a stop gap, to which the power supply company will only deliver power at tariffs acceptable to the boiler proprietor when the amount of water power available is sufficiently big and the load diagram shows that it is feasible to do so.

In many cases, the electrical energy which can be used for the boiler will not exactly meet the heat requirements of the boiler proprietor, either as regards the time at which the energy can be supplied or the amount of it. When the energy made available and the quantity required do not coincide as regards time alone with the needs of the consumer, it is often possible to modify the working hours of the boiler in the interests of economizing coal.

In most cases, however, this measure will not suffice. In order that the energy supplied at inconvenient times and in unsuitable quantities be made available at such times and in such quantities as are required, storage capacity must be resorted to.

Here, boilers of large water space, which are often encountered, such as the Lancashire boiler for example, can be used for the purpose. When the plant under consideration utilizes steam, these boilers are equipped with charging pipes which lead the steam from the electric boiler into the interior of the Lancashire boiler and distribute it uniformly in the water space, where it raises the temperature of the water. Fig. 1 shows steam pipes of the type in question which are led into four boilers of the Lancashire type. If, now, the consumption of steam by the plant exceeds the amount the electric boiler can generate alone, there will be a drop in pressure and the storage boiler will deliver a certain quantity of steam at this lower pressure dependent on its water space. In order to avoid too heavy losses of heat, it is recommendable to improve the insulation of boilers transformed into storage units. In any case the flue dampers must be made tight as they can be the source of very big loss.

It is obvious that a boiler of this kind used as a storage unit will always be inferior, as regards heat losses, to a storage unit built for that purpose alone and properly insulated. As, to-day, it is hardly possible to find the material for making big storage boilers and as, on the other hand, the method described here is only resorted to, on account of war conditions, these additional losses may well be disregarded if by so doing it is possible to utilize excess power and thus save coal.

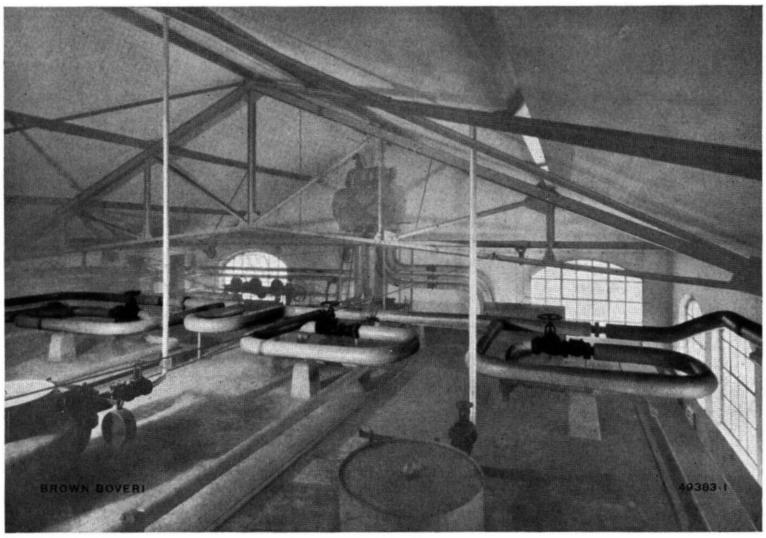


Fig. 1. — Steam pipes leading the steam from the electric boiler into the water space of four Lancashire boilers each of 120 m² heating surface and 30 m³ water capacity.

These pipes serve to heat up the boilers with steam from the electric boiler so that they can be used as storage units. Owing to the scarcity of materials for building big storage plants, the present solution is frequently an advantageous one. Allowing for a pressure drop from 9 to 5 kg/cm² gauge, the four boilers working together can deliver 4500 kg of steam.

As a typical example of a plant adapting its needs to present-day difficulties, we would mention a brewery which only gets electrical energy during night hours. As the highest steam consumption takes place during the boiling process, arrangements were made, so that this process takes place at night. As soon as it is permissible to switch in the boiler in the evening, a Lancashire boiler is put under pressure by the steam from the electric boiler; during the subsequent steam consumption peaks it can deliver steam under a drop in pressure. In the pauses between the first and second heating up of the mash and the boiling of the malt liquor, the storage boiler gets charged and put under pressure again by the electric boiler. After the boiling process is over, the boiler is again charged and the lye heated for bottle washing while sufficient hot water is prepared for cleaning purposes. When the electric boiler is cut out, the storage boiler now delivers the steam needed for bottle washing. If it happens that the steam stored does not suffice entirely, coal firing can be resorted to.

Thus, coal can be very considerably economized by the method described, without having to put in expensive new plant.

(MS 866) *A. Strub. (Mo.)*

Saving fuel in our own plant with a heat pump.

ENCOURAGED by the economic results obtained with the heat pumps delivered to various clients, Brown Boveri are now building a heat pump to be used for the heating system of their own plant. The object is to save coal during the present period of scarcity of that commodity and, apart therefrom, to gain further experience in our own plant.

The heat consumption of shops and offices amounted to about 7500 million kcal during the winter of 1937/38. The heat pump to be installed will have a calorific capacity of 6200 million kcal per year. For atmospheric temperatures below $+1^{\circ}$ C an additional heating system will be added, which should deliver the further 1300 million kcal required to attain the figure of 7500 million kcal mentioned above. For 170 heating days the heat pump is supposed to supply all heating requirements alone and for 50 days with the additional heating system. The temperature of the water in the heating system of the plant is to be raised from 40° C to 45° C through the agency of water at 5° C taken from the river Limmat. The saving in coal realized by using the heat pump should amount to about 1360 t per annum.

With the heat pump, which is built for a maximum capacity of 1·7 million kcal/h, a performance coefficient of practically 4 can be expected thanks to the advantageous temperature conditions, so that only $^1/_4$ of the heat energy need be supplied, under the form of electric energy, to the compressor coupling (about 500 kW). The heat pump is designed on the lines of the well-known Brown Boveri Thermobloc and it works with Freon (F 11). A synchronous motor is used to drive the compressor directly.

Fig. 1 shows how the heat pump is inserted in the hot-water generating system of the plant, in series with the heating turbine and the heat exchangers. When heating requirements are moderate, the heat pump can cover them alone while for atmospheric temperatures below $+1^{\circ}$ C it will be necessary to put either the heat exchanger or the heating turbine to work, the latter being then supplied with live steam and the electric power generated supplied to the shop network. The water necessary as a source of heat for the evaporator of the heat pump is taken from the river Limmat by an existing pumping station. The boiler plant of our works comprises two coal-fired water-tube boilers with Riley stokers. The steam capacity is 18,000 kg/h per boiler at 30 kg/cm² abs, 450° C; there is also an oil-fired Velox boiler for 20,000 kg/h of steam at 40 kg/cm² abs, 450° C.

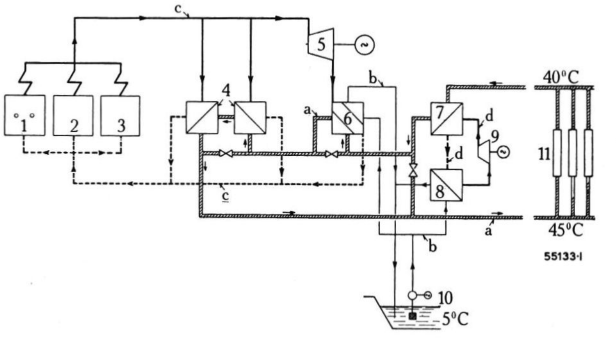


Fig. 1. — Heating power station of the Brown Boveri plant.

1. Velox boiler.
2, 3. Coal-fired boilers.
4. Heat exchangers.
5. Heating turbine.
6. Heating condenser.
7. Condenser of heat pump.
8. Evaporator of heat pump.
9. Cold vapour compressor of heat pump.
10. Source of heat (water from River Limmat).
11. Heating elements.

a. Closed circuit of hot water.
b. Closed circuit of cooling water.
c. Closed circuit of hot steam condensate.
d. Closed circuit of the working medium of the heat pump.

Heat pumps are very suitable for industrial plants. They are especially suitable for heating big rooms, the heat pumps being used in winter for heating and in summer for cooling.

(MS 870) *Ad. Baumann. (Mo.)*

Recent applications of the heat pump.

THE air heat pump[1] mounted in the *Papierfabriken Landquart A. G.*, Landquart (Switzerland), works on the cell-wheel principle and has a capacity of 115,000 kcal/h. It raises the temperature of fresh air, which has already

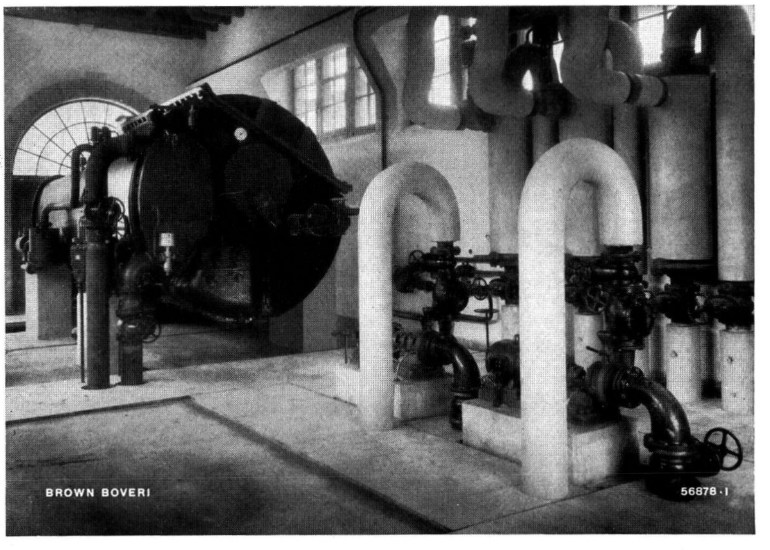


Fig. 1. — Thermobloc in the Steckborn Kunstseide A. G. plant, Steckborn (Switzerland).
Capacity 1·7 million kcal/h. Utilizes the heat available in the water of the Lake of Constance.
By putting heat pumps in big industrial plants considerable savings in fuel can be effected which helps the trade balance of Switzerland as it reduces the import of foreign fuels.

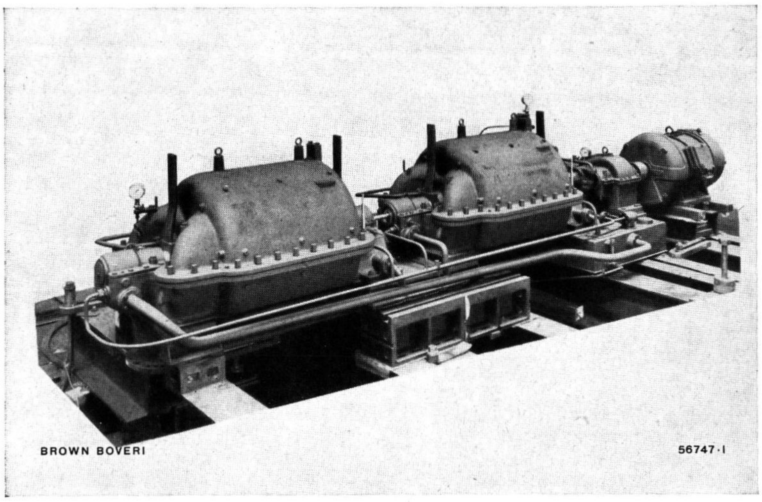


Fig. 2. — **Thermo-compressor for the suction of 700 kg of water vapour per hour for concentrating a solution, erected in a chemical plant.**

Brown Boveri thermo-compressors have high efficiencies and can be built for the biggest capacities needed.

been preheated, and which is then used to dry the felts of the paper-making machines. Here the exhaust air from the machinery hall serves as source of heat. After several months of satisfactory operation this heat pump has proved its value and that its installation is industrially justified.

There are to be two heat pumps[1] each of a capacity of 1·7 million kcal/h working in the plant of the *Steckborn Kunstseide A. G.,* Steckborn (Switzerland). They utilize the heat contained in the water of the Lake of Constance and serve to prepare hot water. The results attained on the test bed with the first of these sets justified entirely the utilization of heat pumps in big industrial plants. At the present time, the first set is being erected and will be set to work immediately afterwards (Fig. 1).

In the thermo-compressor field (compressors of evaporating plants) the present economic conditions have led to the installation of plants which will certainly justify their economic existence after peace conditions return. The application is especially interesting for concentrating fluids — solutions and lyes — in the food-supply industry and in the chemical industry.

Plants for concentrating skimmed milk, obtained from the making of butter, and turning it into powdered milk under vacuum, so that it can be used as food, are especially interesting. Further it is possible to make lactin economically out of serum of milk obtained as a by-product from the manufacture of cheese and casein. By using 80 kWh, as much as 1000 litres of condensed milk can be obtained. It should be mentioned here that with this new system the condensing of skimmed milk by compression of the vapours does not increase the cost of the plant to any considerable degree, as would be the case with a standard fuel-fired steam boiler.

Heat pumps are also used to condense fruit juices under vacuum. The most nutritious parts of the fruits such as vitamines, phosphates, etc. are preserved, as they are not destroyed at the low temperatures met with in this process.

Instead of the usual steam jet apparatus, the chemical industry is showing more and more interest in evaporation under vacuum by means of thermo-compressors used as heat pumps (Fig. 2).

A further application for which Brown Boveri have brought out new designs is the preparation of distilled water. This water can be used in the chemical industry or for drinking or medicinal purposes (Fig. 3).

(MS 871) *Ad. Baumann. (Mo.)*

[1] Ad. Baumann: "Instead of coal", The Brown Boveri Review 1942, page 110.

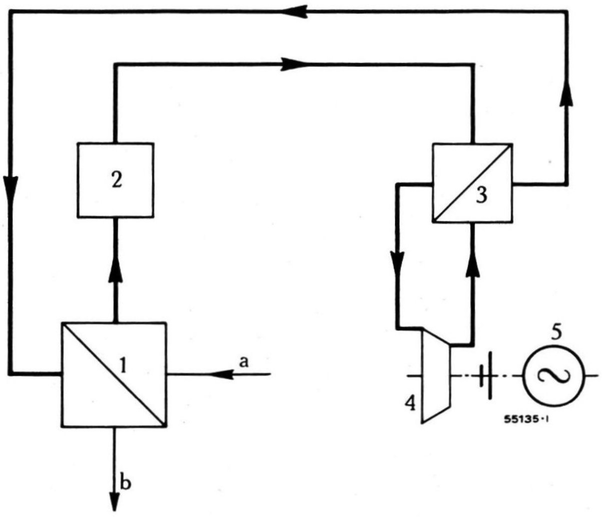


Fig. 3. — **Diagram of a mobile salt-water distilling plant to produce 500 kg of drinking water per hour.**

1. Evaporator. 2. Water separator. 3. Dryer. 4. Compressor. 5. Driving motor.
a. Salt-water inlet. b. Distilled-water outlet.

The raw water is evaporated in evaporator 1, flows through the water separator 2, is freed from its last impurities in dryer 3, and reaches compressor 4 as pure steam. The steam heated by the blower is first used for drying the absorbed vapour in dryer 3 and then for heating the evaporator 1, after which the condensed steam is drawn off at b in the form of distilled water.

BROWN BOVERI

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