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NEW EQUIPMENT FOR OXYGEN STEELMAKING PLANT[1]

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[1] The views and opinions expressed in this paper are those of the authors and do not necessarily reflect the views of the secretariat of UNIDO. The document is presented as submitted by the authors, without re-editing.

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Contents

1. Some Aspects in the Design and Layout of Oxygen Steelmaking Plant

The planning of a steelmaking plant and, consequently the selection, layout and design of the plant and equipment, are governed by a number of factors and requirements which vary with the local conditions prevailing in each case. In many cases, where existing steel plants are reconstructed or expanded, the existing facilities interfere with an efficient arrangement of the new installations so that compromise solutions must be found. Cases of this nature will not be discussed here.

But even for a new oxygen steelmaking plant which is built on virgin soil, there is no standard approach. In each specific case, there are certain basic factors which influence the design and layout and must be duly considered:

The major factors are as follows:

Required production capacity,
Available raw materials and utilities,
Steel grades to be produced
Air and water pollution control requirements
Location relative to the blast furnaces,
rolling mills, etc.

Further important design factors, such as the weight of melts, lot sizes or number of converters, frequently depend to some extent on requirements within the overall organization of the enterprise or are determined by the internal requirements of the steel plant.

These requirements affect the sequence of operations and the flow of materials and thus determine the layout of a steelmaking plant. The major plant units are required for the following sections:

Hot metal and scrap-handling
Storage and handling of fluxes and process alloys
Steelmaking vessels (converter installations)
Oxygen-lance equipment
Waste gas cooling and dust collecting plant
and the necessary
Instrumentation and control systems
Equipment for automating the process
Slag handling and disposal
Teeming and handling of ingots

Only the important details of the key facilities (underlined) are going to be discussed here, as these are being constantly improved and modified to incorporate the latest experience in the operation of the new oxygen steelmaking processes.

An oxygen steelmaking plant recently planned for a Spanish integrated iron and steelworks on the basis of the latest advances is cited here as an example of such an engineering task. The fact that it is proposed to expand this plant later by including continuous casting plant is of particular importance. Figs. 1 and 2 show the ground plan and cross-section of this steel plant project.

2. Oxygen-blown Converters

2.1 Design and Size of the Vessel

The basic design of the vessel and its principal dimensions are based on studies made to determine the optimum specific volume and the height/diameter ratio of the vessels. The evaluation of a large number of available data, for instance, gave the following specification for a 110-ton converter designed for blowing normal basic iron:

Weight per heat	110 tons
Total volume	84 m^3
Specific volume	0.75 m^3 per ton
Height, outside	8350 mm
Height, inside, incl. lining	7000 mm
Outside diameter	6440 mm
Inside diameter incl. lining	4500 mm
Height/diameter ratio, outside	1.3
Height/diameter ratio, inside	1.55

Fig. 3 shows the shape and principal dimensions of the converter cited as an example. Particular attention must be given to the conditions caused by the ingress of air at the converter mouth in order to avoid a harmful increase of the nitrogen in the bath and to ensure a long life of the converter mouth. The level of the metal bath and slag when the converter is in its slagging position, also requires careful consideration in order to minimize pickup of phosphorus which is of particular importance when high-phosphorus iron is converted into steel.

After the shape of the vessel has been fixed, work is started on the design computations and drawings. For this purpose, an electronic computer operating with a specially prepared programme for computing the centres of gravity and torques of tilting vessels can be used. The overall centres of the gravity of the filled and lined vessel are computed as a function of the tilting angle α. From these results the torques required through the whole tilting range are computed and plotted against the angle of tilt, and the maximum and minimum values are determined, as shown in Fig. 4. Bath level and centres of gravity are determined by interlaced intervals followed by interpolation. The computations can be carried out rapidly and accurately. From the results obtained, the horsepower required for every operating condition and for specific emergency conditions can be determined and the drive designed for economic operation.

A cooled converter top section may be regarded as a design detail of the vessel proper. This consists of the liquid-cooled nose ring and cooling boxes which may help to reduce wear in cases where the nose section is exposed to extreme thermal stresses.

2.2 Trunnion Ring, Trunnion Bearings and Tilting Drives

For tilting into the different positions required for charging, blowing, slagging, sampling and pouring, the welded converter vessel is fitted with a trunnion ring, trunnions and drives. To ensure satisfactory operation, it must be possible to tilt the vessel through 360 degrees in either direction. These important components must be designed with the greatest care. Fig. 5 shows the basic design features of an 80-ton converter which has now been in operation for several years and has proved very successful.

The trunnion ring carrying the vessel can be designed in various ways either as a steel casting, as in the present case, or as a welded construction. Wedges and claws are used to connect it to the vessel. This type of joint safely absorbs the radial and axial stresses occurring during operation as a result of thermal expansion.

The trunnion ring rests in two pedestal bearings. The trunnion on the drive end carries a bullwheel driven through pinion, gear coupling and reduction gearing. The drive gear is arranged beneath the working stage.

Trunnion ring, trunnion ring support and tilting drive can be designed in different ways. What design should be selected depends largely upon the local conditions.

Depending on operational or manufacturing requirements, the trunnion ring can be built up of two halves or of several segments (Fig. 6); the number of parts and joints should be restricted to a minimum.

Worth mentioning here is a trunnionless special converter design of welded construction which has proved highly successful over many years in oxygen steel plants (Fig. 7) although considerable trouble is known to have been encountered with other similar designs.

In case of a recently commissioned converter (Fig. 8) another type of trunnion ring support had to be used owing to the distance between the converter stands which the customer had specified. The trunnion ring is supported at either end by two tilting wheels, one of which is designed as a lantem or pin gear. This photograph shows the trunnion ring during shop assembly. It is of two-piece construction and has a box-shaped cross-section; the two halves are bolted together so that the joints coincide with the tilting axis.

Bodyfit bolts connect trunnion ring and tilting wheel. This design offers the advantage that the joints are shifted from the point where the largest bending moment occurs to the point where the bending moment is very small. Another advantage is that the number of flanged joints is reduced to the minimum.

Fig. 9 shows the design of this converter. Each of the two tilting wheels rests on two rollers. The drive consists of two pinion assemblies attached to the tilting wheel.

Fig. 10 shows a twin-output gear unit specially designed for use with oxygen-blown converters which has now been installed in three 100-ton converters. This gear unit has been developed from time-tested cement mill gearing and incorporates all the experience accumulated in that application. Two output pinions engage with the bullwheel mounted on the trunnion. The two pinion shafts carry helical gears which are in engagement with a pinion having heringbone toothing. The latter being axially adjustable, it readjusts itself to ensure uniform load distribution so that each pinion is subject to the same tooth pressure. The entire gear unit floats on the trunnion and can therefore readily follow any deviations from the centerline caused by excessive service stresses. The overall reactions caused by the difference between the input torque and the output torque are transmitted by torque supports to the foundation. The torque supports are hinged to give them the necessary degree of freedom of movement. The gears are fully enclosed in a dust-tight gear case. This makes for ease of maintenance and reliability so that this gear unit is particularly suitable for the tough operating conditions encountered in steelworks.

2.3 Oxygen Lances and Lance Hoist Assembly

The oxygen lances and their hoist assembly serve to supply tonnage oxygen or a mixture of oxygen and pulverized lime to the converter where it is blown onto the surface of the metal bath. Their design, particularly the lance tips, must be closely adapted to the metallurgical requirements of the different processes. The single orifice nozzles previously used are now replaced by multi hole nozzles which give a sufficiently large hot spot with shorter oxygen jets. As is known from published work, the individual gas jets issuing from the multi orifice nozzle in a divergent manner do not interfere with each other if they are at an angle of at least 18 degrees to each other. In the case of three-hole lances, this means that the jets are at an angle of 10 - 12 degrees to the lance centerline. It was further pointed out that, if momentum density, chemical and thermal properties of the oxygen stream remain unchanged, i.e. with a given number (n) of jets having roughly the same metallurgical effect, the distance between lance tip and the surface of the bath can be shortened by the factor $1/\sqrt{(n)}$. In the case of four-hole nozzles, for instance, it can be reduced to about half. This is particularly of advantage in the case of large capacity converters for melts up to about 300 tons which must be designed for oxygen flow rates of up to 900 m^3 NTP per minute and where the use of five or six-hole nozzles make it possible to obtain the desired lance to-bath distance of 1.2 to 2.5 m. Another advantage of multi hole nozzles is the fact that the jets impinge upon the bath at an oblique angle. Special designs such as two-circuit lances, for instance, were developed to meet special requirements such as the blowing of oxygen and mixtures of oxygen and lime in the processing of high-phosphorus types of iron.

The lance hoist assembly, Fig. 11, carries and moves the oxygen lances and accomodates the drives for hoisting and lowering. It must be so designed as to permit a standby lance to be put into operation readily if the operating lance should fail. For operational and metallurgical reasons, it is necessary to design the normal lance hoist for two hoisting and two lowering speeds. If it is desired to design the unit for future automation of the process, the drive should permit a much higher number of operations per hour than is usual to day. Furthermore, the lance, if adapted to the Krupp-developed method of process automation, should be provided with instruments for measuring the electrical conductivity in the converter space. For this purpose, the lance must be electrically insulated from the lance-support frame.

Oxygen and, where necessary, powdered lime is supplied through hoses or articulated pipes.

The movements of the lance are electrically interlocked with the converter, the oxygen supply system, the cooling-water system and the gas cooling and dust collecting plant. This effectively prevents the lance from being lowered when there is a failure in coolant supply or a breakdown in the blower.

For each converter there are two operating lances which are connected to the oxygen line, to the oxygen/lime line and to the cooling water circuits. New types of lance suspension enable the lance to be easily realigned if it should deviate from the perpendicular. This ensures that the lance is accurately centered when passing through the dome of the gas hood and that it is suspended in the centerline of the converter so that unilateral wear of the lining is avoided. Realignment of the lance is effected by means of adjusting screws at the lance suspension gear and by readjusting prismatic pads at the clamping device (Fig. 12).

Each lance is attached to a carriage which is moved up or down by chain or rope hoist and is guided in a travelling frame which can be moved horizontally so that each of the two lances can be moved over the center of the converter. In case of a power failure, the lance can be pulled out of the converter by the action of a counterweight after the brake has been released.

3. Converter Plant with Rotating Vessels

While the majority of oxygen-blown converters are fixed in the vertical position during the blow and the metal bath is refined by a stream of oxygen issuing from a vertically suspended lance, converters have also been developed which rotate rapidly around their longitudinal axis in an oblique position. Of these special applications, Kaldo converters may be mentioned here in which the vessel is inclined at an angle of approx. 20° during the blow and rotates at speeds of up to 30 rpm. Several designs have been developed which differ in detail design. The rotating vessel can, for instance, be fitted with two running rings or with only one running ring, as shown in Fig. 13, on which the vessel rests and rotates. Although rotating converters have a relatively small share in the world production of steel, it may well be said that their mechanical problems can be regarded as solved.

A combination LD/Kaldo converter is a new development. The unit shown in Fig. 14 represents a test installation and is so designed that the oxygen blow can take place both with the converter in the fixed, vertical position (LD) and with the converter inclined at about 20 deg. and rotating around its longitudinal axis (Kaldo).

The interior shape and dimensions of this vessel are just as important as in all oxygen steelmaking processes. Consequently, a compromise was made between the requirements of both processes and the vessel designed with an inside volume of 26 m^3 and a weight of approximately 62 tons. In addition, there are the weights of the running ring, refractory lining, metal bath and slag, giving a total weight of the rotating mass of 260 tons. The speed can be infinitely varied up to 30 rpm. At maximum rpm, the circumferential speed is 3.5 m/sec.

The oxygen and flux feeding systems as well as the gas cooling and dust collecting plant enable the LD (Fig. 15) and Kaldo processes to be operated separately as well as jointly with all variants (Fig. 16). The LD gas cooling and dust collecting plant (Fig. 17), which is combined with the Kaldo system, operates on the Krupp suppressed-combustion principle in which the induced-draught fan is so controlled that the volume of waste gas entering the cooling stack corresponds to the gas volume evolved in the converter. In this way after-burning of the converter gases is avoided in the cooling stack during the main blow. The combination unit represents an efficient and economic solution.

4. Gas Cooling and Dust Collecting Plant

In view of the considerable CO-content of the fumes emitted from oxygen-blown converters, conventional precipitators or venturi scrubbers were used in the first dust collecting systems built for such installations. These were preceded by gas coolers which were run with a considerable amount of excess air. Fig. 18 presents a review of the dust collecting methods which were used.

Plant A	Dry precipitator	Air ratio $n_{min} = 4$
Plant B	Fabric filter	Air ratio $n_{min} = 2.5$
Plant C	Venturi scrubber	Air ratio $n_{min} = 1.5$
Plant D	Dry precipitator	Air ratio $n_{min} = 1.5$
Plants E & F	Venturi scrubber	Air ratio $n_{min} = 0.1$

Investment costs, space requirements and operating costs caused designers to change-over from excess air to air deficiency. Existing plants operating with a deficiency of air are all based on the wet process.

The idea was that where explosive mixtures must be handled, plants based on some wet process provided no source of ignition. Development work in this area took an almost parallel course in France, Japan and Germany. While in Japan and France the oxygen/blown converters were built for converting basic iron into steel, the first installations built in Germany were designed to handle high-phosphorus pig iron (lump lime or powdered lime process). In order to ensure a deficiency of air, the gas hoods were designed to prevent the ingress of combustion air almost completely during the blow.

While in the normal oxygen-blowing process the gas hood can be lowered onto the converter mouth, the blowing of basic Bessemer iron requires a minimum clearance of 0.5 m between converter mouth and gas hood because of the formation of a foaming slag.

To obtain credits for the waste heat recovered from the converter gas, endavours were made to utilize the steam generated in the gas cooling system.

Fig. 19 shows the attainable steam yield as a function of the air ratio with uncontrolled gas removal. The steep rise in steam yield with air ratios from 0.1 to 0.3 is conspicuous and is of considerable importance in the selection of the waste heat recovery system.

As can be seen from Fig. 20, controlled combustion with a constant air ratio of approx. 1 gives only a small increase in steam yield as compared with uncontrolled gas extraction where the air ratio varies from n = infinite to approx. 1 during the main blow. Owing to the need for gas analysers and control gear, operation becomes, however, more complex.

Further possibilities to obtain credits for waste heat recovery were investigated and some of them put into effect in Japan. The credits obtainable from the recovery of CO when blowing basic iron can be seen in Fig. 21.

This graph shows that up to a heat energy price of DM 7.50 per 10^6 kcal no credit can be obtained since the costs for the handling, storage, cooling and secondary cleaning of recovered CO-bearing gas run up to the same amount. In a plant designed for a minimum air ratio of 0.3, which utilizes only the steam generated, a breakeven point in operating cost can only be attained if the heat energy price is DM 17.50 per 10^6 kcal. Compared with the utilization of steam, the recovery of CO-bearing gas does not yield any economic benefits unless the price of heat energy exceeds DM 17.50. As shown in Fig. 19, these correleations are due to the steep rise in steam credits at air ratios between 0.1 and 0.3.

The following photographs present a review of some typical installations built so far:

Figs. 22 and 23	Fried. Krupp Hüttenwerke AG. Rheinhausen Works Dry precipitator Utilization of steam	90 tons hot metal Air ratio 1.2 min.
Fig. 24	Belval Arbed Works Venturi scrubber Utilization of steam	110 tons hot metal Air ratio 0.3/0.7 min.
Fig. 25	Dortmund Hörder Hüttenunion Venturi scrubber Steam discharged into atmosphere	150 tons hot metal Air ratio 0.1/0.3 min.
Fig. 26	Ilseder Hütte, Peine Venturi scrubber Controlled extraction Steam discharged into atmosphere	70 tons hot metal Air ratio 0.1
Fig. 27	Cockerill-Ougrée Providence Works Venturi scrubber Controlled extraction Steam discharged into atmosphere	33 tons hot metal Air ratio 0.1
Figs. 28 a and b	Usines Gustave Boel Works Venturi scrubber Uncontrolled gas extraction Steam condensed	70 tons hot metal Air ratio 0.1 min.

The controlled gas extraction system is shown diagrammatically in Fig. 29. Constant air ratios of approx. 0.1 are achieved in the main gas flow by means of a secondary gas offtake which extracts the combustion products from the periphery of the free gas jet, and by means of automatic controls. If control of gas extraction is dispensed with, an air ratio of 0.1 (dotted line) is merely achieved at the maximum blow when the secondary gas offtake is used. If the secondary system is also dispensed with and gas extraction is not controlled, a minimum air ratio of approx. 0.3 can be achieved at the maximum blow. Under these conditions there is no excessive evolution of gas. Owing to the increase in the air ratio from 0.1 to 0.3, the throughput of gas compared with conditions at an air ratio of 0.1, increases by the amount of the gas throughput obtaining with secondary extraction. Using the secondary system and controlled extraction is, according to present standards of engineering, advisable only if it is intended to minimize feedwater losses in such cases where the steam generated is allowed to escape into the atmosphere or where CO-bearing gas is to be recovered. Uncontrolled gas extraction without a secondary system involves a less complex design and its investment and operating costs are not higher.

Fig. 30 shows a gas hood with secondary offtake.

Some operating diagrams of the controlled gas extraction system are shown in Fig. 31. Air temperature, gas hood pressure, waste gas volume, differential pressure in the wet scrubber and the steam quantity produced by the cooling stack are plotted against time. The effectiveness of the secondary system becomes evident if one follows the temperature curve of the secondary gas (air temperature).

Fig. 32 is a true-to-scale diagram of a wet scrubber installation for uncontrolled extraction without secondary offtake, based on the suppressed-combustion principle.

In an endeavour to lower the high operating cost of a wet scrubber and to recover the dust in dry form, Krupp developed a dry electrostatic precipitator for the gas process (Fig. 33) which is at present being tested in a commercial-size plant. The use of dry electrostatic precipitators for the gas process requires the provision of proper flow conditions by suitable design measures. The system must be satisfactorily scavenged when it is changed over from air through flue gas to gas or vice versa. The flow velocities within the plant are shown in Fig. 34. It is only at the inlet and outlet of the precipitator that sudden changes in velocity occur.

Another important reason for using the dry precipitator is the possibility of returning the dry dust direct to the converter. Tests to this end were carried out satisfactorily in a conventional precipitator installed in Krupp-owned iron and steelworks.

In order to get some idea of the cost, the investment and operating costs incurred with different processes are discussed for a plant comprising three 100-ton converters on the basis of German conditions. Fig. 35 gives the investment costs of different dust collecting systems for a steel plant with three converters, one of which is being lined. In contrast to wet-scrubbing systems in which each converter has its own cooling stack, condenser, primary and secondary collectors, the dry-dust collection systems have common secondary dust collectors. Because of the high initial cost of the latter, three converters are connected through a gas damper station with two dust collectors.

A comparative diagram of operating costs is shown in Fig. 36. The upper stepped line represents the operating costs without credits for steam and the lower stepped line represents the operating costs including possible credits for steam or for steam and CO-bearing gas when the plant has an air ratio of 0.1.

Fig. 37 shows the influence which credits exert on the net operating costs. The individual air ratios are assigned to the relevant types of collector. Optimum net operating costs are obtained at an air ratio of 0.3 in conjunction with a dry precipitator and utilization of the steam. If steam and gas are utilized, the same net operating costs as mentioned above can only be achieved if the gas credit adds up to DM 0.90 per ton of ingot steel, corresponding to a heat energy price of DM 17.50 per 10^6 kcal. Assuming a realistic heat energy price of DM 10.-- per 10^6 kcal, the net operating costs for a plant providing for the utilization of steam and gas add up to 1.80 - 0.55 = DM 1.25 per ton of ingot steel compared with DM 0.60 per ton of ingot steel for a plant with one dry precipitator which is operated at an air ratio of 0.3 and utilizes the steam generated.

Owing to the many alternatives, it is difficult for anyone planning a steelmakin plant to select the most suitable process for cooling and cleaning the converter fumes.

The influence exerted by wages, utility rates, interest, depreciation and maintenance costs must be carefully weighed and gives somewhat different results in each specific case.

When it comes to the construction of the plant, reliability will, of course, be the main consideration apart from the theoretical, technological and commerc aspects.

5.1 Instrumentation and Control Systems

Provisions for Automation of the Metallurgical Process

Owing to the fact that in modern oxygen steelmaking the heats weigh up to abou 300 tons and tap-to-tap times are very short, there are very high outputs and flow rates which must be coped with. It is therfore of decisive importance tha all process variables are measured and controlled within the shortest possibl time. This requires a lot of instrumentation and controls, which are also necessary to ensure reliability in operation.

To put it briefly, the following instrument and control circuits and monitors are necessary or recommendable for a modern steelmaking plant:

1. Instrumentation and controls for oxygen and cooling water supplies to the lance and for positional control of lance and converter.

2. Instrumentation and controls for the gas cooling and dust collecting plant.

3. Monitoring the entire flow of materials from a central control board connected to several control panels.

4. Rapid-analysis laboratory

5. Central data recording and logging system

6. Automation of the blowing process

Most of the instrumentation and controls used are of the commercial type, but there are also some items which have been specially developed for the oxygen steelmaking process.

The purpose of every automatic control system is to establish, maintain or, in case of danger, stop a measurable condition (temperature, weight, for instance) or a process (oxygen flow rate, for instance) even if there are external disturbances.

We distinguish between set-point controllers, timepattern controllers (programme controllers) in which the desired value is automatically changed in accordance with a preset time pattern, and follower controllers in which the set point changes according to some outside variable unaffected by the automatic control system.

Fig. 38 shows diagrammatically the arrangement of the above mentioned instrument and control circuits normally installed in oxygen-steelmaking plant.

Fig. 39 shows the control and shutoff valves required for the instrument and control circuits for oxygen and cooling water supplies to the lances, as well as the orifice plates, pressure and temperature measuring elements with the necessary transmitters installed in the piping for the lance and connected to a central valve station. These systems measure and automatically control the following variables:

Oxygen:

a) Pressure upstream of the control valve (3)
b) Flow rate (2, 3, 4, 5)
c) Pressure downstream of the control valve (6)
d) Change-over to lance 1 or lance 2 (7)

Cooling water:

a) Supply pressure (9)
b) Flow rate (9, 10, 12, 13)
c) Water temperature (13)
d) Flow rate (14)

Monitoring the entire flow of materials

As mentioned above, the entire flow of materials, i. e. the handling and proportional-feeding of materials within the steel plant must be accurately measured and recorded in terms of weight, properties and time. To what extent and with what accuracy this is done depends upon the aims of the shop management. If, for instance, it is desired to automate the process as far as possible, then this requires extensive and accurate recording and processing of all data. In this case the following data must be logged:

1. <u>All weights:</u>

   of metal, additives, fluxes

   In addition, the following must be weighed:

   Residual slag, slag removed during every slagging period, finished steel, amount of dust and sloppings per campaign.

2. <u>All analytical data</u>

   of hot metal
   scrap
   and other materials as well as in-process samples and finished-steel samples

3. <u>Temperatures</u>

   of the bath and of the waste gas in the gas hood, etc.

4. <u>All important times</u>

   such as time when scrap was charged, when hot metal temperature was measured, when hot metal charging began and ended, when lime feeding began and ended, when ore charging began and ended, when fluxes were added, when oxygen blowing started and finished, when steel temperature was measured, when steel and slag samples were taken, when ferroalloys were added, when the melt was poured, when the converter was relined, etc.

5. Oxygen flow rate, oxygen pressure upstream of the lance, oxygen consumption (cm^3 per melt), cooling water flow rate in the gas hood and in the lance.

The feeding of materials to the converter has today been largely automated. The quantities are determined by electronic scales fitted with strain gauge load cells. The entire flow of materials in an oxygen steelmaking shop is controlled and monitored from a central point - called the central control board from which all data and instructions are transmitted to the various control panels situated in the shop. From these panels, all actual values are transmitted to the central control board. The main control panels are situated in the following areas:

Converters
Hot metal mixer
Scrap yard
Ferro-alloys hoppers
Teeming area

These control panels and the central control board monitor and provide direct control of the entire production cycle; the basic arrangement is shown in Fig. 40.

The functions of the central control board are as follows:

1. Preparation of "metallurgical recipes" for the individual heats

2. Calculating the quantities of hot metal, scrap, feed ore, fluxes, oxygen and ferro-alloys for each melt or each blowing period.

3. Monitoring the process of the blow by automatic recording of the actual weights and composition of all materials introduced into the converter, the analysis of all samples taken from the converter and the relevant temperatures of mixer metal and steel.

4. Recording all actual values from tap to tap and printing out the logs of each melt.

5.2 Provisions for Process Automation

The purpose of automation is to establish optimum conditions during the course of the blow. From the aspect of operation, this means shorter blowing times, lower oxygen consumption, larger production rates and higher yield, closer compliance with specified steel compositions and temperatures. From the aspect of investment costs, automation enables the waste gas cooling and cleaning system to be given a smaller size.

The application of process automation requires

a) that the plant is well run in

b) that the operating crew is well acquainted with oxygen steelmaking

c) the provision of suitable instruments and control gear to enable the process to be automated.

Although the requirements under a) and b) cannot be met straight away when a new steel plant is built, provisions should nevertheless be made during construction for the future installation of the equipment required for automating the metallurgical process.

Since direct continuous and temperature measurement of the melt have not been feasibile so far, other variables must be resorted to which are related to the metallurgical reactions taking place during the blow. As shown in this diagram of a Krupp test setup (Fig. 41) the following variables are used to provide the necessary information:

Quantity of waste gas
Waste gas analysis CO, CO_2, O_2, N_2
Gas pressure, humidity

The methods developed to measure the formation of a foamy slag are based on measurements of the electrical conductivity and on the level of the converter noise. Electronic computers are used to calculate from the individual readings new characteristics for automatic control of the process, namely, the oxygen distribution $\dot{O}_c$ and the heat flow Q_w. Using special automatic control loops (Fig. 42) these variables enable the distance between lance tip and bath and the oxygen flow rate to be controlled dynamically. Tests carried out with a 3-ton converter of the Krupp research department were completed successfully so that afterwards it was decided to employ the same method in full-scale production on a 90-ton converter installed at the Rheinhausen Works of Krupps. Work on this plant has now reached an advanced stage.

6. Other Steel Plant Equipment

In addition to the above key facilities, such items of steel plant equipment will be discussed here which represent new or improved designs or are particularly adapted for oxygen steelmaking.

6.1 Hot metal mixers

Compared with the conventional type of mixer having a horizontal, cylindrical shell mounted on rollers or rockers, a new type of mixer, Fig. 43, having a shell similar to that of a converter offers the following basic advantages:

a) Hot metal can quickly be charged through the mouth of the vessel

b) Slag can quickly be removed through the mouth and the hot metal can be poured through the taphole, so that, as in the case of converters, it is discharged free from slag.

These advantages add to the mixer's equalizing effect on temperature and composition of the hot metal. Another important benefit is that the mixer can be relined with similar bricks and the same technique as used in converters resulting in reduced relining time. The first mixer of this type had a holding capacity of 700 tons and was built for a Swedish steel company. Even after the first mixer campaign it was found there that these advantages do make themselves felt, although the results certainly cannot be regarded as final at this stage. Relining after the first campaign required only about 1250 working hours, including removal of the old lining, relining and heating up. Relining a conventional hot metal mixer takes several times longer.

6.2 Scrap-charging Machine

Oxygen-blown converters can be charged with batches of scrap and similar solid materials by means of scrap-charging machines which travel on the working stage and are capable of carrying several scrap chutes (Fig. 44). They enable several converters to be charged at short intervals and offer the advantage of independence from the hot metal crane, so that expensive waiting times of the converters as a result of overlapping crane cycles are avoided.

6.3 Slag Pot Transfer Cars

Large converters produce large quantities of slag which must be removed and disposed of. For this purpose, it was found advantageous to use transfer cars running on short tracks under the converters in conjunction with rubber-tyred slag pot trucks, which take over the filled slag pots and return the empty ones. Fig. 45 shows a new slag pot car fitted with an electronic scale. The shaded parts refer to the rubber tyred vehicle to which the slag pot is transferred. This arrangement can easily be incorporated in any existing layout and the scale meets the requirements of data logging or process automation.

6.4 Relining Stands

Fig. 46 shows a relining stand for oxygen-blown converters with detachable bottom. This stand enables brick pallets to be raised from floor level to the required level within the converter. It carries a working platform on which the bricklayers can work in safety. This simple aid enables the shutdown period of converters for relining to be reduced to the minimum. In the case of detachable-bottom converters where the worn lining cools rapidly and the broken-out bricks can easily be discharged by tilting, it is certainly of advantage that the gas hood arranged above the converter mouth need not be moved aside or provided with an opening.

Prospects

The converter installations described here are in no way intended to show all the developments that have taken place nor to single out a specific, generally applicable design. They are merely intended to demonstrate that each of these layouts was the best solution for the particular application.

Figure 1

Ground plan of an oxygen steel plant recently planned for a Spanish iron and steelworks. The plant is now under construction and in its first stage is scheduled to produce 1.6/2 million tons/year of ingot steel

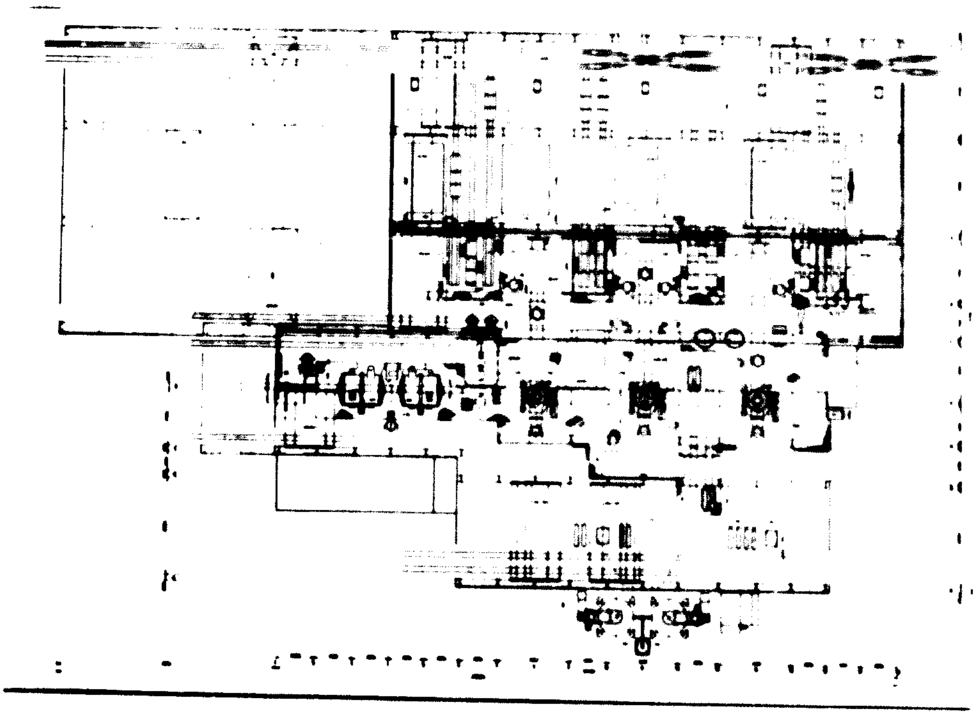


Figure 2

Cross-section of the oxygen steel plant for a Spanish iron and steelworks

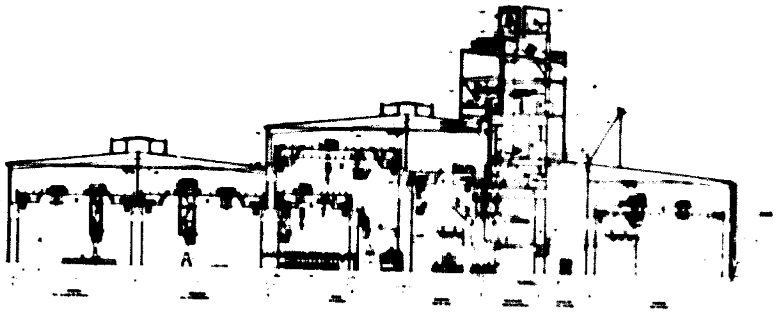


Figure 3

Shell of a 110-ton oxygen-blown converter for the blowing of basic iron

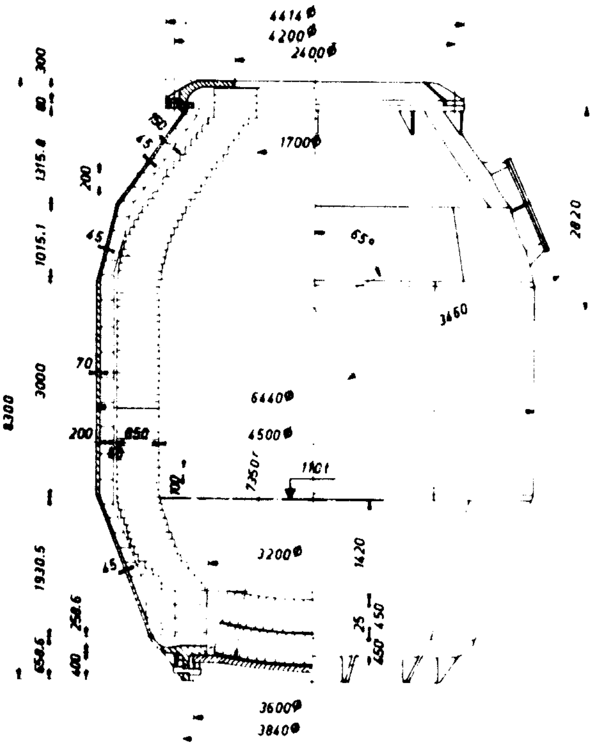


Figure 4

Calculation of torques as carried out by electronic computer

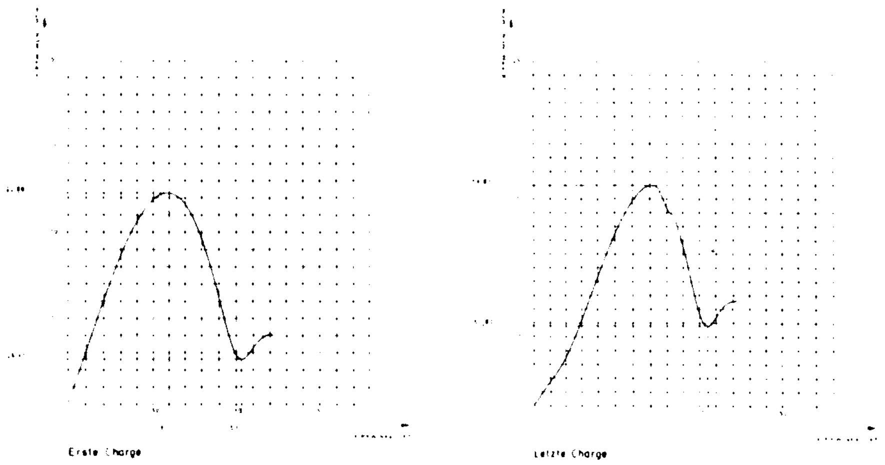


Figure 5

Layout of an 80-ton converter installation which has been in operation for several years

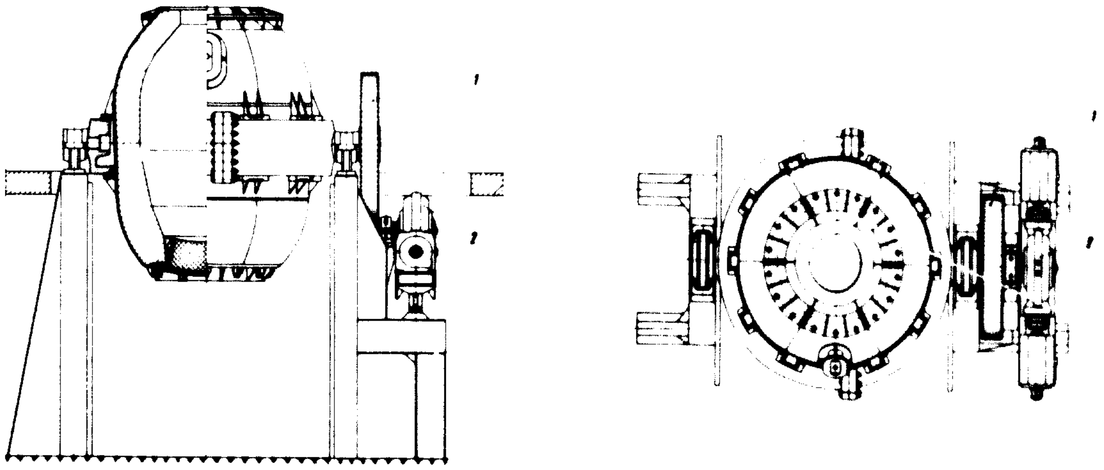


Figure 6

Cast-steel trunnion ring of two-piece construction with integral trunnions for a 80-ton oxygen-blown converter

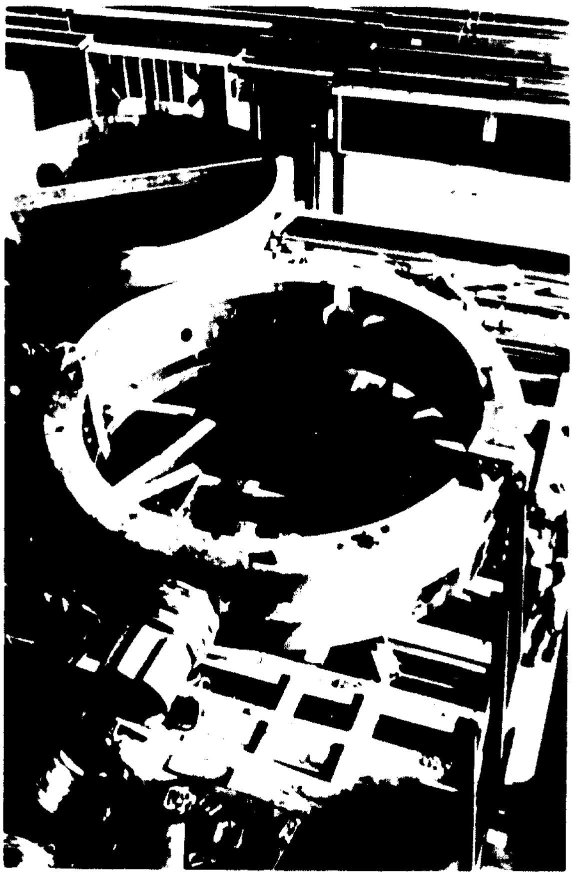


Figure 7

160-ton oxygen-blown converter of trunnionless design during erection in a Japanese steel plant

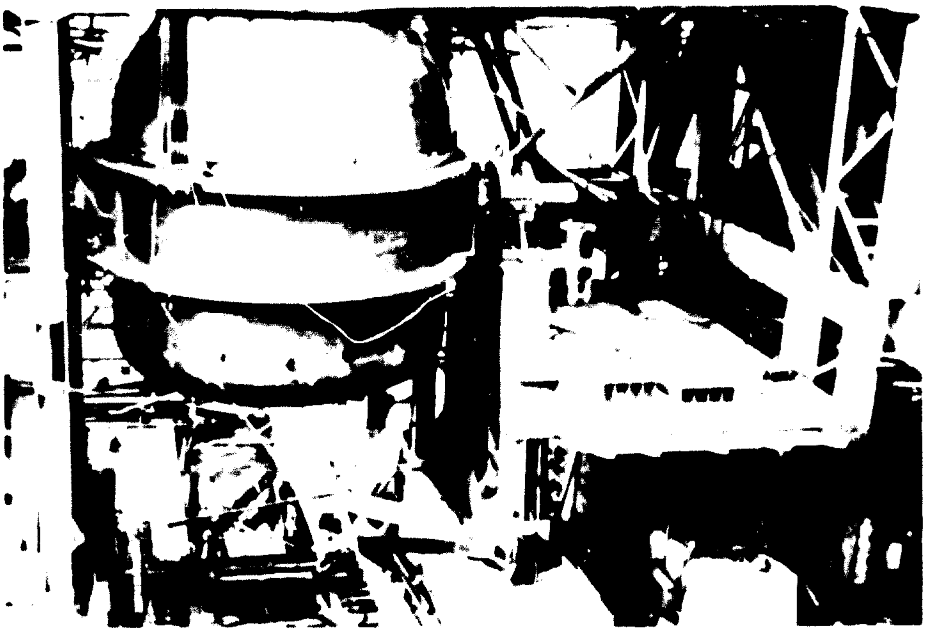


Figure 8

Shop-assembly of a box-section trunnion ring of two-piece construction for a 1[illegible]0-ton oxygen-blown converter featuring two tilting rings

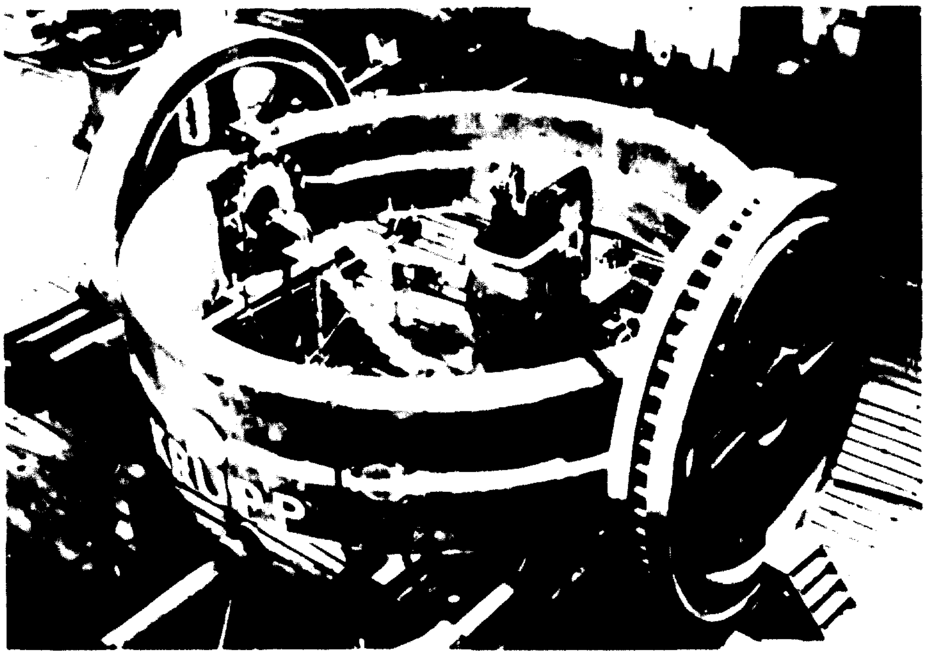


Figure 9

Design of a 180-ton converter installation. Owing to space limitations, two tilting rings were used instead of the usual pedestal bearings

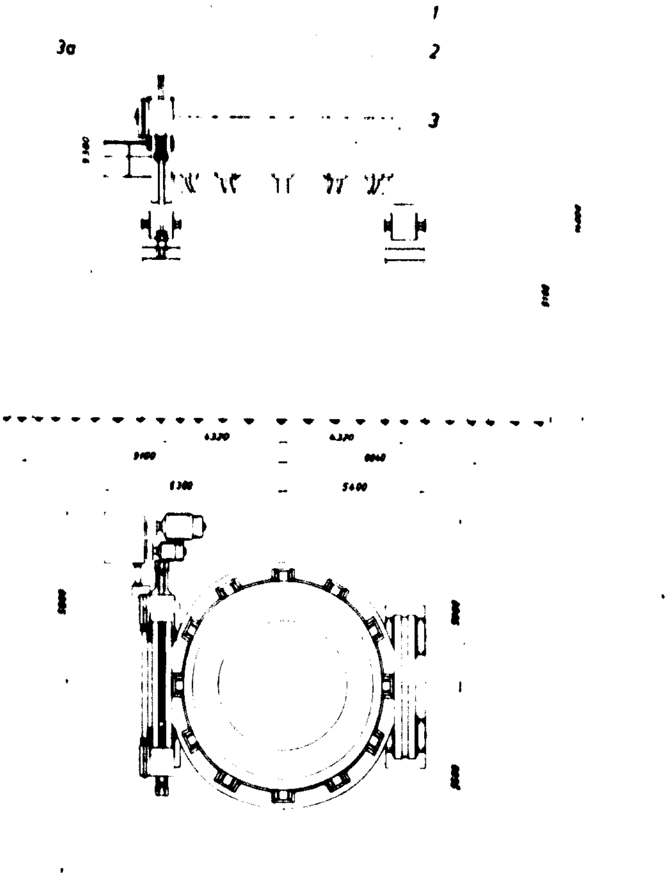


Figure 10

Twin-output gear unit for a 110-ton converter

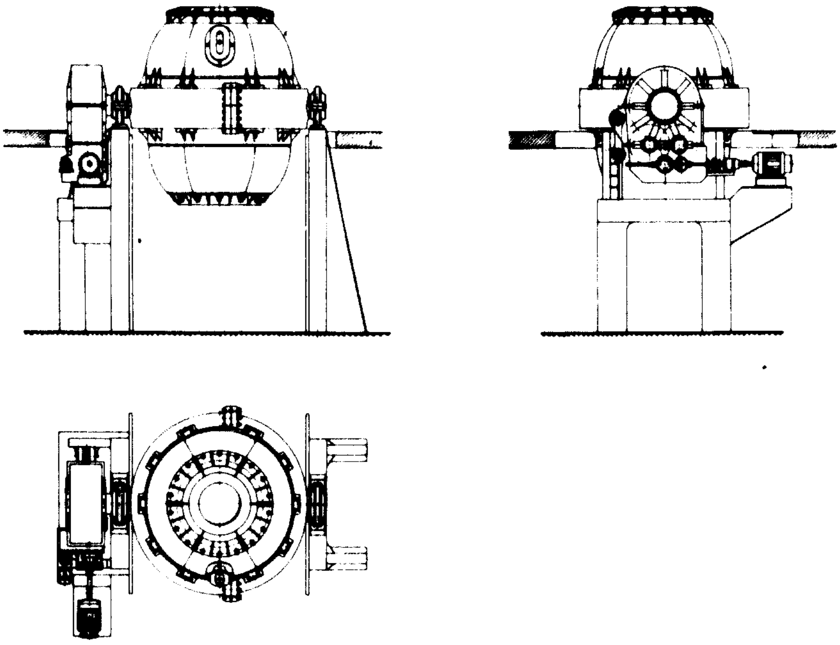


Figure 11

Oxygen lance equipment for oxygen-blown converters designed for blowing basic iron

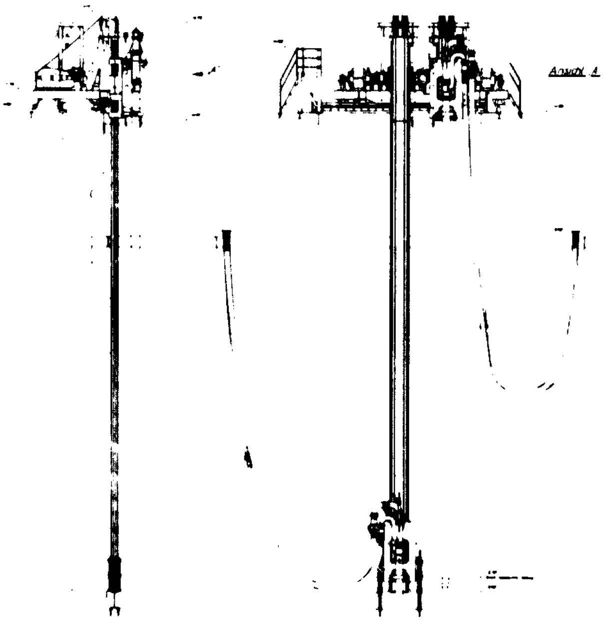
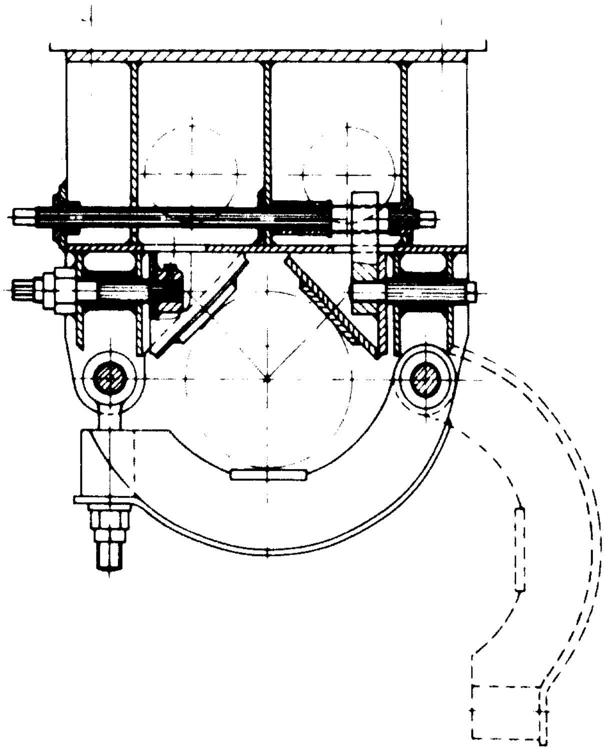


Figure 12

Mechanism for readjusting the oxygen lance by shifting prismatic pads



[illegible]re 1[illegible]

Single-ring Kaldo converter after [illegible]

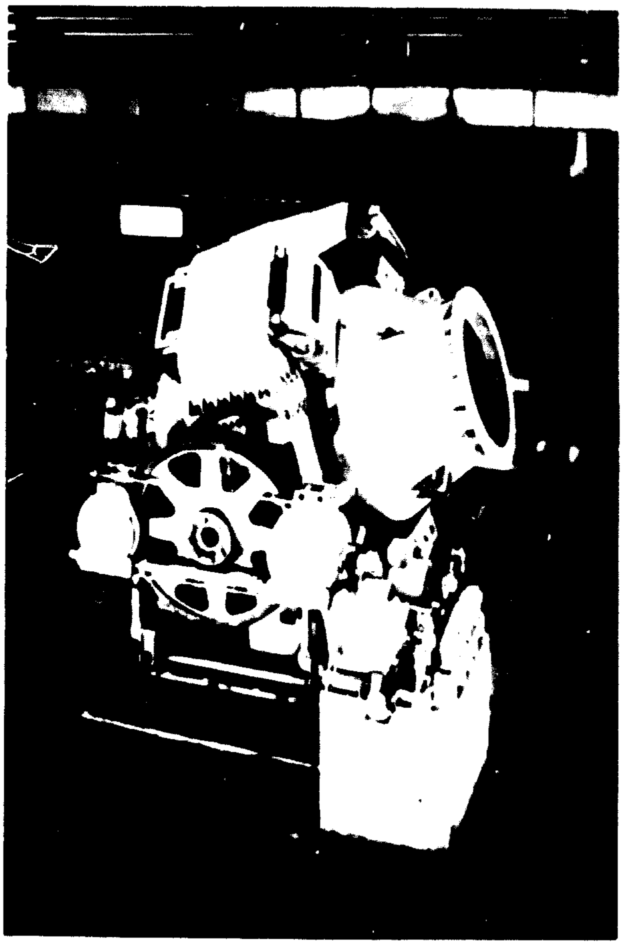


Figure 14

Diagram of a converter installation for LD and Kaldo operation; left-hand side: LD; right-hand side: Kaldo

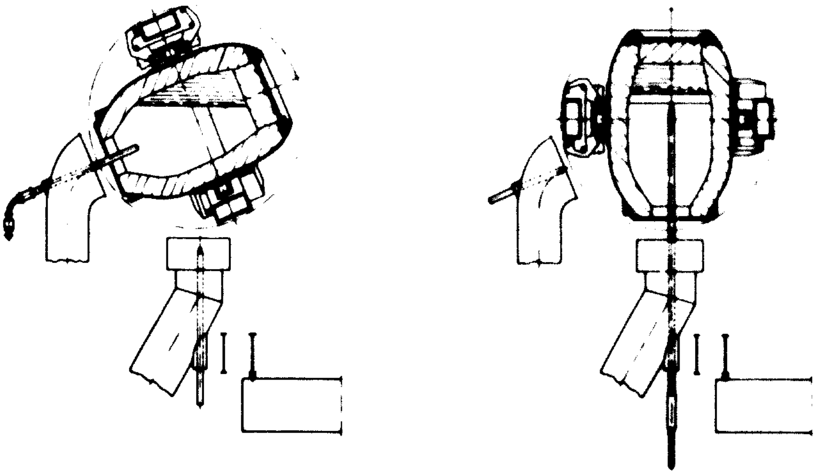


Figure 15

50-ton LD/Kaldo converter during the blow with the vessel in the vertical position

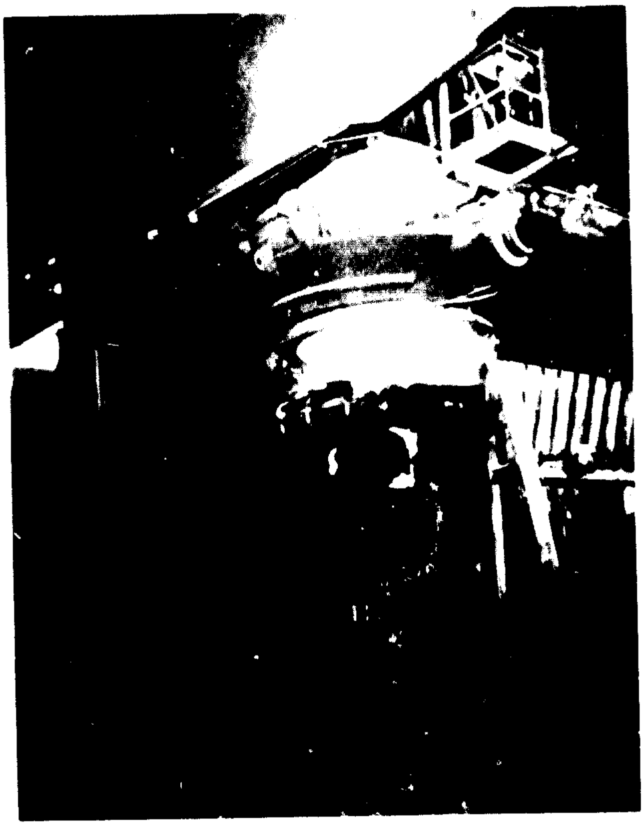


Figure 16

50-ton LD/Kaldo converter during the blow with the vessel rotating in an inclined position

Figure 17

Diagram of a waste gas cooling and dust collecting system for a 35-ton LD/Kaldo plant

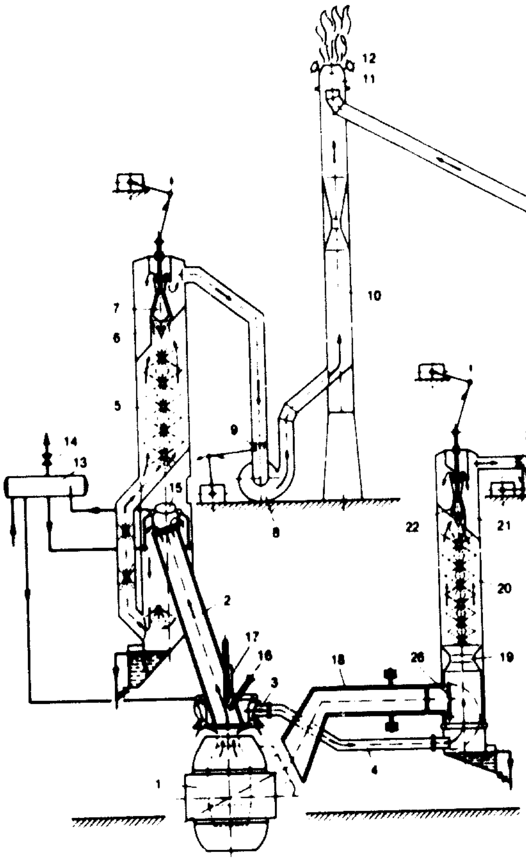


Figure 18

Gas cooling and dust collecting installations operating at different air ratios, gas volumes and gas temperatures

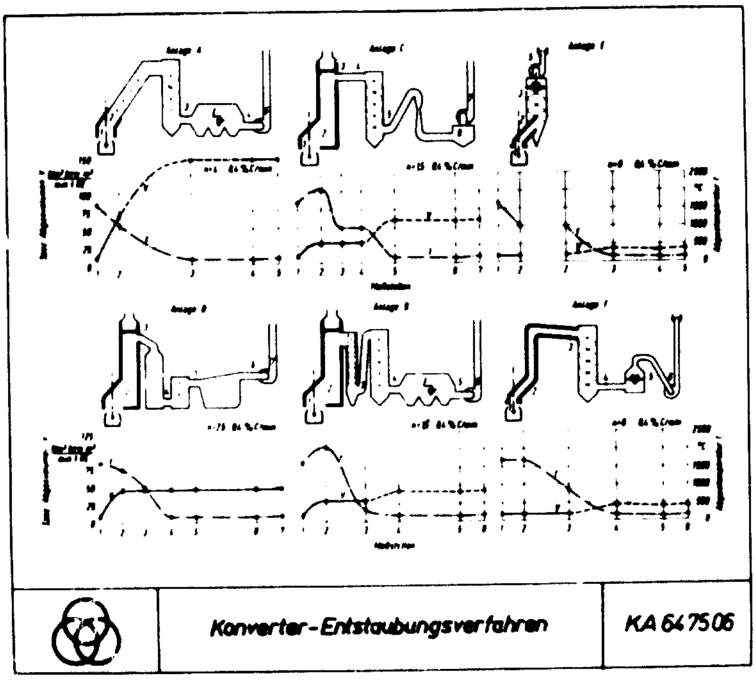


Figure 19

Yield of steam as a function of air ratio with uncontrolled gas extraction

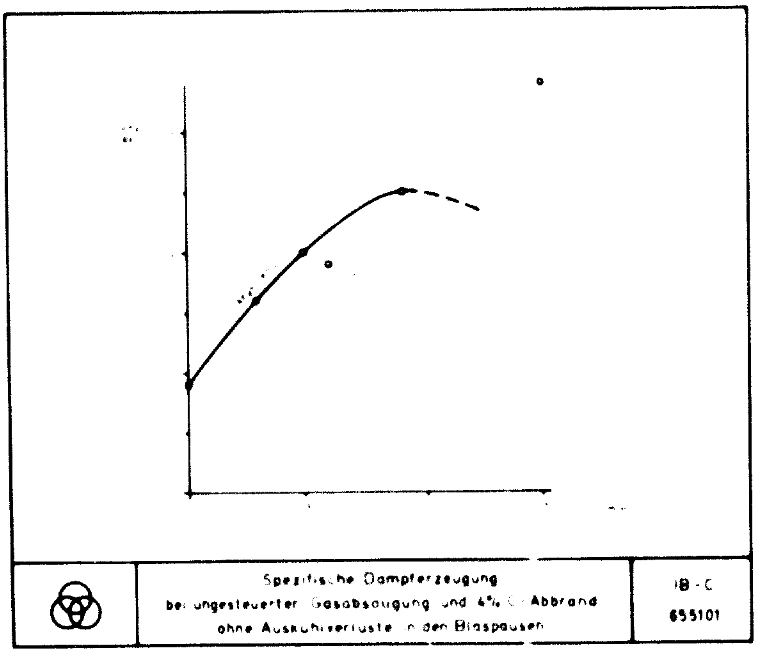


Figure 20

Heat recovery with different waste gas cooling systems (controlled and uncontrolled combustion) and different waste gas temperatures at the discharge end of the cooling stack

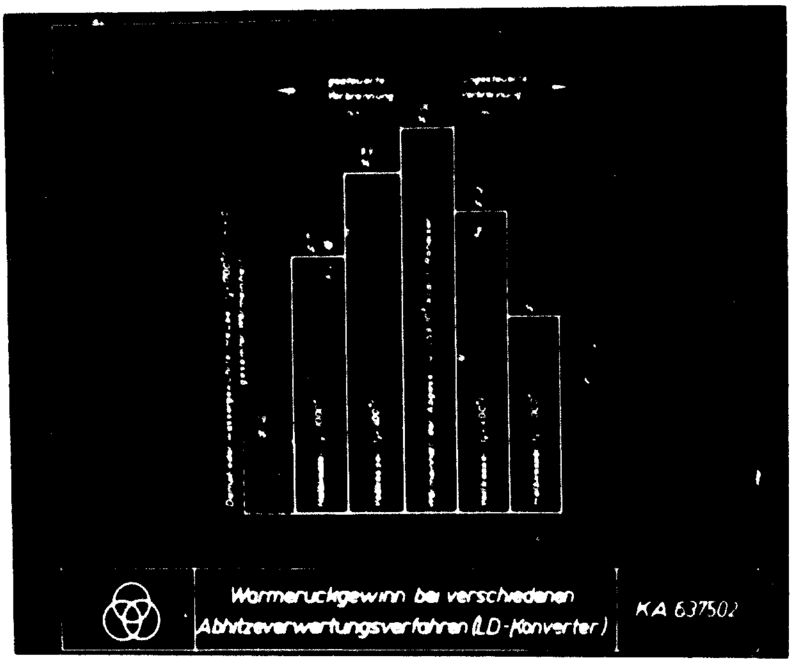


Figure 21

Credit for CO as a function of heat energy price with cooling and dust collecting systems for oxygen blown-converter-fumes

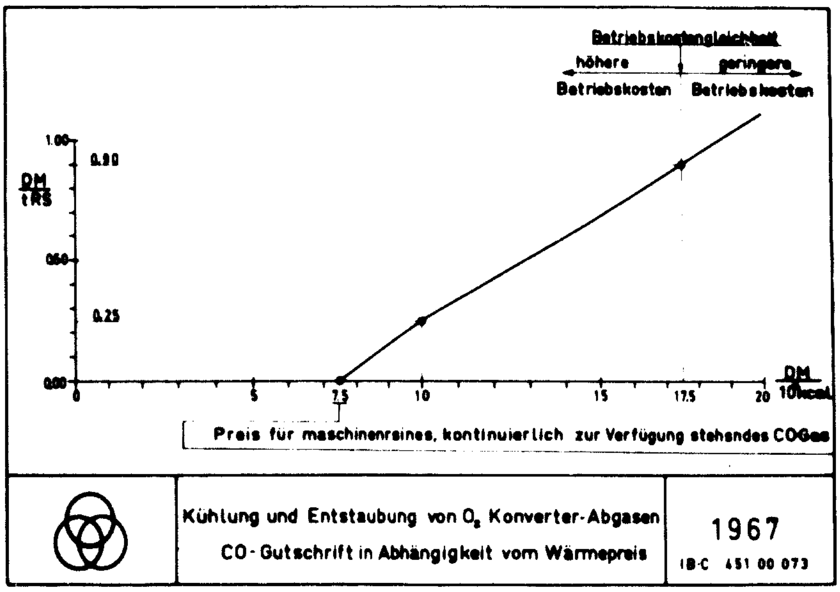


Figure 22

Diagrammatic representation of a conventional converter gas-cooling and dust collecting plant with dry precipitator

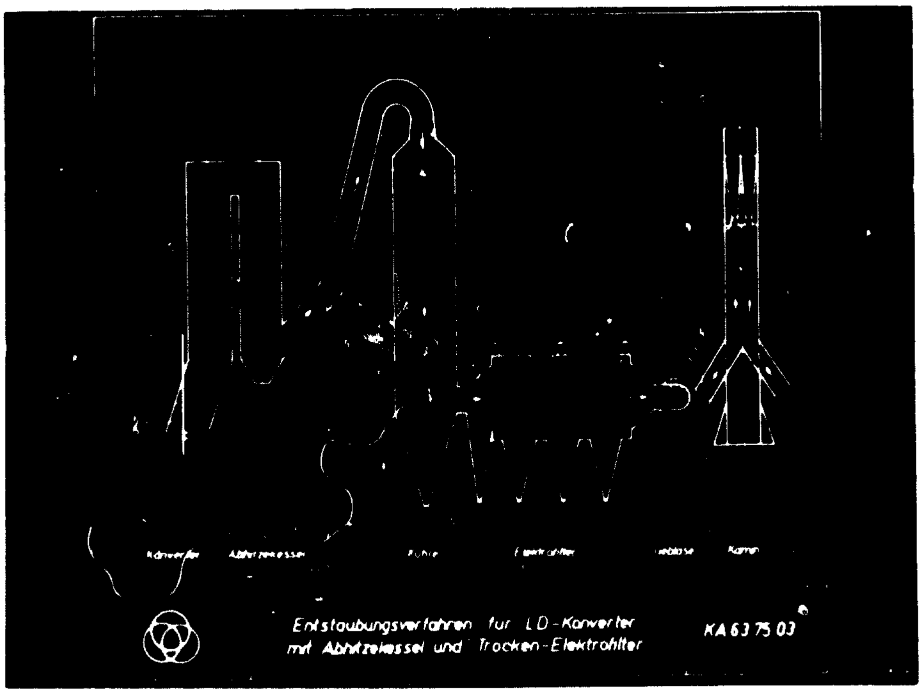


Figure 23

Waste gas cooling and dust collecting plant with dry precipitator

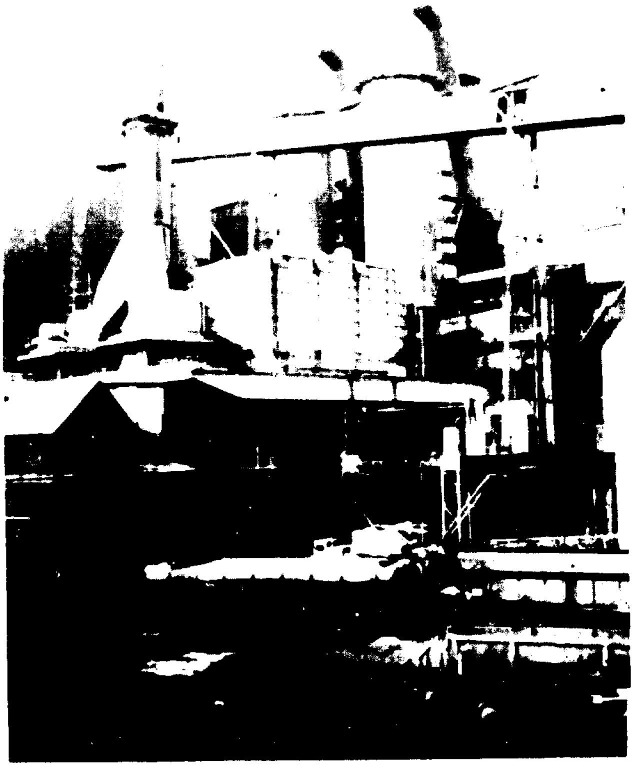


Figure [illegible]

Converter gas cooling and dust collecting plant featuring partial combustion and uncontrolled extraction of the gas

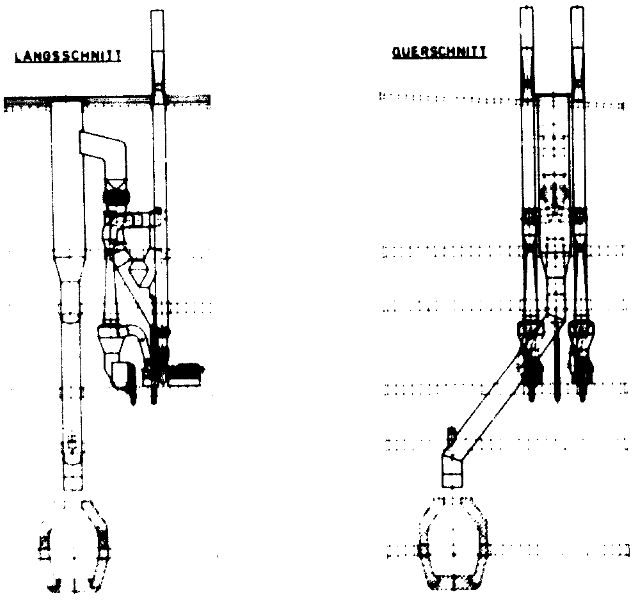


Figure 25

Diagram of a gas cooling and dust collecting plant operating on the Krupp suppressed-combustion process using wet scrubbers

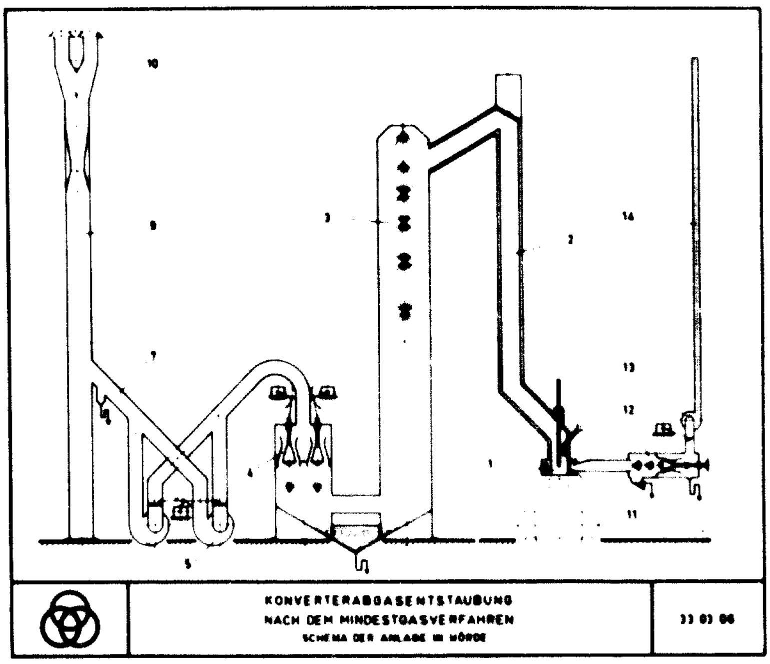


Figure 26

Diagram of a converter gas cooling and dust collecting plant operating on the Krupp suppressed-combustion process

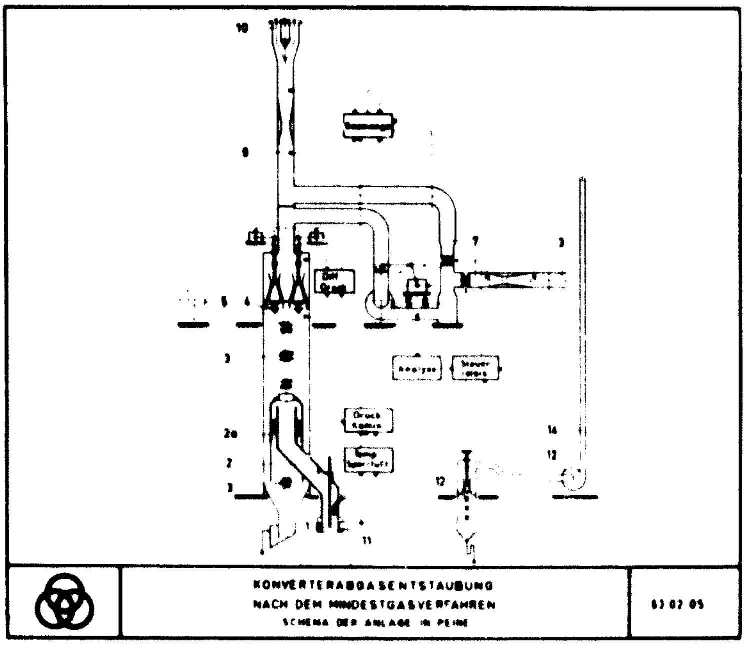


Figure 27

Diagram of a plant for the cooling and cleaning of converter fumes by the Krupp suppressed-combustion process. Designed for use with an LD/Kaldo-converter

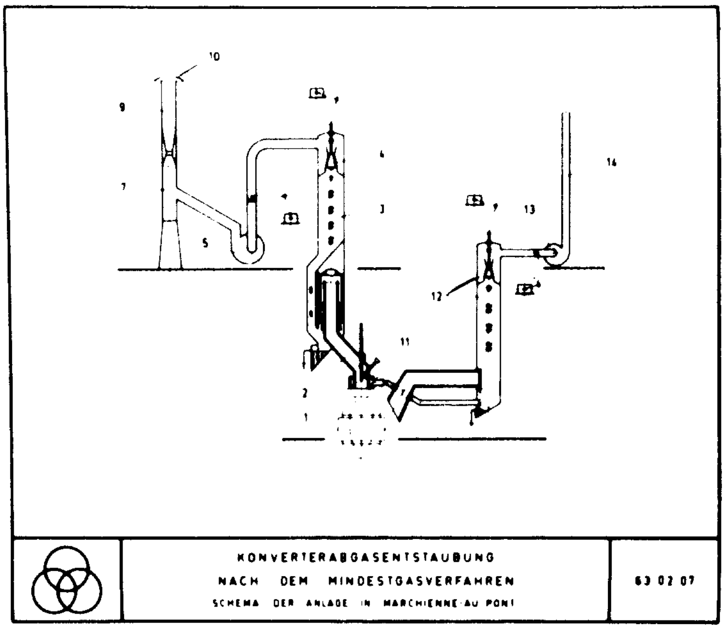


Figure 28a

Converter gas cooling and cleaning by the Krupp suppressed-combustion process without after-burning

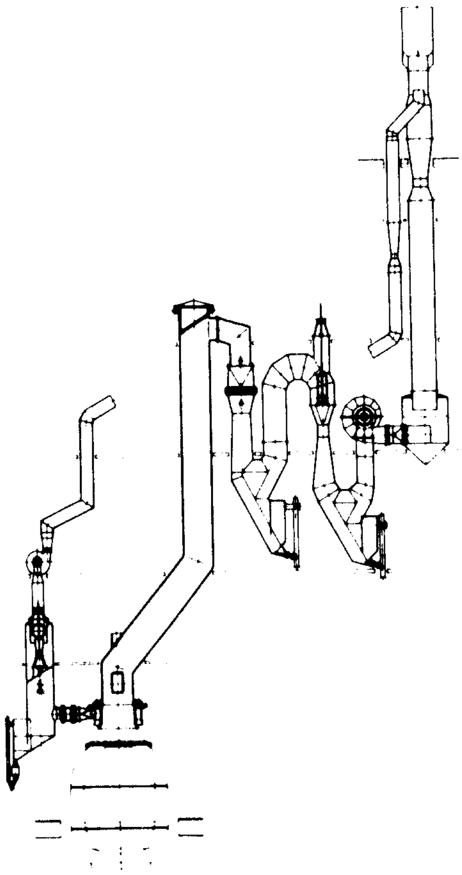


Figure 21

Gas cleaning by saturator and disc washer

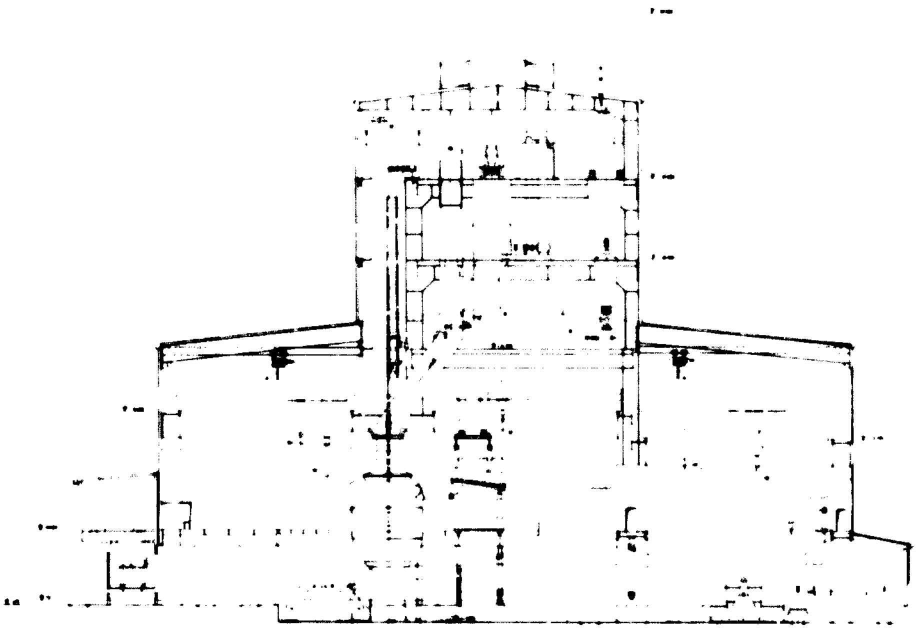
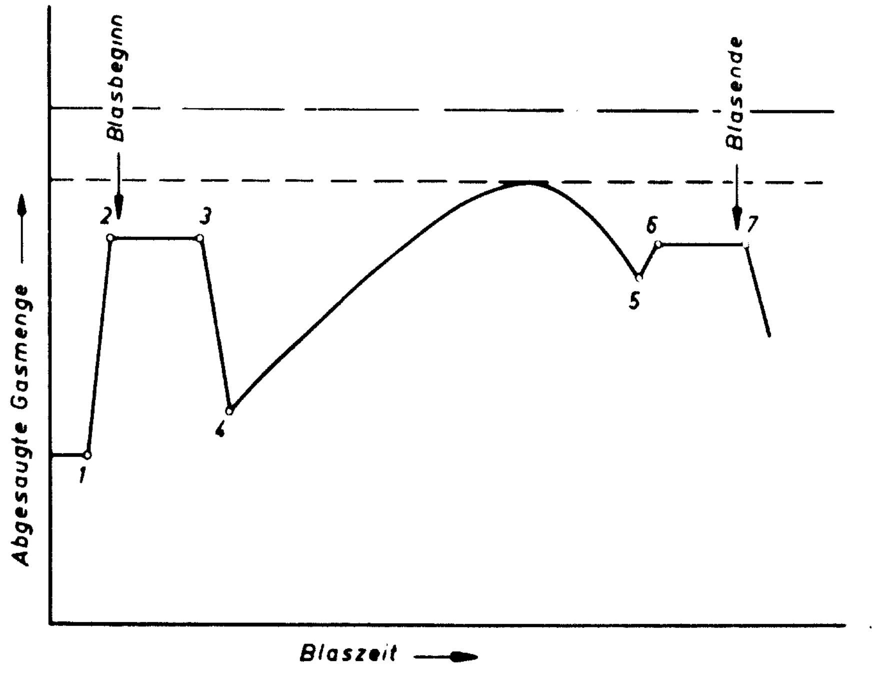


Figure 22

Extracted gas volume as a function of blowing time in the Krupp suppressed-combustion process



With controlled extraction and secondary system (continuous line);
with uncontrolled extraction and secondary system (broken line);
with uncontrolled extraction but without secondary system (dash-dot line)

Figure [illegible]

Gas [illegible] process

Figure [illegible]

Air temperature, [illegible] pressure, waste gas volume, differential pressure and steam rate as a function of melting time

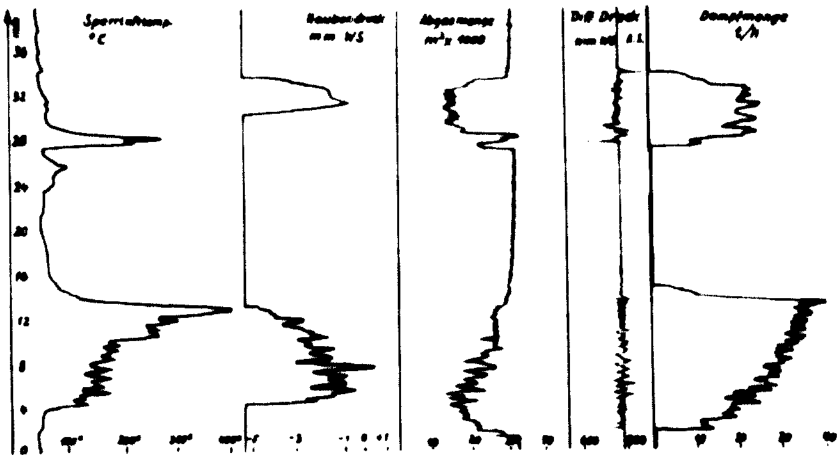


Figure 32

Diagrammatic representation of a plant for the cooling and cleaning of converter fumes by the Krupp suppressed-combustion process using wet scrubbers

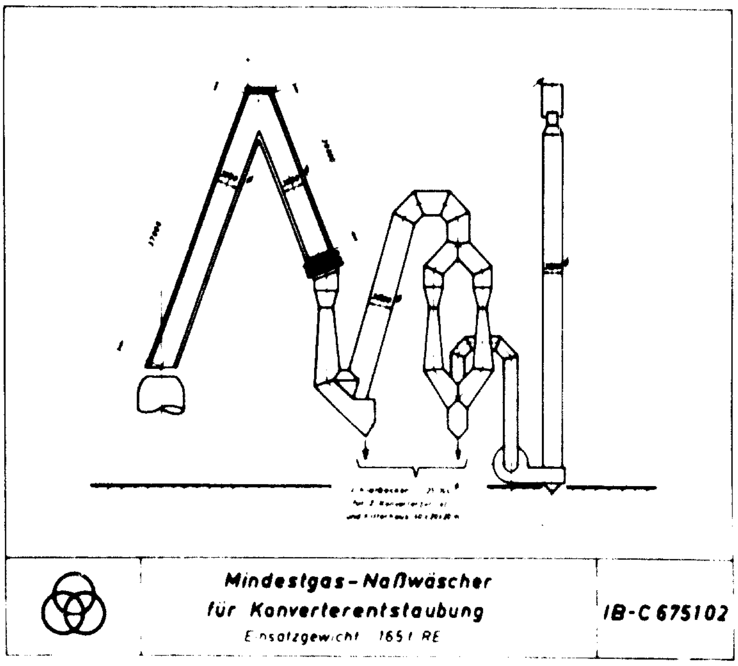


Figure 33

Krupp suppressed-combustion process using electrostatic precipitator for a 165-ton converter

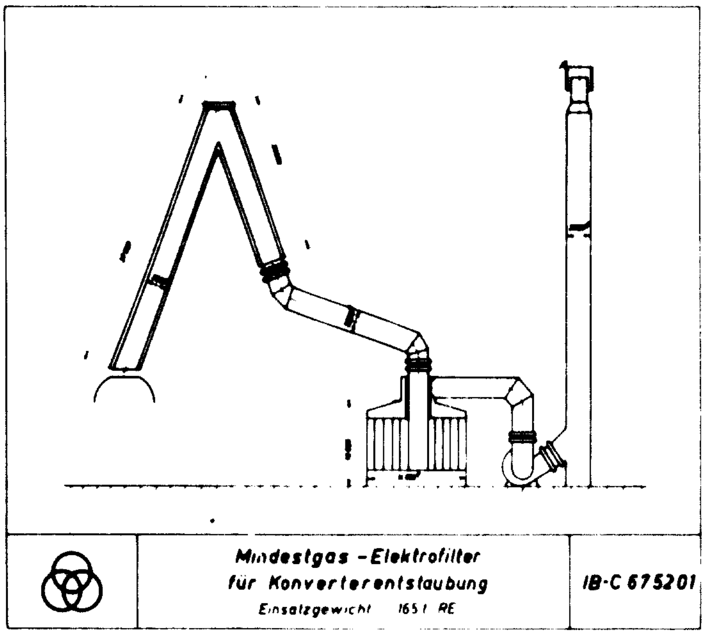


Figure 34

Gas velocities in a gas cooling and cleaning plant operating on the Krupp suppressed-combustion principle and featuring a precipitator

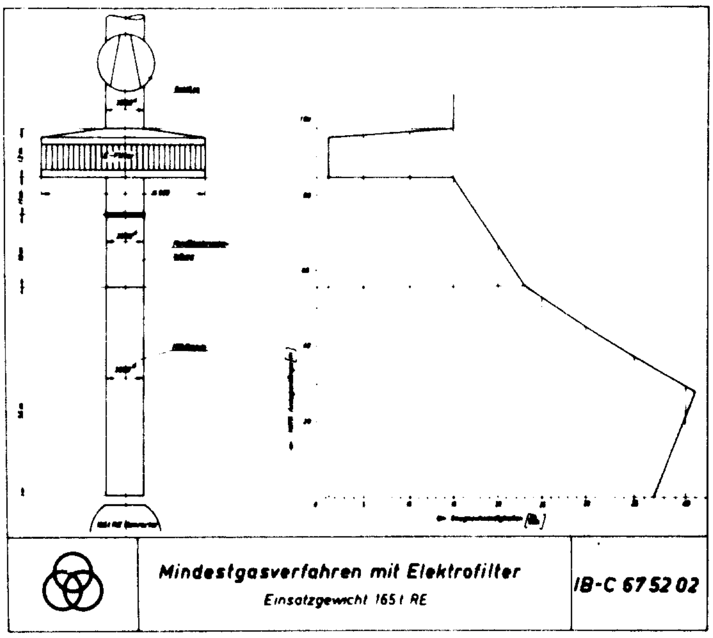
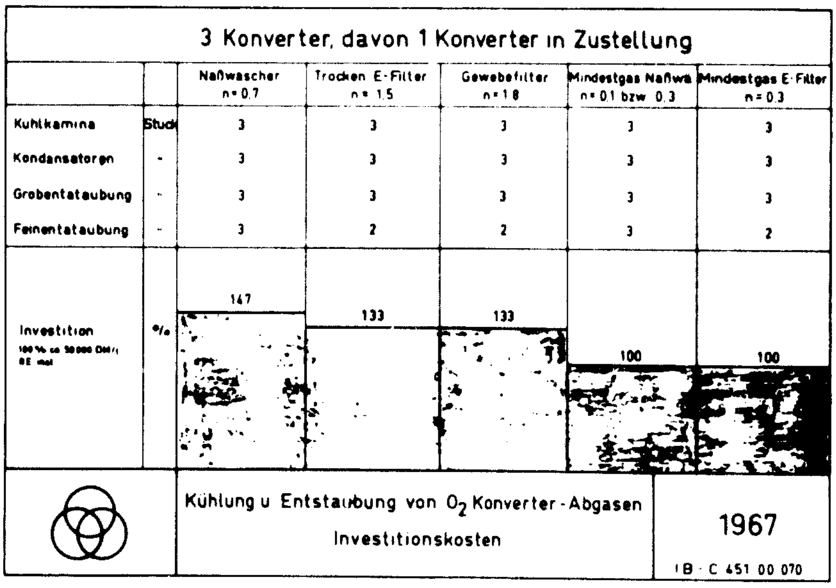


Figure 35

Investment cost of gas cooling and cleaning plant for three 100-ton converters



3 Konverter, davon 1 Konverter in Zustellung

		Naßwascher n = 0,7	Trocken E-Filter n = 1,5	Gewebefilter n = 1,8	Mindestgas Naßwa n = 0,1 bzw 0,3	Mindestgas E-Filter n = 0,3
Kuhlkamina	Stuck	3	3	3	3	3
Kondensatoren	-	3	3	3	3	3
Grobentstaubung	-	3	3	3	3	3
Feinentstaubung	-	3	2	2	3	2
Investition [illegible]	%	147	133	133	100	100

Kühlung u Entstaubung von O_2 Konverter-Abgasen
Investitionskosten

1967

IB - C 451 00 070

Figure 36

Operating costs of gas cooling and cleaning plant for three [illegible]

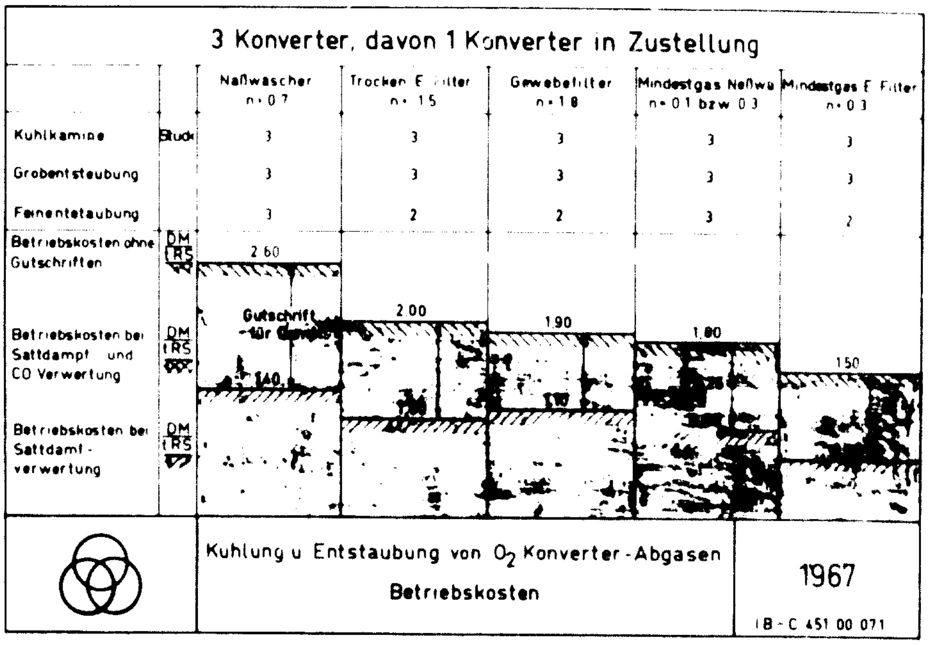


Figure 37

Operating costs and credits for steam and CO of gas cooling and cleaning plant for three converters, one of which is being lined. There is one venturi scrubber for each converter, while two precipitators or two fabric filters sever all three converters

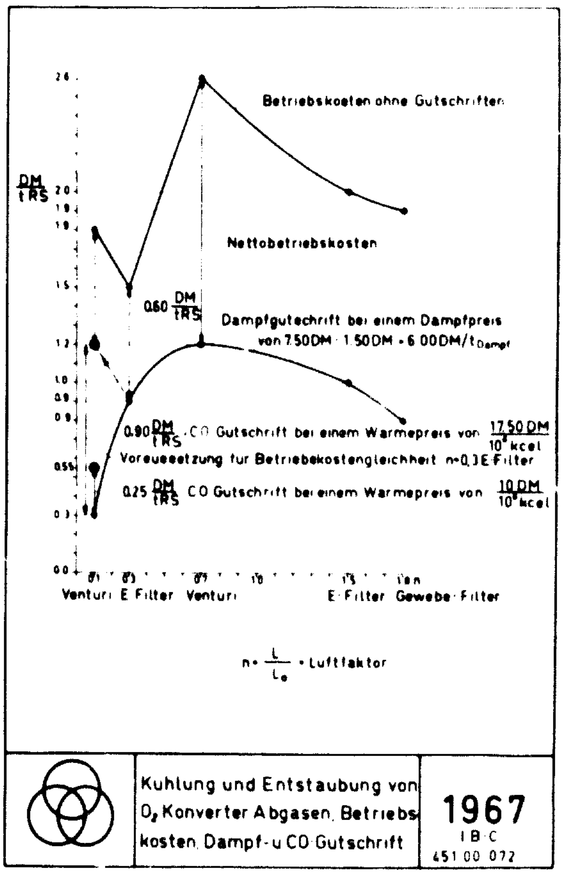


Figure 38

Instrumentation and controls for oxygen-blown converters

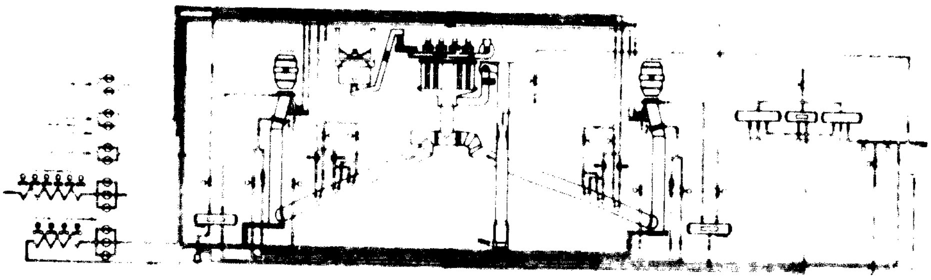


Figure 39

Diagram of the instruments and controls for the oxygen and cooling water systems of the O_2-lances

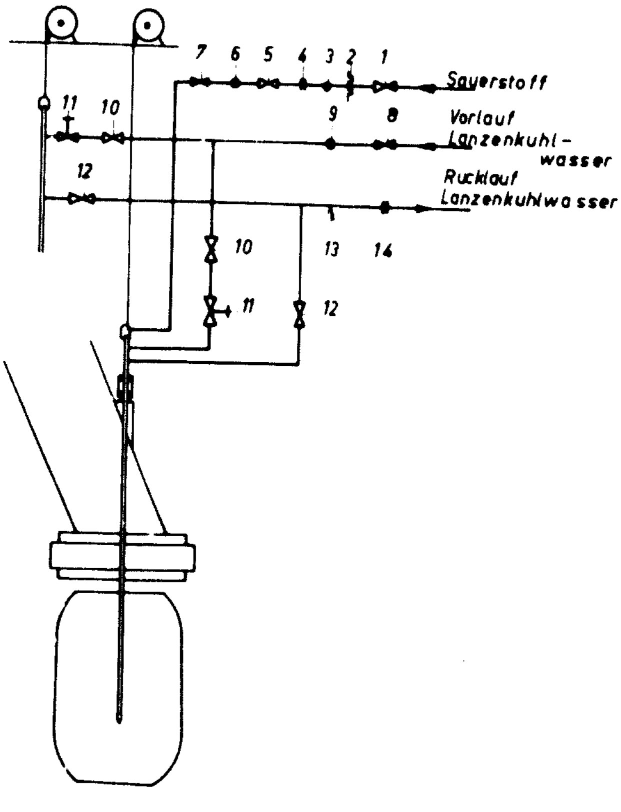


Figure 40

Production diagram showing the flow of materials in an oxygen steel plant featuring a central control board and several control panels

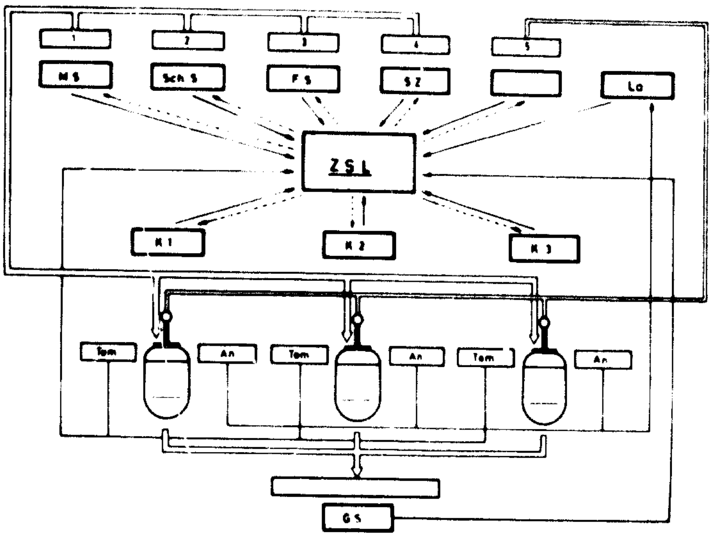


Figure 41

Pilot converter with equipment for process automation

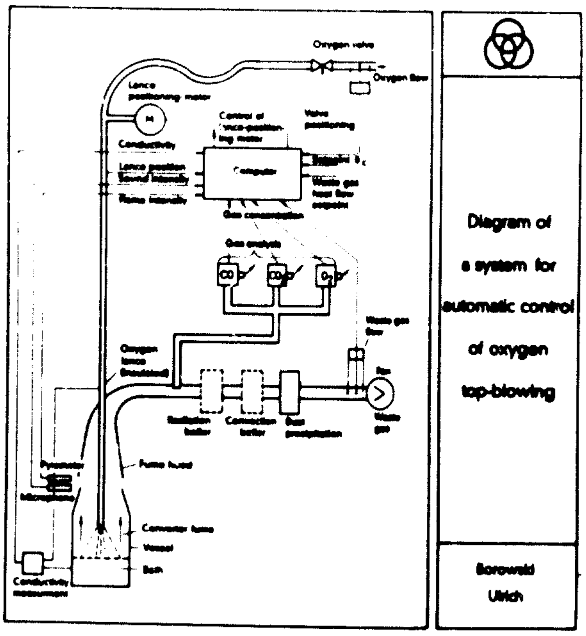


Figure 42

Automatic control of oxygen distribution and heat flow

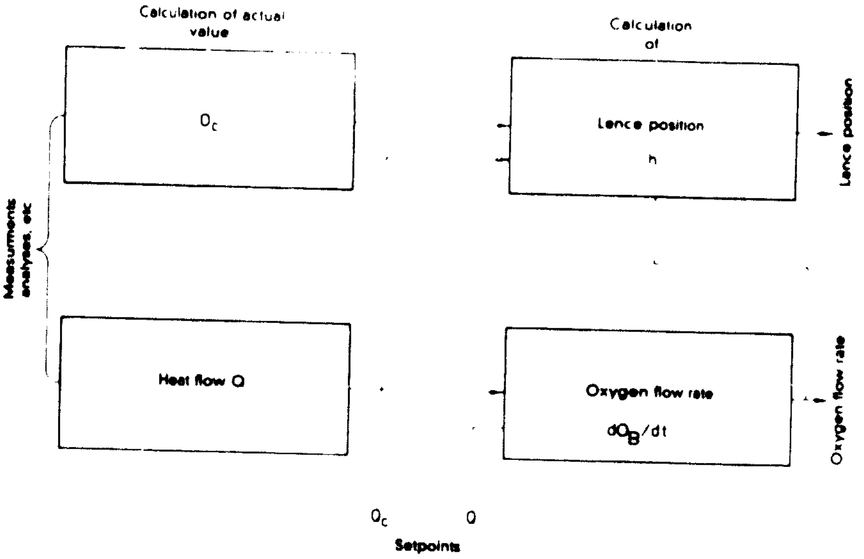


Figure 43

00-ton hot-metal mixer installed in a Swedish steel plant

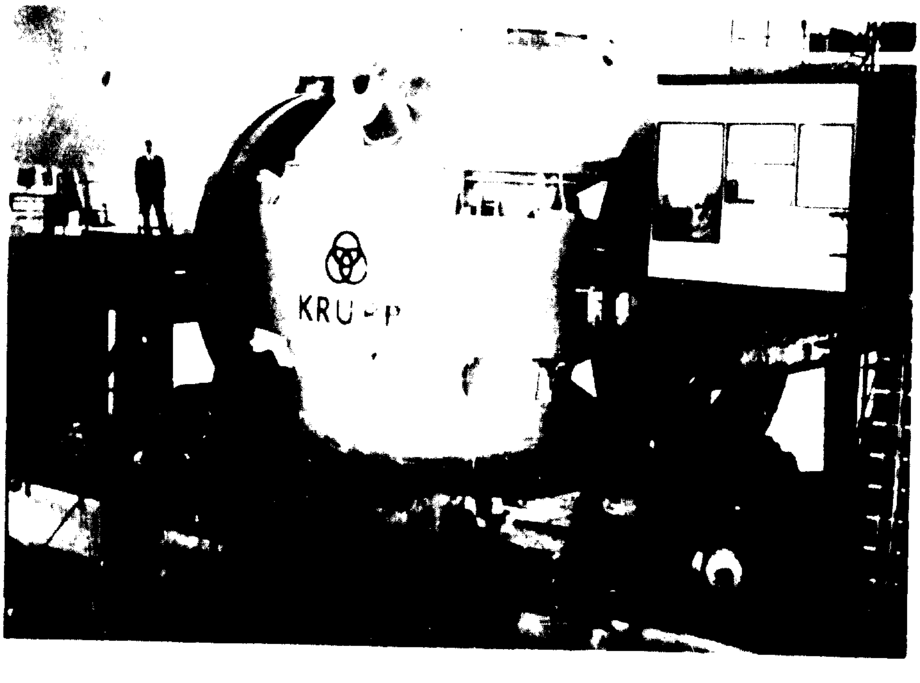


Figure 44

Scrap-charging machine for oxygen-blown converters

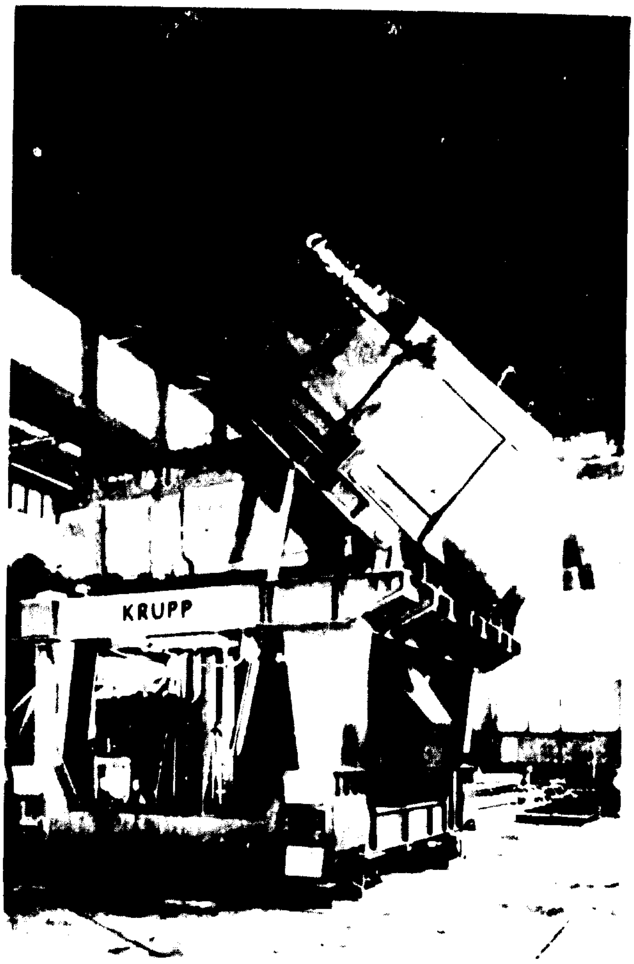


Figure 45

Slag-pot transfer car

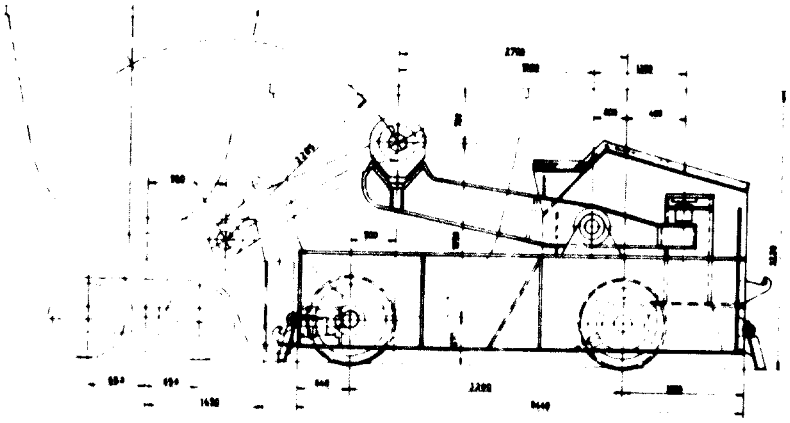
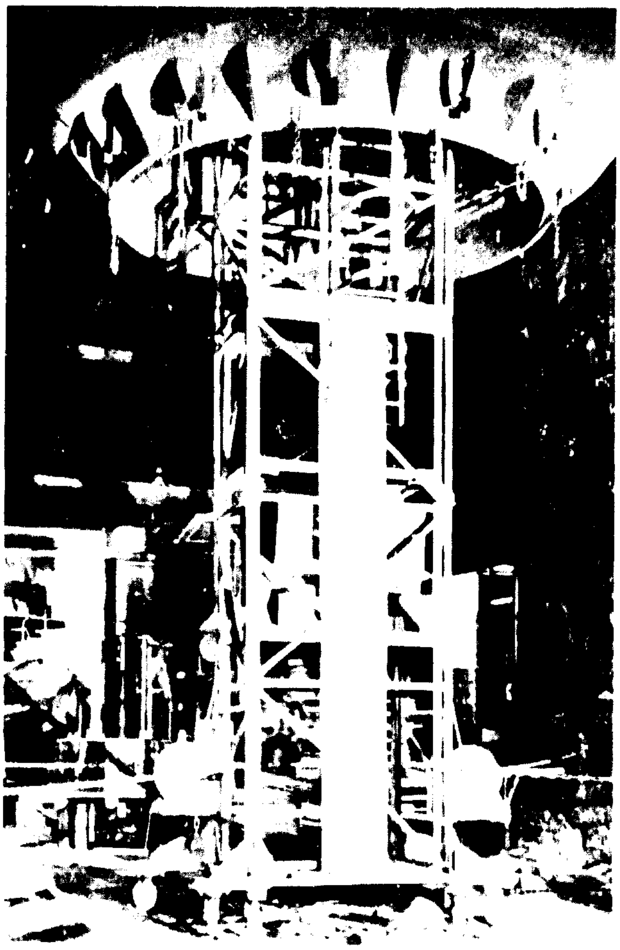
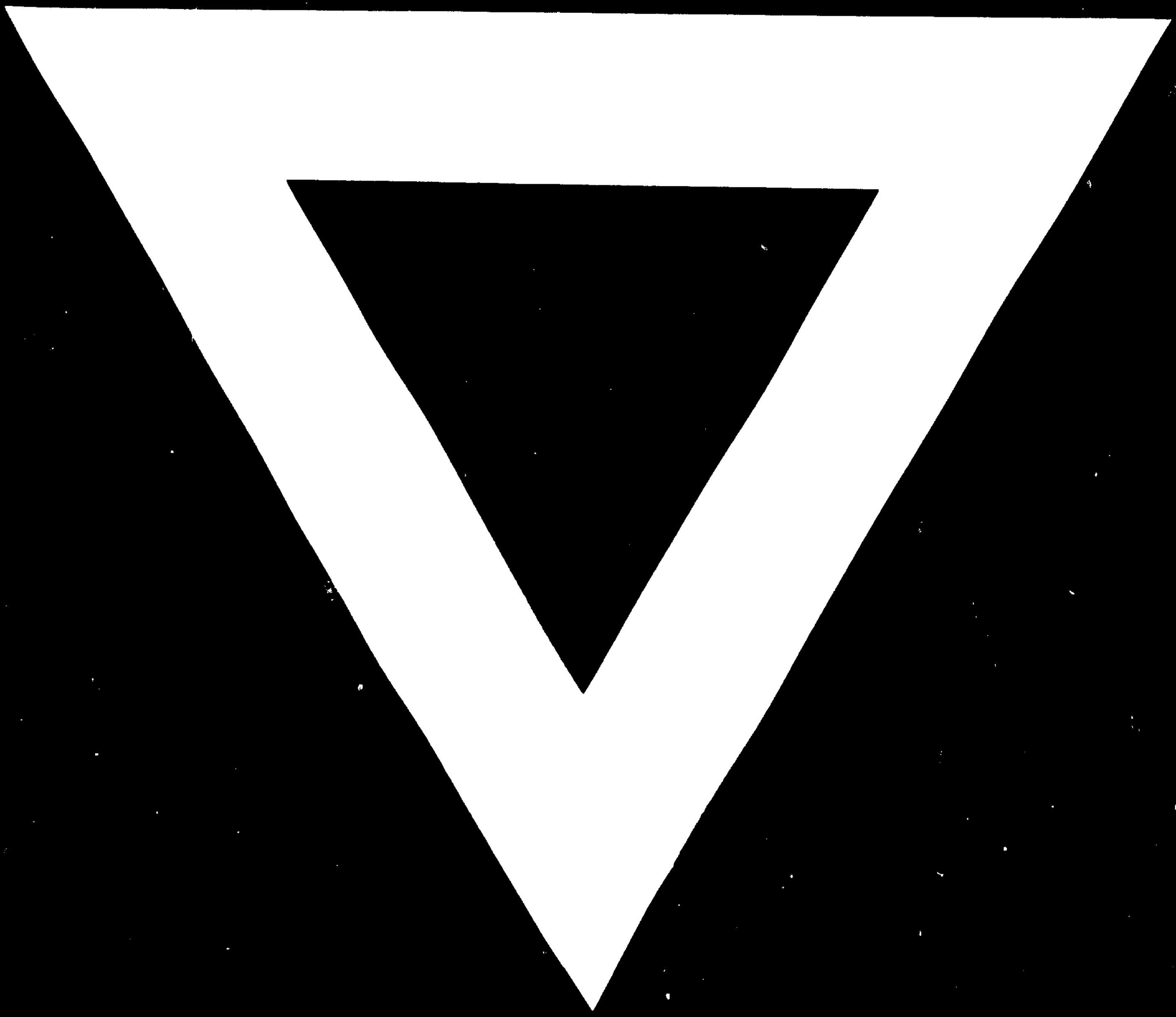


Figure 4

Converter [illegible]





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