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Moscow, USSR, 19 September – 9 October 1968

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MODERN EQUIPMENT FOR OXYGEN STEEL-MAKING[1]

presented by

Vereinigte Oesterreichische Eisen-
und Stahlwerke Aktiengesellschaft

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MODERN EQUIPMENT FOR OXYGEN STEEL MAKING[1/]

by

K. Langer,
Austria

SUMMARY

For the LD steel making, the reaction vessel i.e. the LD vessel is of fundamental importance for the correct course of the process. Therefore, the trends are indicated which led to the actual shapes of vessels. Special attention is being paid to the fixation of the vessels in the trunnion rings and to the latest deve - opment in this field.

A special chapter is dedicated to the planning of the LD vessel plants in existing steel works bays. By installing movable vessel plants of the same production capacity, the investment costs can be reduced. The ancillary equipment required therefore, e.g. vessel lifting and transfer car, is also dealt with in detail. For the exact development of the LD process, the lance equipment serving for introducing the oxygen into the reaction vessel is of great importance.

* This is a summary of a paper issued under the same title as ID/WG.14/60.

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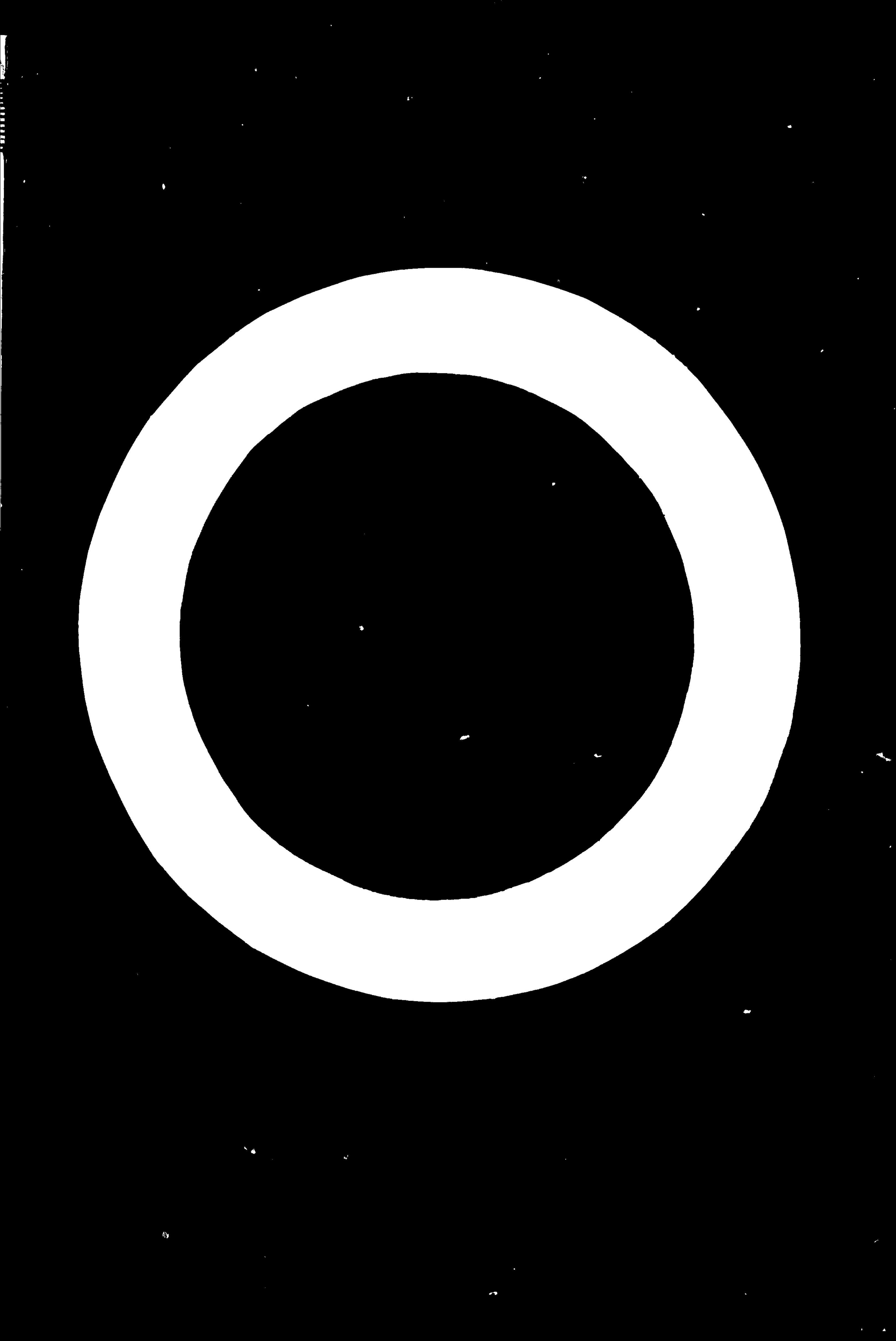
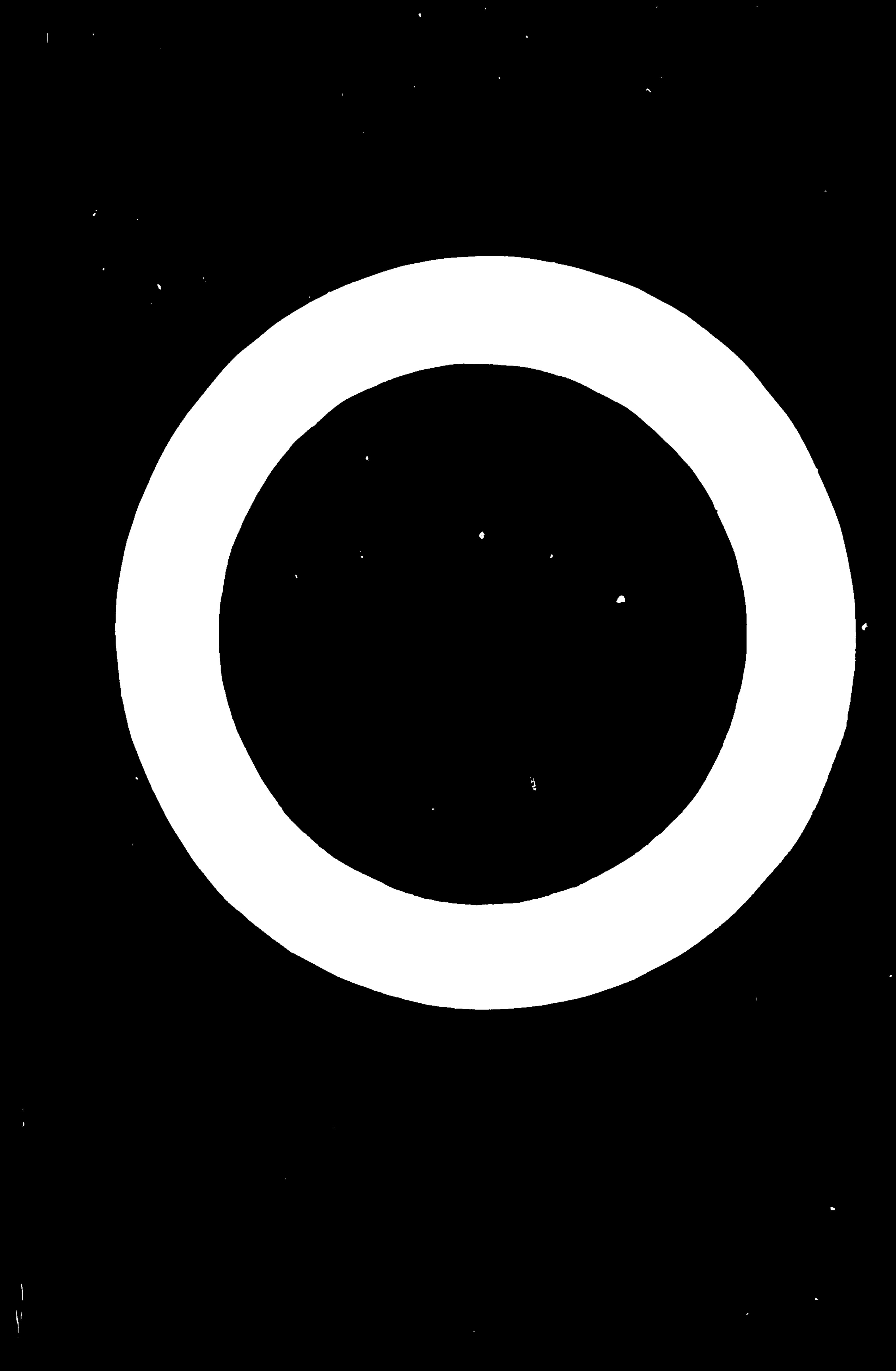




Therefore, the paper will treat the development of the lance equipment from the single-hole to the multiple-hole lance and other special designs. These especially refer to the ring-nozzle lance and other developments for simultaneously blowing-in solid materials such as e.g. lime powder.

In the last part of the paper, steel plant installations will be dealt with assisting in the automation of the steel producing process, e.g. the continuous bath temperature measuring and the handling equipment for the fully automatic performance of various functions.

For illustrating the above statements, slides will be shown.

Contents

1. Introduction

Today, everybody knows of the world-wide importance of the LD process for the production of steel. By building even larger and even more productive plants, the installations of LD steel plants have been improved so that they meet their specific purposes. The coherent development is still going and it is the aim of this paper to give some information on the successes obtained in this field and on possible trends.

When building the first LD plants after World War II, it was a matter of course to revert to the examples and experience available in Thomas steel plants with bottom-blowing converters. If in the past time, experience, tradition and, in some cases, only the grasping by intuition of technical problems have been of importance for the design of a structure, it is now the utilization of exact results of calculation, trial and development which is decisive. As steel production is combined with very high temperatures, questions especially relating to the supply and removal of heat and the selection of materials suitable to meet the manifold requirements of the process play an important part.

Aiming at an always quicker and more economical production of oxygen-blown steel has led to the continuous increase of the reaction vessels and to the speeding-up of the process. If in 1952 the LD vessels had a capacity of about 30 to 40 tons of steel/heat, the more recent plants show a steel yield of 300 tons. The hourly capacity of the plants has been continuously increased and the whole production has been automated as far as possible.

In the following, the development of various steel works installations will be described in the light of concrete examples.

2. LD Vessel Plant

The Vessel

The LD vessel is the part in which the conversion of hot metal to steel takes place, thus representing the core of all the LD plants . Its interior is lined with refractory materials having thicknesses of about 500 to 1000 mm. This lining thickness is necessary to protect the vessel shell against the high temperatures prevailing in it and ranging between about 1600 and 1800° C.

The shape of the vessel is of decisive importance for the correct development of the process. Among others, the following has to be considered:

the quantity of the hot metal, the scrap and the additions charged, the ratio of bath depth to bath diameter, the lining, the r action room, and the vessel mouth.

When installing an LD plant, first of all the question of the shape and size of the reaction vessel will arise. In the course of time, various shapes have been developed, typical cases of which shall be treated now.

(Fig. 1)

To begin with, there is the traditional shape usual in Thomas steel plants. There, we have a cylindrical vessel with an oblique cone part, but without a removable bottom, because this is not required for the LD process. Vessels of this kind are fully suitable for the LD process, but maintenance and renewal of the lining represent difficulties, because the asymmetric shape does not favour this work. As a rule, tapping of the liquid steel is via the convex part of the vessel.

The transition to the symmetric shape represented a progress, which was carried out nearly simultaneously with the installation of a taphole in the cone part of the vessel. Thus, the problems of relining have been simplified.

The vessel cone diameter is of some importance for a good process development. On the one hand, the mouth should be as large as possible, in order to facilitate the rapid charging of the hot metal and scrap, and, on the other hand, metallurgical reasons (heat balance) call for an as small as possible mouth. Considering these and other circumstances, we have developed an optimum ratio of mouth area and bath area and have realized this ratio in the practical operation.

Owing to the larger LD units, also the original ratios of diameter and height have changed. The large vessels being built now are of more compact shape than the original small units, because we succeeded in the meantime in increasing the so-called ignition spot (area of oxygen jet impingement) and, consequently, in increasing the bath diameter.

For the blowing of high-phosphorous hot metals, e.g. in the LD-AC process, special experiences gained have been used for the dimensioning of the vessels. I should like to mention the "tulip" shaped vessel, the reaction room of which has been enlarged to the top which ends in a relatively small mouth. This type of vessel is very suitable for the process but entails a very high thermal load of the cone part and which has to be considered when designing the vessel. Also special shapes have been developed, e. g. the cylindrical vessel with removable top and bottom covers. Such a vessel has been manufactured for the Skopje Steel Plant, Yugoslavia. By this shape of the vessel, the reline work is especially facilitated because the cover can be removed if the lining is worn and can be replaced by a newly relined stand-by cover.

For maintenance and relining purposes, the accessibility, available space as well as the supply and removal of the refractories is of great importance. Whilst originally the LD vessel has been relined from the top, i. e. through the vessel mouth, as a rule we can now observe the trend of relining from the bottom, especially for large vessels. In this case, the vessel bottoms have to be detachable.

During the LD process, the vessel mouth as well as the vessel cone part are extremely subjected to the radiation heat, liquid slag, mechanical forces (e.g. during the de-skulling operation) and other influences. Therefore, these parts have to be of especially rugged design and exchangeable in case of failure.

(Fig. 2)

The following shapes have been manufactured by us:

- vessel with independent lip ring
- elements of fixation are protected

- vessel with solid lip ring
- the vessel mouth continuously changes to the vessel shell
- superimposed lip ring
- the vessel cone is of flanged type on which the lip ring rests
- cooled lip ring

In the case the vessel cone tightly encloses the stack hood as e. g. with the CO exhaust plants (in order to prevent the access of air), the thermal load of the cone part may become so large that it must be water-cooled.

The Trunnion Ring

The vessel is swingably supported in a trunnion ring having on its outer parts two diametrally opposed trunnions.

As the trunnion is of very great importance for the functioning of the vessel plant, its design is very carefully studied. For the exact dimensioning of this component highly stressed both from a mechanical and thermal point of view, extensive calculations of strength have to be carried out.

Three possibilities of vessel suspension in the trunnion ring are offered:

a) The trunnion ring is a component independent of the reaction vessel. The connection of the vessel is predominantly by means of claws.

b) The trunnion ring is part of the vessel shell, trunnion inner wall and vessel shell being identical.

c) A zone of the vessel shell is used as trunnion ring. The trunnions are resting on trunnion sockets connected to the vessel.

In order to illustrate the great variety of trunnion ring design, it is enough to mention the characteristic features of the different types of trunnion rings:

<u>ad a)</u> Separate trunnion ring

(Fig. 3)

General design: of cast or welded type

Trunnion fixing on the trunnion ring:

- integral trunnion: welded or cast
- flanged trunnion: in the plane of connection, the shearing forces are absorbed by centering ledges, the bending moment is absorbed by draw bolts, and the torsion moments by radial wedge type blocks.

Split-up of the trunnion ring for reasons of transportation:

- solid rings with integral trunnions
- solid rings with flanged trunnions
- two-part rings with integral trunnions
- two-part rings with flanged trunnions
- four-part rings with integral trunnions
- four-part rings with flanged trunnions

The individual trunnion ring parts may be connected either by usual flanges or by flanges with "lost" bolts which are tightened inside the trunnion ring and are no more accessible from the outside after completion of the welding.

Trunnion ring cross-section:

- Box-type design
  This type is possible both for cast and welded trunnion rings.
  Originally, there was a limitation to the size of welded trunnion rings (lower limit) because of the demand for access.
  Today, this limitation is no more valid as a suitable welding possibility has been developed.

- Open design
  e. g. in the shape of an E

ad b) Integral, i. e. trunnion ring welded to the vessel

Here, the same variety of possibilities exists as for the separate trunnion ring.

Where, for reasons of space, an as small as possible centre distance of the trunnion bearings is aimed at, the integral trunnion ring will be preferred to the separate ring.

Although, as experience shows, the integral trunnion ring can be mastered from the constructional point of view, the separate trunnion has to be given the preference for the following reasons:

- by selecting the vessel support joints on the trunnion ring, this can be definitely determined by calculation, while for the integral trunnion ring in the theoretical calculation a definite distribution of the load can be assumed to a certain approximation as in case of vessel deformations other conditions will prevail as can be presupposed originally.

- In case of lining ruptures in the zone of the trunnion ring of the vessel, this will become red hot. With a separate trunnion ring, this rupture can be observed and the measures necessary for preventing damages can be taken. The integral trunnion does not have this advantage.

- If, after a prolonged time of operation or in case of improper operation, the vessel with separate trunnion ring has been heavily damaged, the vessel can be replaced in a relatively simple manner by installing a new vessel in the old trunnion ring. The costs of investment for replacing the vessel with trunnion ring - as it would be required for an integral trunnion ring - are essentially higher than the costs for the vessel only.

For these reasons, we give preference to the separate trunnion ring of welded design.

The demands to be met by an integral trunnion ring are as follows:

- the elasticity of the vessel shell must be maintained, in order to prevent damages to the vessel interior by the lining pressure

- ventilation of the whole vessel surface must be ensured
- the trunnion ring should represent a structure of continuous, uniform stiffness. Rigid elements are

to be avoided because of the stress peaks caused by them.

- with regard to taking over of static loads, the trunnion ring should be as stiff as possible in order to ensure a correct support in the trunnion bearings. In the end, this demand comes out to the design of the box-type integral trunnion ring.

Suspension of the Vessel in the Trunnion Ring

For a vessel with separate trunnion ring, the connection of the two components is of essential importance. These connection parts are called carrying claws. Even before the development of the LD process, the converters have been built with carrying claws which, however, have been continuously modified and improved for the LD vessel. A usual standard design of the vessel suspension by means of carrying claws

(Fig. 4)

shows that these are fixed to the vessel shell on the one hand and supported by the trunnion ring on the other hand. Because of the unclear static conditions (several times indeterminate support) plus the vessel deformations due to thermal influences (the converter is a vessel "operating at high temperatures"), the often used suspension of the vessel by means of several carrying claws distributed over the circumference represents a not satisfactory solution of the problem.

For this reason, we changed over to a three-point suspension by means of three carrying claws. Due to the static determination, the calculation and the dimensioning are simplified. These three claws are distributed on the trunnion ring circumference so that, with a vertical vessel, the two claws supported by the trunnions of the ring introduce the weight of the vessel into the trunnion ring. With a tilted vessel, the third claw takes its function by counterbalancing the tilting moment. Diametrically to this third claw, the so-called tilting claw, is a fourth one, the guide claw (actually a bracket) which, in normal operation, has no function.

It is only used in the case of fixation of the position when the vessel is displaced or shifted by shearing forces (e.g. de-skulling) against the trunnion ring.

As the vessel is tilted, such a three-point support is required both from the top and bottom side of the vessel (vessel viewed in blowing position).

In the course of a heat, the vessel diameter and, consequently, the position of the top and bottom claws is changing, due to the heating-up of the vessel. As, due to its higher temperature, the vessel expands more in the direction of its axis than the trunnion ring, a thermal expansion gap will be formed. During the tilting operation, an abrupt support of the claws on the trunnion ring may result. In order to eliminate these disadvantages leading to damages, we have installed sliding wedges between the claws and the trunnion ring, which are fastened either to the claws or the trunnion ring.

In spite of the results obtained, difficulties arose - especially with large vessel plants - which are due to local overloads on the connection points. Therefore, we have thoroughly studied the suspension of the vessel in the trunnion and have developed the following new solution:

(Fig. 5)

The approved three-point suspension has been maintained in principle. Instead of the brackets acting as carrying claws, the new design provides for suspension discs arranged on the trunnion ring inner wall.

Opposite to these discs, suspending rings have been welded to the vessel into which the suspension discs are projecting. The disc diameter should be as large as possible so that the forces are not introduced into the vessel over a too small area.

The suspension discs centrelines coincide with those of the trunnions so that, in any tilting position, the discs take over the weight of the vessel as well as the reaction force due to the tilting moment. The function of the above mentioned tilting claw is now carried out by the tilting disc which, compared to the suspension discs, may be of a smaller diameter.

At the same time, the tilting disc performs the function of the above guide claw, with regard to the displacement in the direction of the trunnion. As a prevention against displacement in other directions, a fixation of the vessel against the trunnion ring has been provided by arranging a guide ledge diametrically to the tilting disc.

The suspension of the vessel by means of suspension discs ensures a gap-less, permanent transmission of forces.

In the suspension disc, sliding rolling motions are resulting which are obtained by the appropriate geometric shape and by choice of the kinematics.

The advantages offered by the disc suspension are based on the fact that by appropriate dimensioning of the suspension discs, statically determinate loads can be obtained and, further, that, due to the sliding rolling motions, overlcading, e. g. due to thermal expansion and deformation, of individual components of the suspension can be avoided.

In order to make the picture more clear, I should like to summarize the above statements as follows:

Starting from the LD vessel, we have illustrated the suspension of the vessel shell in the trunnion ring, especially considering the design of the separate trunnion ring. In the following, we will treat in common the trunnion bearings of the two types of plants: with integral and separate trunnion rings. Finally, we will describe the tilting drive, the last component of an LD vessel plant.

The Vessel Bearings

(Fig. 6)

Via the trunnion ring, the vessel is pivoted by means of the trunnions already mentioned. Of the two vessel bearings, one is an expansion bearing, the other a fixed bearing. The bearings have to meet very high demands which are summarized as follows:

With regard to the loadability:

Very high static radial loads are produced (up to 1000 tons with large plants), which, however, do not represent any dimensioning problems. The vessel must be tiltable through 300°, but usually it is operated in a range determined by the charging, tapping, and deslagging operations.

With regard to the trunnion alignment:

Due to the great bearing centre distance, misalignments arise due to manufacturing tolerances, erection errors, load deformations, thermal deformations and the like.

With regard to the axial forces and the relatively great thermal expansion of the trunnion ring (about 20 mm) in the direction of the trunnion axes.

With regard to the loads due to the tilting operation:

In accordance with the type of drive, the vessel bearings are additionally loaded by the weight of the coupling and gearing as well as by the tooth pressure and gearing support pressure reaction forces.

With regard to thermal influences:

On these, the choice of the bearing seating, the type of lubrication, and the dimensioning of the trunnion cooling depend.

With regard to mounting and dismantling:

The change of the bearings necessary because of possible damages must be performed in a quick manner.

For solving these numerous problems which may be combined in the most various manner, the designer of the steel plant is dependent on the cooperation with well-known bearing manufacturers. Up to now, the following kinds of bearings have been used:

Slide bearings:	with a rigid or adjustable housing
Antifriction bearings:	of solid or split-up design, both cylindrical roller bearings and self-aligning roller bearings being used.

Both types of bearings, i. e. slide and antifriction bearings, show advantages and disadvantages:

The slide bearing is extremely rugged and dampers the vibrations which are introduced into the bearing substructures during the oxygen blowing. Thermal expansions do not represent a problem.

But it is true that a greater trunnion friction arises and to ensure a good lubrication is critical. Furthermore, the vessel level is changed because the bearings are worn during the operation.

The antifriction bearing does not require much maintenance work and its friction moments are smaller. However, it is sensible to the above vibrations. The possibility of trunnion displacement in the expansion bearing must be ensured by special designs.

To point-out the extremely difficult calculations and characteristics of the vessel bearings would be beyond the scope of this paper. However, I should like to mention that today the bearing problem can be considered as solved in a satisfactory manner.

The Vessel Tilting Drive

For hot metal and scrap charging, tapping and deslagging, wrecking of the lining, relining and for other reasons, the vessel has to be tilted. Each of the above operations has to be carried out in a definite vessel position which is obtained by means of a tilting drive equipped, as a rule, with various speeds. The tilting drive motors are fed either with three-phase current or continuous current.

With three-phase drives, a quick and a slow motion are obtained by two motors arranged one behind the other and connected by a planetary gear in such a way that the not driving motor is braked down. Thus, a speed ratio between 1 : 10 and 1 : 16 can be achieved. This kind of drive is especially used for smaller plants up to a maximum torque of about 400 meter tons measured on the trunnion.

With a continuous current drive, the speed is electrically infinitely regulated in a ratio of 1 : 10. For vessel plants of a torque exceeding about 400 meter tons, this type of drive is preferred.

Independent of the type of the drive (continuous or three-phase current), the following types of construction are used for the drive of an LD vessel:

a) Spur gear with direct coupling to the trunnion is arranged on the working platform.

   This design requires the appropriate space on the working platform and, furthermore, a gear coupling dimensioned according to the vessel tilting moment. This type of drive is always used as one-sided drive.

(Fig. 7)

b) A bull gear is fixed to the trunnion which is in mesh with a pinion (or two pinions). This pinion is supported in a rocker which in turn rests on the trunnion. This construction ensures that the pinion can follow possible trunnion movements (oblique position) so that the correct mesh is not disturbed. A thrust and stress rod, the so-called torque arm, absorbs the reactions produced by the vessel tilting torque.

By means of a coupling, the drive pinion is connected to the other components of the drive, i. e. the intermediate gear and the motor. This coupling is of the crowned tooth gear type to be able to absorb angular and parallel misalignments which may be due to anormal trunnion movements. In our plant (VÖEST), the above described type of drive is preferred, two-pinion designs also being customary with larger plants. This type of drive can be used as one-side or two-side drive. By arranging the intermediate gearing and the motor underneath the working platform, space can be saved.

c) A certain development of the above drive consists in directly arranging four or more motors on the bull gear circumference and by installing small intermediate gears between motor and pinion. In this type of design, the bull gear hub serves for supporting pinion carriers with intermediate gear and motor. For this type of the vessel tilting drive, up to now only continuous current has been used.

This kind of drives may result in savings of weight, but in the severe steel plant operation rugged designs, e. g. those described under b) are of interest for the steelworkers, because of their overloadability.

3. Vessel Changing Plants

It is generally known that, as a rule, the following modes of operation have proved successful for LD steel plants:

1) Two stationary vessel plants installed
of which one in operation and
one being relined or stand-by

2) Three stationary vessel plants installed
of which two in operation and
one being relined or stand-by

During the reline operation, also the stack with the waste gas cooling and cleaning plant is being prepared for the next campaign.

A further mode of operation is offered by exchangeable vessel plants which preferably will be used where it is required by space conditions e. g. installation or annex to existing Thomas or O.H. steel plants or at very congested space conditions in the overall plant.

The system of the exchangeable vessel plant essentially consists in that relining is not performed in the blowing station but in a separate reline station. Exchange of vessel is by means of a special vessel changing car running on a sturdy track. By this, it is obtained that in one blowing station one vessel is always in operation, a production breakdown of 3 to 8 hours occurring only during the time of vessel changing. One can say that this mode of operation corresponds nearly to that of two stationary vessels installed.

The largest changing vessel plants have a steel tap weight of about 100 tons; essentially larger units are being planned.

For the changing, there are two possibilities:

- The vessel shell is lifted from the trunnion ring and removed.
- The connection between the vessel and the trunnion ring remains unchanged. In this case, the bearing fixing bolts are loosened, so that the whole trunnion ring together with the bearings can be removed and deposited in a separate wrecking and reline station.

Essentially, the vessel changing plant comprises:

- 2 exchangeable vessels
- 1 vessel changing car

  After loosening the connection elements with the trunnion ring, the vessel is lifted and removed.
  In this case, the horse-shoe type trunnion ring is open on one side.

(Fig. 8)

- 1 sturdy track as a runway for the vessel changing car

- 1 blowing station, comprising:
  - vessel tilting device
  - lance equipment
  - vessel additions charging system
  - waste gas cooling and cleaning plant
    Here, it must be pointed out that when selecting the system of the waste gas cooling and cleaning plant special attention has to be paid to the safety of operation as practically every breakdown means a reduction of production.

- 1 parking station

  The vessel is parked in order to have available the changing car for the transport of the newly relined vessel.

- 1 wrecking and reline station

  As soon as the changing car has brought the newly relined vessel to the blowing station, it transports the worn vessel to the wrecking or reline station where the worn lining is demolished and the new lining is bricked.

  For this purpose, a similar trunnion ring as in the blowing station must be available in the wrecking station. A tilting drive is also required. When relining the vessel with "green ' tar dolomite or tar magnesite bricks, the lining must also be heated-up in the reline station.

As an integral part of the vessel changing plant, the changing car should meet the following requirements:

The car must have a jacking device in order to lift the vessel from the trunnion ring. To exactly align the vessel axis to that of the jacking device, the support platform must be transversely movable. Furthermore, the vessel must be turnable around the lifting axis.

The car must be designed in such a manner that the sense of direction may be changed as the track for removing the vessel perhaps will be perpendicular to that leading to the parking and/or wrecking station. On the crossing, the whole car is automatically lifted, the wheels are turned into the new direction of travel. Subsequently, the car is lowered and continues its travel.

Although this vehicle represents a rather complicated machine, it works to the whole satisfaction of the client.

Similarly as described for the exchangeable vessel, the changing of the vessel with trunnion and bearings is carried out. Owing to the additional weight of the trunnion ring, trunnions and bearing must be of a more rugged design.

When comparing the investment costs of a changing vessel plant with those of two stationary vessel units, it can be said that those of the exchangeable vessel are somewhat lower. However, the savings are not such as they would seem to be at the first glance, due to the omission of the waste gas cooling and cleaning plant, the lance equipment and other installations because the additional expenditures for changing the vessel are also very high, due to the heavy loads to be lifted and handled.

4) Oxygen Supply

In the LD process, the oxygen required for refining is blown onto the bath surface by means of nozzles forming the lower end of the oxygen supply pipe which is surrounded by a cooling sheath. For cooling, water is used.

This pipe which is called blowing lance must be lowered into the vessel for the blowing operation and after this it must be removed. For this purpose, lance lifting devices are used ensuring a quick and correct adjustment of the lance to each level above the bath. Further devices are available permitting a quick exchange of the damaged blowing lance. There exists a great variety of various designs of lance lifting devices, a typical one is shown on the following picture.

(Fig. 9)

For a successful blowing operation, the shape of the nozzle, its material and method of manufacture is of essential importance. The original single-hole nozzle had a cylindrical bore and was operated at an oxygen pressure of about 9 to 11 at. gauge. The results obtained have not been satisfactory because it was impossible to expand the oxygen to the counter-pressure in the vessel so that vibrations and compression shocks resulted at the nozzle exit. By changing over to conically diverging nozzles, this inconvenience has been abolished.

Owing to the construction of vessels with even greater capacity, the oxygen supply had to be increased compulsorily. By this, also the cinetic energy of the emerging oxygen jet has been increased. With vessels of a capacity of about 100 tons yield, this led to disturbances in the refining process , such as strong splashing, excessive ejection and disturbances in the formation of the slag.

By the multi-hole nozzle showing - instead of one hole - several holes arranged in definite angle to the lance axis, we succeeded in obtaining favourable conditions also in the operation of large vessels. The oxygen supply per unit of time has been increased and, as a consequence, the blowing time has been decreased because the multi-hole nozzle produces an ignition spot (zone of oxygen impingement) of a greater diameter. Three-hole nozzles with an oxygen throughput up to 1000 m3/hr for large vessels up to a yield of 300 tons are in operation.

(Fig. 10)

Of special interest are oxygen nozzles for special purposes, such as for the simultaneous blowing of combustibles,e. g. fuel oil,or powdered additions, e. g. lime powder. Even in the last years, the so-called ring-nozzle lance for blowing iron oxide powder from the precipitator of an LD plant has been successfully used. The steel plant is that of the Košice Iron Works, CSSR, where VÖEST, together with the client, have carried out such tests during the continuous operation.

(Fig. 10)

All steel workers are highly interested in blowing lances, especially nozzles, showing a long life. The choice of the material, the treatment and the manufacture know-how play an important part but it would lead us too far to mention more details. The fact is that in our own plants nozzle lives of some hundreds of heats are continuously obtained.

5. Auxiliary Devices With Possibilities of Connection for Plant Automation

Continuous Bath Temperature Measuring in the LD Process

With regard to the increasing rationalization and improvement of the steel production, a continuous control of the bath temperature during the whole heat seems indispensable and, at the same time, means a considerable progress towards a complete automation of the LD steel production.

When starting tests for a continuous measuring of the bath temperature, thermocouples were already available meeting the requirements for continuous measurings in a temperature range between 1000 and 1800° C. But there were no available materials suitable for high temperatures and of a satisfactory strength against attacks by the bath and which could be used as protective materials for the thermocouples. As a result of many years of cooperation between Messrs. Metallwerke Plansee A.G. and VÖEST, a metal-ceramic material (Cermotherm) as well as various methods of continuous bath measuring have been developed.

One of these measuring methods using a suitable temperature sensor which is introduced into the vessel bath by means of a water-cooled probe has been developed to industrial application. In the following, the corresponding device will be explained in detail:

(Fig. 11)

After the beginning of the blowing process, the probe is introduced into the steel bath along a guide by means of a lifting and lowering device. Towards the end of the refining process, it is again removed. For lifting and lowering purposes, a rope winch is used.

The movements of the measuring probe are controlled by an electronic device offering, among others, the following possibilities:

Digital indication of the relevant position of the measuring probe with regard to the bath surface and correction of the indication by changing over to relative indication in case of differences in the bath level.

Automatic correction of the lifting and lowering device rope elongation due to the operation and mechanical storing of the corrected value.

Connection of a computer.

From the water-cooled measuring probe, the not-cooled temperature sensor is projecting. The probe tip as well as a part of the temperature sensor are surrounded by a ceramic body. Independent of the geometry of the vessel, measuring has to be performed in a place of the bath ensuring a good average temperature.

Besides its being very resistant to metallic baths, Cermotherm consisting predominantly of molybdene and zirconium has a good thermal conductivity, good resistance to changes in temperature, and strength.

Up to now, Cermotherm protective tubes have shown lives of 12 to 15 heats.

The measuring probe shown in the picture has been provided as an annex to the existing LD lance equipment; therefore, it is movable as a whole, because in the most cases of LD lance installations the local conditions do not permit measuring probes of the stationary or swingable type.

By means of the continuous temperature measuring, it is possible to correct the bath temperature in such a way that the turn-down temperature aimed at will be within very narrow limits of dispersion.

Additions Supply

Normally, vessel additions and the possibly required ore are supplied from underground bunkers situated outside the steel plant, via belt conveyors to the elevated bunkers arranged in the steel plant vessel bay. From there, they are conveyed into the vessel via weighing bunker plants.

(Fig. 12)

The underground bunkers located outside the steel plant usually have a capacity of one week's requirement. They will be charged from railway cars.

By means of discharge devices, the selected vessel additions are conveyed to a belt conveyor under the underground bunker group. Here, they are weighed by a belt scale and handled to the elevated bunkers by means of inclined conveyors or tubular feeders.

It is customary to design the elevated bunkers for a capacity of 8 to 24 hours.

Level control probes installed in the elevated bunkers permit a control of the available additions. In case of a shortage, they will signalize the time of the refilling required. The choice of sequence of elevated bunker filling in most cases is by hand, filling proper of a predetermined quantity is automatical. Vessel additions are discharged by dosing devices into the weighing bunkers located on load cells.

Whether the vessel additions are directly charged from the weighing bunkers into the vessel via feed chutes or collecting chutes has to be determined on the basis of the general layout.

Vessel additions charging is controlled from the central control pulpit of the steel plant. Times and quantities can be determined on the basis of preselected inputs.

Data accumulation plants in the central control pulpit permit recording of the additions charged. The devices are of such a design that a computer can be connected ensuring a fully automatic operation of the process.

The use of electronic weighing equipment instead of the original mechanic scales had a special influence on the exactness of weighing, representing one of the preconditions for the automation of a steel plant.

Besides the vessel additions system, also the alloying elements system is of increasing importance, due to the increased use of alloying elements in LD steel plants. If in a solid and cold state, the alloying elements can be conveyed into the vessel by the above equipment too.

Cranes and Industrial Trucks with Weighing Equipment

In modern steel plants, electronic weighing devices in cranes and steel plant vehicles are generally used.

Hot metal charging cranes and teeming cranes often are equipped with electronic weighing devices. For this purpose, the electronic load cells have to be installed in the beam of the crane lifting beam or in the trolley. By using load cells in the cranes, it is possible to carry out the weighing operation without the need of depositing the ladle. The results can be immediately indicated and recorded.

Today, also slag ladle transfer cars and steel ladle cars frequently are provided with load cells. Weighing of the accumulating slag is of importance for the LD-AC process where the slag can be further used.

(Fig. 13)

shows a typical example of such a car.

Summarizing, it can be stated that the above mentioned installations such as continuous bath measuring device, mechanized and telecontrolled additions system as well as use of load cells on cranes and vehicles represent an essential contribution to the full automation of the steel plant aimed at.

6. Conclusions

From the time, the first LD vessel of the world started its production in Linz, all the steel plant installations have been gradually improved, adjusted to their purpose or newly designed. In the framework of this paper, the attempt has been made to show, at least in the main fields, the development viewed from an international point of view and to give a general idea of the technical possibilities prevailing today.

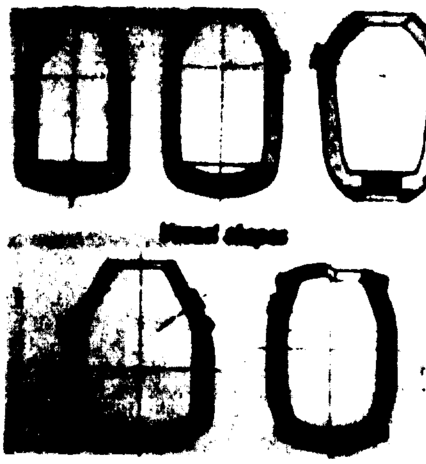
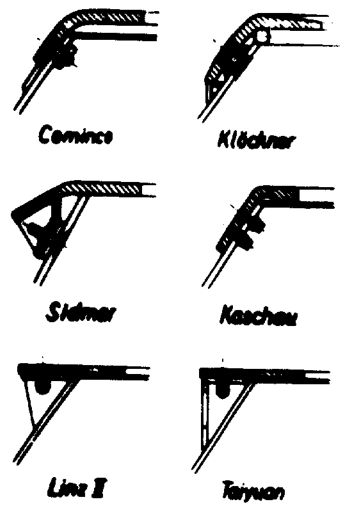


Fig. 1

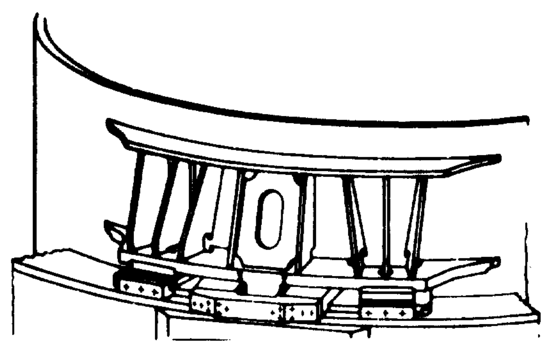


lip ring designs

Fig. 2

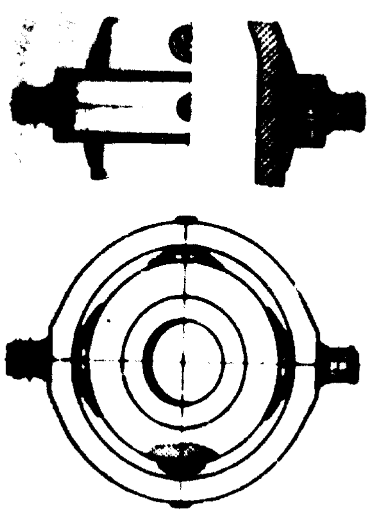
trunnion ring

Fig. 3



trunnion claws suspension

Fig. 4



disc suspension

Fig. 5

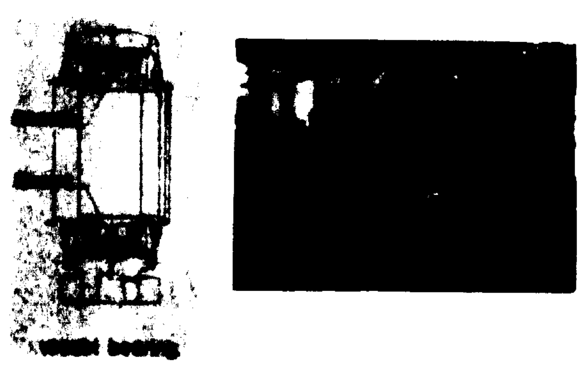


Fig. 6

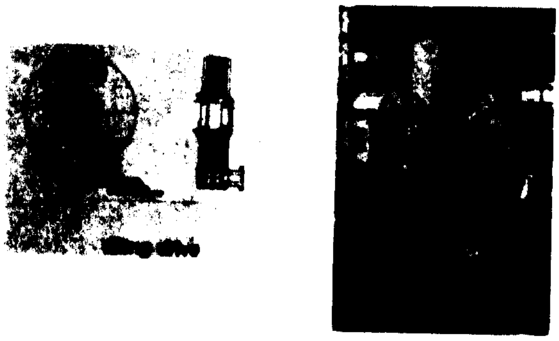


Fig. 7

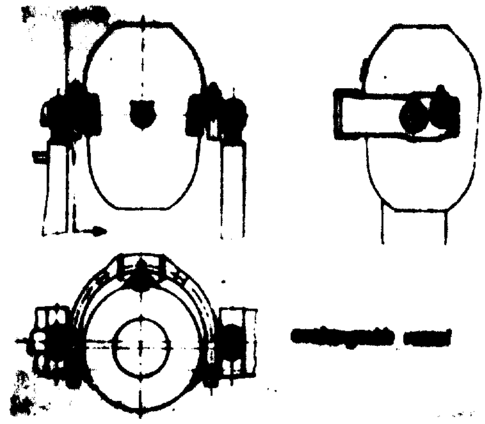


Fig. 8

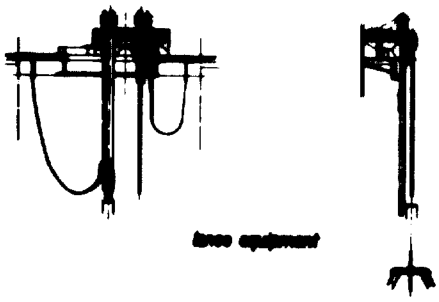


Fig. 9

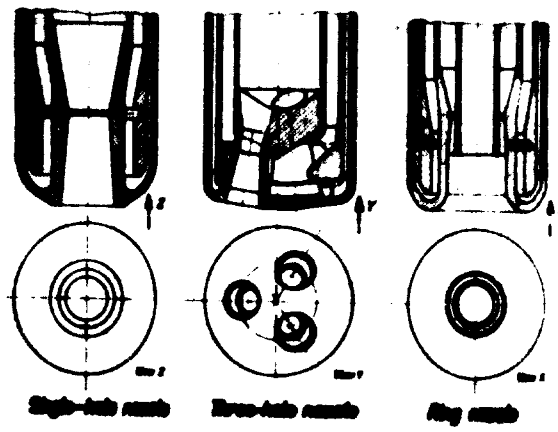


Fig. 10

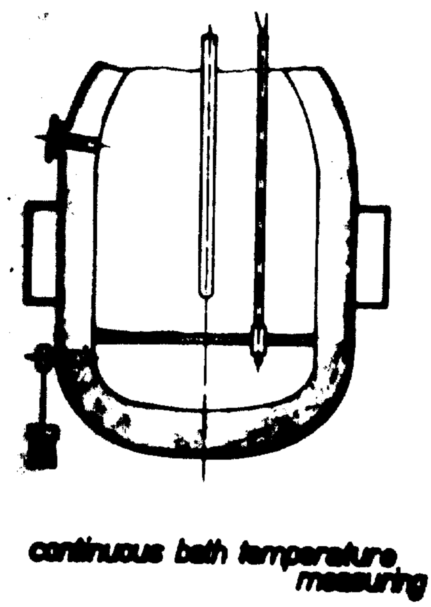


Fig. 11

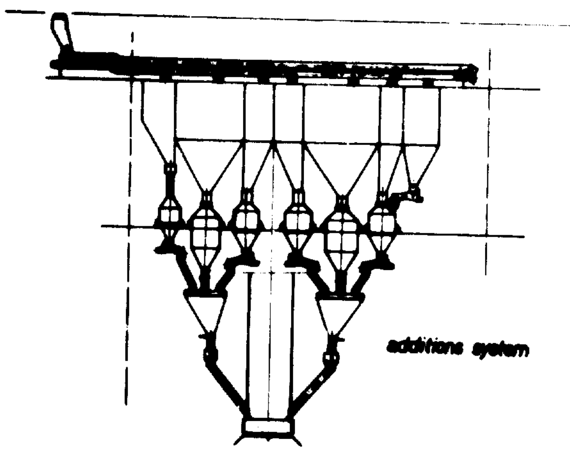


Fig. 12

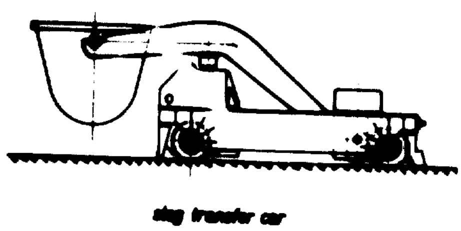


Fig. 13

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