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UNITED NATIONS INDUSTRIAL DEVELOPMENT ORGANIZATION
Vienna International Centre, P.O. Box 300, 1400 Vienna, Austria
Tel: (+43-1) 26026-0 · www.unido.org · unido@unido.org

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SOME DEVELOPMENTS IN TOP-BLOWN BOF EQUIPMENT[1]

by

I. Hamabe, S. Yamazaki, J. Tsunoda
S. [illegible] and K. Yanagida
Kawasaki Heavy Industries Limited
Japan

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Summary

Oxygen steelmaking is widely used for open-hearth furnaces, electric furnaces and converters. Among various processes of oxygen steelmaking, the LD process developed in Austria in 1952 has grown to play the leading role in steelmaking around the world in a brief span of only twenty years. The amazing growth of the LD process has been accompanied by marked improvements on its operating and equipment techniques.

This paper discusses the progress of the LD process particularly in respect of equipment techniques, supplying up-to-date information on the vessel, vessel tilt drives, waste gas cooling and cleaning system and others.

1. INTRODUCTION

The LD basic oxygen furnace currently plays the leading role in steelmaking throughout the world for its high productivity, economical advantage and its recent improvement in steel quality, and is gradually making its way even into the field of special steels which was monopolized by the electric furnace in the past. In 1971, world LD basic oxygen steel production reached 237,800,000 tons, 41 percent of the raw steel production amounting to 583,100,000 tons. In Japan where the LD steelmaking process has accounted for a rapidly increasing propotion of steel production and its steelmaking capacity is the highest in the world, more than 90 LD basic oxygen furnaces, in 1972, produced raw steel amounting to 76,980,000 tons, 79 percent of the total.

This paper presents the recent information on vessel, vessel tilt drives, lance, waste gas cooling and cleaning system, sensor-lance and relining machine in LD BOF plant, mainly in Japan.

2. VESSEL

Fig. 1, as well as fig. 2, shows a vessel with tilt drives. Performance of the vessel can be enhanced by design improvement on its configuration, support system and cooling devices.

FIG. 1 EXTERIOR VIEW OF LD VESSEL

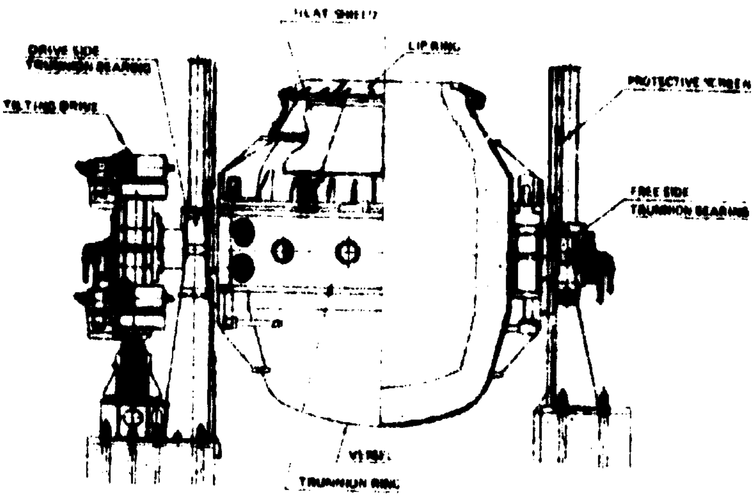


FIG.2 GENERAL ARRANGEMENT OF LD VESSEL

2-1 Configuration of vessel

In determining the configuration of the vessel, are invited proper considerations on the following factors together with properties of materials, hot metal ratio, quality prescription of steel, and refractories.

a) Restraint of slopping

b) Optimum stirring and decarburization of metal bath

c) Minimum fluctuation of bath depth throughout a campaign

d) Easiness of lining

e) Reduction of building height

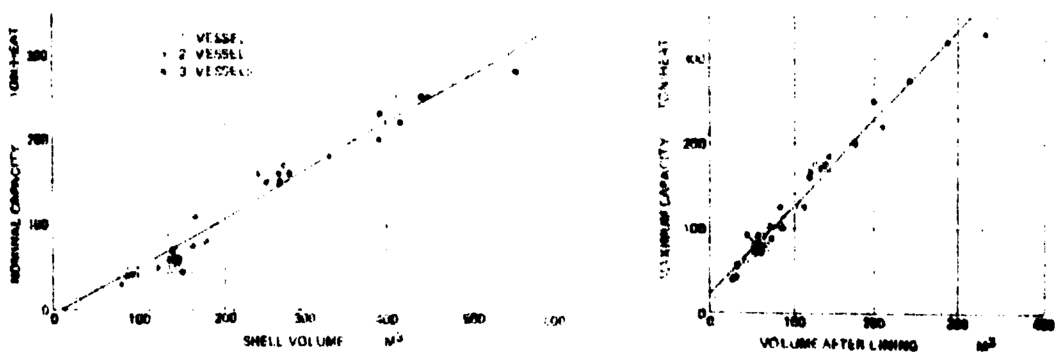
f) Reduction of required tilting torque

Figs.3-(a) ~ 3-(e) show the main dimensions of about 90 LD BOFs in operation or under construction as of 1972 in Japan, together with the regression curves determined by the method of least squares.

As shown in these figures, vessel up to about 150 tons/heat grows in capacity mainly by the enlargement of the vessel diameter. This was due mainly to the restrictions of the building height and the capacity of vessel tilt drives. And the blowing troubles arising from a relative drop of the height-to-diameter ratio have been solved by employing multiplenozzel oxygen lances. These vessels have the shell diameter up to about seven meters.

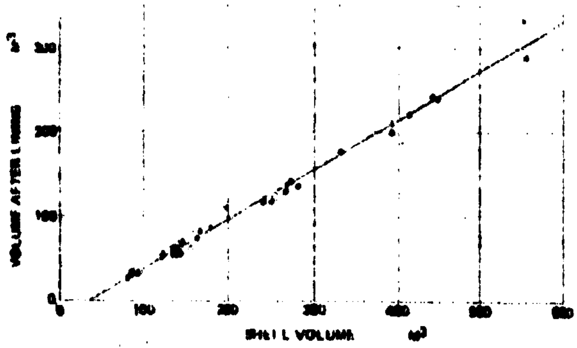
Recently built large-capacity vessels, however measure more than eight meters in shell diameter and some of them have a height-to-diameter ratio of over 1.5.

As shown in fig. 2, recent vessels are generally of a tulip type with the bottom section narrowed down by 10 to 40 degrees. This is intended mainly for securing desired bath depth and uniform decarburization of metal throughout a campaign.

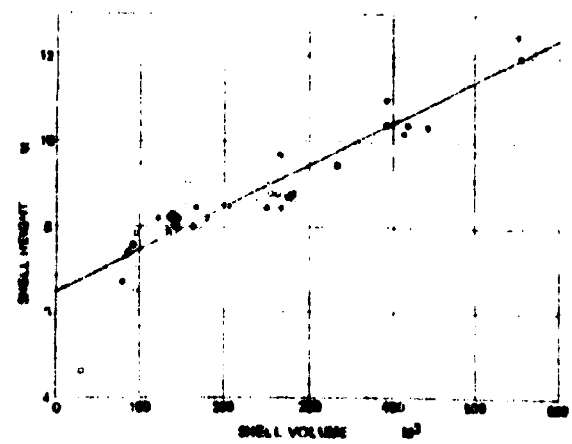


(a) NOMINAL CAPACITY - SHELL VOLUME (b) MAXIMUM CAPACITY - VOLUME AFTER LINING

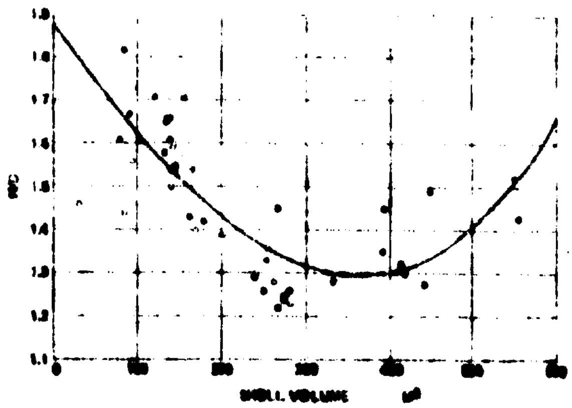
FIG. 3 DIMENSIONS OF LD VESSELS



VOLUME AFTER LINING - SHELL VOLUME



SHELL HEIGHT - SHELL VOLUME



SHELL HEIGHT/SHELL DIAMETER (H/D) - SHELL VOLUME

FIG. 3 DIMENSIONS OF LD VESSELS (CONTINUED)

2-2 Support system

The support systems of early vessels which were generally small in capacity were often of an integral trunnion type (fig. 4) which meant the direct bolting or welding of trunnions to the outer surface of the shell. With the increase of furnace capacity, however, a separate trunnion type (fig. 5) gained general acceptance, because it keeps trunnion free from the direct effect of the thermal expansion and creep of the vessel.

The separate trunnion type generally consists of a number of brackets mounted on the shell above and below the trunnion ring. The weight of the vessel is supported by the upper brackets in its upright position and by the lower brackets in its inverted position. And the weight of a tilted vessel is partially supported by the stoppers provided on the upper and lower surfaces of the trunnion ring (fig. 5-(a)).

Since the distortion is not uniform all around the shell, the load distribution among supports become non-uniform in course of time and this often causes damage on brackets, stoppers or shims. Recently, the weight of vessel is often supported on only one side of trunnion ring in both upright and inverted position, allowing for free expansion of the vessel in its axial direction (figs. 5-(b), 5-(c)).

Some of the recent large-capacity vessels adopt a support system which has only two or three supporting points instead of the conventional support systems having more than four points. For example, in the support system shown in fig. 5-(c), two points above the trunnion ring support all the axial weight of the vessel and the supporting devices under the trunnion ring simply support the unbalanced moments of the vessel in its tilted position. More than thirteen vessels with this two-point support system are in operation with satisfactory results.

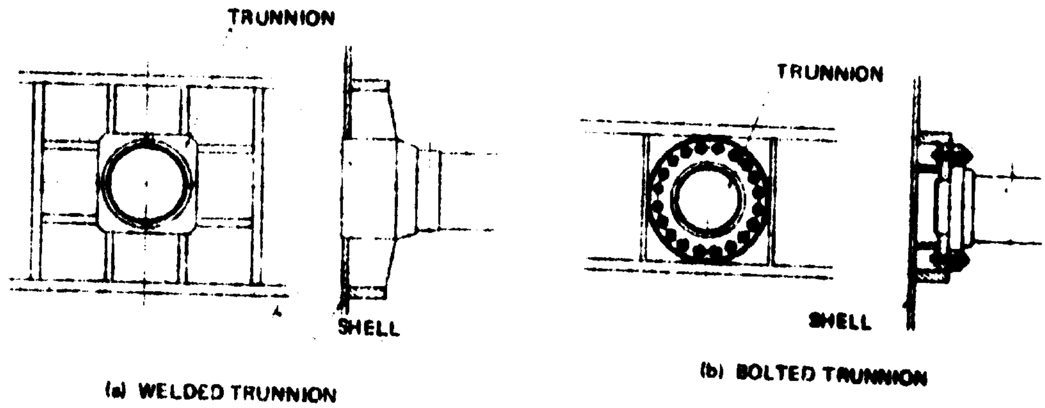


FIG. 4 INTEGRAL TRUNNION TYPE

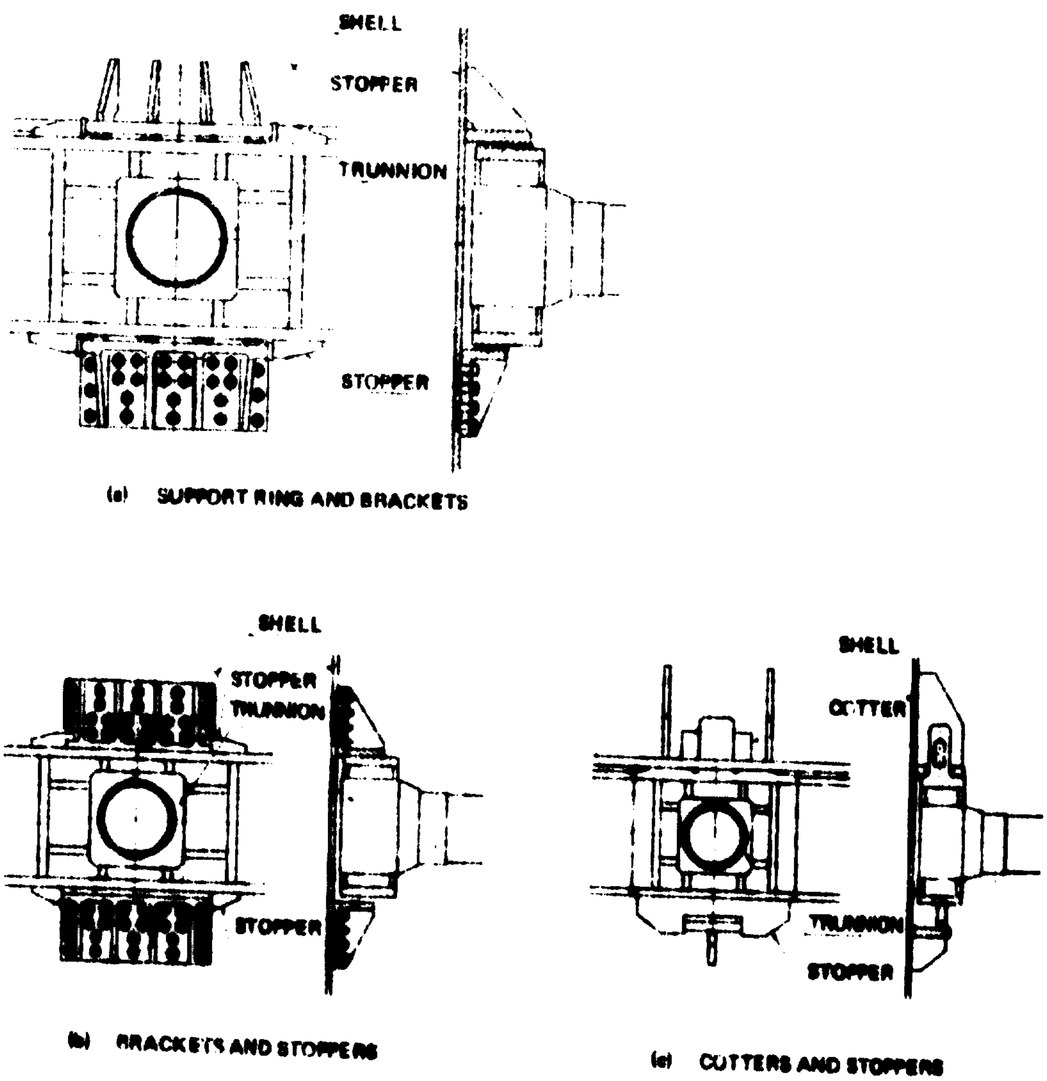


FIG. 5 SEPARATE TRUNNION TYPE

2-3 Cooling of vessel

One of the major concerns to users of LD basic oxygen furnaces in an adequate cooling system. It can be said that the cause of most problems on the shell of LD BOF can be directly attributed to its high temperature. Shell temperature often reaches 400° C at the end of its lining life, and rises even higher when slopped slag and metal build up on the shell. The top section of the shell is usually exposed to combustion gas around the mouth, to radiant heat from the hood, and also to high radiant heat from the molten metal in the ladle during charging and teeming operation.

The metallographic analysis of the used material removed from the top section of vessel after several years operation proved that a shell without an effective slag shield could reach 400° to 700° C locally.

An elevated temperature deteriorates the mechanical properties of carbon steel used as shell material and causes considerable creep deformation due to thermal stress. Fig. 6 shows an example of such a distorsion of a shell after three and a half years operation. LD BOFs without any cooling devices generally show significant distortion in the top section of the shell in three or four years after they tapped their fist heat and also in the middle section of it in another one or two years.

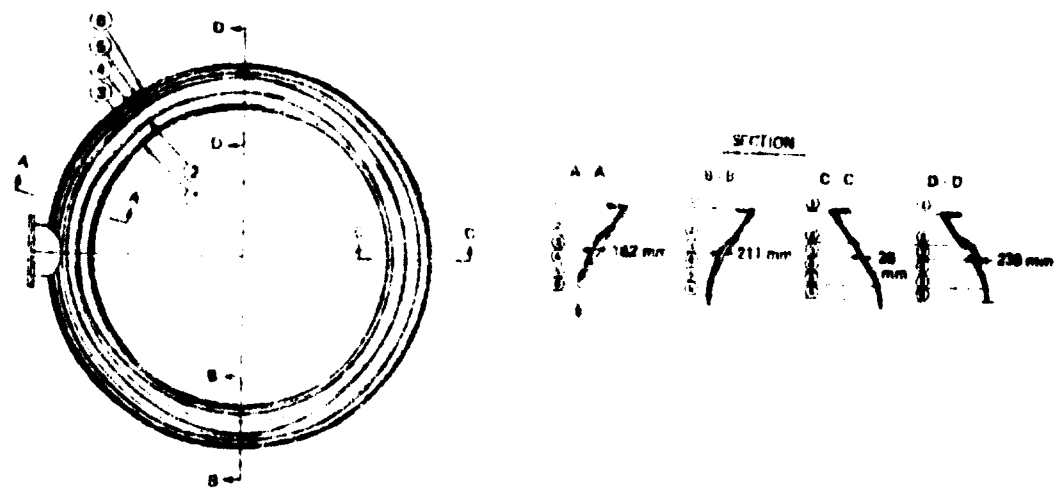


FIG. 6 DISTORTION OF SHELL

Trunnion ring also shows considerable distortion in six or seven years and sometimes serious cracks due to thermal fatigue occur on its tapping side.

A number of shells and trunnion rings have been constructed of carbon steel plates such as BS4360-43D and JIS-SM41, which are characterized by high weldability. Other steels considered for this construction have included carbon steel plates for pressure vessels, such as ASTM A-516 grade 60, A-201 grade B and JIS SB42. But some of the recent shells are built with ASTM A204 grade A or JIS SB46M, a carbon steel containing 0.5% Mo, or with Cr-Mo steel such as ASTM A387 grade D. Conclusive results, however, are not available due to an insufficient experience with the vessels constructed of these types of steels.

A reduction of the radiant heat from the hood and the ladles may be obtained by using heat shields over the top section of shell and the trunnion ring. The problem with this type of heat shield is that heat from the vessel itself cannot escape sufficiently. A further advance in this field has been recently made by using a water-cooled heat shield.

It is also useful to provide a heat shield on the side of the trunnion ring, particularly on its tapping side, to protect it against radiant heat from tapped steel.

These heat or slag shield are usually simple and inexpensive devices, and yet an adequate design promises an effective way to prolong the life of shell and trunnion ring.

Among all components of the vessel, the lip ring is exposed to the severest thermal condition and generally lasts one or two campaigns before requiring replacement or repairs. Some lip rings are made of cast steel considering the effect of impact in deskulling operation, some of ductile cast iron to prolong their life time. The distortion as well as partial melting of them usually increase accumulation of skull and chance of lining drop. And the repairing work of the lip ring accounts for about ten percent of all the vessel relining time. Since it is hardly possible to effectively extend the life of the lip ring only through the selection of appropriate materials, water cooling is probably the only practically available method to expect the best performance of lip ring.

Design trends of typical cooling devices for the LD basic oxygen furnace are as follows:

a) Top section of shell

Among the various types of patented cooling systems, are widely used a nose flange with water channels and nose cone with semi-annular water tubes welded on its outer surface.

Cracks occurred in the water-cooled nose flange of the early days design. Subsequent improvements on design and fabrication, however, have realized a successful cooling system.

b) Middle section of shell

A cooling system which forces air through the gap between the shell and the trunnion ring to cool the outer surface of the shell is now in use.

c) Lip ring

The water-cooled lip ring shown in Fig. 7 has operated successfully over five years. This lip ring is made of segmental iron castings with cast-in water channels, with such improved design and casting technique as not to cause water leakage even in case the iron castings crack.

From the operational results obtained, one can conclude the followings:

1) The lip ring's life time has been extended up to about one year.

2) The accumulation of slag and metal on the lip ring has been reduced considerably, and easy deskulling operation has been experienced even if slag and metal build up on it.

3) The improvement of the usuful life of the lip ring results in lower operating cost and higher productivity of LD BOF.

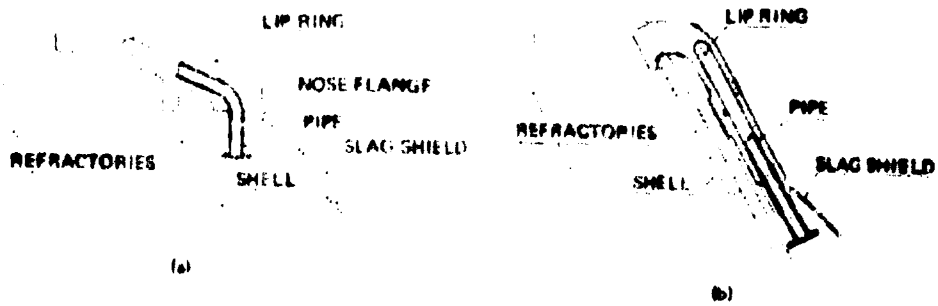


FIG. 7 WATER-COOLED LIP RINGS

d) Trunnion ring

Recent trunnion ring has usually an enclosed construction for its rigidity and requires some consideration on the cooling of it.

Some trunnion rings are internally cooled by forced air, but sufficient cooling effect can be hardly expected.

An advanced cooling system uses water circulating through trunnion ring. The temperature of the water-cooled trunnion rings is always close to ambient temperature so that no added care need be taken into account about creep strength of its material. There are not so many vessels in operation that have a water-cooled trunnion ring as yet. For example, there are only five of them in Japan. But their satisfactory operational results point to an increasing acceptance of this type of vessel in the future.

e) Heat and slag shields

The slag and heat shields for the top section of the vessel are built of steel plates with water pipes welded to the inner surface.

Nearly two years operation shows little distortion of the shield and no build-up of skull.

3. VESSEL TILT DRIVES

LD vessel is started and stopped about twenty to thirty times during the charge, tap and slag-off operations. The tilt drives have to resist unbalanced loads as well as impacts peculiar to LD BOF and provide the required service life and reliability for the duty cycle imposed. The capacity of the vessel tilt drives in basically determined by static peak torque, torque due to friction loss, acceleration-deceleration torque, torque required for deskulling practices and duty cycle.

3-1 Torque load

The value of unbalanced static torque of the vessel varies with vessel capacity as well as the configuration of the vessel.

Figs. 8-(a) and -(b) show the torque curves for newly lined 200-ton vessels with shell volume of about 400 m^3. The figures give the unbalanced static torque at the vessel trunnion M versus tilting angle θ. Curves (1) in these figures show the torque during the time when the vessels are tilted toward tapping position, and curves (2) torque toward upright position after the tapping. As is evident from these curves, the motor is subject to negative loads.

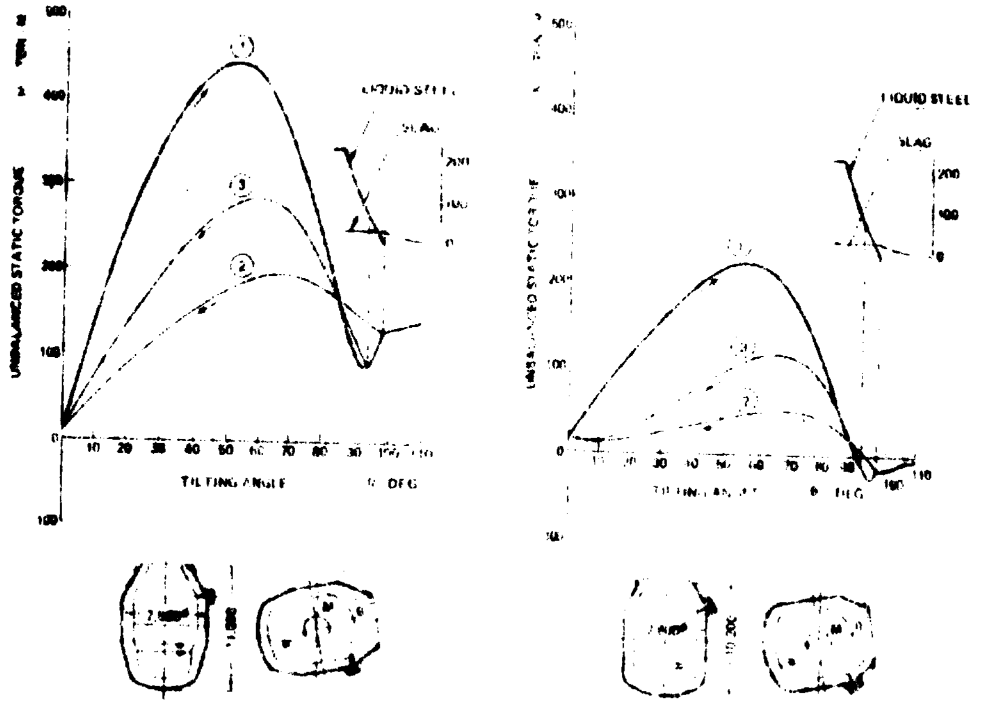
Although torque curve (1) changes significantly with the location of the tilting center, the distance from the highest point occuring between 50 and 70 degrees to the lowest point located just before the end of tapping keeps around a certain value peculiar to the configuration of each vessel. Therefore, the peak torque of vessel (a) is about 40 percent higher than that of vessel (b), even if the lowest points on these two curves are adjusted to have the same value by shifting the location of the tilting center of either vessel.

Curves (3) show the unbalanced static torque of a vessel which is rotated toward its upright position with about 30 percent metal inside of it because of an accident during tapping operation.

It follows from the curves that the vessel (a) will be restored from the tapping position by self-righting force if the brake is released, but the vessel (b) requires some sort of auxiliary drive unit to rotate it toward the upright position without the aid of tilting motors.

It is desirable to lower the height-to-diameter ratio from the view point of saving of tilt-drive capacity and building height. And this allows a considerable saving of expense especially for the construction of large-capacity vessels. By reason of the blowing technique, however, some of the recent vessels with a capacity of more than 300 tons have a height-to-diameter ratio of grater then 1.8, and the above distance on the torque curve of these vessels reaches around 700 ton-meters.

By choosing the location of the tilting center suitably the lowest point on the torque curve can be made to move far into the negative section below the zero torque line and the curve has much lower peak than that of full positive values. However, the vessel system so designed, loses the self-righting feature as that realized from a curve of full positive torques. This kind of vessel is often provided with the above auxiliary drive unit as a means of securing operational safety.



(a) VESSEL WITH HIGH H/D RATIO

(b) VESSEL WITH LOW H/D RATIO

FIG. 8 UNBALANCED STATIC TORQUE CURVES

3.2 Vessel-tilt control

It is not seldom that AC wound type induction motors are employed for tilting LD vessel with a modest capacity. Usually this type of drive consists of two motors, one for high speed and the other for low speed. The AC drive system possesses the advantage of an economic saving in installation and operation costs. The problem introduced with system, however, is an unavoidable difficulty in speed control and electrical braking.

The DC motor drive system is higher in price than the comparable AC system, but has compensating advantages in its control performance. Specifically, the application of DC motor system to the vessel tilt drives has the following merits :

- Stepless speed control
- Efficient control of negative load torque
- Effective application of an electrical brake
- Simplicity of load balancing between multiple motors

The power supply for the DC tilt drives is trending toward Thyristor-Leonard system away from Ward Leonard system with M-G set. The features of the Thyristor-Leonard system of LD vessel tilt drives are as follows:

a) Rectifier connection method

The tilting operation of LD vessel requires reversing of the motor. Usually two kinds of method of reversal for Thyristor drive are used.

The cross connection system involves circulating current, consequently it requires a DC reactor, necessitates large-capacity transformer, Thyristor, etc., and produces loss due to the circulating current. Although the system is expensive from this reason, it is commonly used for loads requiring forward and reverse operation because of ease of the reversal.

The anti-parallel connection system has come to be used for LD vessel tilt drives because the improvement of Thyristor control equipment in performance has made it possible to reduce the time required by the anti-parallel connection system for forward-reverse switching.

b) Speed control system

A voltage control system feeding back the terminal voltages of a motor as speed signals may be acceptable for the tilting of LD vessel which does not require high accuracy in speed control.

c) Brake system

Due to the application of a regenerative braking system, a mechanical braking is used, in many cases, mainly for the purpose of holding the vessel at a fixed position after the stopping motion. Dynamic braking is seldom provided in combination with the above regenerative one.

d) Power supply system

Increased capacity of the vessel has required a drive system with multiple motors. Consideration must be given to the selection of the power supply system: a common power supply system which drives a plurality of motors with a Thyristor-Leonard set, or an independent power supply system which employs a Thyristor-Leonard set for each of the motors. The common power supply system has the advantage of lower installation cost but involves problems that the load balance is liable to be affected by the difference between the characteristics proper to each motor and that all motors fail to operate in case the Thyristor-Leonard set should develop troubles. Although the independent power supply system comes more expensive, it has no disadvantages of the common system. A hybrid system which uses two Thyristor-Leonard sets for four motors is now suggested for one of the profitable systems.

3-3 Drive arrangement

A drive arrangement is generally composed of primary reduction units driven by prime movers and a final bull gear unit connected to the trunnion.

Among the many different styles of drive arrangements the following three types have been popularly used with consideration for an unavoidable trunnion misalignment which results in changing the gear tooth contact between trunnion-mounted bull gear and floor-mounted pinion. One type adopts a flexible coupling connecting the trunnion to the output shaft of drives. Another is of a semi-shaft-mounted drive system of which bull gear and pinions are supported on the trunnion and flexible couplings are used between the pinions and floor-mounted primary reduction units. The third is a fully-shaft-mounted drive system where the prime movers, primary reduction units and a final bull gear unit are all supported on the trunnion.

Currently large-capacity vessels employ a multi-pinion system for distributing the loads on the bull gear over two or more points and also increasing the reliability of tilt drives through multiple prime movers.

The shaft-mounted drives require a torque resistor employing torsion bar or links to transmit furnace torque into the foundation.
Fig. 9 shows a fully shaft-mounted tilt drive with four pinions.

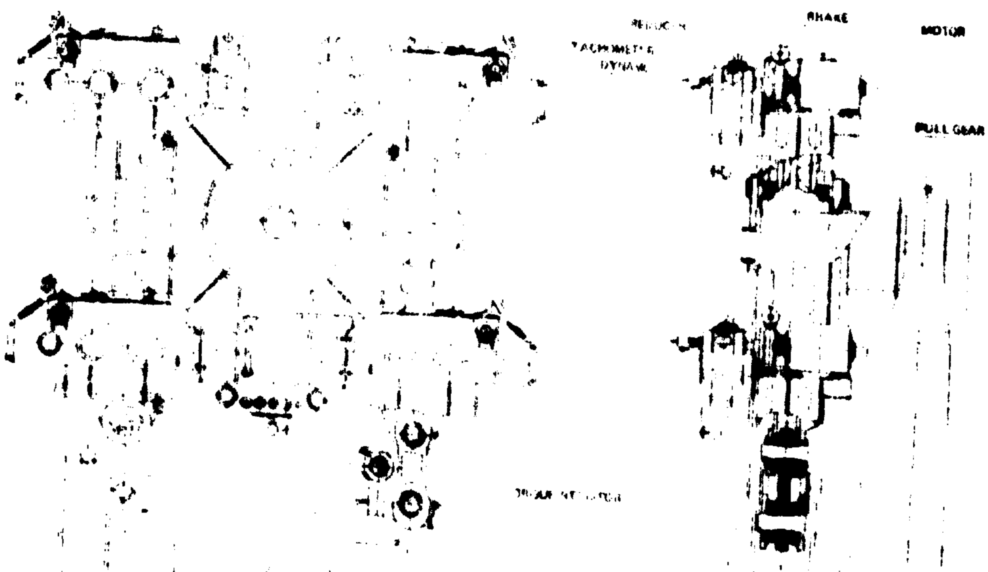


FIG. 9 SHAFT-MOUNTED TILT DRIVE

3-4 Emergency drive

With an inclination to the added reliability of the tilt drives, an emergency drive unit has been employed for some of the vessels having no self-righting feature. The emergency drive unit usually utilizes such motive power as that of DC battery or accumulated compressed air or pressurerized hydraulic fluid stored up in an accumulator.

Although DC battery is often applied because of its simplicity, it can be said that other type of power source is preferable in view of the fact emergency drive unit is available even in case of prime motor troubles.

A hydraulic motor is usualy connected to the shaft of the prime motor through a clutch while due to the limitations on its capacity an air motor with a pneumatic clutch is mainly used for a small-capacity vessel with an AC two-speed tilt system which provides a sufficiently high gear ratio.

4. LANCE HOIST CONTROL

For raising and lowering the lance, a two-speed winch system with two AC induction motors has been widely used in combination with a planetary gear reducer.

The high speed operation in this system, however, has the problem of its incompetibility with precise setting of the lance position. For this reason, a Thyristor-Leonard controlled DC motor system which allows continuous speed control has come to be employed and a pulse generator is taking the place of the conventional synchronous transmitter as a lance position detector. The pulse generator allows an accurate detection and easy automatic correction of the lance position through its digital signal system.

Another improvement on lance position control is a constant deceleration system which keeps the tension of lance hoisting cable uniform during the lowering operation of lance.

5. WASTE GAS COOLING AND CLEANING SYSTEM

The quantities of the waste gases released from LD process is far beyond those of the other conventional steelmaking processes and the cooling of and dust removal from the gases pose a serious problem. Waste gases from the vessel range from 1250°to 1600°C in temperature and contain more than 90 percent CO and about 120 gr/Nm^3 iron oxide dust.
The waste gas cooling and cleaning system has a particular influence on the initial investment, the operation cost and the layout of a LD BOF shop.

The waste gas cooling and cleaning system can be roughly classified into two types, i.e. combustion type and suppressed-combustion type. Fig. 10 shows the volumes of waste gases leaving fume hood in these systems.

The combustion system has been widely employed because it imposes little restrictions on the operation of the BOF and is easy to control. However the suppressed-combustion system is currently employed in an increasing number of steel mills confronted with the problems of increasingly rigid requirements for air pollution control and of the rising installation cost of the equipment resulting from the use of large-capacity vessels. This tendency is shown in fig. 11.

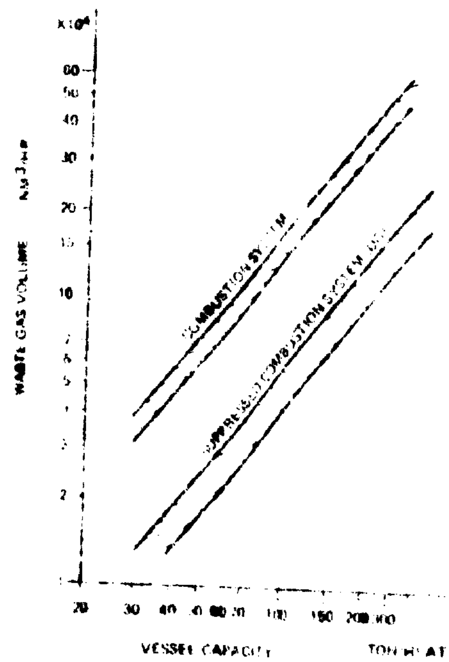


FIG.10 WASTE GAS VOLUME LEAVING FUME HOOD

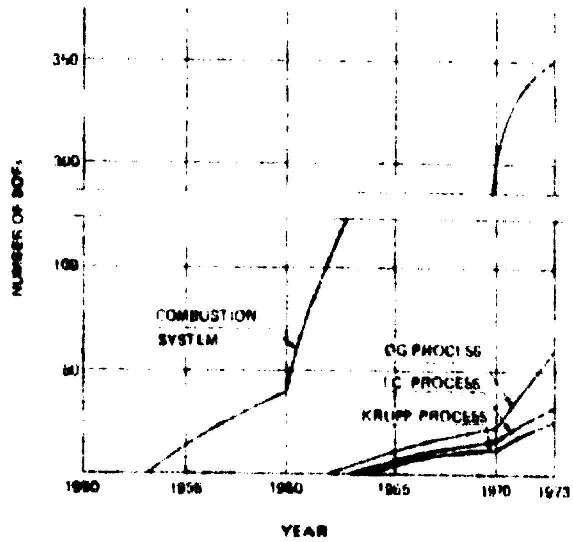


FIG.11 NUMBER OF WASTE GAS COOLING AND CLEANING SYSTEMS

5-1 Combustion type

In the combustion-type waste gas cooling and cleaning system, the combustibles in waste gases are burned with excess air. Then the gases are cooled, cleaned and eventually discharged into the atmosphere.

According to the degree of utilization of the energies in waste gases, the system can be classified as shown below.

- Waste heat recovery system
  - Full combustion boiler
    - Full boiler
    - Half boiler
  - Half combustion boiler
- Waste heat non-recovery system

The full boiler makes full use of the heat energy of waste gases. The waste heat boiler which was developed in the early days of the LD process belongs to this type. The generated steam is fully utilized in such steel mills as is in need of large quantities. All the wall surface of the combustion chamber are lined with water tubes to serve as radiative heating zone, which is connected to the refractory-lined flue which suspends water tubes in it and serves as a contact heating zone. The boiler is generally designed to have an outlet waste gas temperature of about 500 °C and a thermal effeciency of around 70 percent.

Because of the cyclic furnace operation, the volume of steam generated in the boiler varies largely from zero to a maximum and back to zero. In order to reduce the fluctuating load swings from the boiler, it is necessary to incorporate the steam accumulator into the system. The full boiler is generally provided with an auxiliary burner for increasing and smoothing steam generation and a soot blower for removing soot on the contact heating water tubes.

This system is most expensive in equipment cost among all combustion systems because of its wide heating area and a variety of accessories. Fig. 12 shows an overall view of a full boiler and fig. 13 illustrates the open-loop type water-circulating system of the full boiler.

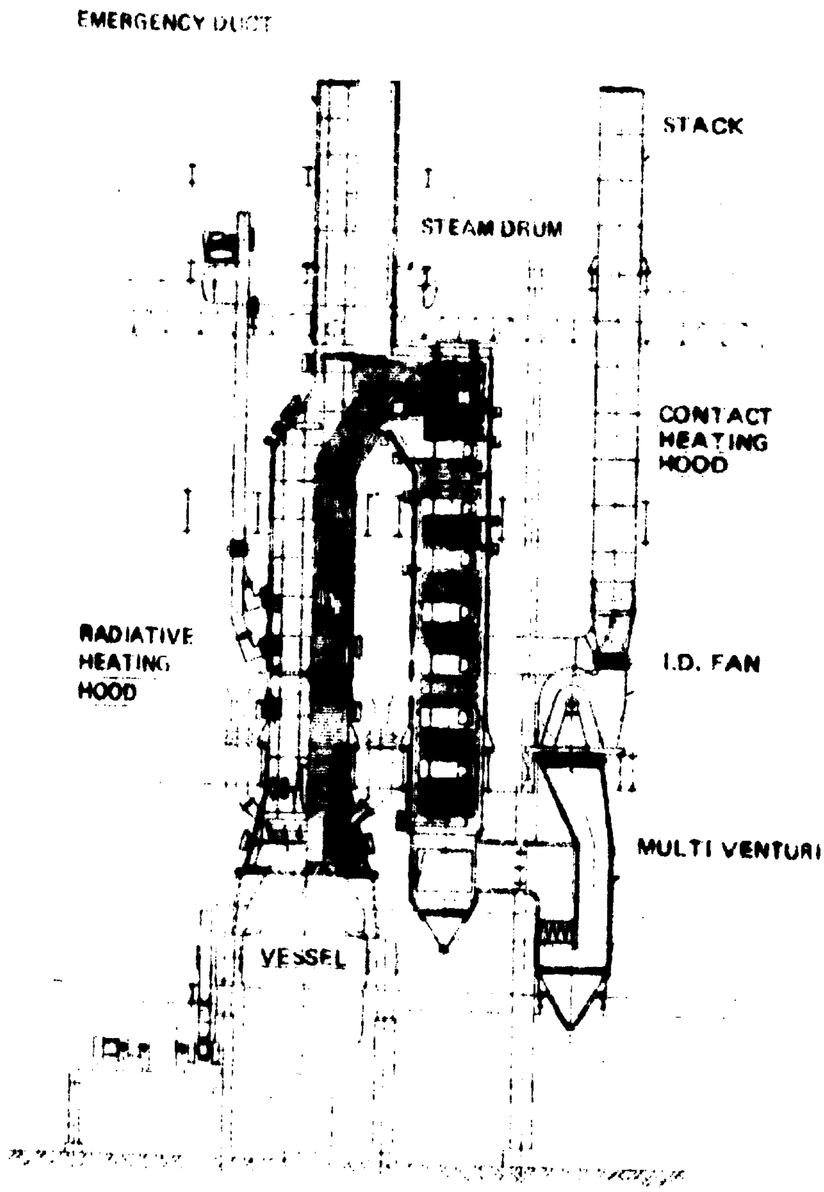


FIG. 12 GENERAL ARRANGEMENT OF FULL BOILER

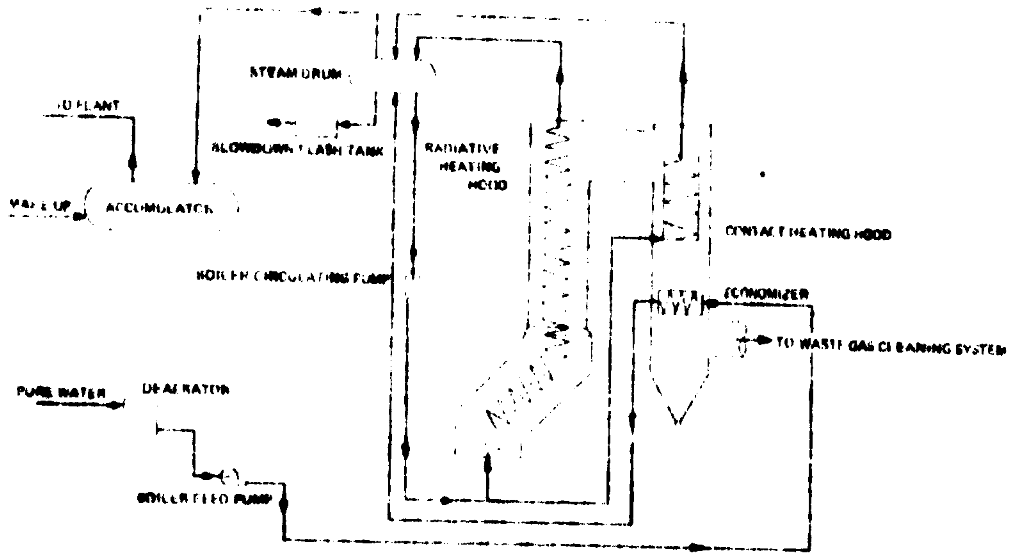


FIG.13 SCHEMATIC ARRANGEMENT OF FULL BOILER

In cases where a steel mill has a network of steam piping through which the required volume of steam can be obtained from other boilers, or where the use of a full boiler poses difficulties in the effective disposal of the large quantities of steam generated by it, a simplified boiler called half boiler is adopted for restricting the generation of boiler steam.

The half boiler dispenses with the contact heating surfaces resulting in less circulating water and smaller capacities of auxiliary equipments. However, the temperature of waste gases at the outlet of the boiler reaches as high as about 1200°C and it is necessary to cool the gases to the temperatura suitable for the dust collector through an injection of water into the gas streams. Fig. 14 is a general view of a half boiler and fig. 15 the open-loop type water-circulation system of a half boiler.

The half combustion boiler is usually designed to burn about 50 percent of waste gases from the furnace and the gases at the boiler outlet contains approximately 30 percent CO. After passing a wet scrubber, the waste gases are delivered to the stack with an induced draft fan and the unburnt CO gas is burned by a flare burner on the top of the stack. This system demands carefull consideration to the design and operation of the equipment because the CO concentration in the wet gases must be kept above about 15 percent for the normal burning of CO gas. Currently, there are but few half combustion boilers in operation.

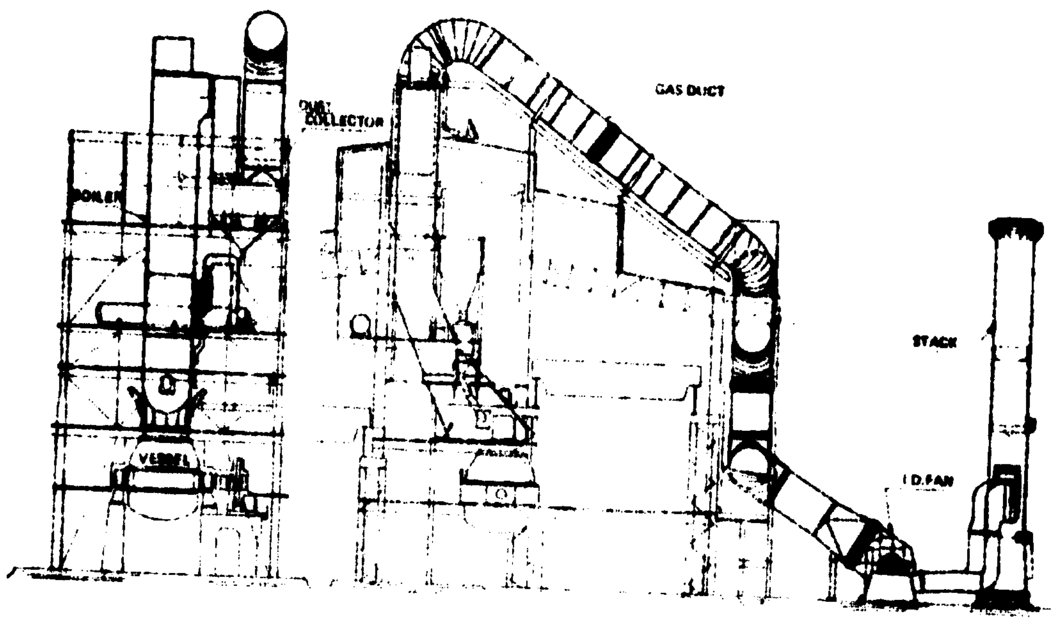


FIG. 14 GENERAL ARRANGEMENT OF HALF BOILER

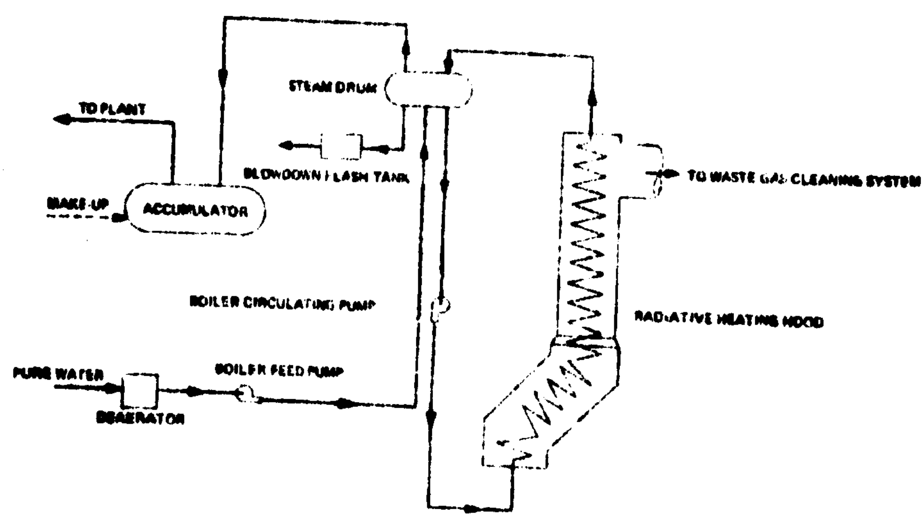


FIG. 15 SCHEMATIC ARRANGEMENT OF HALF BOILER

Waste heat non-recovery system makes no use of the heat energy of the waste gases at all and the burnt gases are discharged into the atomosphere. Waste gases are cooled by the addition of considerable quantities of air and by water injected into the stream, thus the volume of waste gases to be disposed of by this system becomes greater than that by other systems.

These combustion type waste gas cooling and cleaning systems use a venturi scrubber or an electrostatic precipitator as a means of the dust removal. Although the venturi scrubber is generally less expensive than the electrostatic precipitator, it requires the high velocity of waste gas and the total pressure loss often runs in excess of 1,600 mm-H_2O to reduce the concentration of the discharged dust to about 0.1 gr/Nm^3.

6.2 Suppressed-combustion type

In the suppressed-combustion type waste gas cooling and cleaning system, the waste gases are cooled and cleaned without burning them or with their combustion held normally to less than 10 percent. Compared with the combustion system, it has the following advantages.

- Less volume of waste gases to be disposed of
- Lower gas temperature
- Low oxidation state of iron oxides and relatively large size of particles
- Reuse of the recovered gases consisting mostly of CO

The comparison of the volume of the gases leaving fume hood to that of the full combustion system is shown in fig. 10.

The suppressed combustion system can be roughly classified into three types, i.e. OG process, IC process and Krupp process.

a) OG process

This process is the first commercial suppressed combustion type and commenced the operation in 1962 with a 130 tons/heat furnace. Subsequently, various improvements have been made on the process and it is most widely used of all the suppressed combustion type processes in the world.

Fig. 16 shows a general view of OG equipments and fig. 17 a flow sheet of OG process. Waste gases from the nose opening of a vessel run through the hood into the first dust collector and then the second dust collector. Cooled and cleaned through this procedure, the gases reach the outlet of the induced draft fan with a temperature of about 80°C and a dust concentration less than 0.1 gr/Nm^3.

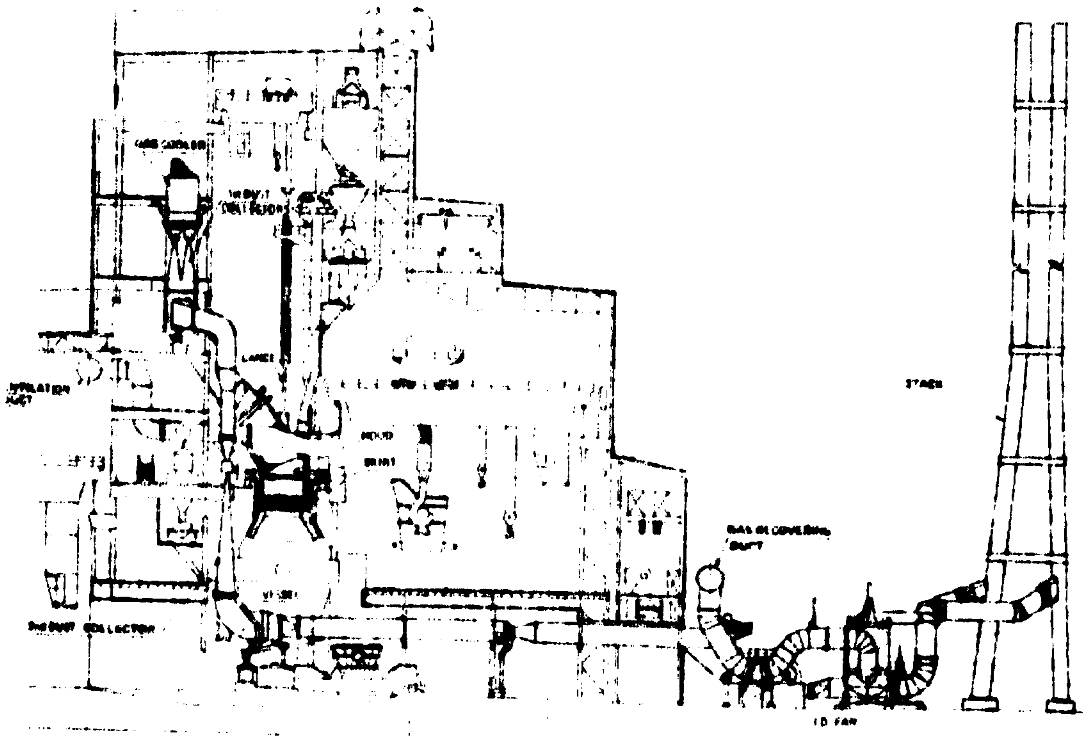


FIG.16 GENERAL ARRANGEMENT OF OG EQUIPMENT

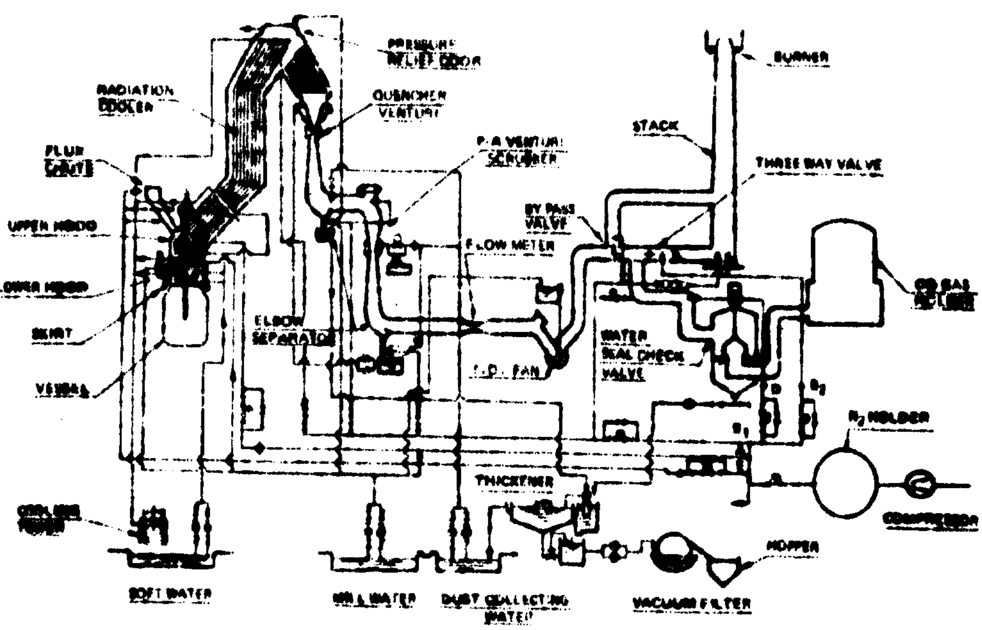


FIG.17 SCHEMATIC ARRANGEMENT OF OG PROCESS

in the beginning and last stage of blowing, these waste gases are discharged out of the stack because of the low concentration of CO, but are recovered into a gas holder by means of a three-way valve during the CO gas concentration is more than 60 percent.

The composition of waste gases reaches a range of explosion at the beginning and end of blowing. Therefore, N_2 gas is injected into the cooler to dilute the waste gases reducing CO and O_2 contents in waste gases to less than 14 and 6 percent respectively. However, in the normal operation of the present OG installations N_2 dilution of waste gases is not employed because it has been proved that the utmost safety can be secured in the actual operation with burning the CO Air mixture into the inert gas.

The features of the major components of OG system are mentioned below.

1) **Hood**

A hood part is fabricated of water tubes and consists of an upper hood mounted on a carriage, a lower hood fixed on the support beams and a moveable skirt which lowers down close to the nose opening of the furnace in order to collect the waste gases in an unburnt condition. A cross sectional view of the hood part is shown in fig. 18

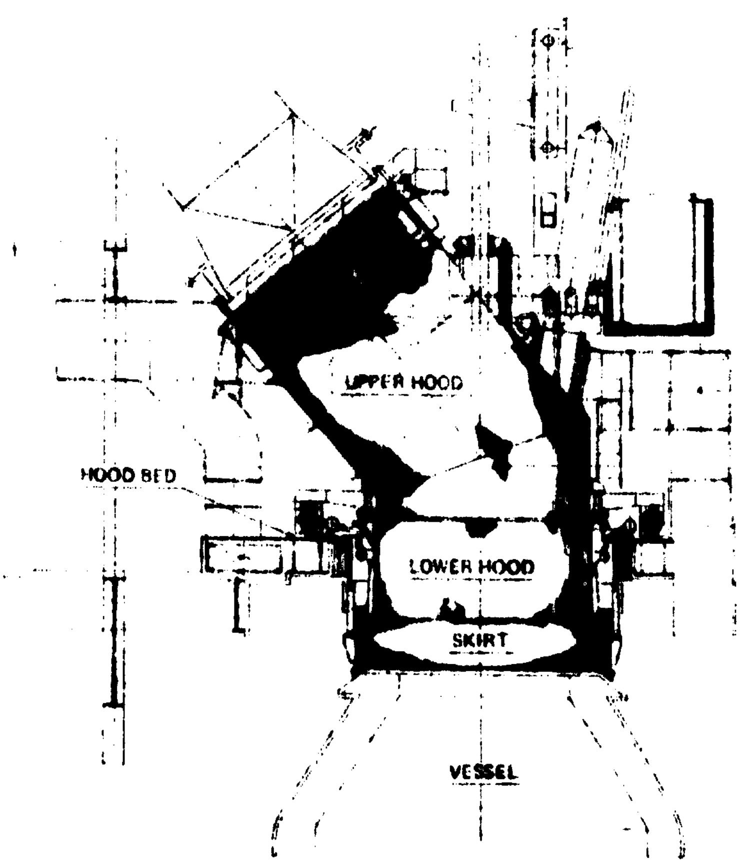


FIG. 18 HOOD

2) Gas cooler

Waste gases are cooled to approximately 1000°C after passing through the gas cooler which is recently provided with radiative heating surfaces only. Basically, there are, at present, four different systems in use for the water cooling, i.e. the open-loop water recirculation system, closed-loop water recirculation system, high-temperature high-pressure closed-loop water recirculation system, and the evaporation boiler system. The optimum choice is determined by the conditions peculiar to each steel mill. Fig. 19 shows the gas cooler.

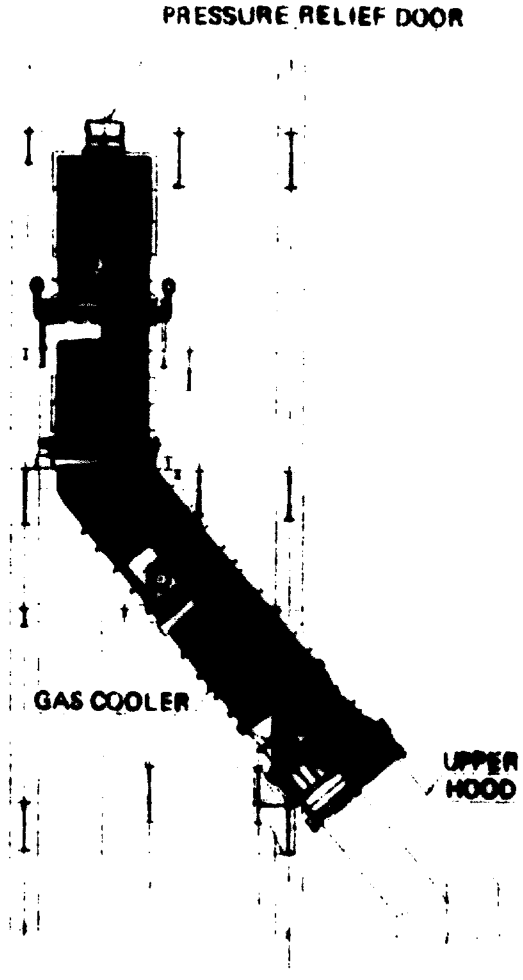


FIG.19 GAS COOLER

3) Dust collector

For fear of CO gas explosion in an electrostatic precipitator, a wet type venturi scrubber is employed. Fig. 20 and fig. 21 show the first dust collector using a quencher venturi and the second dust collector using a P-A venturi respectively.

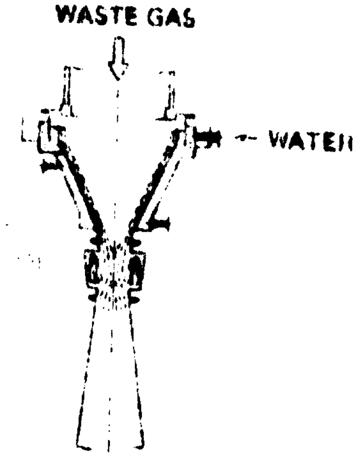


FIG.20 QUENCHER VENTURI

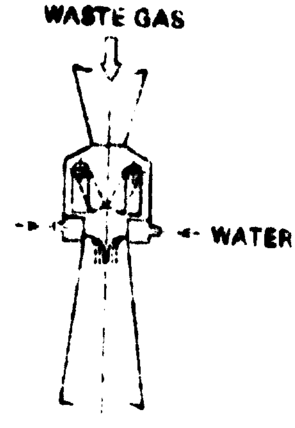


FIG.21 P-A VENTURI

As shown in fig. 17, scrubbing water is stored in the bottom tank of the second dust collector before it is pumped up into the first dust collector and the water is used again after separating dust particles in the thickner.

Recent data on this process show a dust collecting efficiency of more than 99.9 percent and dust contains of 0.04 ~ 0.08 gr/Nm^3 in the waste gases discharged out of the stack.

4) Induced draft fan

A single-stage turbo fan and its drive motor are designed to have so great a moment of inertia that, even in case of power failure, all waste gases inside the system can be discharged.

5) Hood pressure control device

As shown in fig. 18, the inner pressure of the hood is measured at a few points on the upper hood, and the throat damper of the P-A venturi is automatically adjusted to control the inner pressure of the hood at constant level.

6) Slurry disposal device

Usually, dust laden water from the wet scrubber is clarified with a Dorr-type thickener and the resultant slurry is dehydrated by an Oliver type vacuum filter or a press-filter.

7) Stack

The stack is currently provided with a flare burner of a pulse igniter type to completely burn the remained CO gas.

b) IC process

Fig. 22 shows an example of IC process. This example has an evaporation type cooling hood located over the furnace and the next water-tube type cooler from where high-pressure steam is obtained.

Collected by an open type sleeve located around the nose opening of the furnace, waste gases pass into the hood and cooler, and are led into the first dust collector "Granivore" where the gas are cleaned by spray water. From there, the gases run into the second dust collector "Solivore", where their dust concentration is reduced to the required level, and through an induced draft fan are eventually led into the stack or into the gas holder. A recent type of this process, however, employs a ring-slit-washer, a king of high pressure-differential type variable venturi, in place of the above dust collectors.

Although former types of this process controlled the rate of gas flow by adjusting the damper located at the inlet of an induced draft fan through the detection of gas pressure inside the sleeve, some of the recent types use the variable venturi, instead of the damper. According to the "tampon-process", the preset volume of the gas and air is drawn into the system at the beginning and the end of an operating cycle, and all the combustibles are burned into the inert gas.

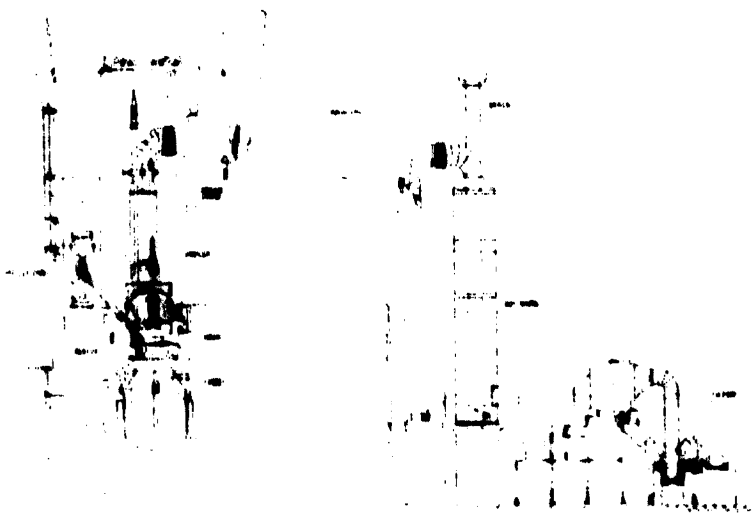


FIG. 22 GENERAL ARRANGEMENT OF IC EQUIPMENT

c) Krupp process

Krupp process employs the "Sperr Luft System" and has a concentric double-hood above the vessel. Waste gases overflowing from the inner hood are drawn into the outer hood with air. The rate of gas flow is controlled by the operation of a guide vane at the inlet of an induced draft fan. Like the former two processes, the Krupp process prevents the explosion of waste gases through the formation of the inert gas zone. This process also employs a ring-slit-washer as dust collector.

5-3 Secondary fume collecting and cleaning system

In addition to the problem of waste gases, an LD basic oxygen steelmaking plant is faced with the serious problem of preventing pollution of working environment, arising from large amounts of fume and dust produced in handling hot metal, liquid steel and flux materials.

The main sources of fume and dust include the following:

a) Pouring of hot metal into and out of a mixer, or pouring of hot metal out of a turpedo car

b) Desulfurization of hot metal

c) Charging of hot metal into the vessel

d) Leakage of waste gases from the hood of a waste gas cooling and cleaning system during blowing period.

e) Tapping of molten steel from the vessel

f) Transportation of flux materials

Secondary fume collecting and cleaning system has been rapidly increasing in capacity and has become of major interest in the recent LD BOF shops. Fume suction fans with a total capacity of more than 1,000,000m^3/hr are often installed in recent LD BOF shops.
From the view point of economy, a positive-pressure type bag filter and a fume-suction fan located in front of the bag filter have come to be used recently.

The fume emitted by the hot metal charge into the vessel is found to reach about 10m/sec in the emission speed as measured by various methods. Consequently, a high suction-rate of the fume is required with the size limitation of the intake hood, resulting from the operational ease of a charging crane. The peak temperature of the fume from hot metal reaches around 1000°C at the intake hood. On account of the cooling effect of a long duct and a large volue of induced air the fume, however, is cooled to about 100°~150°C at the inlet of the dust collector. The bag cloth is usually made of a polyester fiber "Tetron". The apparent flow speed of gas through the bag filter is, in many cases, set to about 1m/min.

An intense interest has been shown toward an overall-building fume collecting system recently, because of much difficulty in preventing air pollution strictly through this system employing a local hood for each fume source. In some small electric furnace steelmaking shops, this type of fume collecting system is already in practical use. But in large LD BOF shops, there is not an established overall-building fume collecting system as yet, and various ways of approach to this end are being studied.

6. NEW AUXILIARY EQUIPMENTS

The latest LD BOF shop still requires manual labor at various operations of steelmaking. Such manual labor directly affects the productivity of the LD BOF and the quality of the products. Since it is hard kind of manual work to be performed under unfaborable conditions, mechanization or automation of it has long been awaited. However, some notable systems have been developed in this field recently. Of them, a sensor lance and a relining machine are especially noteworthy.

6-1 Sensor lance

In the operation of LD BOF, the accurate measurement of turndown carbon and temperature is essential to the efficient operation and the high quality of the product. Due to the absence of a continuously detecting device at present, an expendable carbon determinator and immersion thermo-couple are widely employed for the turndown carbon and temperature measurement. For this procedure, the vessel is tilted with a temporary interruption of blowing or after the blowing.

A sensor lance has been developed recently for such measurement during the blowing. The sensor-lance equipment has a similar construction to the main oxygen-lance. Many of the sensor lances, however, operate at a higher speed than the main lance and complete a measuring cycle in about 100 sec. A water-cooled triple-tube sensor lance has a probe holder on its end to which various probes are fitted. An automatic fitting and removing device for the probes has recently been developed. The signal from the probe is fed to the recorder in the operation room via a compensating lead wire.

The sensor lance has improved the accuracy on turndown performance. Various probes are now in use with the following functions.

a) Hot metal level measurement

Hot-metal level is detected with the function of a pair of electrodes attached to the tip of a probe.

b) Hot metal temperature measurement

An expendable immersion thermo-couple is used for this purpose. A thermo-couple which can be repeatedly used has been developed lately.

c) Carbon content measurement

This is measured with an expendable carbon determinator "Tectip sampler". Sampled metal is killed with an appropriate amount of aluminum.

d) Sampling

Metal is taken into the chamber in the probe and sampled out of the vessel.

6-2 Relining machine

Relining a vessel is a kind of hard labor under unfavorable conditions, and takes about 50 percent of the total time of vessel repair, thus directly affecting the productivity of the plant.

A semi automatic relining machine which mechanizes brick handling to save manual labor is used in several LD BOF shops. An example of this machine is shown in fig. 23

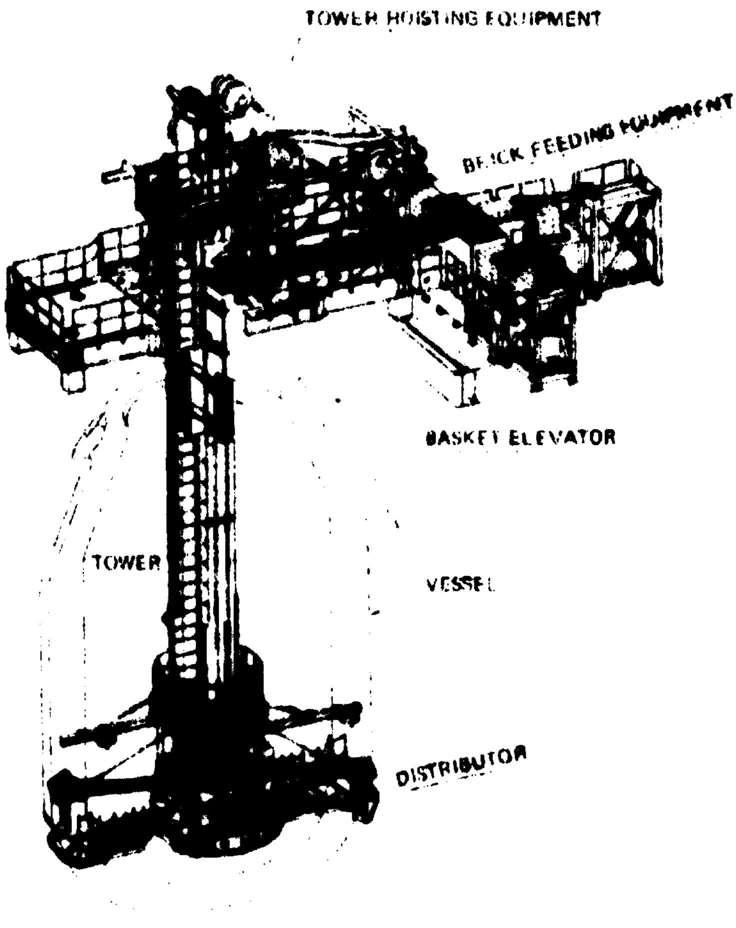


FIG. 23 RELINING MACHINE

After the hood of the waste gas cooling and cleaning system is moved away, this relining machine is mounted over the vessel by means of a service crane. The machine consists mainly of a brick feeding equipment, a basket elevator, a distributor and a tower hoisting equipment. Bricks are taken out of pallets by means of the brick feeding equipment and automatically fed into the basket elevator one by one according to a relining program. As the bricks are lowered into the vessel, the distributor feeds them to the vessel wall. After each course of bricks is laid around the vessel periphery, the distributor is raised by the tower hoisting equipment.

The relining machine eliminates all manual work except some simple adjusting works of the bricks which have already reached the required position. This machine cuts relining man power requirements by 60 percent and is capable of relining the vessel at the rate of about 1000 bricks per hour.

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