FUTURE-ORIENTED OXYGEN STEEL PRODUCTION
SMS Demag, a synonym for leading know-how and long-term solutions for the entire process chain of metallurgical technology and steel production.

Planning, project engineering, design and delivery, as well as operator training and the supply of metallurgical know-how for an optimised sequence of production in integrated steel mills, characterise the wide range of equipment and services offered by SMS Demag.

The constant further development of all steelmaking modules and process steps forms the basis for optimised steel mill design concepts for the enhancement of investment profitability.

Extensive relations with reputed steel mill users worldwide and with national and international research institutions contribute considerably to the successful accomplishment of this aim.

Engineers with ample experience in all pertinent disciplines and utilising the most advanced data-processing techniques are constantly engaged in translating the process parameters into optimum module and component designs.

Steel refining in a converter is an important link in the chain of interrelated production steps in the manufacturing and further processing of steel.

The advent of the oxygen blowing practice in the fifties marked a giant step ahead and a new epoch in steelmaking. The basic practice was the blowing of pure oxygen on top of the metal bath in the converter vessel. The resulting quick conversion of material and energy were the basis for success.

The 30-t vessels of the mid-fifties quickly became production units capable of holding up to 400 t of melt weight and yielding 600–650 tonnes per hour.

Optimisation, further development, and innovations led to increased production and tangibly contributed to quality improvements and the cost effective manufacture of high-quality products.
2 = 3 = Future-oriented oxygen steel production
4 = 9 = Converters
10 = 11 = Change vessel converters
12 = 13 = Blowing lances
14 = 15 = Slag splashing and bottom stirring
16 = 17 = Substances
18 = 19 = Waste gas analysis Sonicmeter
20 = 23 = Automation Slag retaining devices
24 = 25 = Relining equipment
26 = 27 = Dust collection, gas cleaning and gas recovery
28 = 29 = Erection and commissioning
30 = 31 = SMS Demag converter equipment
For the production of quality steels, the LD converter with its oxygen top blowing lance and vessel bottom tuyeres for inert gas stirring has found general acceptance.

Special steels are chiefly made in MRP (Metal Refining Process) or AOD (Argon Oxygen Decarburisation) converters in conjunction with electric arc furnaces and vacuum degassing facilities.

Depending on the blowing method, whether LD, AOD or MRP (with or without top blowing lance), the shapes of the converter vessels are more or less slender or big-bellied, with symmetrical or non-symmetrical vessel top cones or with integral or replaceable bottoms.

Special attention is paid in the designing of a converter to the service life of the converter vessel and of the trunnion ring. The material of which a converter vessel is made is subject to extreme thermal stressing during the steelmaking process. The temperatures in the vessel walls attain about 420 °C and in the trunnion rings about 210 °C. This implies load values not far below the yield strength of the materials.
Comb-blowing 1977
- Bottom and top-blowing with O₂
- Lime injection
- Post-combustion
- Higher scrap rate

KMS converter 1978
- Bottom and top-blowing with O₂
- Coal injection and/or scrap preheating
- Lime injection
- Post-combustion
- Very high scrap rates
- Large amount of valuable offgas

LD-CB 1981
- Increased yield
- Savings in ferro-alloy and fluxes
- Reduction of inclusions

MTBI (MWH) 1981
- Higher yield
- No slopping
- Additive savings

MRP 1983
- High mixing energy
- Low carbon content
- Low gas content
- Very low sulphur
- Fewer inclusions

<table>
<thead>
<tr>
<th>Heat size [t]</th>
<th>MRP converter volumes.</th>
<th>AOD converter volumes.</th>
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3.8 17.4 4.3 1960 2760 4200 5500
5000 2760 1960 2.2 6.8 48
3.8 36
1360 1225
3.6 2
122
10 2220 1525 114 5
3.8 36
1360 1225
3.6 2
122

SMS Demag now uses a highly temperature-resistant, fine-grained structural steel specially developed by a reputed German steelmaker.

This new grade offers a higher yield strength than, for instance, German steel grades 13 CrMo 4–5 or 10 CrMo 9–10 or American steels ASTM A387, grade 12 and grade 22, and thereby significantly improves the service life of the converter vessels and the trunnion rings.

The yield strengths of the new material, as well as the chemical analysis and mechanical properties, are compared with the conventional steels in the diagrams/tables.
MECHANICAL PROPERTIES

<table>
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Charging of a converter vessel.
Another important criterion for trouble-free operation is the method of vessel suspension in the converter trunnion ring.

Two fixing systems have proved their worth in the course of many years here:
- The lamella packs for stationary converters.
- The tensioning elements for change-vessel converters.

The essential feature of the fixing systems is the fact that the vessels are able to expand to the greatest possible extent without any hindrance.

These designs locate and center the vessels troublefree in every tilting position and without any backlash in the trunnion ring, thereby ensuring a uniform loading of the latter.

Other noteworthy features of the SMS Demag converter system are the replaceable bottom, the cooling of the vessel top cone, and the specially developed drive, which allows 100% torque equalisation among the drive trains and freedom from backlash in the gear flanks when the converter is in its working position.
Suspension for stationary converters.

Suspension for change-vessel converters.

LD converter.

AOD converter.
The change-vessel converter design represents an alternative to equipping a meltshop with several permanently installed converters, each with all of the necessary ancillaries for a steelmaking station, such as bins, fume exhaust system, lance equipment, ladle and slag transfer cars, etc.

The advantage of the change-vessel type is that it is possible to lift the vessel out of the trunnion ring when the refractory brickwork is eroded and replace it by another vessel newly lined in an off-converter rebricking area. Vessel changing times range between two and 16 hours (approx. six hours on average). Vessel changing is carried out when the converter is down for scheduled maintenance anyway. Accordingly, the annual capacity of the change-vessel converter is equal to a conventional one-two operation.

The investment costs for the additional equipment necessary for the change-vessel type, such as vessel changing car, wrecking and rebricking stand as well as waiting stand for the newly lined vessels, are relatively low compared with the costs of an additional, fully equipped converter operating station.
Illustration of a change-vessel facility.
Oxygen blowing lances decisively influence the process of decarburisation.

The blowing lances are exposed to extreme stresses in the reaction space. Steel and slag skulking on the lances is frequent. The oxygen exits from the lance tip nozzles at high velocities, which is conducive to rapid wear and negatively influences the shape of the oxygen jet.

One consequence is that lance changing is a necessity.

In conventional lance systems, the media connection pipes are generally an integral part of the lance. Thus, lance changing means the unbolting of numerous flanges and the separate disconnection of the media supply and return hoses.

Lance changing often takes up to six hours as safety regulations prescribe that work in the area above the converter is permitted only during blowing breaks.

SMS Demag, in close cooperation with Thyssen Krupp Stahl AG, has developed and uses an automatic blowing lance system, which minimises the times required for lance changing.

The characteristic features of the system are a coupling bell integrated into the lance carriage and equipped with fixed media connections, and a specially configured coupling head on the lance.

Quick lance changing is ensured by a manipulator, which is arranged opposite the blowing lance and which accepts a new lance before the changing operation.

For instance, lance changing in the oxygen steelmaking shop of Ispat takes 10 minutes on average.

A C-hook can be used for lance removal and installation where structural steel space restrictions do not allow the installation of a manipulator.
Chemical reactions.

\[
\frac{1}{2} \{O_2\} = [O] \\
[Si] + 2 [O] = (SiO_2) \\
[Mn] + [O] = (MnO) \\
2 [P] + 5 [O] = (P_2O_5) \\
[Fe] + \frac{1}{2}[O_2] = (FeO) \\
2 (FeO) + \frac{1}{2}[O_2] = (Fe_2O_3) \\
[C] + [O] = (CO)
\]
SLAG SPLASHING

Constant efforts at improving vessel lining service lives have resulted in a number of new developments, such as changes in the chemical composition of the bricks and the coating of the brick lining with residual slag, which have finally led to the present and widely adopted Slag Splashing method.

This method means that a sharp jet of nitrogen is blown onto the slag that remains in the converter vessel after steel tapping, to the effect that slag is splashed onto the converter vessel walls, adheres to the brickwork and forms a protective layer on the refractory lining.

Slag adherence is significantly influenced by the chemical composition and the wear resistance of the brickwork. Additionally, the consistency of the slag plays an important role in this technique.

In general, the melter visually judges the condition of the slag and decides whether lime or dolomite should be added to obtain the desired consistency. Appropriate process automation is another method of achieving the required slag condition. The tests carried out during the past few years, chiefly in the USA, show that the service life of a vessel lining on which slag splashing is additionally employed ranges between 10,000 and 20,000 heats.

The nitrogen jet is injected by means of the existing oxygen lance, which is connected to a separate nitrogen control loop for the purpose. The lance travel distance is adapted accordingly to enable the lance to be lowered deeply enough into the converter vessel.
STIRRING THROUGH THE VESSEL BOTTOM

Bottom stirring in converter vessels was developed in the late seventies/early eighties. Steel bath agitation in a BOF vessel is chiefly produced by the energy input of the jet of oxygen which hits the bath surface and by the energy of boiling, assisted by the formation of CO. CO formation is high during the main period of decarburisation in the jet impact area and in its immediate vicinity on the bath surface. Dead zones, where the reaction potential is lower, exist in the marginal surface regions.

To achieve homogeneity of composition and temperature uniformity in the melt, it is expedient to inject inert gas, either argon or nitrogen, through the vessel bottom into the melt. The injected gas improves bath agitation and conveys the carbon to the oxygen impact area during phases of low CO formation. The amount of injection gas varies in accordance with the different phases of the steelmaking process. The amount of iron contained in the slag are significantly reduced and hence the overall yield of the converter is improved.

An additional crucial consideration in modern process technology is a low phosphorus content of the melt at the end of blow. The injection of stirring gas through the bottom during the steelmaking process and post-stirring at the process end significantly contribute to achieving this aim. Special tuyeres whose flow rates are separately variable are employed for the introduction of oxygen and inert gas.
Steelmakers have been quite familiar with sublance technology since the eighties and have been using it as an integral part of automatic oxygen steel production. Nevertheless, SMS Demag sees further potential for production enhancement and quality improvement in this field.

The use of industrial robots for probe handling has significantly shortened the intervals between successive measurements at the end of blow. The high memory capacity of present-day robot control systems makes it possible to task the robot with a variety of functions which positively influence the entire process sequence in respect of sample-taking and sample evaluation. One example is the Complete Ad-Hoc Analysis of melt samples taken with the help of a sublance.

A system developed by SMS Demag uses a laser-based analyser to render it possible to analyse within a minimum of time those elements which are most important in the course of production. Upon extraction from the converter, the probe tube is pulled by the robot from the sublance and conveyed to a severing station where the sample is cut off while still inside the cardboard tube of the probe. After this, the robot takes the probe with the cut face of the half-sample to the laser analyser. Contrary to the conventional sample-analysis method, this technique does not require any special sample preparation for analysis.

The laser beam creates plasma on the cut surface of the sample. A spectrometer uses the radiation from the plasma to determine the chemical analysis of the heat. Differences in the wave lengths of the plasma radiation from the individual elements indicate the amounts of carbon, chromium, manganese, aluminium, cobalt, copper, molybdenum, nickel, phosphorus, sulphur, silicon, and titanium contained in the steel.

Reductions of up to seven minutes in tap-to-tap time can be achieved through the use of this new technology, compared with the previous standard practice of sample unpacking, sample dispatching through a pneumatic tube system to the central laboratory, sample preparation, and spectral analysis.
Typical spectral lines.

Sublance in measuring position; robot in waiting position.

Robot with gripper.
Waste gas measurement is now an integral part of most process control systems in oxygen steel production.

In addition to a static model for the prediction of process events, waste gas measurement allows continuous observation and control of the process in a dynamic model provided in conjunction with the sublance system.

The decrease in the decarburisation rate towards the end of blow indicates when sublance measurement should be performed. It is thus possible to reliably achieve the carbon content and the temperature target. The calculation of iron, manganese, phosphorus and sulphur slagging on the basis of the oxygen balance makes it possible to tap and alloy most of the heats without having to take a random sample and await its analysis results.

The rate of chromium combustion can be observed by continuous analysis of the waste gases and by automatic intervention in the blowing process. This is highly important in respect of chromium slagging, above all in special steel production in the MRP/AOD converter.

When decarburisation is nearing its end-point, the rates of oxygen and inert gas flow through the top blowing lance and through the bottom tuyeres can be controlled to meet the oxygen requirement as the decarburisation rate declines.

### Waste gas analysis using mass spectrometer.

- Waste gas analysis using individual components.

### Diagram of waste gas analysis.

- Conventional measurement
  - Weak points
    - Time delay (30–40 s)
    - Additional measurements for thermodynamic control
    - Waste gas flow measurement
    - Only C and O₂-balance

- Mass spectrometry
  - Weak points
    - Time delay (30–40 s)
    - Appearance until high Ar flow
    - Short maintenance interval (1–2 weeks)
    - Only C and O₂-balance

- Waste gas analysis
  - CO, CO₂, O₂
  - Infrared measurement
  - Waste gas flow
  - Vent. device
  - Restr. device
  - Thermodynamic correction

- Weak points
  - Time delay (30–40 s)
  - Additional measurements for thermodynamic control
  - Waste gas flow measurement
  - Only C and O₂-balance

- Waste gas analysis
  - CO, CO₂, O₂, Ar, N₂, H₂, He
  - Mass spectrometry

- Conventional measurement
  - Weak points
    - Time delay (30–40 s)
    - Appearance until high Ar flow
    - Short maintenance interval (1–2 weeks)
    - Only C and O₂-balance

- Waste gas analysis
  - CO, CO₂, O₂
  - Response time: 0.5 s 0.5 s 0.5 s

- Waste gas sample
  - Delivery pumps
  - Waste gas preparation
  - Vol. approx. 0.5 l
  - Response time: 0.5 s 0.5 s 0.5 s
  - Transport time: 2 s
  - Preparation time: 23–26 s
  - Response time: 1.5 s
  - Delay time: 26.5–29.5 s

- Waste gas pipeline
  - Waste gas inlet
  - Test gas inlet
  - Processor
  - Measuring head
  - Pressure converter
  - Main pump
  - Turbomolecular pump
SONICMETER

Sound level measurement during steel-making in a converter serves to monitor the formation of slag during the blowing operation in order to simplify production and augment the yield of the process as slopping (boiling over) is avoided.

During blowing, the sound level is influenced by
- slag formation during silicon removal,
- CO formation starting when main decarburisation begins,
- CO formation declining at the end of main decarburisation.

The sonicmeter method, using an enveloping curve, represents the containment of the standard curve of the sound level within a minimum/maximum design range. This containment is monitored by software specially developed for the purpose. Any overshooting or undershooting of the limits corrects the position of the lance and influences the formation of slag.

The lance is lowered if the slag volume in the converter vessel is excessive. The lance is raised if the slag volume is insufficient. Reliable determination of the optimum frequency band for measurement of the sound level is contingent upon preliminary testing of the noise emitted during converter blowing. The tests are intended to make certain that no noise from external sources in the vicinity of the converter can corrupt the measurement results and that the required microphone is optimally positioned in the sound tube.

The use of sound level measurement allows control and adaptation of the
- Si content (as an indicator of the amount of slag formed in the process) and of the
- distance between the blowing lance and the bath according to changing operating conditions.

![Sound level measurement graph](image-url)
Automation during the manufacture of steel is no longer confined to process control and process monitoring.

Ever more stringent customer demands for optimum steel grades and cost-effective steelmaking make it necessary to employ systems which optimise the process as a whole and the process events.

The systems are structured hierarchically as follows:
- Level 0 – Field equipment
- Level 1 – MSR equipment, including visualisation
- Level 2 – Process optimisation by means of process models
- Level 3 – Production planning and management
- Level 4 and higher levels – Administrative functions

The SMS Demag automation systems are able to cover all these needs. The BloCon model is available on Level 2 for steelmaking by the BOF process. The BloCon model is based on the metallurgical description of the blowing process of a BOF converter. It calculates the mass and the thermal balance with the help of an optimisation algorithm.

The design of the model enables the calculation of all charging materials concerned. BloCon supports all technologies applied to a modern BOF converter, such as bottom stirring, sound measurement, offgas analysis, and the use of sublance measurement.
SMS Demag also offers the SecMet metallurgical model, which was developed for the production of special steels in AOD/MRP converters and which covers the particular needs of low-carbon austenitic and ferritic steels.

Statistics reflecting heat data, tapping temperatures, analyses, material consumption, etc., must be created and must be retrievable without delay to enable the quickest possible reaction to changing conditions. Customer specific requirements in connection with steel grades and lot sizes necessitate a higher production planning level to enable individual process events and the sequence of melts to be controlled. This encompasses all steps, from the supply of hot metal to the sequence of conticasting ladles.

As a valuable aid for this purpose, SMS Demag offers a production planning and control system (PPS), which has been specially developed for such steelmaking demands.

It forms part of the company-wide management and information system and has interfaces with Sales, Procurement, Material Practice, Logistics, and the subordinated Level 2 process computer systems. On the basis of sales planning and customer orders received for finished products, it is the objective of production planning and control to coordinate and manage production in all steelmaking and steel rolling areas for the purpose of obtaining, within specified time scales, the tonnages and grades agreed with the customer.
AUTOMATION

CUSTOMER BENEFITS:

The benefits of a production planning and control system are reflected in the following:

- Production consistent with orders (even for small lots),
- Production for just-in-time delivery,
- Flexibility with regard to short-term orders,
- Satisfaction of the customers’ quality requirements in the melt, casting and rolling sequences,
- Coordination of events in the melt-shop to permit long continuous casting sequences,
- Efficient personnel assistance in the elimination of malfunctions.

The orders (melts) to be processed in a steel plant are plotted in a Gantt diagram. The diagram includes all processing stations (converters, alloying stations and continuous casting facilities) with specified sequences and processing times.

The diagrams are updated dynamically by the process status messages from the Level 2 systems. The central coordinating function is able to intervene manually to change schedules and start new planning computation runs.

Without flexible automation it is, from the present point of view, hardly possible any longer to produce steel economically in conformity with today’s stringent quality requirements.
Steelmaking process slags generally serve to absorb unwanted tramp elements, stabilise non-metallic inclusions segregated in the melt, and prevent radiant heat loss from the molten metal. Slags having special properties are indispensable within specific process steps. However, any such slag entrained to the next process step will not only delay subsequent progression but will also result in a production cost increase.

The SMS Demag slag retaining system employs specially developed floating plugs as well as ultrasonic and/or laser-based measuring methods. These floating plugs delay the formation of the outlet whirl and automatically close the taphole.

The equipment serving to insert the floating plug is arranged on the converter floor near the vessel, either mobile, suspended, or slewable, depending on the space situation.
SMS Demag offers different converter vessel relining systems. Either a platform is lowered down into the vessel by means of rope winches in the case of integral bottom converters or, in replaceable bottom vessels, the working platform is introduced from below by means of hydraulic jacking cylinders and/or a spindle drive.

The relining bricks are lifted by means of a hoisting cage in the middle of the device. Robots serving to facilitate vessel rebricking are being developed.

The removable bottoms of change-bottom converters are lined with bottom bricks on a separate stand off the converter.

Changing of the vessel bottoms, measuring up to 4 m in diameter and weighing up to 60 t, depending on the converter size, is fast and easy to perform by means of a hydraulic bottom jacking device.
Converter being relined with the use of a raising and lowering rebrickling platform with four-rope suspension (two rope drums).

Diagram I: Relining equipment, working platform raised and lowered from above.

Diagram II: Relining equipment, working platform raised and lowered from below.

Bottom jacking devices.

Relining equipment with spindle drive.

Jacking the bottom of an 80-t LD change vessel converter.
Oxygen steel production is accompanied by considerable dust emission.

Optimised adaptation and design of the dust collecting and cleaning equipment and possibly the use of a gas recovery system allow optimum operation of the oxygen steelmaking plant.

In this case also, SMS Demag offers a variety of methods and equipment to meet this requirement.

High-performance venturi scrubbers or dry electrostatic precipitators according to the LT (Lurgi-Thyssen) process are available for the treatment of primary/process gases.

The secondary gases can be treated either with fabric filters or electrostatic precipitators.

Both the Demag-Baumco system and the LT process for gas cleaning and recovery are capable of recovering much of the energy contained as carbon in the melt in the form of carbon monoxide (CO) gas during the converter process.

The recovery of the gas and the selective utilisation of the CO gas depreciate the investments required for the entire system within a very short time.

Process sequence diagram:
CO system
1. LD converter
2. Cooling stack with adjustable skirt
3. Water-cooled hood system
4. Venturi scrubber tower
5. Fan
6. Clean gas stack with flare
7. Transfer station
8. Gasometer
ERECTION AND COMMISSIONING

The range of supplies and services which we offer is complemented by the erection and commissioning of individual steel mill modules up to and including integrated turnkey plants.

Our planning offer refers both to preliminary assembly and to the complete erection work and allows for country-specific infrastructures, local manufacturing facilities, and the availability of qualified erection personnel.

Erection inspectors and chief erectors with international experience can be made available for supervision and for ensuring qualitatively perfect performance within agreed time scales.

Our metallurgists supply technical know-how of worldwide reputation during the commissioning of the equipment.

Preassembly of a 300-t converter.

Transport of a completely preassembled 300-t converter.

Erection of MRP-L converter with secondary dust collection and lance equipment.
MRP-L converter with partially installed enclosure and ladle transfer car under the converter floor.
Dust collection, gas cleaning and gas recovery systems.

Bottom stirring systems.

Oxygen blowing lance systems.

Sublance systems.

SMS DEMAG CONverter equipment
Converters.

Change-vessel converter systems.

Slag retaining devices.

Bottom jacking and converter relining equipment.