

Draft *Indian Standard*

**CODE OF PRACTICE FOR USE OF OXYGEN IN IRON, STEEL AND
NON-FERROUS METAL FOUNDRIES**

(First Revision of IS 8939)

FOREWARD

This Indian Standard (First Revision) is to be adopted by the bureau of Indian Standards, after the draft finalized by the Foundry and steel casting Sectional Committee has been approved by Metallurgical Engineering Metals Division Council.

This revision has been brought out to bring the standard in the latest style and format of Indian Standard and to update the cross referred standards.

One of the main uses of oxygen in iron foundries, steel foundries and non-ferrous metal foundries is to assist the melting operation by air enrichment and to increase the temperature of the molten metal for quality castings. The use of oxygen in foundries also reduces the coke consumption in cupola operation which helps in utilizing low grade coke.

For the purpose of deciding whether a particular requirement of this standard is complied with, the final value, observed or calculated, expressing the result of a test or analysis, shall be rounded off in accordance with IS 2 : 2022 "Rules for rounding off numerical values (*second revision*)". The number of significant places retained in the rounded off value should be the same as that of the specified value in this standard.

CODE OF PRACTICE FOR USE OF OXYGEN IN IRON, STEEL AND NON-FERROUS METAL FOUNDRIES

(First Revision)

1. SCOPE

1.1 This standard covers methods of use of oxygen in foundry melting practices, and quantity and quality (purity) of oxygen required for such operations.

2. REFERENCES

The standards listed below contain provisions, which through references in this text constitute provisions of this standard. At the time of publication, the editions indicated were valid. All standards are subject to revision and parties to agreements based on this standard are encouraged to investigate the possibility of applying the most recent editions of the standards indicated below;

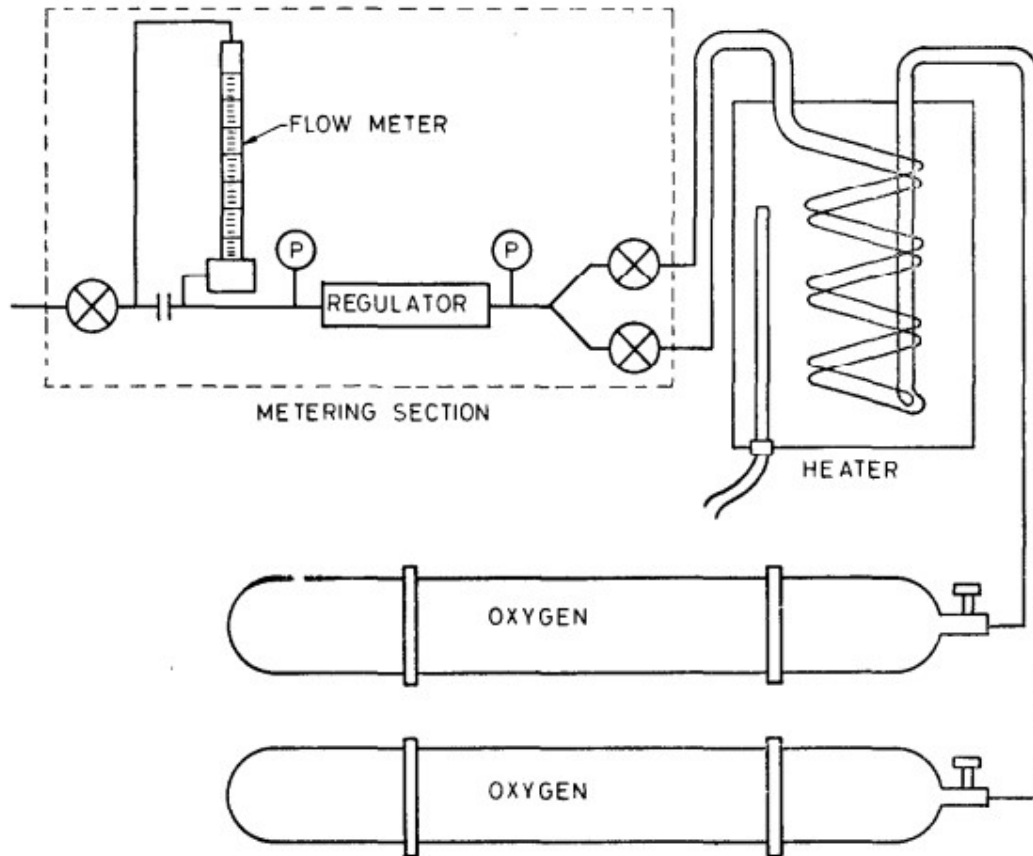
IS No.	Title
309 : 2023	Oxygen Compressed gas and Liquid-Specification (Fifth Revision)

3. SUPPLY OF MATERIAL

3.1 Quality of Oxygen— The quality of oxygen covered by IS : 309 is suitable for foundry application.

3.2 Mode of Supply Depending on the availability, any one of the following modes of oxygen supply may be adopted.

3.2.1 Supply in High Pressure Cylinders [Pressure about 13 MPa (13 kgf/cm²) (see Fig. 1) — Supply in small cylinders of 6.23 m³ capacity which could be interconnected to form a manifold as per the Fig. 1. Depending on the demand pattern — additional numbers of cylinders could be added to the manifold system. If the requirement is more, oxygen can be supplied in large cylinders of 62.3 m³ capacity, two or three of which can be manifolded and installed on a trailer for transportation purposes, thereby reducing the time for handling small cylinders.



NOTE- For use of oxygen from cylinders, the requirement of heater is optional.

FIG. 1 ARRANGEMENT OF EQUIPMENT

3.2.2 Supply from Liquid Oxygen Storage and Evaporator System — If the demand of oxygen is more and oxygen is readily available in liquid form, it is considered economical to instal a liquid oxygen storage and evaporator system for supply of oxygen. The liquid oxygen can be evaporated by passing it through an atmospheric air/steam vaporiser system.

3.2.3 Oxygen Supply through Pipeline — If the demand of oxygen is more and the foundry is located adjacent to an oxygen plant, the supply of oxygen through a pipeline system directly from a captive oxygen plant is the usual practice. Oxygen is normally supplied from the plant at a pressure of 1.5 MPa and the pressure is reduced to 0.8 to 1.0MPa prior to distribution for end use in the plant.

4. REQUIREMENTS

4.1 Iron Foundries

3.1.1 Use of Oxygen in Cupola — Oxygen is used for the following specific advantages, which lead to higher productivity, better quality and lower rejection:

- a) Increased metal temperature,
- b) Coke economy,
- c) Possibility of using inferior grade coke,
- d) Increased carbon pick up,

- e) Decrease in silicon loss,
- f) Low sulphur pick up,
- g) Increased melting efficiency, and
- h) Reduction of iron losses.

4.1.1.1 *Ways and methods of using oxygen in cupola practice*—Two convenient ways to use oxygen in cupola are:

- a) larger quantities of oxygen added to the air blast for shorter time cycle (intermittent enrichment), and
- b) smaller quantities of oxygen added to the air over a prolonged period (semi-continuous or continuous operation).

4.1.1.2 *Modes and quantities of oxygen to be used* — Normally in cupola operation oxygen is used up to a level of 1 to 2 percent of the combustion air for getting effective result without any harmful effect on the refractory lining.

a) *Direct oxygen enrichment of the blast*—The air blast is enriched by the addition of oxygen by which oxygen content of the blast is increased to about 22 to 23 percent. The oxygen is fed to the air blast by means of a copper pipe from a bank of cylinders or liquid oxygen vaporisation system. Pressure of oxygen meeting the air blast varies between 0.1 to 0.3MPa.

b) *Direct injection either in the combustion zone or near the forehearth(see Fig. 2 and 3)* — Injection of oxygen in the combustion zone or near the forehearth is done by providing a circular ring of stainless steel pipe round the cupola below the tuyere zone and introducing oxygen injector tubes inside the cupola at the combustion zone or near the hearth from the pipe ring, the circular pipe being connected to the main oxygen source. This procedure of injection gives better utilisation of oxygen.

c) *Oxygen injection below the metal level inside the cupola well (see Fig. 4)* — This injection is to be done by means of built-in' oxygen opening system with a special refractory or graphite sleeve through the refractory lining of the cupola well and introducing oxygen injection nozzle through the sleeve. The process is used for effective increase of metal temperature and for improved carburization of iron as compared to the process of direct oxygen injection in the combustion zone.

4.1.1.3 *General recommendations* — Oxygen for assisting combustion is injected into the coke bed as far as possible below the tuyeres. The normal distance is 150 mm below, but the distances may vary from 50 to 600 mm depending on the size of the cupola.

Injection below tuyeres may be used on continuously tapped cupolas as these operate with a fixed slag level. With tuyeres below the wind belt, it is relatively easy to insert oxygen nozzles through the cupola shell and lining. Oxygen injection into the hearth is recommended for cupolas above 3 tonnes/hour capacity. Oxygen injection into the hearth may also be done in intermittent cupolas just before tapping.

Advantages of using oxygen in cupolas are more predominantly felt in cold blast cupolas.

4.1.2 *Use of Oxygen in Rotary Furnaces* — In the case of rotary furnace the main purposes of oxygen enrichment are:

- a) increase in the metal temperature, and
- b) reduction in the iron losses by increasing melting efficiency.

Normally in rotary furnace, oxygen up to 1.5 to 2 percent of the combustion air is used for getting effective result. The introduction of oxygen is made by post mixing into the flame through stainless steel tubes or high duty alumina tubes. Water cooled lance may also be used for bigger furnaces.

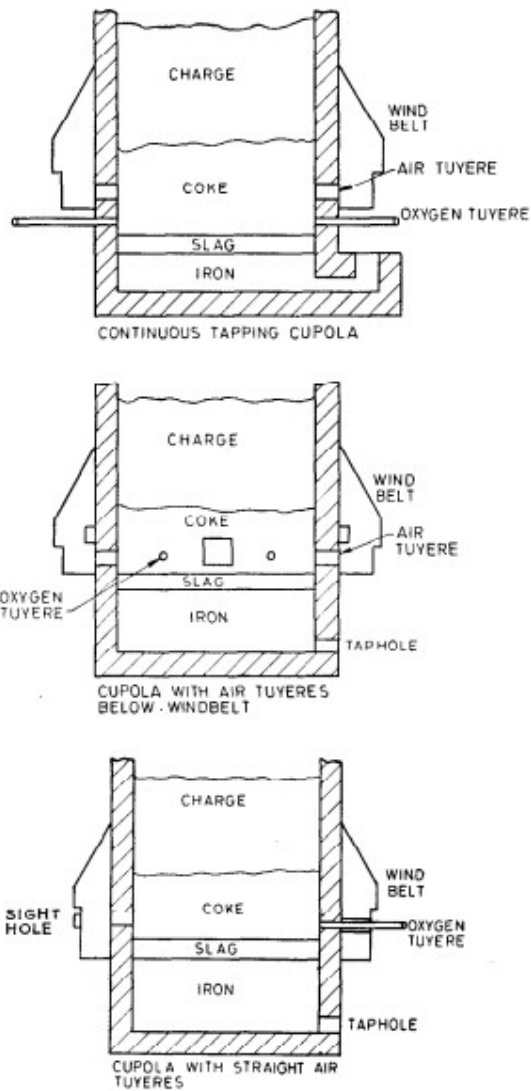


FIG. 2 CUPOLA'S SHOWING DIRECT OXYGEN ENRICHMENT OF THE BLAST

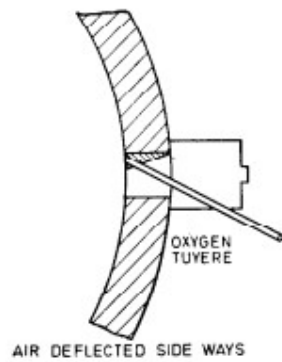
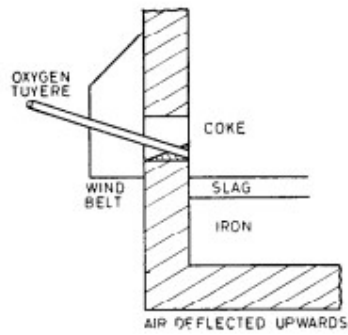
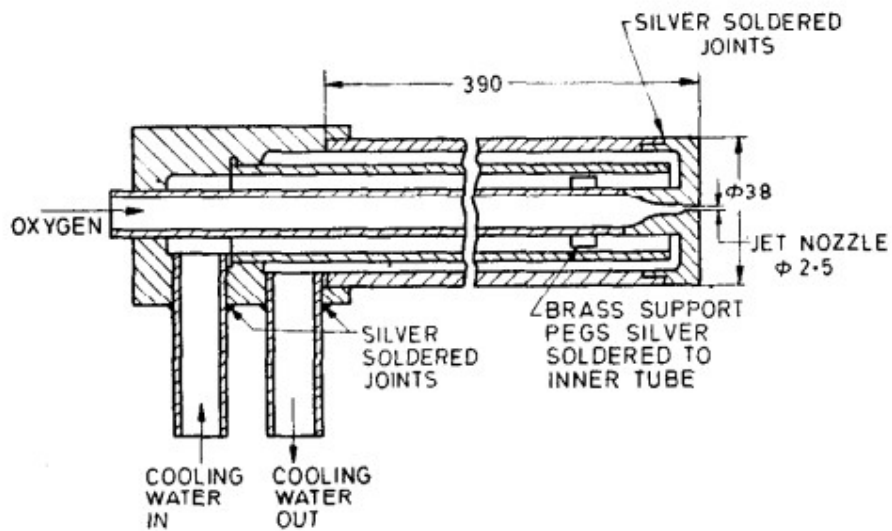


FIG. 3 OXYGEN TUYERES THROUGH AIR TUYERES



NOTE Material for all the tubes, nozzles and end caps is recommended to be of stainless steel.

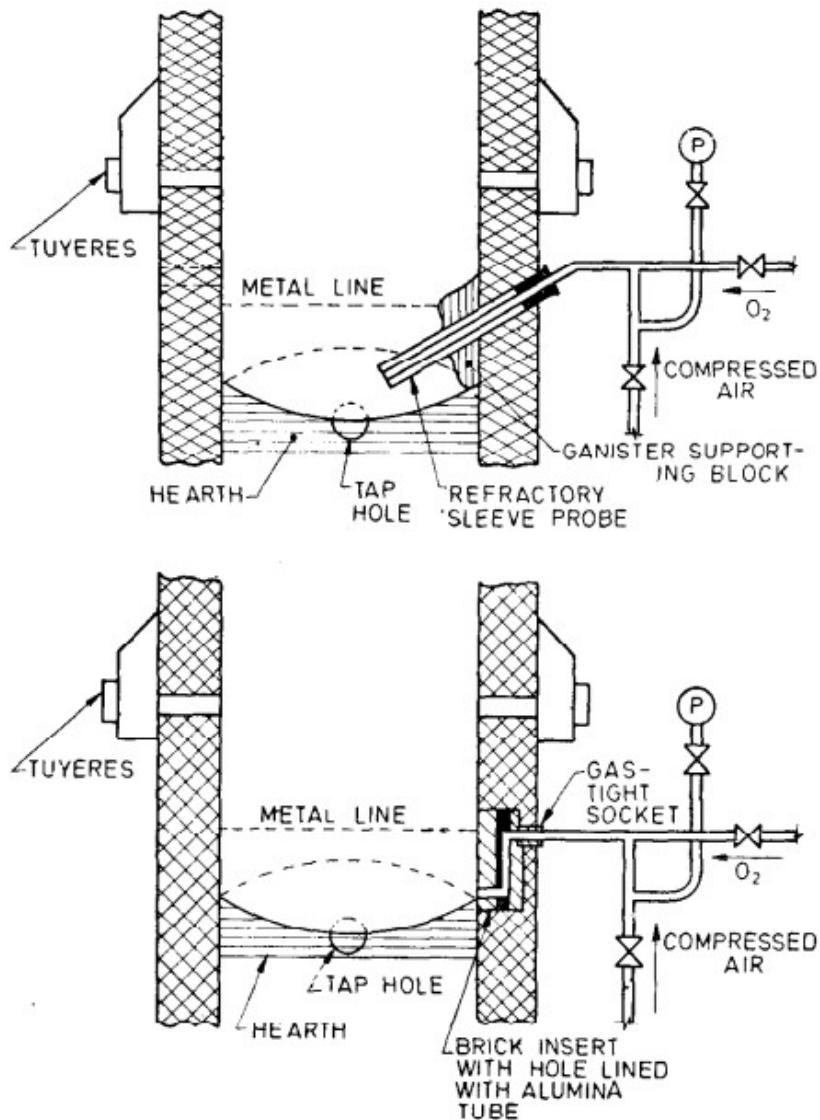
4A DETAILS OF WATER-COOLED LANCE

4.2 Steel Foundries —For the various processes of manufacturing steel castings, oxygen is used conveniently during melting of the charge and also for blowing out of carbon from the melt, particularly for the low and medium carbon ranges. Steel foundry units in which use of oxygen is recommended are as follows.

4.2.1 Use of Oxygen in Electric Arc Furnace

4.2.1.1 Cold charge electric furnace using oxygen injection for assisted melting and subsequent carbon blow of the bath by oxygen lancing— Oxygen is used mainly for assisted melting and also lancing of the bath through the door. Lance pipes of steel of various sizes are used depending on the requirement and size of the furnace. Lance pipes are held by a lance holder (*see* Fig. 5A) and oxygen is supplied through a flexible hose from the supply point 0.8 to 1.0 MPa pressure. A large quantity of oxygen is required for bigger furnaces particularly for low carbon alloy castings where two lances can be used at a time for higher oxygen flow rates. Water-cooled oxygen probes (*see* Fig. 5B and 5C) have also been developed for supply of large quantity of oxygen for assisted melting and also for carbon blow.

NOTE — To reduce the consumption of steel lances, refractory coated lance pipes (calorised) may be used.



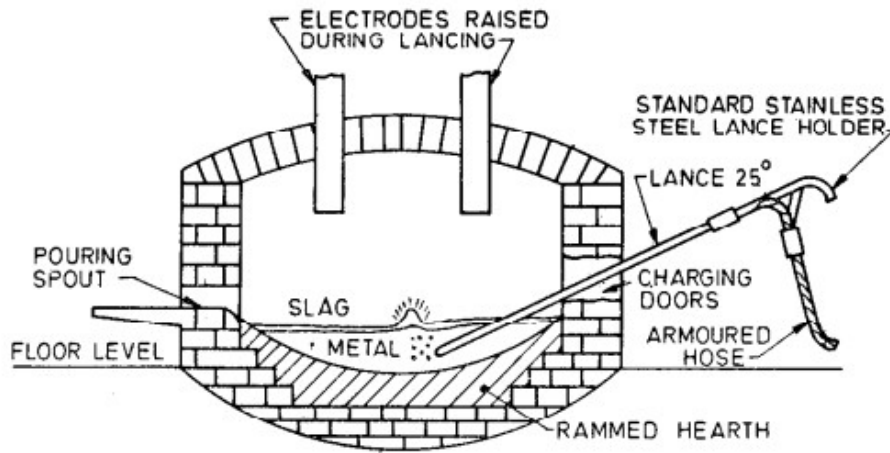
4B DETAILS OF INJECTION

FIG. 4 OXYGEN INJECTION BELOW THE METAL LEVEL INSIDE THE CUPOLA WELL

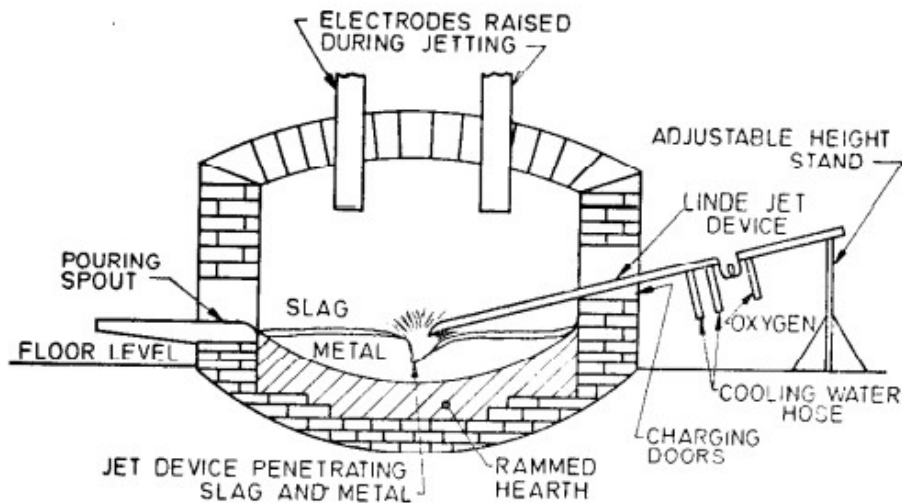
4.2.1.2 Cold-charge electric furnace using oxy-fuel burner for assisted melting of scrap and refining — Usually oxy-fuel burners are fired with oxygen and fuel oil. They can be worked with other types of fuel such as propane, coke oven gas, natural gas, synthetic natural gas, etc. The burners can be used from the furnace door for heating as the burners can be mounted on carriages thus permitting the burners to enter through the side walls of the furnace. Heat loss is reduced when the operation is done through the doors and consequently the production rates are higher with less consumption of fuel and oxygen.

The oxy-fuel burners may be used either (a) alone without any electrical heating during melting, or (b) along with normal electrical heating, or (c) with normal electrical heating during the premelting period followed up with considerably reduced electrical heating to do the rest of the refining job.

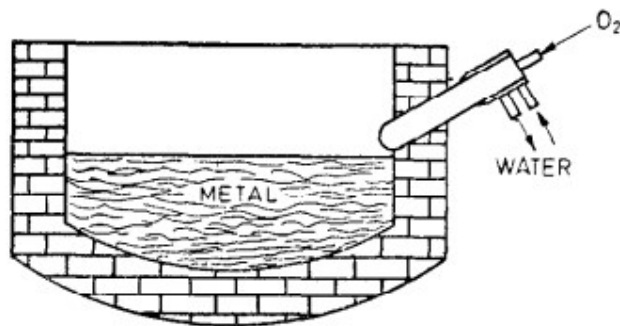
The process is of interest mainly to steelmakers desiring higher productivity from the existing plant. The higher cost of fuel and oxygen can well be compensated with higher productivity even up to 30 percent from the same furnace.



5A CROSS SECTION OF ELECTRIC FURNACE SHOWING LANCE POSITION



5B CROSS SECTION OF ELECTRIC FURNACE SHOWING POSITION OF LINDE DEVICE



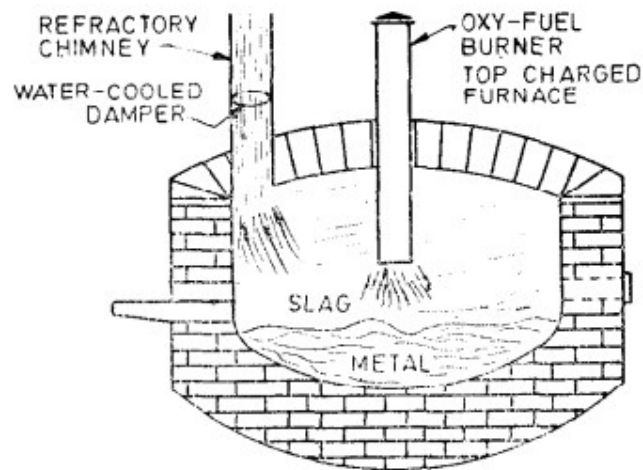
5C ARC FURNACE WITH BACK WALL OXYGEN PROBE

FIG.5 USE OF OXYGEN IN ELECTRIC ARC FURNACE

4.2.1.3 Cold-charged electric furnace using oxy-fuel burners only (see Fig. 6) — The process commonly known as fuel-oxygen scrap process (FOS) may use various types of oxy-fuel burner for 1 to 5 tonnes melting unit. Oxygen in this case is used along with the burner assembly.

The process has also been worked in small electric furnaces by removing the electrodes and suitably placing the oxy-fuel burners for melting and subsequent refining of 100 percent cold charge. The total charge to tap time can be decreased up to 1.5 hours with consumption of oil and oxygen of the order of 90/110 litres and 140/170 m³ respectively per tonne of finished steel with a cold furnace. Metal yield is about 90/91 percent and thermal efficiency of about 45 to 50 percent.

With the rising cost of electric power and electrodes in arc furnace steelmaking, the cost of steelmaking using oxygen and fuel is estimated to be lower particularly for smaller installations for foundry scale steelmaking. Oxygen required for the ' FOS' system can either be supplied by cylinder manifold system, liquid oxygen supply system or pipeline supply from captive oxygen plant.



4.2.2 Use of Oxygen in Converters

3.2.2.1 Small and medium basic lined converter vessel using special oxy-fuel burners for melting and refining cold pig iron or scrap (see Fig. 7A and 7B) — The process, particularly suitable for small foundry, operates by melting a cold charge of scrap or pig iron or other pre-reduced burden or a mixture of them and refilling it to steel in a continuous operation in one and the same converter vessel by using the oxy-fuel burner without the need of any additional melting units such as cupola etc. The oxy-fuel burner is introduced from the top of the vessel.

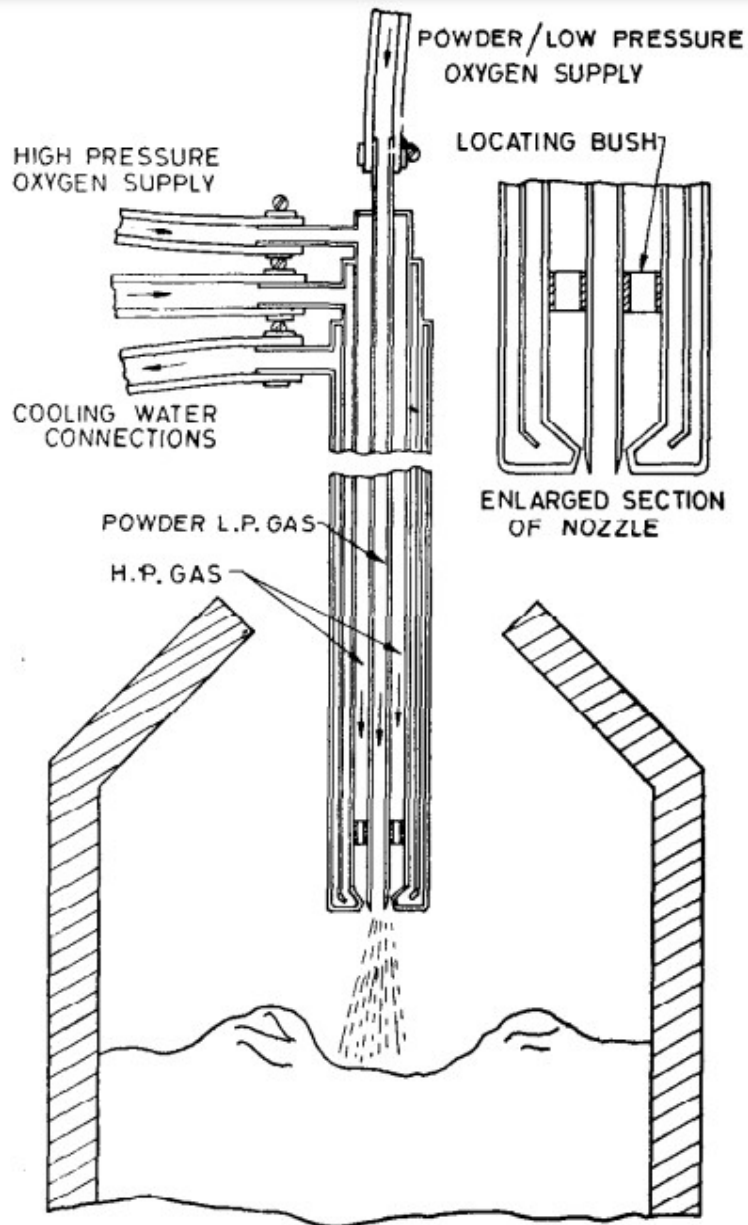


FIG.7A JETTING LANCE FOR MELTING AND REFINING

The water cooled burners are of special design which can be operated with oil and fuel gas along with oxygen during the melting of the cold charge followed by normal oxygen refining with slag forming powder dispensing arrangements, by cutting the fuel injection system.

In a three concentric tube design, the inner tube is used for powder dispensing, the surrounding one for liquid/gaseous fuel and the other tube for high pressure oxygen.

Available data, particularly on small scale operation with 6 to 7 kg cold charge (70 percent scrap and 30 percent pig iron) are as follows:

- a) Total melting/refining time —about 12 minutes.
- b) Metal yield —about 88 percent.

c) Total oxygen consumption —about 110/120m³/tonne.

d) Total fuel consumption (using propane as fuel)— 22/23m³/tonne.

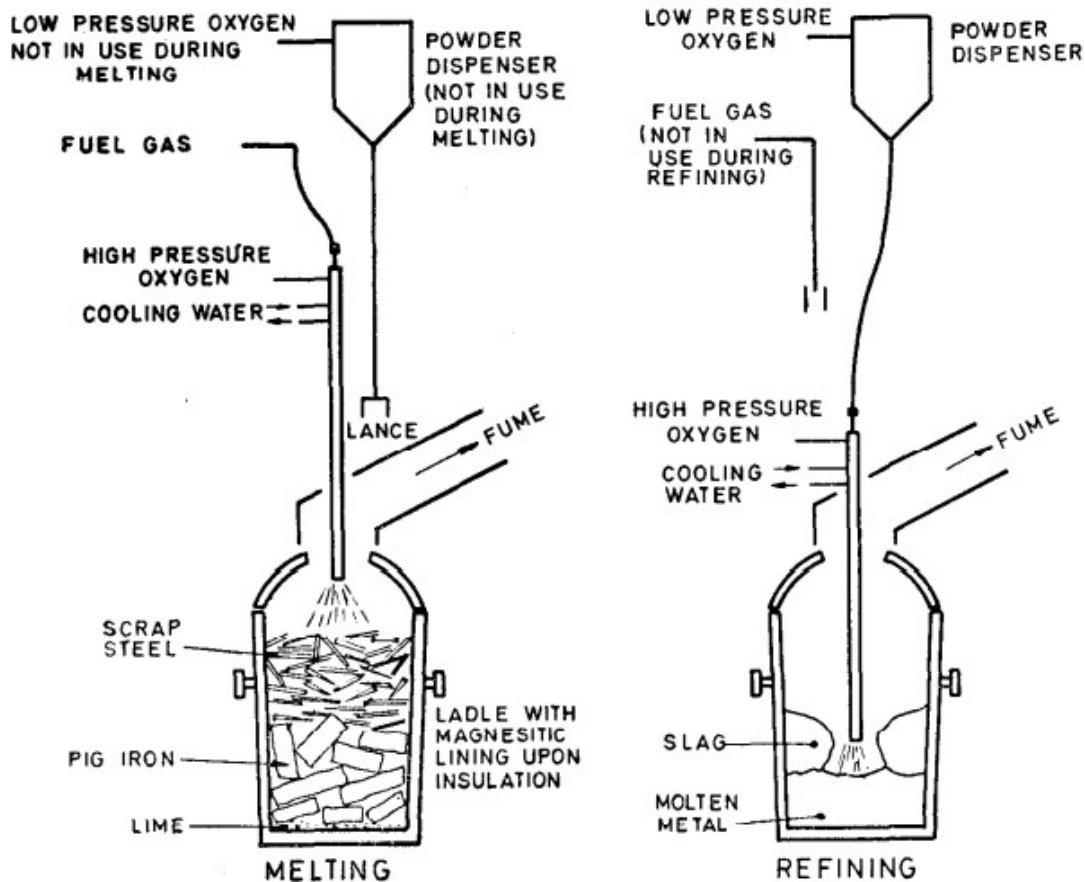
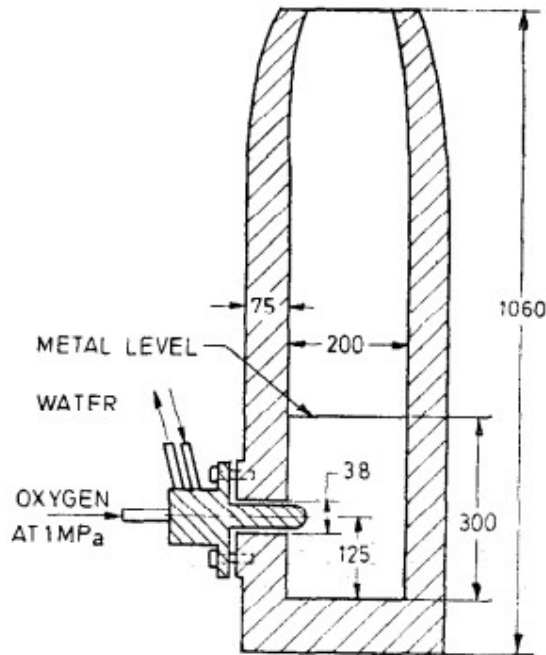


FIG. 7B STAGES OF MELTING AND REFINING WITH JETTINO LANCE

The process can also be worked with a charge containing molten pig iron/scrap as high as 50 to 60 percent. The fuel and oxygen consumption are 5.0 and 90 m³ per tonne of steel. Oxygen is normally supplied from a cylinder manifold or from liquid oxygen storage installation depending on the requirement.

4.2.2.2 Side blown basic lined converter technique with oxygen enriched air in combination with cupola or other melting units (see Fig. 8) — Acid side blown converters using air or oxygen enriched air (if needed) is quite well known to the steel foundries primarily for treating very low phosphorus melt. The basic side blown converter is a latter development, particularly in combination with cupola or other melting units as an aiding tools, to the existing foundries for steel production with low capital investment.

Depending on the composition of the liquid melt to be treated and the quality of castings required, it is a normal practice to use limited oxygen enrichment 1.5 to 2 percent of the air either to initiate the blow or to finish it up as the case may be. The average consumption of air varies between 800/1100 m³ at a pressure of about 0.03/0.04 MPa. The velocity of air blast varies from 80/120 ma/min for converter capacities ranging from 1.5 to 2.5 tonnes. Total heat utilised is about 60 percent.



All dimensions in millimetres.

FIG.8 PROBE POSITION IN CONVERTER

Oxygen for the side blown converter is added to the air feed pipe similar to cupola enrichment from oxygen supply source, for example, cylinder manifold/liquid oxygen supply system.

4.2.2.3 Side blown basic lined converter techniques using submerged watercooled lances installed in the converter — The water-cooled lance injecting pure oxygen below the metal surface for refining molten pig iron can be conveniently mounted on the converter wall thus projecting inside the molten bath in a submerged state. Such oxidation resistant water cooled submerged lances with 100 kg of molten iron in basic lined converter give the following results:

a) Blow time	10/13 minutes
b) Oxygen consumption/tonne	55/65 m ³
c) Oxygen efficiency of metal	75/92 percent
d) Oxygen pressure	1.0 MPa
e) Average yield	80/90 percent

Oxygen may be supplied from a cylinder manifold system or liquid oxygen supply system by incorporating suitable pressure reducing arrangement.

4.2.3 Use of Oxygen in Open Hearth Furnaces

3.2.3.1 Cold-charge open hearth furnace using oxygen for flame enrichment or for bath oxygen lancing (see Fig. 9) — The performance of a cold-charged open hearth furnace can be improved considerably particularly with regard to fuel economy by use of oxy-fuel burners for the assisted melting of scrap and pig iron.

The burners are of special design for suitably mounting them through the roof of the furnace or from any other convenient place. The burners can be fired with liquid or gaseous fuel using either steam or compressed air or oxygen. Moderately big furnaces of 40 to 120 tonnes using 100 percent cold scrap

or mixtures of scrap and hot metal, use oxygen up to the extent of 10 m³ per tonne to increase the productivity by 15 to 25 percent, decreasing the total heat time by about 30 to 40 percent.

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Bath lancing of oxygen in foundry scale open hearth furnaces is done with mild steel consumable lances through the door. Average consumption of oxygen for decarburization and dephosphorization is about 10 to 15 m³ per tonne. Oxygen is also used in open hearth furnace for simultaneous decarburization, dephosphorization and desulphurization along with lime, mill scale, fluorspar etc, through various types of powder dispensers.

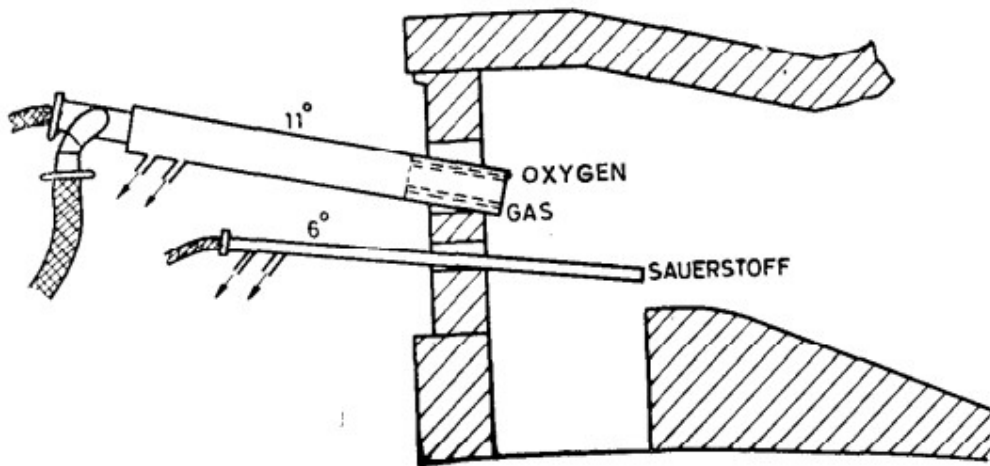


FIG.9 OPEN HEARTH FURNACE, PORT END, SHOWING BURNER AND OXYGEN PROBE

Oxygen can be supplied for the burners either through a liquid oxygen storage and vaporisation system or pipeline supply from an onsite plant.

4.2.4 Use of Oxygen in Duplexing Units

3.2.4.1 Cupola (hot blast or oxygenated) for high scrap charges followed by LD/electric furnace — The combination of cupola operated with hot blast or with oxygen (if required for high percentages of scrap charges) with normal LD or electric furnace for foundry scale steelmaking can be worked in medium/big foundries for the production of steel including low alloy steel. By combining cupola with electric furnace, the load on the electricity can be substantially reduced by using small amount of oxygen.

For such use, oxygen supply can be made either from liquid oxygen storage/evaporator or pipeline supply from captive units.

4.2.5 Use of Oxygen in Pneumatic Process of Steel Making

4.2.5.1 Pneumatic process of steelmaking — Oxygen for pneumatic processes of foundry scale steelmaking is used directly in the molten bath under oxygen pressure varying between 0.4 to 0.8 MPa. The requirement of oxygen depending on the quality of molten metal varies between 60 to 80

m³ per tonne. The oxygen supply can be made from liquid oxygen evaporators or directly by pipelines from captive oxygen plant.

4.3 Non-ferrous Metal Foundry — Normally oxygen finds its application in extraction and refining of non-ferrous metals which cannot be included as non-ferrous foundry application. However, oxygen finds its use in secondary refining of non-ferrous metals and alloys particularly while using scrap such as for melting of copper base alloys, aluminium base alloys and magnesium base alloys.

In any case, the use of oxygen in non-ferrous foundry application is very much limited. For secondary refining in non-ferrous foundries where oxygen application is necessary, supply can be made through compressed oxygen cylinders or through normal liquid oxygen vaporisation unit.