34 STEEL MILLS

Steelmaking Process

The conventional steelmaking process, in its most basic form, consists of the following sequence of steps.

Blast furnace ironmaking – Three raw materials (iron ore, coal, and limestone) are modified, brought together, and smelted in a blast furnace to produce iron for steelmaking. Iron, usually in molten form, is transported in hot metal cars to the **steelmaking furnaces** where impurities are removed and alloying elements are added.

Molten steel is then cast (usually using a **continuous casting process**) in large blocks such as slabs, blooms, billets, or ingots, which are subsequently reheated, cleaned, and reshaped repeatedly, and often coated, in a series of operations to produce the variety of steel products that we know.

Iron ores are mined in various concentrations. All grades require some improvement. High-grade ore may need only crushing, screening, and washing for a blast furnace. Lesser grades and fines require further treatment to produce usable ore pellets for blast furnaces. Much of this processing occurs away from the steel mill so that only high grade material has to be transported. **Sintering** is a process at the steel mill which makes lump feed suitable for blast furnaces from materials which once were wasted – ore fines, flue dust (reclaimed from blast furnace gases), coal fines, and coke breeze (dust). They are spread on a moving belt and ignite, producing sinter, a clinker-like cake, which is quenched, broken up, and fed to the blast furnaces.

Coke is the strong porous form of carbon used as the fuel mixed with iron ore in blast furnace ironmaking. It is produced by "baking" pulverized coal at high temperatures in coke ovens, after which the hot coke is quenched with water to prevent further oxidation. The coke is crushed and screened to remove finer particles, which are recycled. Many volatile and toxic chemicals, unwanted in blast furnaces, are released during the coking process. The gases are captured and passed through a byproduct plant which produces a number of valuable byproducts such as tar, ammonia liquor, ammonium sulphate, light oils, and fuel gas. The coke oven gas is used for firing in the coke ovens and is piped for use around the plant. Limestone and lime, produced from limestone, are used as fluxes to remove impurities from iron ore and steel respectively. Limestone and lime are normally produced offsite and stored for use.

In steelmaking, molten iron joins scrap steel, lime, and alloying materials in a furnace and with injected oxygen they form a steel heat with the right recipe to meet the required specifications. Since oxygen is needed in considerable quantities in steelmaking, an oxygen plant is often associated with a steel mill. Excess carbon and other unwanted chemicals are oxidized with the help of lime as a flux to form a floating slag of unwanted impurities.

The most common steelmaking furnaces are the basic oxygen furnace (BOF) and the electric furnace.

Basic oxygen furnaces (BOFs) are located close to blast furnaces and are charged with primarily molten iron with some scrap steel. Pure oxygen is blown into the vessel and the resulting reaction generates a lot of carbon monoxide during blowing time, which can be burned in a waste heat furnace built into the hood system before the flue gases are discharged to a precipitator and baghouse system.

Electric furnaces are used in some facilities to produce stainless steels and in others to produce mild steels. Electric furnaces are charged primarily with scrap iron and sponge-iron pellets or steel scrap which has been analyzed and sorted.

Two types of electric furnaces are typically used:

1) the electric arc furnace, generating heat from the arcs from one carbon electrode to the metal and back to the other carbon electrode from the metal and from the resistance of the current flow through the metal itself, and
2) the induction furnace, which behaves like a transformer, in which the metal acts as the core and secondary winding and enough heat is generated to melt the metal.

Once steel is made, the product usually proceeds to the continuous casting stage. This employs a process which utilizes oscillating, cooling molds, going directly in this one stage from molten steel to semi-finished products, including slabs, blooms, and billets.

The conventional intermediate steps, in use for decades, which involved casting ingots and repeatedly passing them through roughing mills, have largely been replaced by continuous casting. The old ingot process may remain in some mills as a backup method.

By the use of reheat furnaces to bring them to hot rolling temperatures, the slabs, blooms, or billets are shaped using hot rolling mills – slabs into sheet and strip, blooms into structurals and rails, and billets into bars, rod, wire, and some pipe and tube.

Beyond this the steel shapes undergo a number of cold forming processes such as cold rolling, pickling, tempering, and forging. They can undergo a number of finishing processes including electroplating, galvanizing, annealing, painting and a variety of proprietary finishes depending on the end use of the steel.

Areas of Steel Plant

Raw materials processing

Iron ore:	- Pelletization, kilns, etc. — normally offsite
	- Sinter plant
Coke:	- Facilities for coal storage, handling, and preparation — coal bins, blended coal bunker
	- Machinery for charging coal, pushing coke and quenching — larry car, quench car and tower
	- Coke ovens — banks of ovens that bake the coal at high temperatures
	- Machinery for transporting and screening coke-coke crusher
	- By-products plant
Limestone	- Quarries
	- Crushing and sintering

Blast Furnaces

Stockshed — coke, iron ore, and limestone bins and hoppers

Stoves

Cast house

Gas cleaning system — dust catchers, scrubbers, precipitators, thickeners

Steelmaking

Steelmaking

Basic oxygen furnaces

Electric furnaces

Teeming and Casting

Slab casting

Hot rolling

Pickling and finishing

Cold rolling

Tinning, electroplating and galvanizing lines

Acid plants and storage

Utilities

Power plants — boiler stations

Water treatment — filtration plants, clarifiers, thickeners

Pressure Vessels

Boilers

Heat exchangers

Furnaces

Ductwork

Precipitators

Tanks — clarifiers, thickeners, holding tanks, etc.

Stacks — breeching

Scrubbers

Cyclones

Bins — coal and coke

Chutes

Health and Safety Hazards

For construction crews working in steel plants, there are many hazards. The following points summarize the main hazard areas.

1) Pinch points and moving equipment

Transportation equipment

Bulk material handling and transport is a major activity for a steel mill. There are railroad systems with tracks all over the plant, hot metal cars, transfer cars, buggies, charging cars, hopper cars, scrapers, coil carriers, slab carriers, and many others.

Overhead cranes

Overhead cranes form an integral part of operating and maintenance practice throughout a steel mill. Many hazards are associated with their use, including overhead loads, hot metal splash, equipment failure, communication breakdown, and the fact that crane operators may not be aware of construction workers in unexpected locations.

Operating equipment

Production equipment may operate on a timed basis, it may be remote-controlled, or operators may not expect non-operating personnel on site.

Construction personnel must learn plant safety practices, alarms, access requirements and limitations, and emergency procedures for whichever section of the mill they must enter. They must follow these procedures.

2) Explosion and burn hazards

Spatters or spills of molten material are an obvious source of burns and fires. Contact between molten metal or slag and moisture will result in violent explosions and spattering of molten material.

A network of piping transports fuel gases and oxygen around the plant – all of which have a potential for explosion and fire. Sparks and fires around oxygen lines are especially hazardous. One area of a steel mill with a high fire hazard is the coke oven byproduct plant, which shares many characteristics with oil refineries.

3) Health and hygiene hazards

Plant operating practices and precautions must be followed at all times. The contents of all storage and piping systems should be determined. MSDSs should be obtained and reviewed in advance. Information should be readily available from the client/mill operators.

The table on the next page relates various locations in a steel mill to the health hazards they pose.

Chemical Hazards

The following is a list of the major chemical hazards present in steel mills identified in the table and their effects. It is not intended to be comprehensive. Chemicals and chemical processes may vary from plant to plant.

Acids

- pickling and tinning lines and acid regeneration plants (hydrochloric)
- hydrochloric acid or sulphuric acid
- highly corrosive, can be dangerously reactive in high concentrations

Ammonia

- very irritating to the eyes, nose and throat
- high exposure can cause choking and breathing difficulties
- coke oven byproducts plant.

Asbestos

- can be present in blast furnace and stoves, by-products plant, steam, generation (either central or waste heat boilers)
- asbestosis, mesothelioma, lung cancer

Byproduct plant light oil

- containing chemicals such as benzene and naphthalene and minor amounts of toluene and xylene
- coke oven byproducts

PRIMARY HYGIENE HAZARD LOCATIONS IN STEEL MILLS		
AREA	**UNIT**	**HEALTH HAZARDS**
Iron ore preparation	Sinter plant - general - baghouse	• dust, primarily iron oxides • possibly silica dust • some BOF dusts may contain lead • dust, confined space
Coke ovens	Coal handling - coal bins - coal bunkers	• coal dust
	Coke handling	• coke dust • coke oven emissions from hot coke
	Coke ovens (in vicinity of batteries)	• coke oven emissions (designated substance) • sulphur compounds (H_2S) • CO
	Byproduct plant	• coke oven gas • carbon monoxide, CO • Hydrogen sulphide, H_2S • benzene • naphthalene • xylene - possible • toluene - possible • coal tar pitch volatiles • asbestos (insulation on pipes and tanks) • ammonia (anhydrous ammonia)
	Miscellaneous - CO gas lines	• driplegs - see above, basically naphthalene
Blast furnaces	Casthouse and around furnace	• carbon monoxide • silica products - from furnace lining (refractory) during a reline and from runner lining • noise - from blast mains & tuyeres • asbestos - possible
	Stoves	• asbestos • carbon monoxide, CO
	Dust catcher, scrubber, precipitator	• carbon monoxide, CO • confined spaces
	Slag Pits	• sulphur dioxide, SO_2
Steelmaking	General	• dusts - mostly iron oxides, lime, silica (during reline) • radiant heat
	Precipitator and baghouse	• dust - mostly iron oxides, including lead from leaded steels (often no longer produced) • confined spaces • lime in baghouse and storage shed
	Waste heat boilers	• mild steel tubes probable (not stainless) • asbestos
Finishing operations	Pickling and acid regeneration	• hydrochloric (HCl) acid - acid mist and vapour - iron chloride dust (irritant) • can be sulphuric acid
	Annealing	• batch anneal - ceramic fibre from blankets at base • possible carbon monoxide, CO
	Cleaning lines	• sodium hydroxide - corrosive
	Tinning lines	• sulphuric acid • other acids
Steam generation	Central boiler facility	• usually fired by CO gas, BF gas, and/or natural gas • high noise in some areas, asbestos
	Waste heat boilers (see also steelmaking)	• mild steel tubes probable • asbestos

- acute effects - typical solvent effects, central nervous system depression
- chronic effects - carcinogens (cancer-causing agents); some cause liver and kidney damage.

Carbon monoxide (CO)

- odourless, colourless, poisonous gas
- makes up a large part of fuel gases (22-30% of blast furnace gas, 5-10% of coke oven gas)
- many hazardous locations, especially around blast furnaces – also coke ovens and steelmaking
- can leak out from tops of blast furnaces, around hot stoves, pipelines; can occur due to sudden shutdown of blowing engines, boiler rooms, ventilation fans, and from insufficient gas removal during electrostatic precipitator cleaning.

Coal tar pitch volatiles

- coke oven byproducts plant
- skin irritant, cancer of the lung, skin, scrotum
- photosensitive dermatitis.

Coke oven emissions

- in the vicinity of the coke oven batteries
- a “designated substance” in Ontario, carcinogenic
- there must be a control/monitoring program.

Coke oven gas

- high in carbon monoxide and may contain trace amounts of carcinogens
- contents can include benzene (0.4%), H_2S, and hydrogen cyanide.

Dusts

- **Iron oxide:** (found in sinter plant, before blast furnace, and around steelmaking) in addition to being irritating to eyes, this causes ciderosis, which is a specifically named type of pneumoconiosis or obstructive lung disease; i.e., dust buildup, not fibrosis
- **coal:** - irritant to the eyes, etc.
  - pulmonary fibrosis, pneumoconiosis
- **coke:** - there is some suspicion that coke is a carcinogen
- **silica:** - silicosis
  - refractory brick lined furnaces and ladles
  - may occur as dust at sinter plant, primarily during furnace repair
- **iron chloride dust:** - around hydrochloric acid regeneration plant
  - respiratory tract irritant to some people.

Hydrogen Sulphide (H_2S)

- around coke oven batteries
- toxic gas (500-700 ppm can be instantly fatal)
- rotten egg smell at very low concentrations - below 100 ppm
- explosive at high concentrations.

Sodium hydroxide (NaOH)

- cleaning lines (tinning)
- corrosive.

Sulphur dioxide (SO_2)

- blast furnace slag pits
- gas irritating to eyes, nose, and throat
- overexposure can cause choking and breathing difficulties
- delayed reaction to overexposure can be fluid buildup in the lungs.

Other Health Hazards

Heat

Heat is generated and used all over a steel plant. Care must be taken to control overexposure. This can come in the form of extreme radiant heat in many locations where there are hot or molten materials. Care must be exercised in these places. There are also many locations where strenuous work may have to be done in hot locations. Heat stroke can be a constant risk, especially during warm weather. See the chapter on Heat Stress in this manual.

Noise

Noise is a hazard at many locations in a steel mill. Hearing protection is often required and warning signs are posted. High noise levels exist, for example, around the tuyeres in the blast furnaces or any rolling mills. For guidelines on noise exposure and hearing protection, refer to the chapter on Personal Protective Equipment in this manual.

General

Before work begins, crews should receive training in the hazards existing in the work area and obtain and review the material safety data sheets for any hazardous materials to which they may be exposed. These should be readily available from the client or owner and, in fact, should be obtained at the time of bidding to facilitate job planning. Any protective equipment used should at least equal that worn by the client's workers in the area.

Piping systems

The contents of piping systems, storage bins, and tanks should be known and identified. Know the system of identification and warning used by the owner. These may vary from one plant to another.

Confined spaces

Special attention must always be paid to confined space entry. Always comply with the Construction Regulation (Ontario Regulation 213/91) as a minimum. The steel mill will usually have an entry permit system and requirements for entry and work in confined spaces. Welding in any confined space must be done with precautions. Pay special attention in cases where welding is being done on stainless steel, since the chromium released is a possible cause of lung cancer.

Emergency Procedures

The steel mill will have emergency procedures in place. Know the warning alarm signals and follow the procedures.

Electromagnetic fields

One controversial topic is the potential for health hazards in the vicinity of high electromagnetic fields. This concern should be monitored for future information and raised when construction crews work near electric furnaces.