Explanation of selected activities

CONTENTS

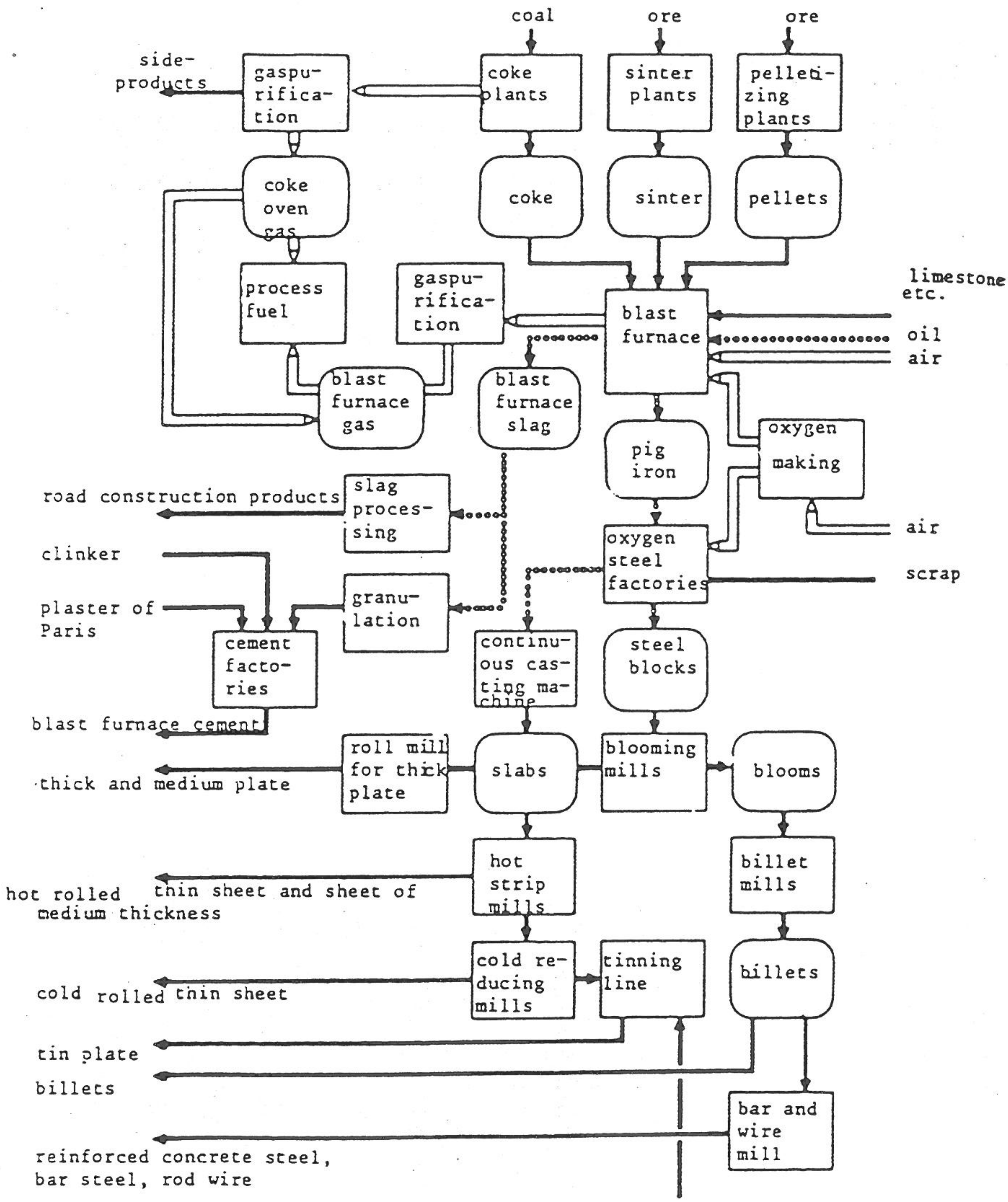
1. Integrated iron and steel plant

Figure 1.1 presents a flow sheet of a classical integrated steel plant. It is possible to recognise the main sources of pollution taken into account the nomenclature:

Coke production: SNAP94 codes 010406 and 040201 (see sheet no. 3)
Sinter Plant: SNAP94 code 030301 (see sheet no. 2)
Blast furnace: SNAP94 codes 030203, 040202 and 040203 (see sheet no. 4)
Steel making unit: SNAP94 codes 040205, 040206 and 040207 (see sheet no. 5)
Reheating furnaces: SNAP94 code 030302
Rolling mills: SNAP94 code 040208
Lime production: SNAP94 code 030312

Many other units may emit pollutants; emissions of these units are generally considered to be much lower or negligible.

Figure 1.1 — **Flow sheet of an integrated iron and steel plant**



2. Sinter plant (SNAP94 code 030301)

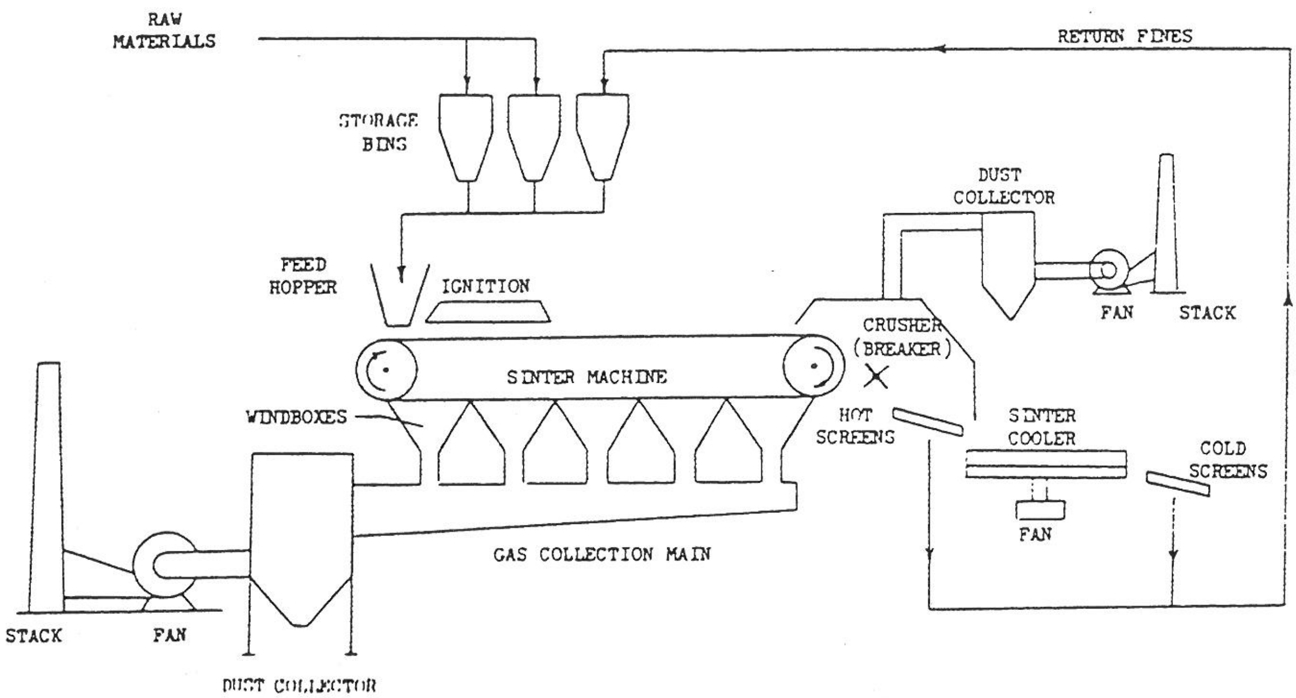
Before entering the blast furnace, ore has to be prepared under two possible processes:

I. pelletization is a cold process which provides solid pellets of mixture of ore;
II. sinterization has been developed because of the increasing amount of fines in available ores. The sintering process fuses some collected dusts, fine ore, and coke fines, and produces a stable mass called sinter which is satisfactory for blast furnace operation. A sintering machine is a continuous line of cast-iron pellets moving over a series of windbox chambers. The mixture of fines is ignited and the draft of air moves the combustion process down through the bed. Most sintering installations are equipped with a sinter cooler (Figure 2.1).

Code 030301 only deals with the sinter process and not the pellet process.

In the sinter process, combustion occurs which provides thermal energy for sintering particles; combustion gases are in contact with the crude material to be heated.

Figure 2.1 – **Schematic diagram of a sinter plant**



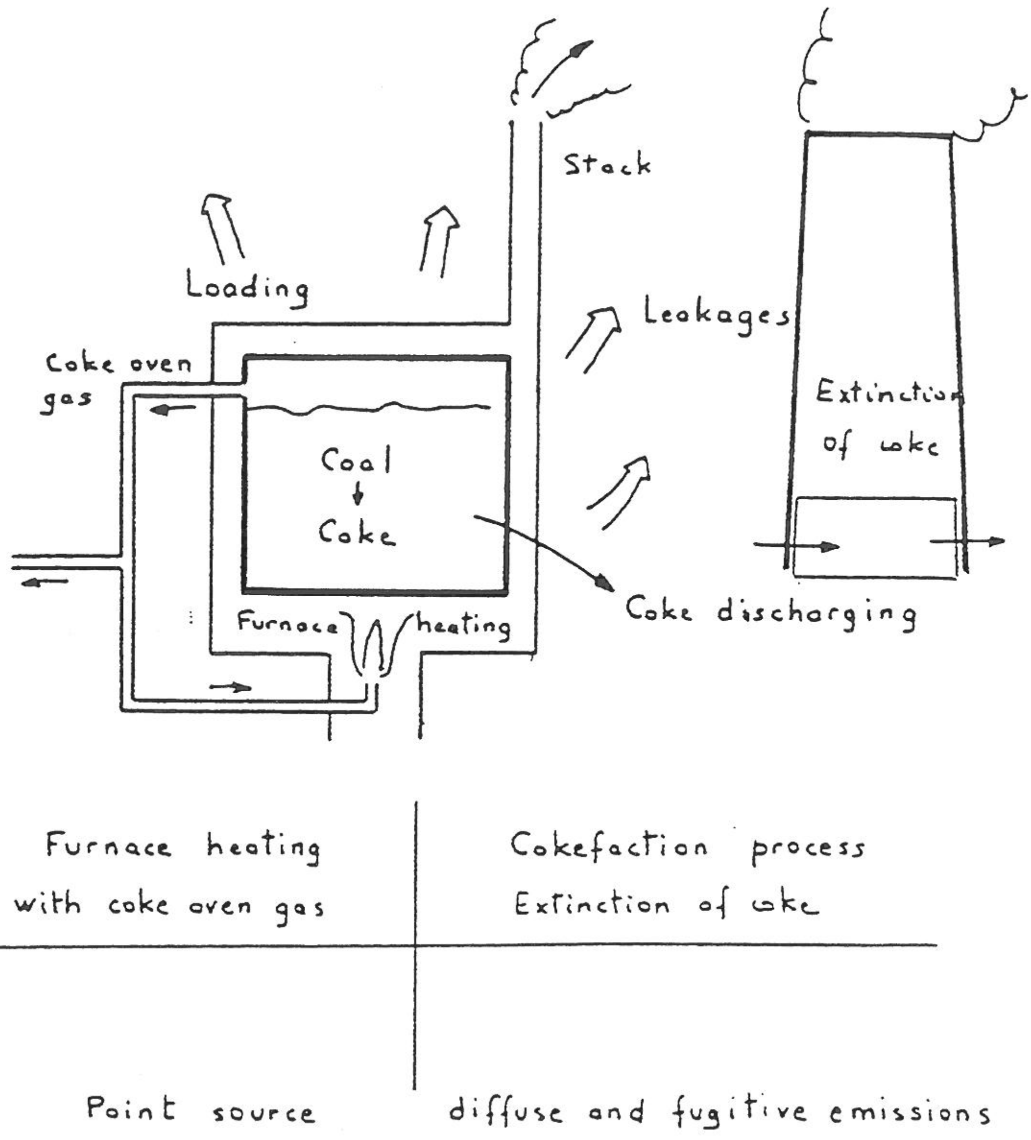
3. Coke manufacture (SNAP94 code 010406 and 040201)

Figure 3.1 presents a simplified drawing of the coke manufacture process. Special furnaces are used; furnaces are fuelled with coal and externally heated by the coke oven gas produced by the furnace itself. When coal is cooked, coke is discharged and generally cooled by using a large amount of spraying water in an extinction tower (quench). Cold coke is removed and the furnace is filled with new coal. The process is discontinuous (batch). Coke can be produced in collieries or in integrated iron and steel plants.

Two kinds of emissions have to be considered:

I. emissions from the combustion of the coke oven gas around the coking furnace. These emissions are included in "Process furnaces without contact" (code 010406);
II. emissions from the coking process (mainly diffuse and fugitive emissions from leakages or during loading of coal, discharging of coke and extinction of coke). These emissions are included in "Processes in iron and steel industries and colliery" (code 040201).

Figure 3.1 – Coke plant



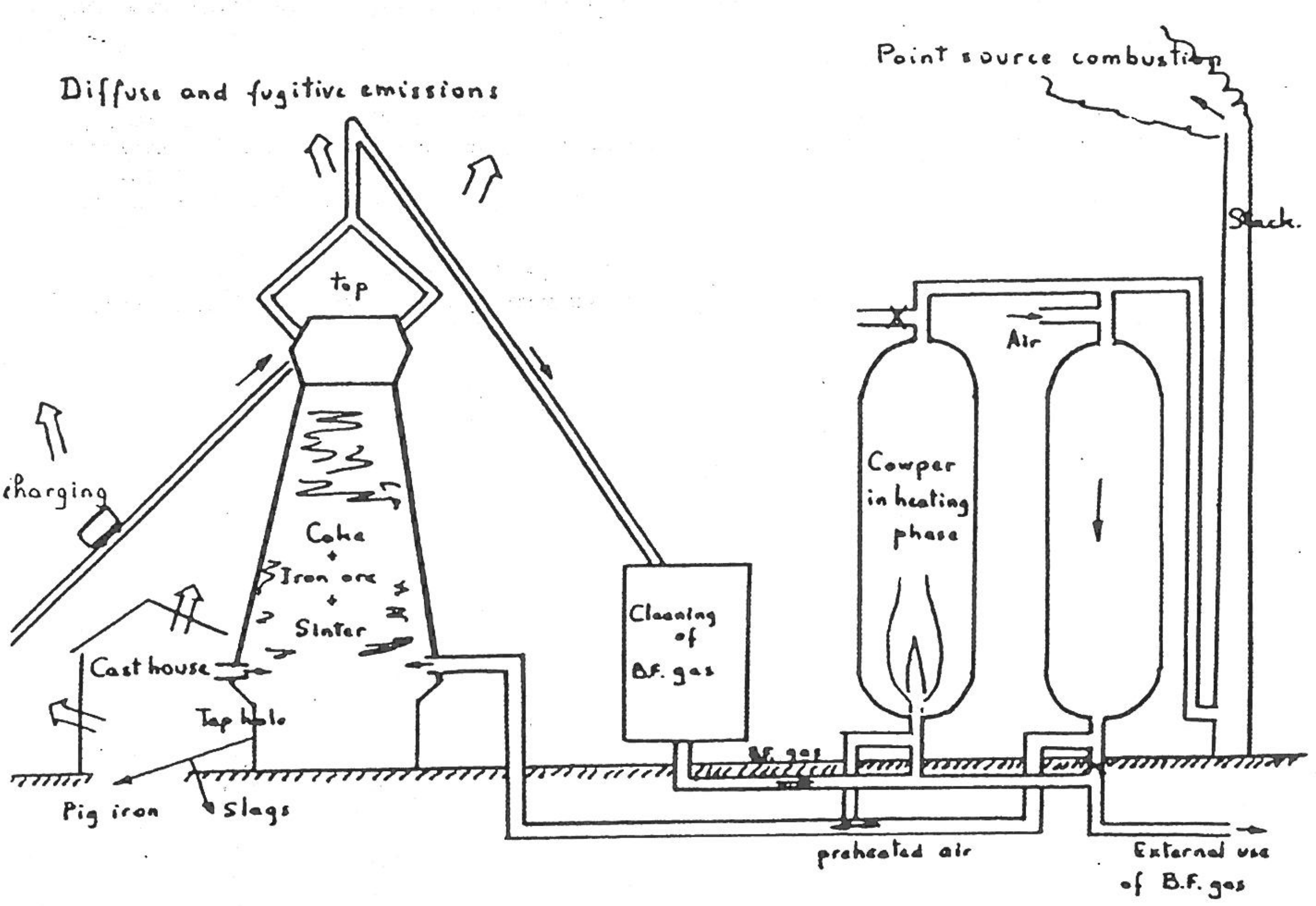
4. Blast furnace (SNAP94 codes 030203, 040202 and 040203)

A blast furnace is used to reduce iron ore (prepared under sinter form in the sinter plant) in pig-iron. Gas coming from the blast furnace is cleaned and is partially used for pre-heating air entering the blast furnace; cowpers are heat recuperators and are used alternatively (see Figure 4.1).

Two kinds of emissions have to be considered:

- emissions from the combustion of blast furnace gas in cowpers. These emissions are included in “Blast furnace cowpers” (code 030203);
- emissions from the process of reduction (mainly diffuse and fugitive emissions, tapping of slags and pig-iron, etc.). These emissions are included in “Blast furnace charging” (code 040202) and “Pig-iron tapping” (code 040203).

Figure 4.1 – **Blast furnace**



5. Steel-making unit (SNAP94 codes 040205, 040206 and 040207)

The most classical and well-known process for converting pig-iron from a blast furnace into steel is the antique Bessemer converter with air blowing; the Bessemer process has virtually disappeared and has been replaced by other steel-making processes (open hearth furnace, basic oxygen furnace, electric furnace).

Figure 5.1 presents the general feature of an open hearth furnace (OHF) (code 040205) with heat regeneration. The OHF, as the Bessemer process, is itself virtually disappearing too; nevertheless some installations may yet be in operation in Europe. Each complete charge of the furnace consists of scrap metal, limestone and pig-iron; some iron ore or other source of iron oxide may also be added.

Figure 5.2 presents a basic oxygen furnace (BOF) (code 040206), also known as the oxygen-blown steel-making process. Initially, the vessel is charged with scrap steel and next with molten pig-iron. In vertical position of the vessel, oxygen is blown into the surface of the metal; after sufficient reaction, the vessel is ready for tapping.

- The L-D process is the oldest version of the process (1950); many other variations have been developed;
- the Stora-Kaldo process from Sweden in which the vessel is not stationary in its ring;
- the Rotor process in which the vessel is able to rotate in a horizontal plane; the vessel is longitudinal, open at both ends;
- the Q-BOP process in which oxygen is blown with fuel in bottom tuyeres.

Figure 5.3 presents an electric furnace (EF) (code 040207). The roof of an EF is like an inverted dish with three large holes for carbon electrodes. Electric arcs (at the tips of these electrodes) melt the steel scrap. Electric furnaces may have vertical oxygen injection. During melting and tapping of molten steel, gases from the furnace are extracted by a "fourth hole" on the roof and dust is separated; during charging; emissions of dust are collected either by a large hood or by a complete housing of the furnace (Figure 5.4).

In the conversion of pig-iron into steel, whatever the process, it is not strictly possible to say that it is a non-combustion process; combustion of fuel or of carbon coming from pig-iron takes place, nevertheless combustion is not provided by classical burners.

Figure 5.1 — **Open-hearth furnace and associated dust collection system**

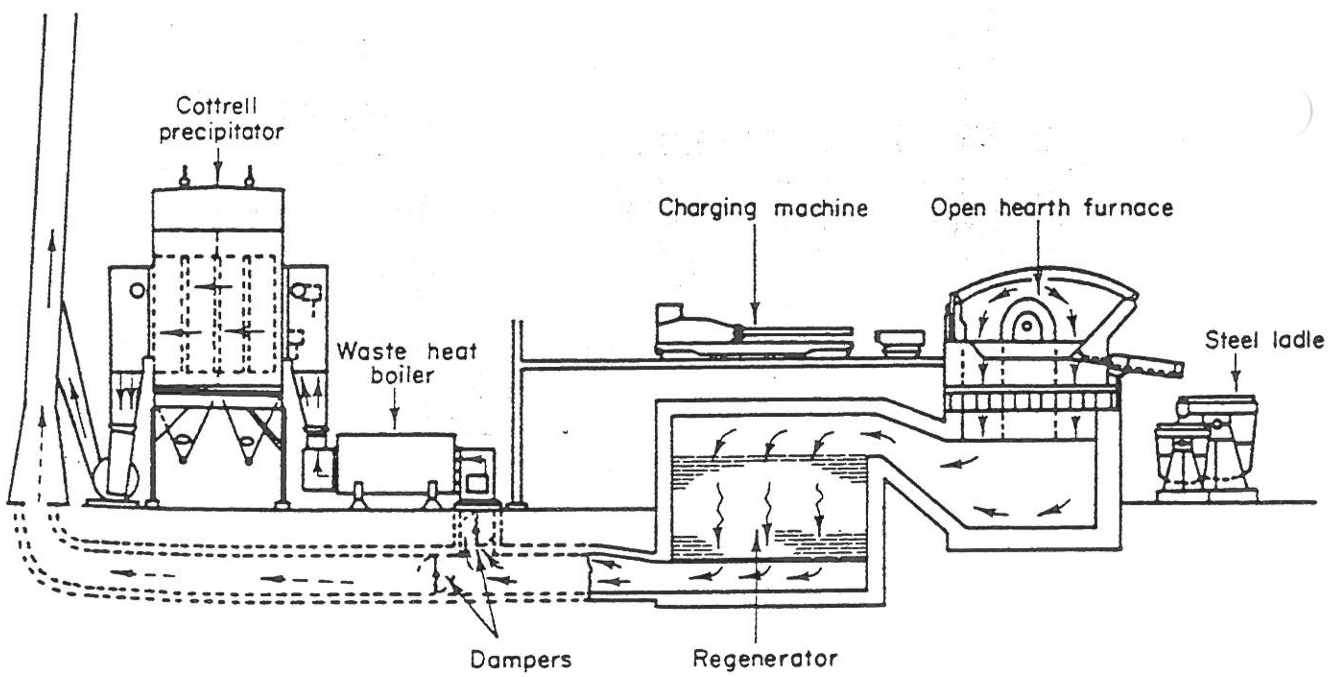
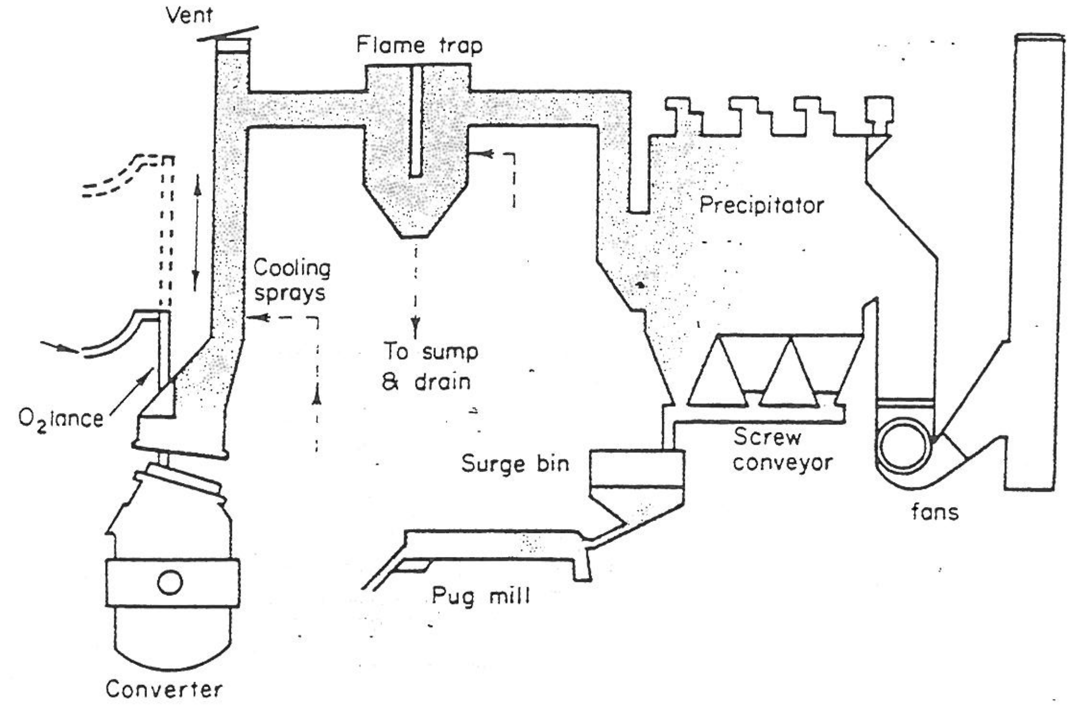


Figure 5.2 – **Basic oxygen converter (L-D process) and associated dust collection system**



Source: Stern.

Figure 5.3 – **Electric furnace**

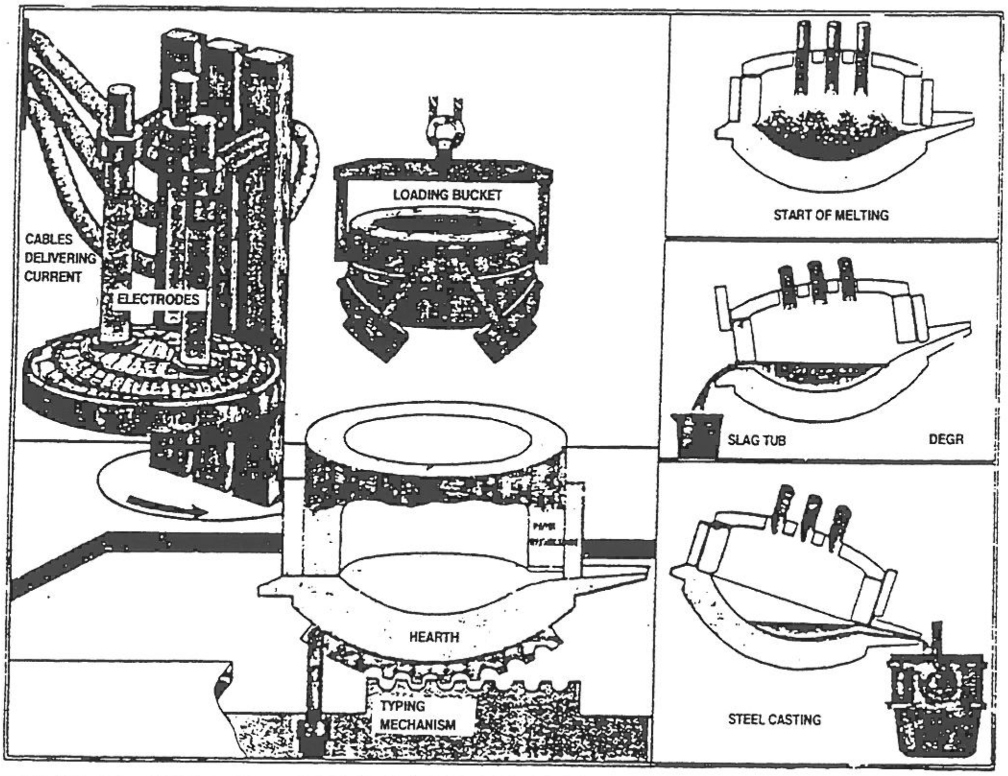
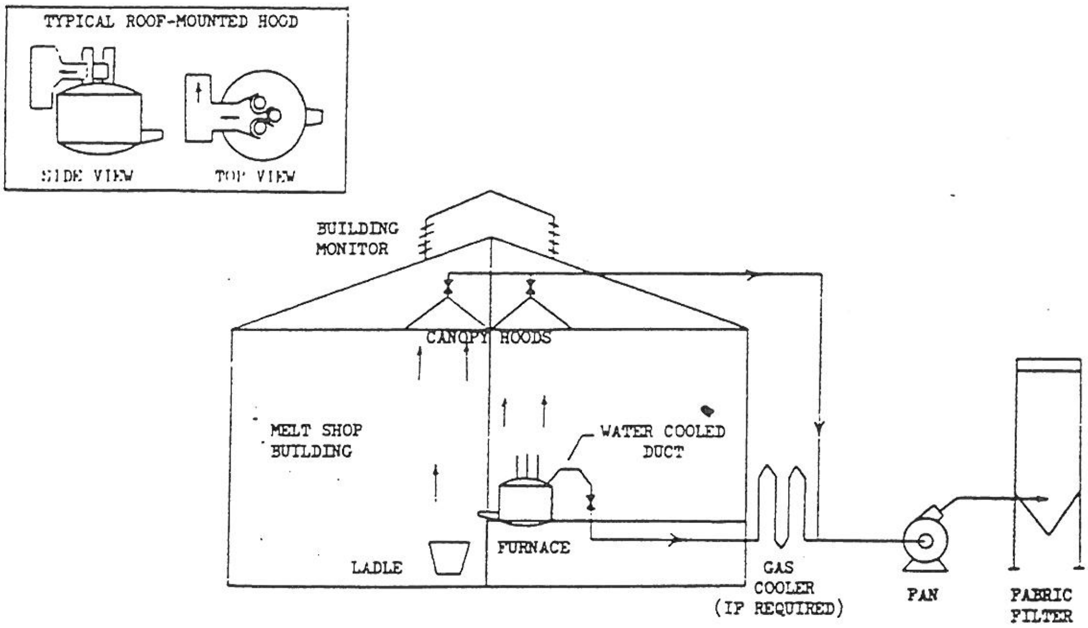


Figure 5.4 – **Electric arc furnace shop with combination canopy hood/direct evacuation control system. Insert shows typical roof-mounted hoods**



6. Grey iron foundry (SNAP94 code 030303)

Figure 6.1 presents a flow sheet of a grey iron foundry.

SNAP94 code 030303 refers to the five main zones of activity:

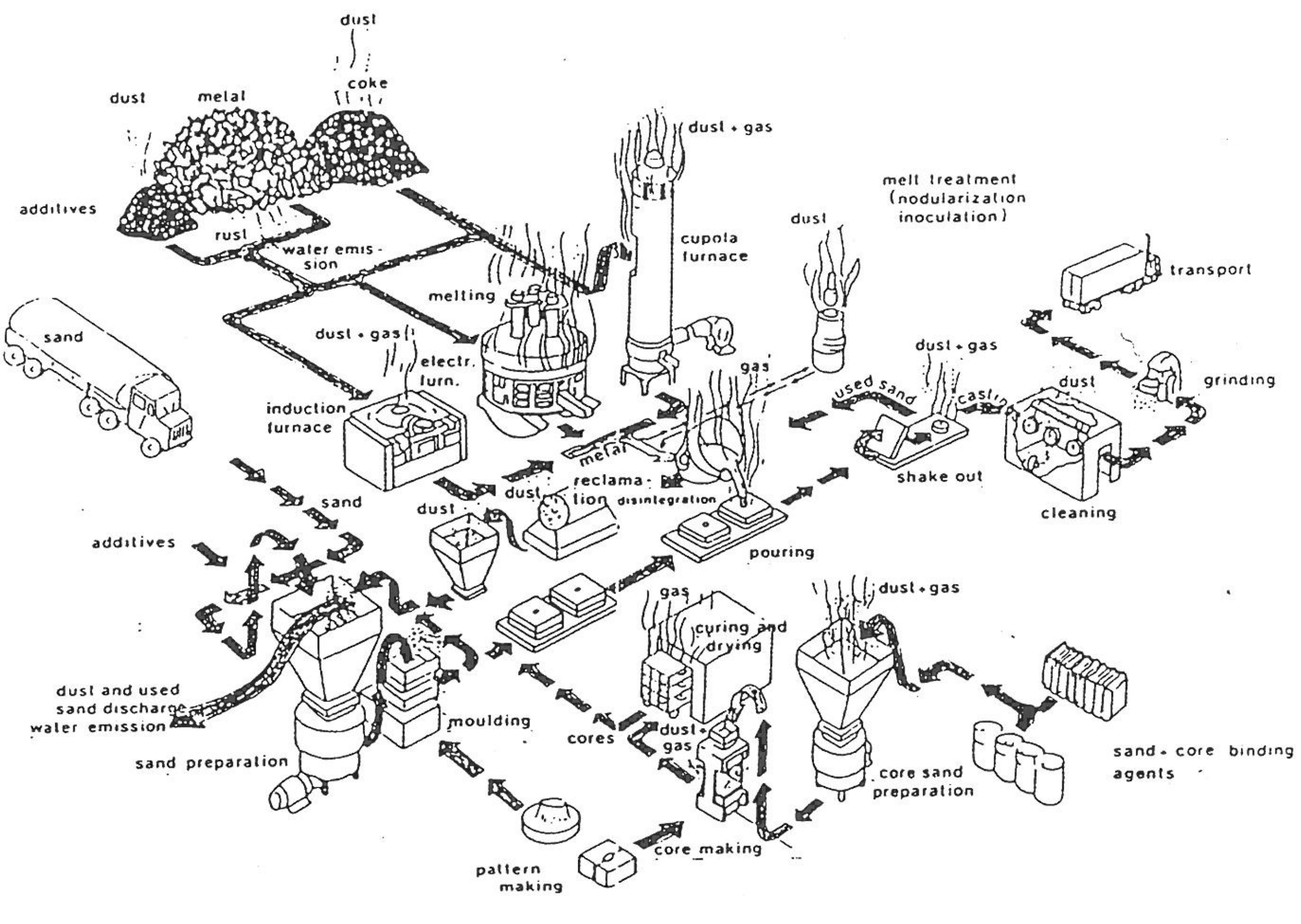
- preparation of molten metal including raw material;
- preparation of sand, mould and core making including raw materials;
- melting, casting, cooling, shake-out;
- finishing and heat treatment;
- sand regeneration.

Four types of furnaces are generally considered:

- cupola furnace (most traditional process for grey iron),
- electric arc furnace (preferably for steel foundry)
- electric induction furnace (for grey iron and steel)
- rotary furnace (for grey iron) (the number of rotary furnaces has increased for some years) (not present on Figure 6.1).

Emissions of pollutants by the cupola are generally considered as the most important (mainly for CO and VOC).

Figure 6.1 — **Flow sheet of a grey iron foundry and emission sources**



7. Lime production (SNAP94 code 030312)

This item includes lime production in the paper industry and in integrated iron and steel plants.

8. Pulp and paper industry (SNAP94 code 030321, 040602 and 040603)

Paper industry refers to two kinds of activities - pulp production and paper production - which can be separated, in come countries, from an economical point of view.

(i) In pulp productions, three main processes can be distinguished:

(a) The Kraft process (code 040602) is the most widely used (Figure 8.1). In this process, lignine of wood is dissolved by alkaline cooking in a solution containing sodium hydroxide and sodium sulphide. The cooking liquor is recovered in a recovery furnace (black liquor boiler) and re-used.

(b) In the acid sulphite process (code 040603) (Figure 8.2), the cations of the cooking liquor include calcium, sodium, magnesium, or ammonia. The cooking salts may be in the form of acid sulphite or bisulphite. Sulphurous acid is always used, but various combinations of combined and free sulphur dioxide may be involved.

The sulphite process involves the cooking of wood chips usually in a batch digester under pressure in the presence of an acid cooking liquor.

Where calcium liquors are used, the spent liquor that is washed out of the pulp or that drains out of the pulp in the blow tank is frequently discarded or undergoes some by-product recovery. If the spent liquor is from a soluble base such as sodium, magnesium, or ammonia, the next step may be a recovery cycle. If recovery is to take place, the liquor is concentrated by evaporation and the concentrated liquor sprayed into a furnace where the organic compounds are burned. In the case of an ammonium base, only the heat is recoverable. In the case of magnesium and sodium bases, residual inorganic compounds may be collected for re-use in the manufacture of additional cooking acid.

In the neutral sulphite semi-chemical (NSSC) process (Figure 8.3), the cooking chemicals consist of sodium sulphite and sodium carbonate in a liquor maintained at about a pH of 7. This provides a mild chemical treatment of the wood chips which does not completely remove all of the cementing material. Thus, the chemical stage is followed by some mechanical disintegration to separate the fibres further.

The liquor resulting from the blow tank and the pulp washing may be discharged to the sewers or may be oxidized in a fluid bed reactor or sodium carbonate and sodium sulphate. If a Kraft recovery system is adjoined, the NSSC spent liquor can be mixed with the spent Kraft liquor up to a limiting percentage and burned in the recovery furnace. The recovered chemicals are used entirely in the Kraft system. Emissions of both sulphur dioxide and hydrogen sulphide from the Kraft recovery furnace may be increased when NSSC liquor is added.

It is difficult to decide whether the black liquor boiler must be considered as a classical boiler for thermal energy recovery or a reactor for chemical recovery. In the present inventory, black liquor is considered as a fuel and the boiler is included in item 3.1.

All other diffuse and fugitive emissions from pulp production are included in code 040602.

(ii) In paper production, the drying of sheet paper is the most important source of pollution; hot gases can be in contact with the paper to be dried. This process is included in code 030321.

In pulp and paper plants, classical boilers using commercial fuels can be also operated for thermal energy and/or electricity generation.

Figure 8.1 — **Typical flow diagram of the kraft process**

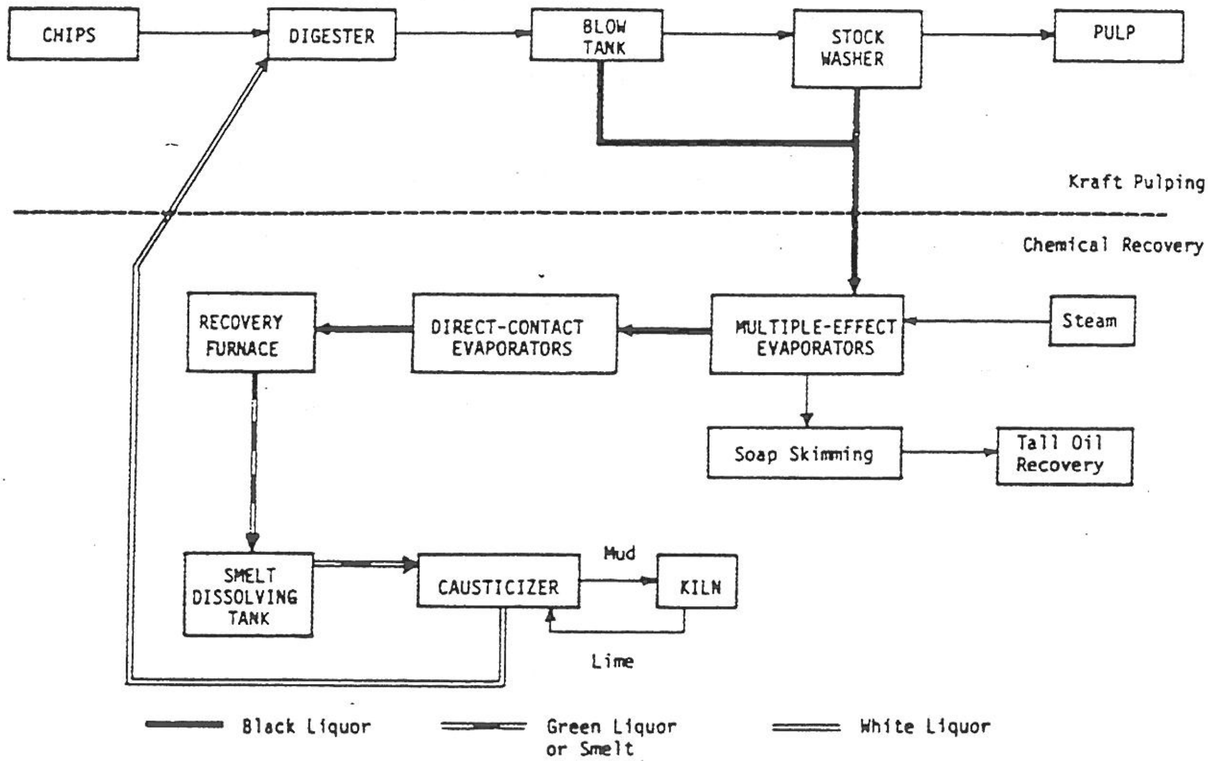


Figure 8.2 — **Simplified flow diagram of the sulphite process**

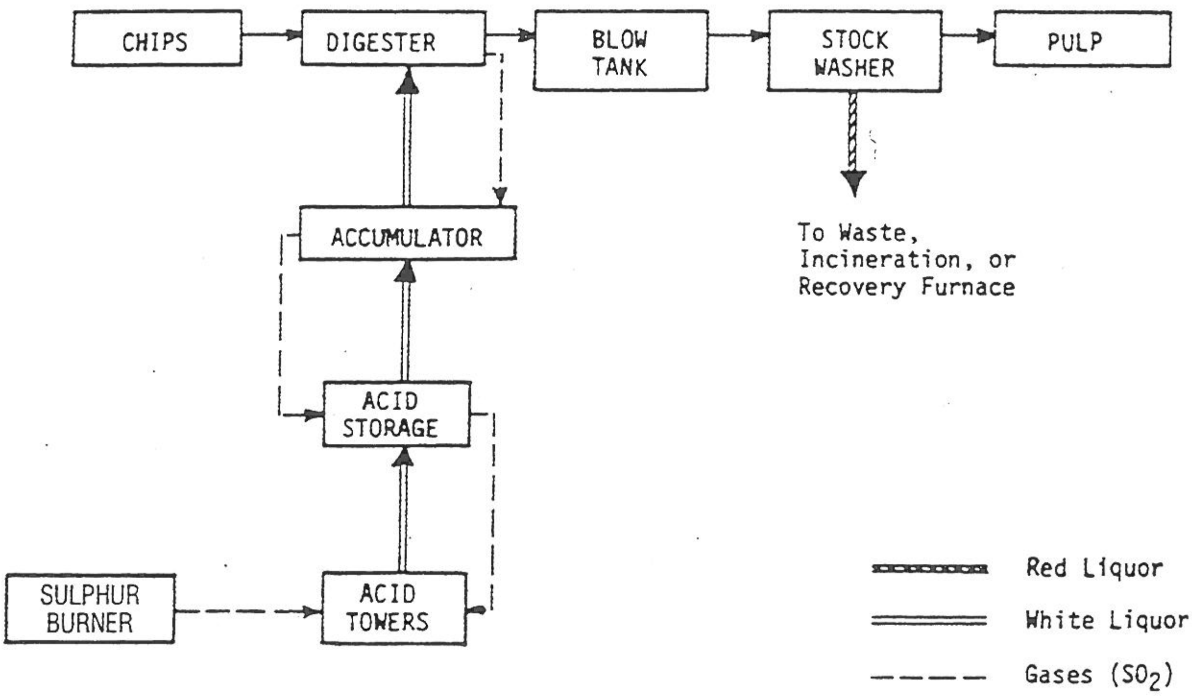
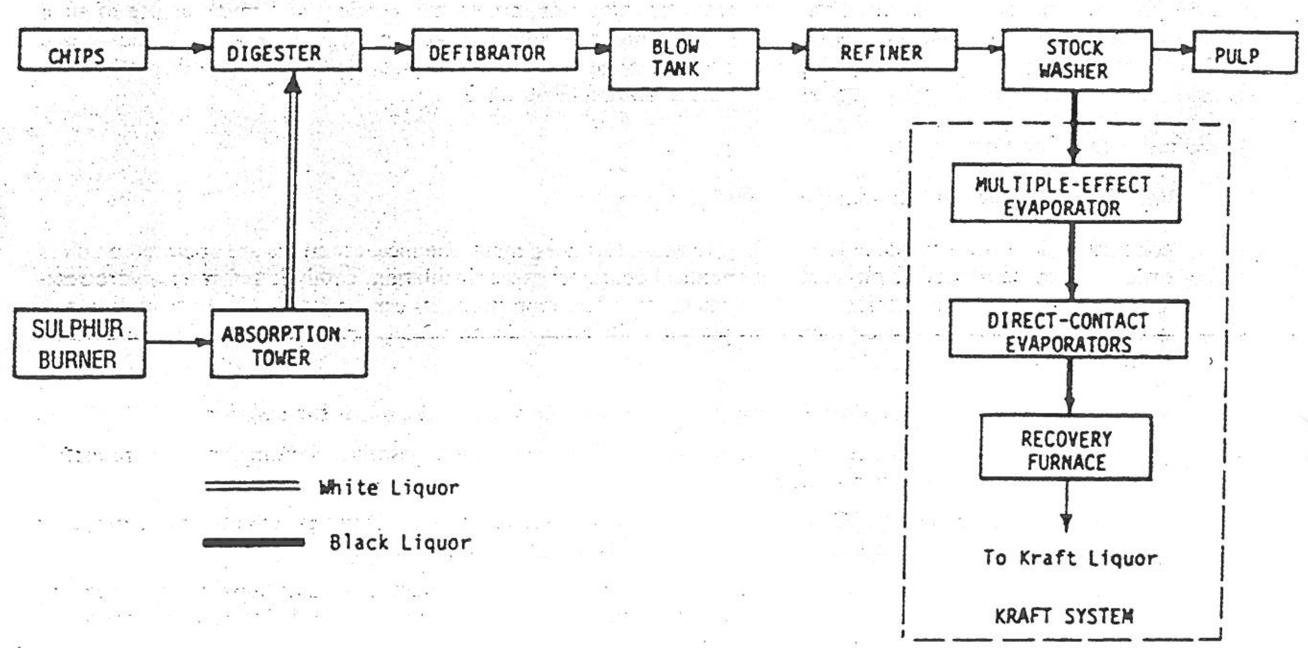


Figure 8.3 – **Simplified flow diagram of the neutral sulphite semi-chemical (NSSC) process (with kraft cross-recovery)**



9. Oil refinery (SNAP94 codes 0301, 010306, 040101, 040103 and 040104)

Individual refineries differ widely, not only as to crude oil capacity, but also as to the degree of processing sophistication employed. Simple refineries may be confined to crude separation and limited treating (Figure 9.1). Intermediate refineries may add catalytic or thermal cracking, catalytic reforming, additional treating, and manufacture of such heavier products as lube oils, and asphalt (Figure 9.2). Complete refineries, generally large in capacity, include crude distillation, cracking, treating, gas processing, manufacture of lube oils, asphalts, waxes, as well as gasoline upgrading processes such as catalytic reforming, alkylation, or isomerization (Figure 9.3).

The main sources of pollution are:

I. boilers, gas turbines and stationary engines (code 0301);

II. combustion in process furnaces (code 010306). In these furnaces, many chemical reactions are operated on oil in order to provide particular physical and chemical characteristics: distillation, catalytic reformer, hydrotreating, catalytic cracker, alkylation, hydro cracker, etc. Petroleum products are obviously always heated in furnaces without contact between flame and products. Pollutants in code 030201 only come from the combustion in the furnace;

III. some processes may have fugitive or non-combustion emissions (code 0401); this is the case for:

a) petroleum products processing (code 030101); gasoline stabilization, gasoline blending, etc., where mainly fugitive VOC emissions may occur;

b) fluid catalytic cracking (FCC) (code 040102) which is associated with a CO boiler (or catalyst regeneration device) where the catalyst covered with some coke is burned and regenerated;

c) sulphur recovery plant (code 040103). Some light and distillated products can be desulphurized by reacting with hydrogen in precise thermodynamic conditions. Sulphur is extracted as H_2S. In the sulphur recovery plant (or Claus plant), a part of H_2S is burned providing SO_2 and:

$$H_2S + SO_2 \xrightarrow[\text{smelt}]{\text{catalyst}} S + H_2O$$

Emissions from this kind of plant are mainly SO_2 and H_2S;

d) storage and handling of petroleum products (code 040104) with mainly emissions of VOCs;

e) API recovery pools or waste water gravity separators were sometimes also included. This device is often a source of odour.

Figure 9.1 – **Processing plan for typical minimum refinery**

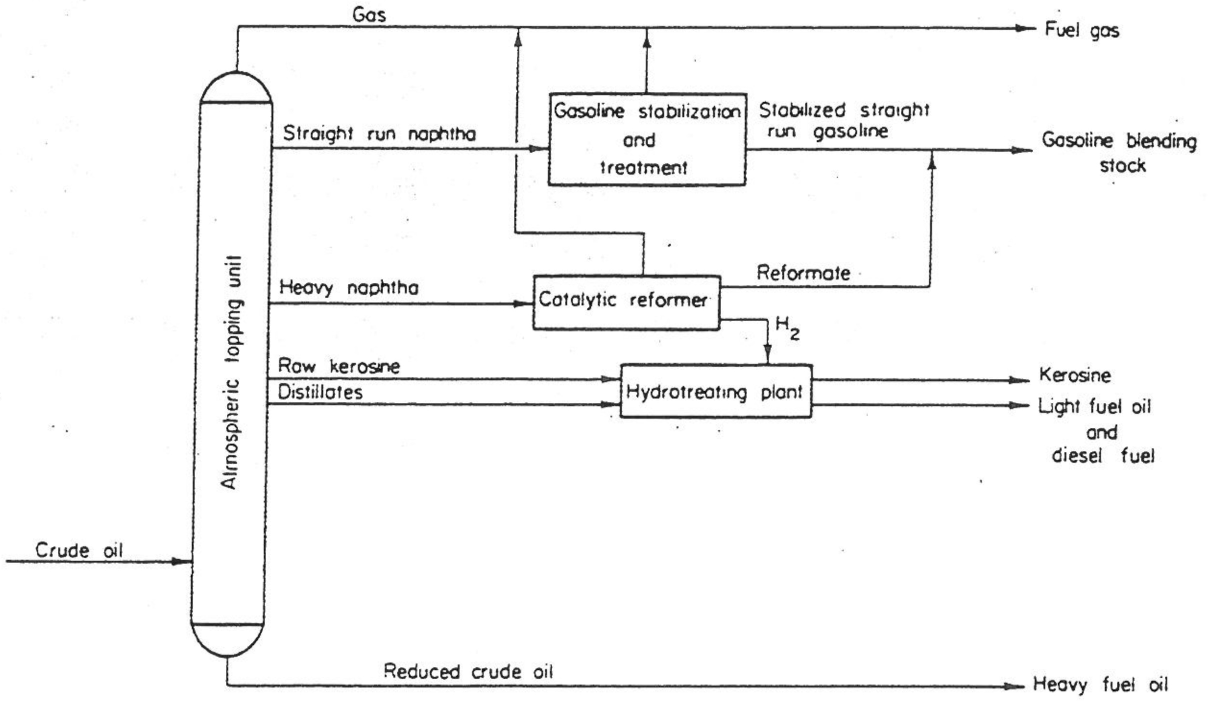


Figure 9.2 – **Processing plan for typical intermediate refinery**

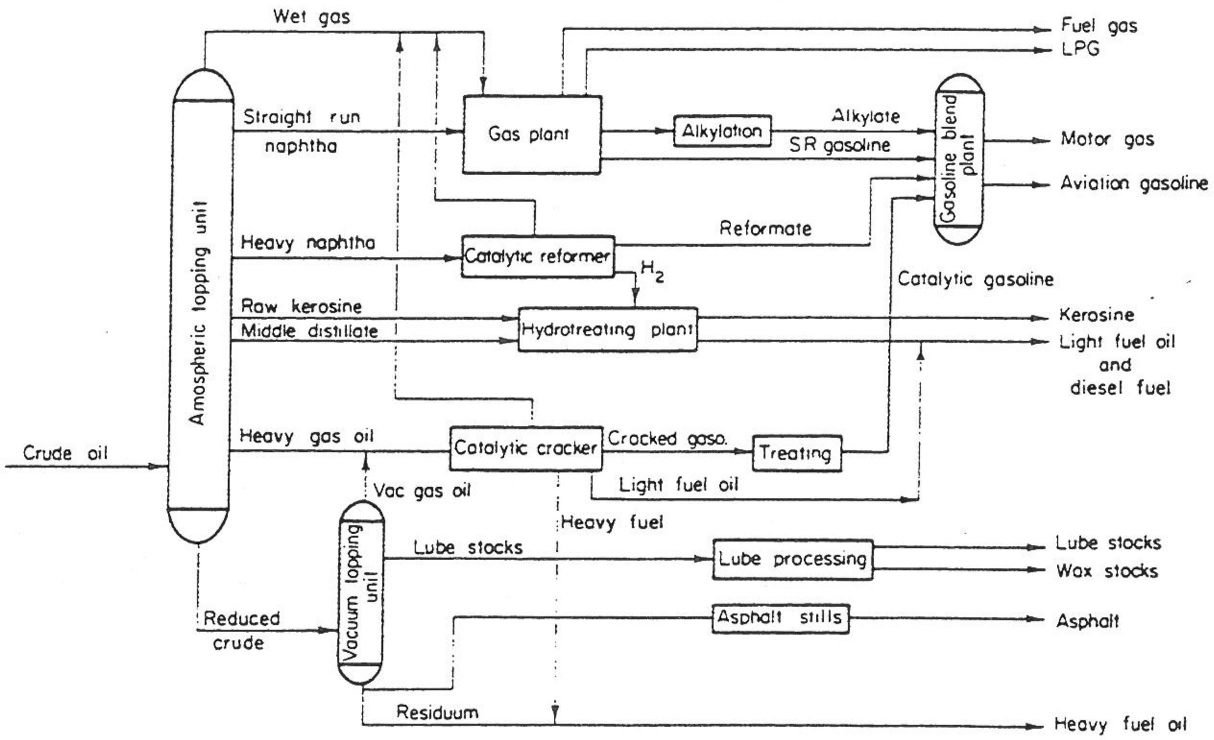
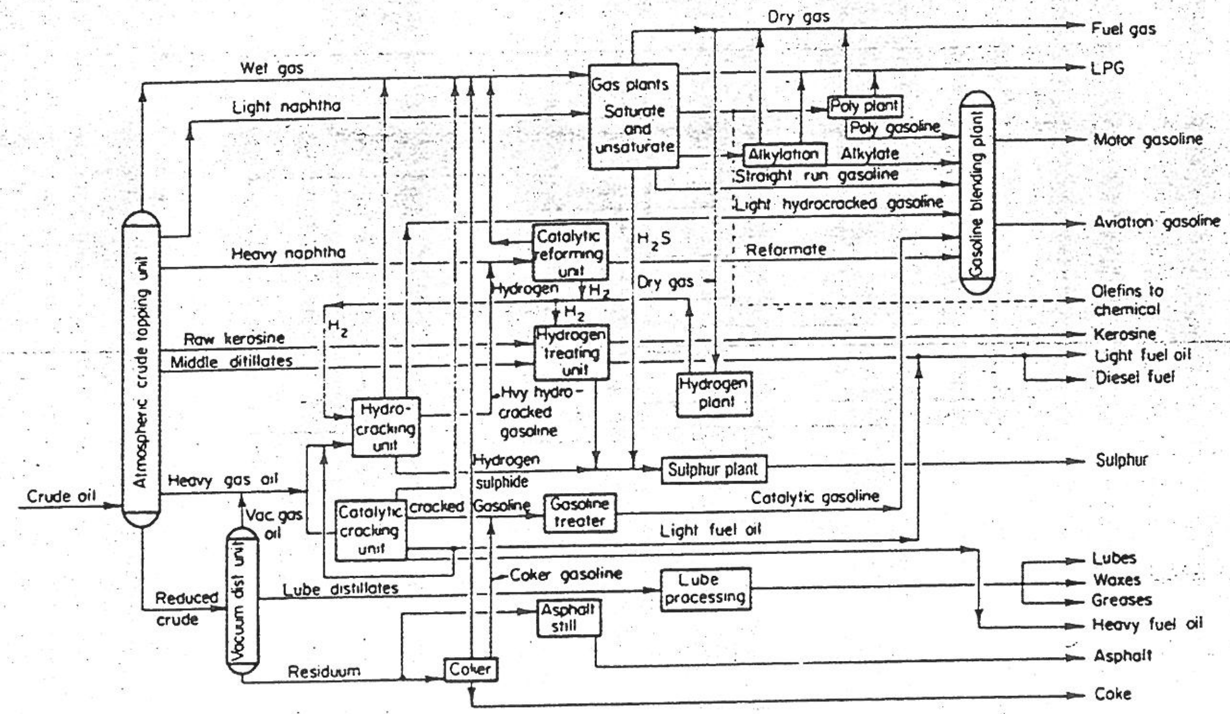


Figure 9.3 – **Processing plan for typical complete refinery**



10. Ethylene production (steam cracking) (SNAP94 code 040501)

The production of ethylene is a reaction of water steam on hydrocarbons followed by units of separation of hydrocarbons and of diverse chemical operations (see Figure 10.1).

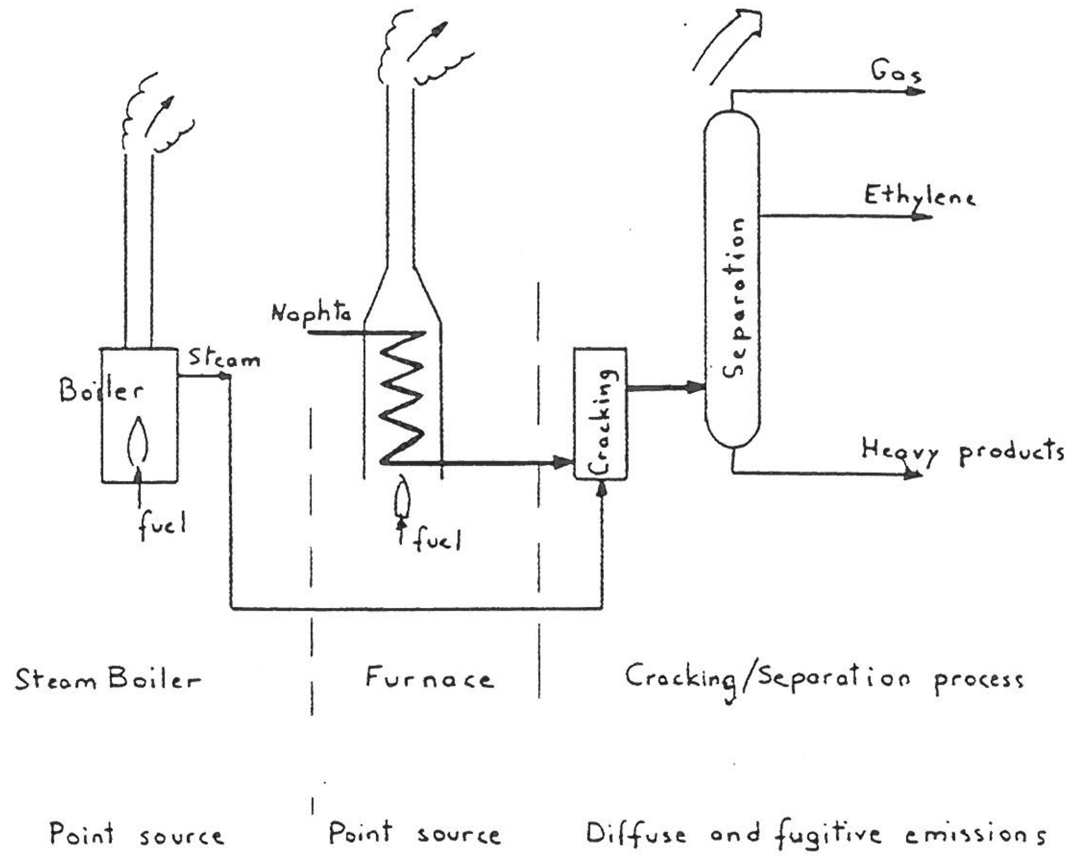
Three kinds of emissions have to be considered:

I. emissions from the steam boiler predicting water steam. These emissions are included in "Combustion in boilers" (item 3.1);

II. emissions from the furnace heating naphtha. These emissions are included in "Process in inorganic chemical industries" (item 4.5.1);

III. emissions from the process itself involving cracking, separation, compression of gas, hydrogenation, etc. These emissions are also included in "Processes in organic chemical industries" (code 040501).

Figure 10.1 — Steam cracking



11. Ferro-alloys (SNAP94 code 040302)

Ferro-alloys is the generic term for alloys consisting of iron and one or more other metals. Ferro-alloys are used in steel production as alloying elements and deoxidants. There are three basic types of ferro-alloys:

- silicon-based alloys, including ferrosilicon and calciumsilicon, including ferromanganese and silicomanganese,
- chromium-based alloys, including ferrochromium and ferrosilico-chrome.

The four major procedures used to produce ferro-alloy and high-purity metallic additives for steelmaking are:

- blast furnace
- electrolytic deposition
- alumina silico-thermic process,
- electric smelting furnace

Because most ferro-alloys are produced in electric smelting furnaces, Code 040302 only refers to that type of furnace.

The oldest, simplest, and most widely used electric furnaces are the submerged-arc open type, although semi-covered furnaces are also used. The alloys are made in the electric furnaces by reduction of suitable oxides. For example, in making ferrochromium the charge may consist of chrome ore, limestone, quartz (silica), coal and wood chips, along with scrap iron.

In an open furnace, essentially all the carbon monoxide burns with induced air at the tops of the charge, and CO emissions are small. Particulate emissions from the open furnace, however, can be quite large. In the semi-closed furnace, most or all of the CO is withdrawn from the furnace and burns with dilution air introduced into the system. The unburnt CO goes through particulate control devices and can be used as boiler fuel or can be flared directly.

12. Railways (SNAP94 code 0802)

Emission of pollutants by electrical railways are not covered; these emissions are globally accounted for in electricity generating plants.

Most railways emissions come from diesel locomotives. Very few locomotives still use solid fuel.