BEST AVAILABLE TECHNIQUES GUIDANCE DOCUMENT ON NON-FERROUS METAL INDUSTRY

FOREWORD

Best Available Techniques Economically Achievable (BAT) document had been prepared as a guidance notes for the nine (9) major industries in Malaysia and to support the implementation of the new Environmental Quality (Clean Air) Regulations 20xx. These documents were prepared based on the latest state-of-the-art technologies, internationally accepted limit values but had been adjusted and tailored to local requirements.

BAT is defined as the effective methods in preventing pollution and, where generally that is not practicable, to reduce emissions from industrial activities and their impact on the environment. This definition implies that BAT not only covers the technology used but also the way in which the installation is operated, to ensure a high level of environmental protection. Implementations of BAT in any specific industrial sectors are under economically and technically viable condition.

It is hope that the technical contents of these documents will prove beneficial to the industries in their endeavour to comply with the environmental regulations and standards through more cost-efficient means. In the identification of BAT, emphasis is placed on pollution prevention techniques rather than end-of-pipe treatment. These documents will be reviewed and updated from time to time.

These documents have been prepared in consultations with the University of Malaya Consultancy Unit (UPUM), Malaysia German Technical Cooperation (GTZ) and the relevant industries/stakeholders. The Department of Environment wishes to record appreciation to representatives of the relevant industrial sectors, government agencies and individuals for their invaluable input.

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LIST OF ABBREVIATIONS

BAT	-	Best Available Techniques
BREF	-	Best Available Technique Reference
$CaCo_3$	-	Calcium Carbonate
CAR	-	Clean Air Regulation Document
CO	-	Carbon Monoxide
DOE	-	Department of Environment
IPPC	-	Integrated Pollution Prevention and Control
mg/Nm^3	-	milligram per cubic meter at standard temperature (273K) and pressure (1atm)
NO_x	-	Nitrogen Oxide
PAH	-	Polycyclic Aromatic Hydrocarbon
PCB	-	Polychlorinated biphenyl
PCDD/F	-	Polychlorinated dibenzo-p-dioxin furan
RAC	-	Regenerative Activated Carbon
ROK	-	Run of Kiln
SCR	-	Selective Catalytic Reduction
SNCR	-	Selective Non-Catalytic Reduction
SO_x	-	Sulphur Dioxide

1.0 PREFACE

1.1 Status of This Document

This document forms a part of a series presenting the guidance notes for selected industries in Malaysia (list given at the end of this preface) to apply best available techniques economically achievable (BAT), associated monitoring and developments in them. This series is published by the Department of Environment (DOE) in accordance to the Environmental Quality (Clean Air) Regulations 2014 (CAR 2014).

1.2 Definition of BAT

In order for the user of this document to understand the legal context of this document, the interpretation on the definition of BAT is taken from Regulation 2 – Interpretation of CAR 2014 and described as below:

“Best Available Techniques Economically Achievable” means the effective methods in preventing pollution and, where that is not practicable, generally to reduce emissions in the air from the industrial activities and their impact on the environment as a whole. In this regard:

“Techniques” includes both the technology used and the way in which the facility is designed, built, maintained, operated and decommissioned;

“Available Techniques” means those techniques that are accessible to the occupier and that are developed on a scale that allows implementation in the relevant industrial sector, under economically and technically viable conditions, taking into consideration the costs and advantages; and

“Best” means effective in achieving a high general level of protection of the environment as a whole;

On the basis of this assessment, techniques, and as far as possible emission and consumption levels associated with the use of BAT, are presented in this document that are considered to be appropriate to the sector as a whole and in many cases reflect current performance of some installations within the sector. Where emission or consumption levels “associated with best available techniques” are presented, this is to be understood to mean those levels representing the environmental performance that could be expected as a result of the application, of the techniques described, taking into account the balance of costs and advantages inherent within the definition of BAT. However, they are neither emission nor consumption limit values and should not be understood as such.

In some cases it may be technically possible to achieve better emission or consumption levels but due to the costs involved or cross media considerations, they are not considered to be appropriate as BAT for the sector as a whole. However, such levels may be considered to be justified in more specific cases where there are special driving forces.

The emission and consumption levels associated with the use of BAT have to be seen together with any specified reference conditions (e.g. averaging periods).

The concept of “levels associated with BAT” described above is to be distinguished from the term “achievable level” used elsewhere in this document. Where a level is described as “achievable” using a particular technique or combination of techniques, this should be understood to mean that the level may be expected to be achieved over a substantial period of time in a well maintained and operated installation or process using those techniques.

The actual cost of applying a technique will depend strongly on the specific situation such as taxes, fees, and the technical characteristics of the installation concerned. It is not possible to evaluate such site-specific economic viability of techniques drawn from observations on existing installations.

The purpose of CAR 2014 is to achieve prevention and control of pollution arising from activities listed in its First Schedule and Second Schedule. More specifically, it provides for a notification system for certain categories of industrial installations to conduct an integrated and comprehensive view of the pollution and consumption potential of their installation. The overall aim is to ensure a high level of protection of the environment as a whole based on appropriate preventative measures through the application of BAT.

1.3 Objective of This Document

The ‘emission minimization principle’ as cited in CAR 2014 requires that the goal of emission abatement is to achieve minimum emissions as a result of applying current BAT. Hence this guideline document is meant to provide the reference information for the permitting authorities to take into account when determining permit conditions. This document should serve as valuable input to achieve better environmental performance.

1.4 Information Sources

The information is mainly based on the European IPPC BREF document where the assessment was achieved through an iterative process involving the following steps:

- identification of the key environmental issues for the sector
- examination of the techniques most relevant to address those key issues;
- identification of the best environmental performance levels, on the basis of the available data world-wide;
- examination of the conditions under which these performance levels were achieved; such as costs, cross-media effects, main driving forces involved in Implementation of these techniques;

- selection of the BAT and the associate emission and/or consumption levels for this sector

1.5 How to Use This Document

It is intended that the general BAT in this document could be used to judge the current performance of an existing installation or to judge a proposal for a new installation and thereby assist in the determination of appropriate BAT based conditions for that installation. It is foreseen that new installations could be designed to perform at or even better than the general BAT levels presented here. It is also considered that many existing installations could reasonably be expected, over time, to move towards the general "BAT" levels or perform better. This reference document does not set legally binding standards, but they are meant to give information for the guidance of industry, the relevant government bodies and the public on achievable emission and consumption levels when using specified techniques.

The structure of the guideline document is as follows:

An overview of each particular sector in the Malaysian context is firstly covered briefly followed by process description, process optimization, sources of pollution, emission control options, recommended practices and emission values and finally emission monitoring and reporting. More often than not, trade-off judgements between different types of environmental impacts and specific site condition are the influencing factors.

Another important point to note is that BAT change over time and this guidance document needs to be reviewed and updated as appropriate.

2.0 OVERVIEW OF NON-FERROUS METAL INDUSTRY IN MALAYSIA

Non-ferrous metal is any metal, including alloys, that does not contain. Non-ferrous metals are used because of desirable properties such as low weight (e.g. aluminium), higher conductivity (e.g. copper), non-magnetic property or resistance to corrosion (e.g. zinc) despite the higher cost compared to ferrous metals. Some non-ferrous materials are also used in the iron and steel industries, for example bauxite is used as flux for blast furnaces, while others such as wolframite pyrolusite and chromite are used in making ferrous alloys.

Important non-ferrous metals include aluminium, copper, lead, nickel, tin, titanium and zinc, and alloys such as brass. Precious metals such as gold, silver and platinum and exotic or rare metals such as cobalt, mercury, tungsten, beryllium, bismuth, cerium, cadmium, niobium, indium, gallium, germanium, lithium, selenium, tantalum, tellurium, vanadium and zirconium are also non-ferrous. They are usually obtained through minerals such as sulfides, carbonates and silicates.

The non-ferrous metal sectors in Malaysia cover products like tin, aluminium, copper, zinc, and lead. The main players however are companies in the aluminium industries sector which produce aluminium sheets/foils, aluminium finstock, aluminium ingots (recycled), aluminium rods and aluminium extruded profiles, and the copper related companies which produce copper rods/wires, copper strips, copper tubes/extrusions and tin metal. There are currently 180 companies in the non-ferrous metal sectors with annual output of RM 7.3 billion and total employment of 14,996 workers.

The non-ferrous metal industries provide linkages mainly in the construction industry, electrical/electronic industry, automotive industry, food and packaging industry. In 2012, imports of non-ferrous metal products amounted to RM20.4 billion. Exports during the same period amounted RM10 billion for non-ferrous metal products (Malaysia Investment Performance Report, 2012).

Aluminum.—Malaysia did not have an aluminum refinery or smelter, most of its bauxite output, therefore was exported to China, and Malaysia imported unwrought aluminum to meet demand, In 2007, Malaysia's unwrought aluminum and aluminum alloy imports and exports totaled 2.7 million metric tones (Mt) and 580, 626 metric tones(t), respectively. The Government approved Sarawak Aluminum Co., which was joint venture between Malaysia Cahya Mata Sarawak Berhad (CMS) and Rio Tinto Ltd. Of Austria, to build a 550,000 t/y aluminum smelter in Similajau, this is located abaout 60 kilometres from the town of Bintulu in the state of Sarawak. The capacity of the proposed $2 billion aluminum smelter would be expanded to 1.5 million Mt/y. Rio Tinto Alcan Ltd., a subsidiary of Rio Tinto, would have 60% share of the Sarawak Aluminum Co. and CMS would have 40% share. Feasibility studies on the project were expected to take between 12 to 15 months to complete, and the construction of the smelter began in early 2009. The smelter was expected to commence operations by the fourth quarter of 2010 and reach full production in 2011. Ray material (alumna) would be imported from the Yarwun Alumina Refinery in Gladstone. Australia. The electricity for the smelter would come from the Bakun hydraulic dam, which was under construction. Domestic demand for aluminum had increased during the past several years and expected to grow by about 6.5% per year for the next 5 year. Products from Sarawak smelter would be sold to customer in Malaysia and would be exported to Southeast Asian countries (Rio Tinto Ltd, 2008)

Lead.—Metal Reclamation (Industries) Sdn. Bhd. (MRISB) (a subsidiary of Metal Reclamation Bhd.) began operation of its new secondary (recycling) lead smelter at Pulau Indah Industrial Park on Pulau Lumut off Port Klang in 2001. MRISB recycled lead-acid batteries, lead oxides, lead scrap, lead wastes, solder wastes, and waste containers contaminated with hazardous waste. MRISB production facilities included a battery breaking plant, a smelter, and an alloying and casting plant. The new facilities had a capacity to recycle 70,000 t/yr of spent lead-acid batteries. The premium-grade (99.97% purity) lead and lead alloys produced by MRISB were distributed under the "MRISB Malaysia" brand to the Malaysian and overseas markets.

3.0 PROCESS DESCRIPTION

Non-ferrous metals are produced from a variety of primary and secondary raw materials.

Primary raw materials are derived from ores that are mined and then further treated before they are metallurgically processed to produce crude metal. The treatment of ores is normally carried out close to the mines. Secondary raw materials are indigenous scrap and residues and may also undergo some pre-treatment to remove coating materials.

Recycling constitutes an important component of the raw material supplies of a number of metals. Copper, aluminium, lead, zinc, precious metals and refractory metals, among others, can be recovered from their products or residues and can be returned to the production process without loss of quality in recycling. Overall, secondary raw materials account for a high proportion of the production, thus reducing the consumption of raw materials and energy.
The product of the industry is either refined metal or what is known as semis or semi manufactures, i.e. metal and metal alloy cast ingots or wrought shapes, extruded shapes, foil, sheet, strip, rod etc.

The range of raw materials available to the various installations is wide and this means that a variety of metallurgical production processes is used. In many instances the process choice is governed by the raw materials. **Table 1** to **Table 3** summarise the furnaces used for the production of non-ferrous metals.

Table 1: Drying, Roasting, Sintering and Calcining Furnaces Used In Non-Ferrous Metal Production

Furnace	Metals Used	Material Used	Comment
Steam coil dryer Fluid bed dryer Flash dryer	Cu and some others	Concentrates	
Rotary Kiln	Most metals for drying. Fuming ZnO. Calcining alumina, Ni and ferro alloys Burning of photographic film for precious metal production. De-oiling Cu and Al scrap	Ores, concentrates and various scrap and residues	Drying, calcining and fuming applications Use as an incinerator.
Fluidised bed.	Copper and zinc Al_2O_3	Concentrates. $Al(OH)_3$	Calcining and roasting.
Up draught sintering machine.	Zinc and lead.	Concentrates and secondary.	Sintering.
Down draught sintering machine	Zinc and lead.	Concentrates and secondary.	Sintering.
Steel Belt sintering machine	Ferro-alloys, Mn, Nb.	Ore.	Other applications possible
Herreshoff	Mercury. Molybdenum (rhenium recovery)	Ores and concentrates.	Roasting, calcining.

Table 2: Smelting and Refining Furnaces Used in Non-Ferrous Metal Production

Furnace	Metals Used	Material Used	Comment
Enclosed refractory lined crucibles	Refractory metals, special ferro-alloys	Metal oxides	
Open Pit	Refractory metals, special ferro-alloys.	Metal oxides	
Baiyin	Copper	Concentrates	
Electric Arc Furnace	Ferro alloys	Concentrates, ore	
Contop/Cyclone	Copper	Concentrates	
Submerged Electric Arc Furnace	Precious metals, copper, ferro alloys.	Slag, secondary materials, concentrates.	For the production of ferro-alloys the open, semi closed and closed types are used.
Rotary	Aluminium, lead, copper, precious metals	Scrap and other secondary, blister copper	Oxidation and reaction with substrate.
Tilting Rotary Furnace	Aluminium	Scrap and other secondary	Minimises salt flux use.
Reverberatory	Aluminium, copper, others	Scrap and other secondary, black copper	Smelting of Cu concentrates elsewhere in the World.
Vanyucov	Copper	Concentrates	
ISA Smelt/Ausmelt	Copper, lead,	Intermediates, concentrates and secondary materials.	
QSL	Lead	Concentrates and secondary	
Kivcet	Lead Copper	Concentrates and secondary	
Noranda	Copper	Concentrates	
El Teniente	Copper	Concentrates	
TBRC TROF	Copper (TBRC), Precious metals	Most secondary inc. slimes	
Mini Smelter	Copper/lead/tin	Scrap	
Blast Furnace and ISF	Lead, lead/zinc, copper, precious metals, high carbon ferro- manganese.	Concentrates, most secondary	For ferro-manganese production it is only used together with energy recovery.
Inco Flash Furnace	Copper, nickel	Concentrates	
Outokumpu Flash Smelter	Copper, nickel	Concentrates	
Mitsubishi process	Copper	Concentrates and anode scrap	
Peirce Smith	Copper (converter), Ferro-alloys, Metal Oxide Production	Matte and anode scrap	
Hoboken	Copper (converter)	Matte and anode scrap	
Outokumpu Flash Converter	Copper (converter)	Matte	
Noranda Converter	Copper (converter)	Matte	
Mitsubishi Converter	Copper (converter)	Matte	

Table 3: Melting Furnaces Used in Non-Ferrous Metal Production

Furnace	Metals Used	Material Used	Comment
Induction	Most	Clean metal and scrap.	Induced stirring assists alloying. Vacuum can be applied for some metals
Electron Beam	Refractory metals	Clean metal and scrap.	
Rotary	Aluminium, lead	Various scrap grades.	Fluxes and salts used for complex matrices.
Reverberatory	Aluminium (primary and secondary)	Various scrap grades.	Bath or hearth configuration can vary. Melting or holding
Contimelt	Copper	Copper anode, clean scrap and blister copper	Integrated furnace system.
Shaft	Copper	Copper cathode and clean scrap.	Reducing conditions.
Drum (Thomas)	Copper	Copper scrap	Melting, fire refining
Heated Crucibles (indirect kettles)	Lead, zinc	Clean scrap.	Melting, refining, alloying.
Direct heated crucibles	Precious metals	Clean metal	Melting, alloying.

3.1 Aluminium Production from Primary and Secondary Raw Materials

3.1.1 Primary Aluminium

Overall there are four main steps in the production of aluminium from primary raw materials. These steps are shown in **Figure 1**.

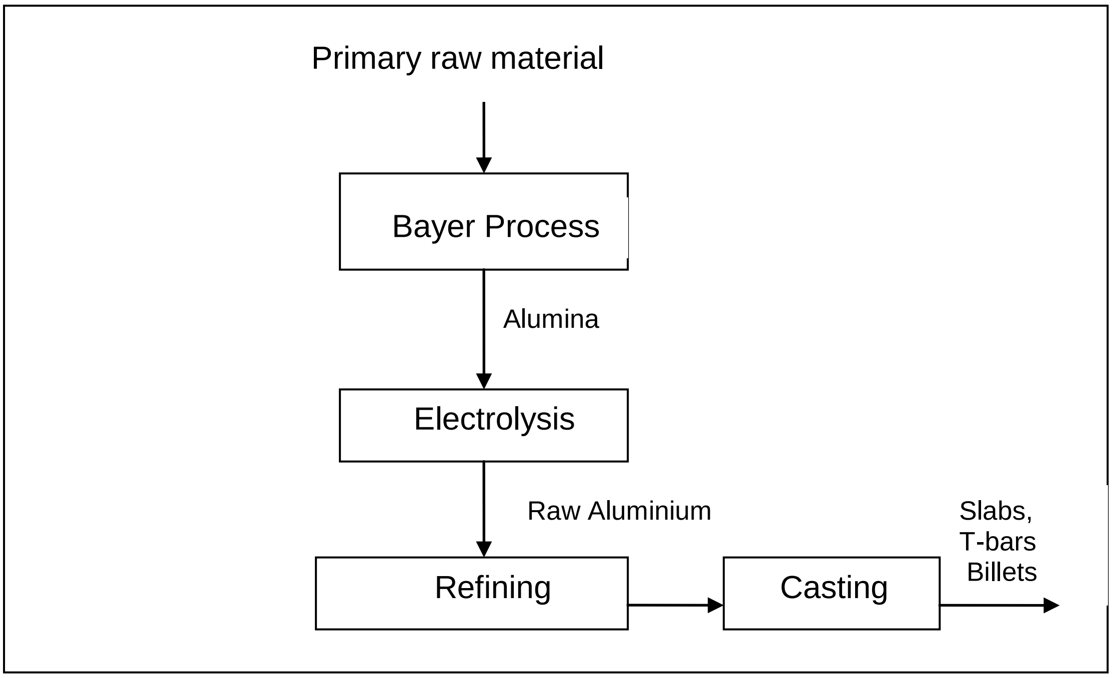
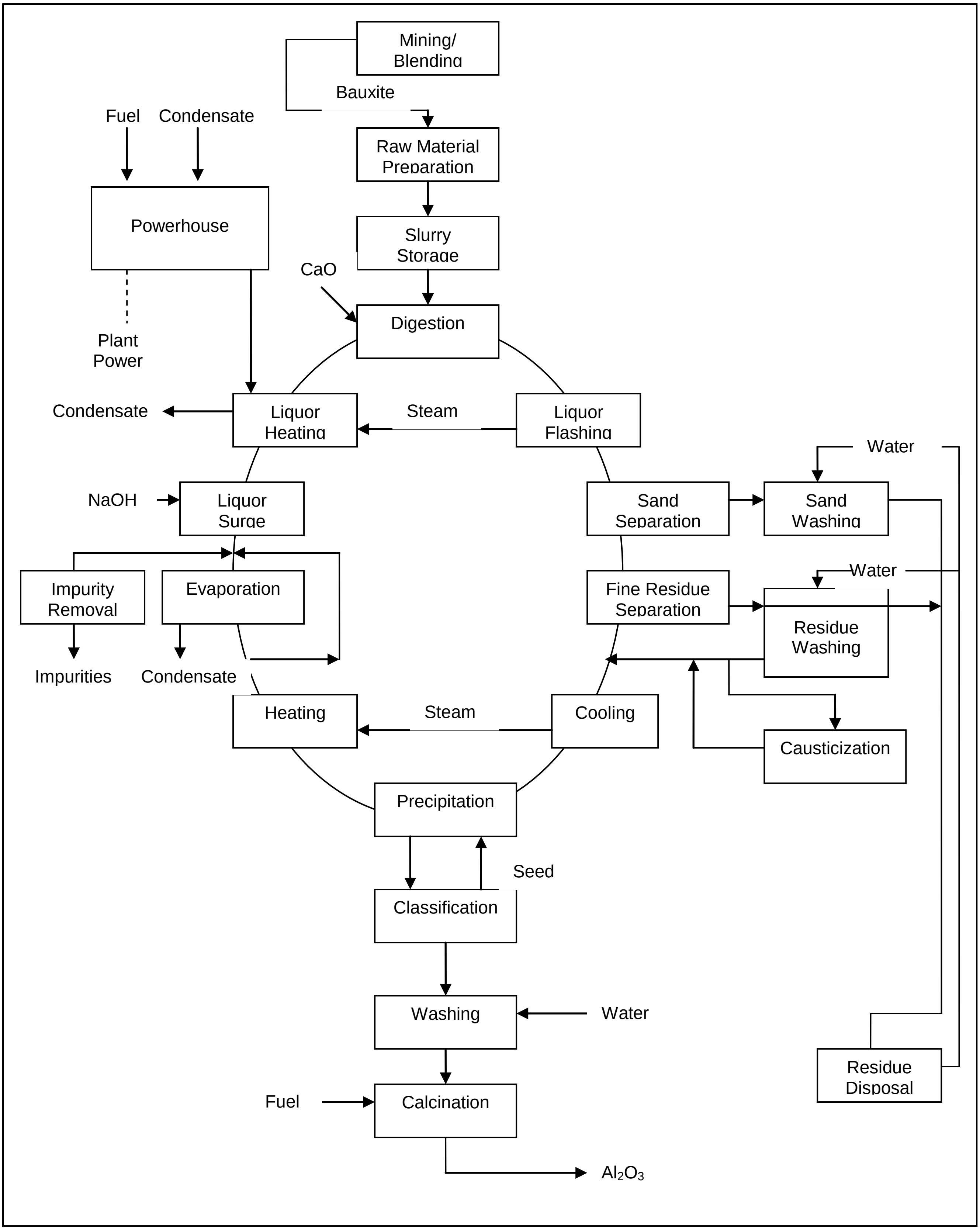


Figure 1: Main Processes in the Production of Aluminium from Primary Raw Materials.

First alumina is produced from bauxite in the well-established Bayer process. This process is normally carried out close to the mine site and in some cases at the same site as an aluminium smelter or at stand alone alumina refineries. The flow sheet of this process is given in **Figure 2**.



Source: Air Pollution Engineering Manual, Anthony J. Buonicore and Wayne T. Davis, ed., Air & Waste Management Association, Van Norstrand Reinhold.

Figure 2: Alumina Production – Bayer Process

The Alumina is then dissolved in a molten bath consisting of mainly sodium aluminium fluoride (cryolite) at a temperature of approximately 960 °C to produce aluminium by electrolysis. The electrolytic cells comprise a carbon cathode, insulated by refractory bricks inside a rectangular steel shell, and a carbon anode suspended from an electrically conductive anode beam. Examples of such cells are given in **Figure 3**.

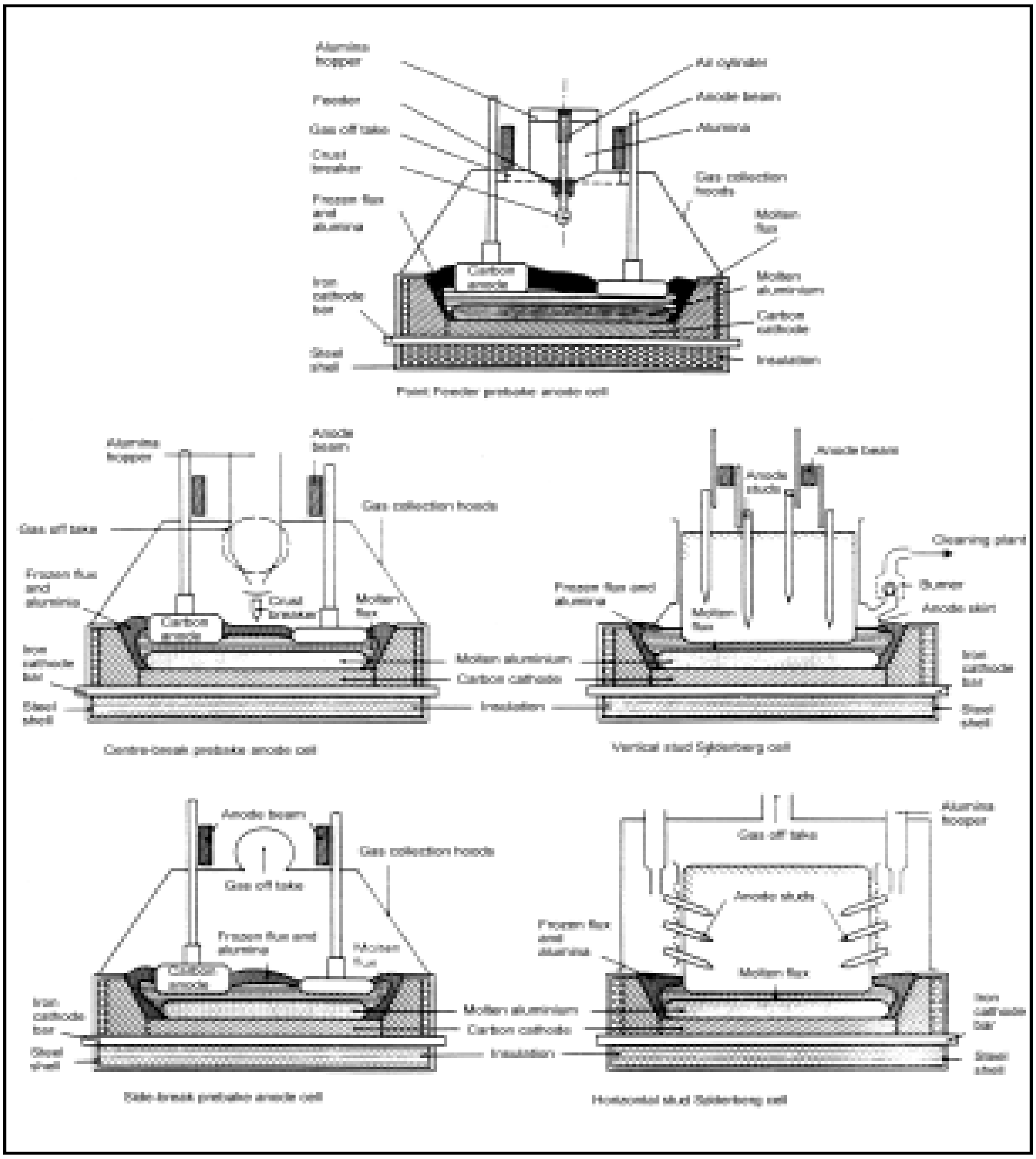


Figure 3: Primary Aluminium Electrolytic Cells

The metal is then sent for refining. The metal is refined at this stage to remove impurities such as sodium, magnesium, calcium oxide particles and hydrogen. This refining stage is performed by the injection of a gas into the molten metal usually in an in-line reactor. The treatment gas used varies depending on the impurities, argon or nitrogen is used to remove hydrogen and mixtures of chlorine and argon or nitrogen is used to remove metallic impurities. Aluminium fluoride is also used to remove magnesium. The metal is then filtered before casting. Finally, Slabs, T-bars or billets are cast in vertical direct chill casting machines that use water-cooled metal moulds and holding table at the bottom part of the moulds.

3.1.2 Secondary Aluminium

The main feature of secondary aluminium production is the diversity of raw materials encountered and the variety of furnaces used. The type of raw material and its pre-treatment is therefore used to judge the best type of furnace to be used for a particular type of scrap with its size, oxide content and degree of contamination among others. Rotary or reverberatory furnaces are used for melting a wide range of secondary raw materials; rotary furnaces can incorporate a tilting mechanism. A generic process is shown in **Figure 4**.

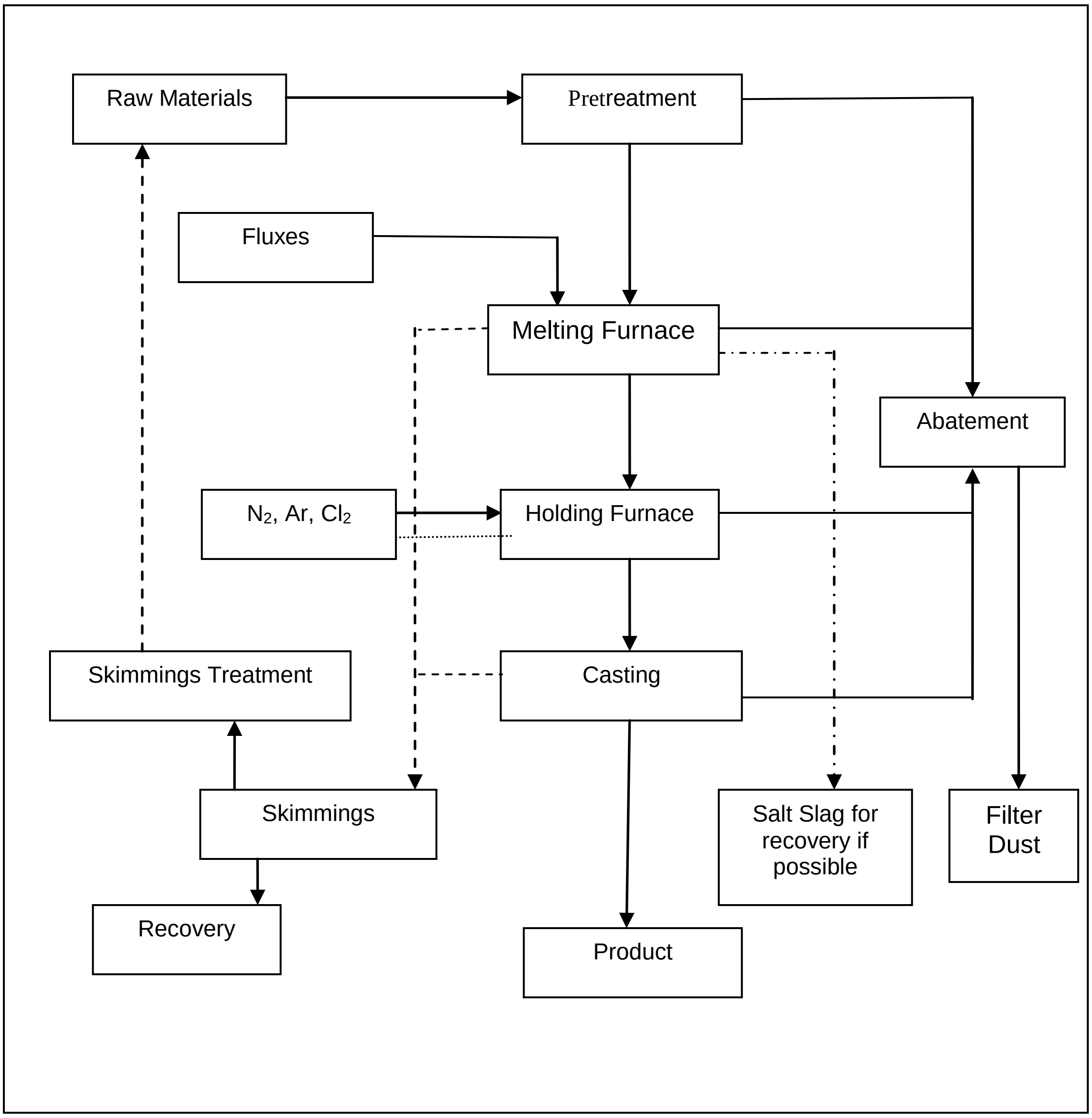


Figure 4: Secondary Aluminium Generic Process

A range of different fluxes is used within the secondary industry to assist in the processing of the metal in a number of ways. An example is the use of fused salt (a mixture of sodium and potassium chlorides and some fluorides) to prevent oxidation and absorb impurities. Furnace gases contain chlorides and HCl produced from the salt. Refractory fluxes and fluorinated fluxes are also used.

3.2 Lead Production from Primary and Secondary Raw Materials

3.2.1 Primary Lead

There are two basic pyrometallurgical processes available for the production of lead from lead sulphide or mixed lead and zinc sulphide concentrates: - sintering/smelting or direct smelting. The processes may also be used for concentrates mixed with secondary raw materials. A typical flow sheet of a smelting plant for lead and zinc is given in **Figure 5**.

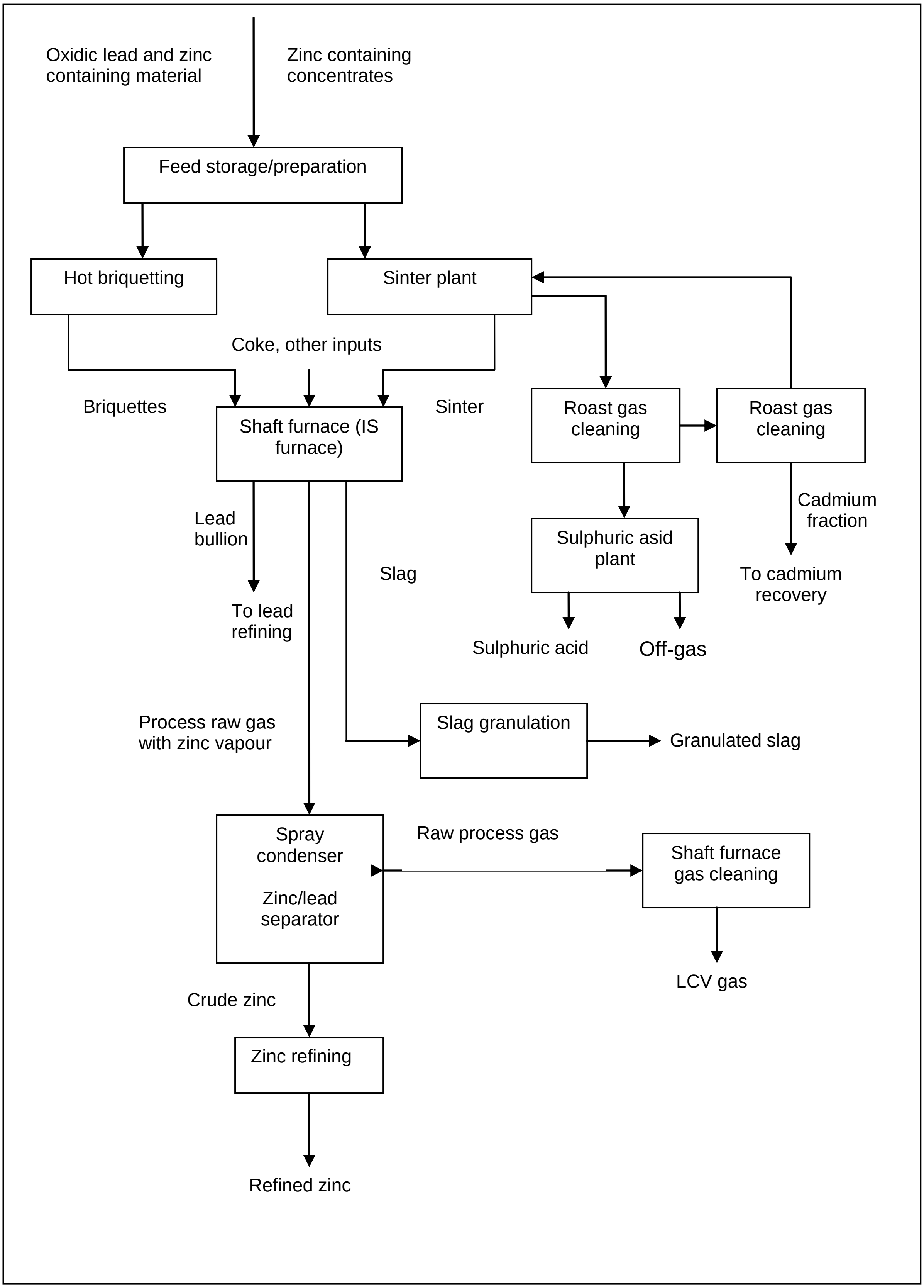


Figure 5: Diagram of a Typical Imperial Smelting Process for Zinc and Lead Production

3.2.2 Secondary Lead

3.2.2.1 The Recovery of Lead from Scrap Batteries

Scrap automotive batteries (automotive, motive power and stand by) are a major source of secondary lead. A typical lead-acid battery scrap can contain up to 30 wt % of lead alloy components. A schematic diagram of lead recovery process is given in **Figure 6**.

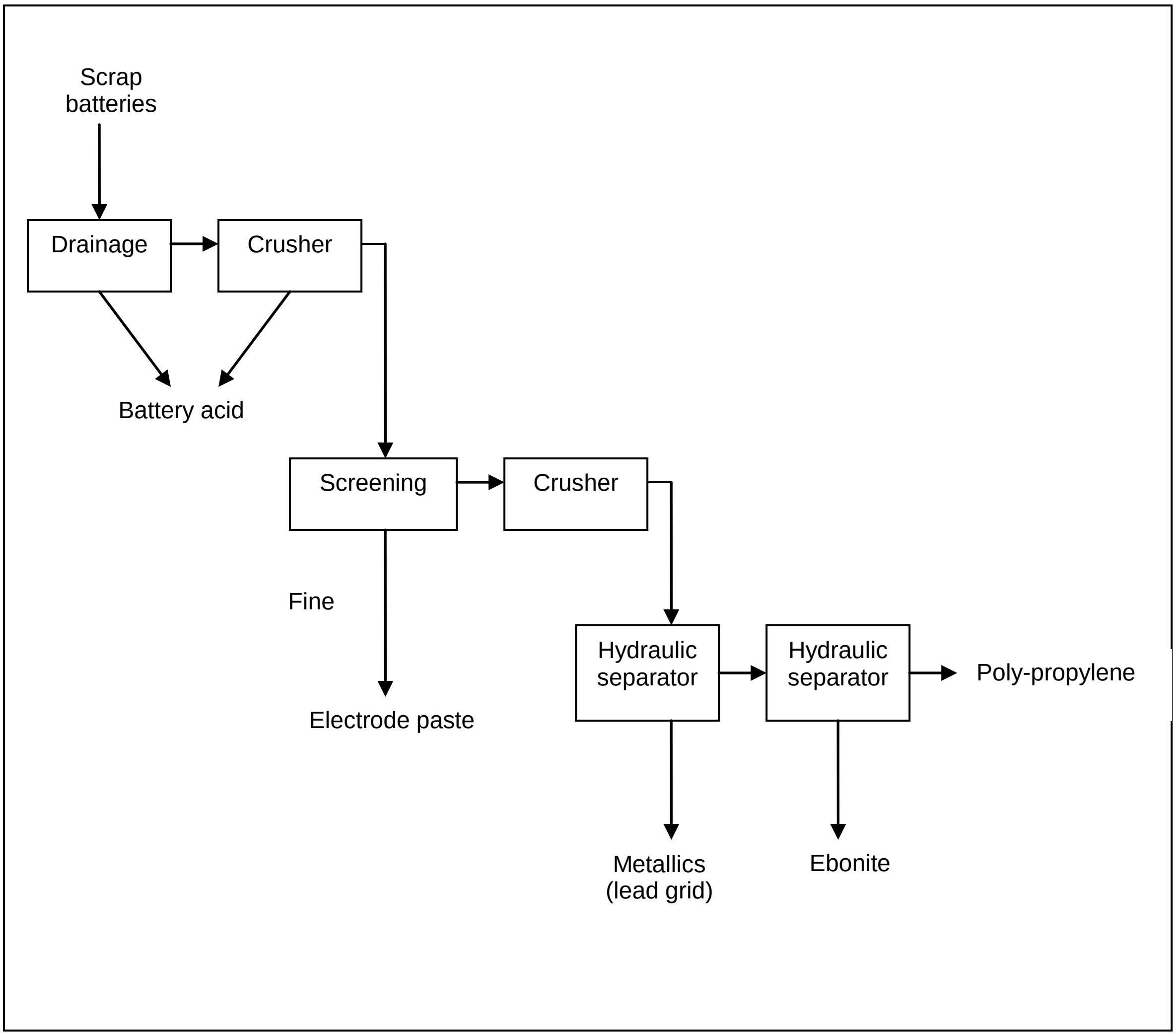


Figure 6: Outline of a Typical Battery Recovery Process

3.2.2 Recovery of Lead from Other Scrap and Residues

Metallic lead scrap may be in a variety of forms, it may be contaminated by plastic material or bitumen and may be alloyed with other elements, notably tin, antimony and silver. Simple melting facilities cannot cope with the partially burnt material in the off-gases. The electric furnace is also used for the recovery of lead from complex lead/copper and lead/precious metals secondary materials. After-burning of the gases is used to destroy CO and hydrocarbons including dioxins. Clean scrap is melted in specially designed kettles, which are indirectly heated by oil or gas.

3.2.3 Refining of Primary and Secondary Lead

Lead bullion may contain varying amounts of copper, silver, bismuth, antimony, arsenic and tin. Lead recovered from secondary sources may contain similar impurities, but generally antimony and calcium dominate. There are two methods of refining crude lead: electrolytic refining and pyrometallurgical refining. Electrolytic refining is very costly. As such a pyrometallurgical process is used. **Figure 7** shows a typical refining process for lead.

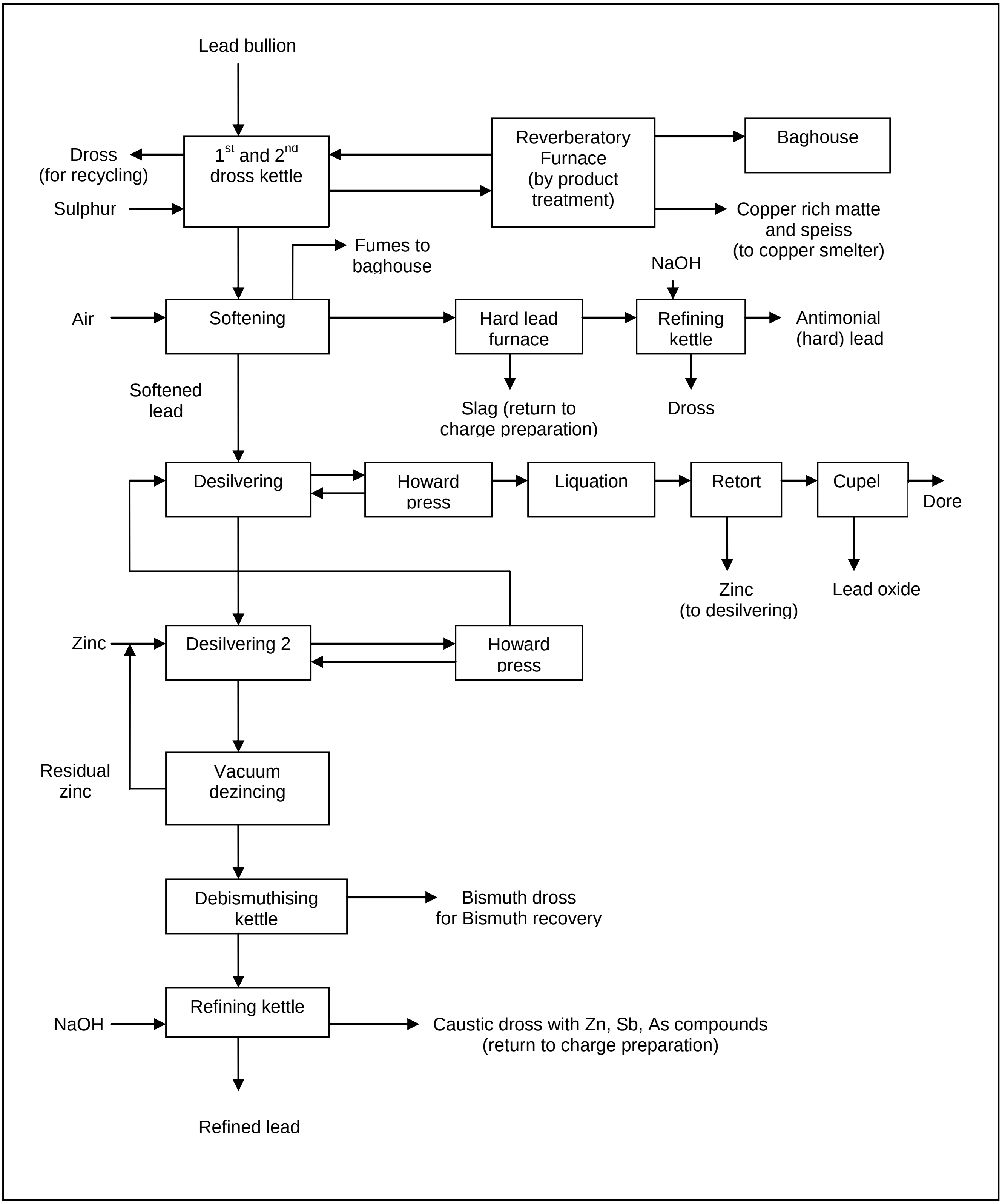


Figure 7: Diagram of Lead Refining Processes

3.3 Zinc Production from Primary and Secondary Raw Materials

3.3.1 Primary Zinc

Zinc can be produced from primary raw materials by pyrometallurgical or hydrometallurgical methods. The pyrometallurgical route is used for mixed zinc/lead concentrates and secondary material and uses the Imperial Smelting Furnace (ISF), which is outlined above in lead production. Zinc produced in the Imperial Smelting Furnace may contain varying amounts of cadmium, lead, copper, arsenic, antimony and iron and the process uses a refining stage. Zinc from the ISF is refined by reflux distillation in columns containing a large number of refractory trays. A schematic diagram of a zinc distillation process is given in **Figure 8.**

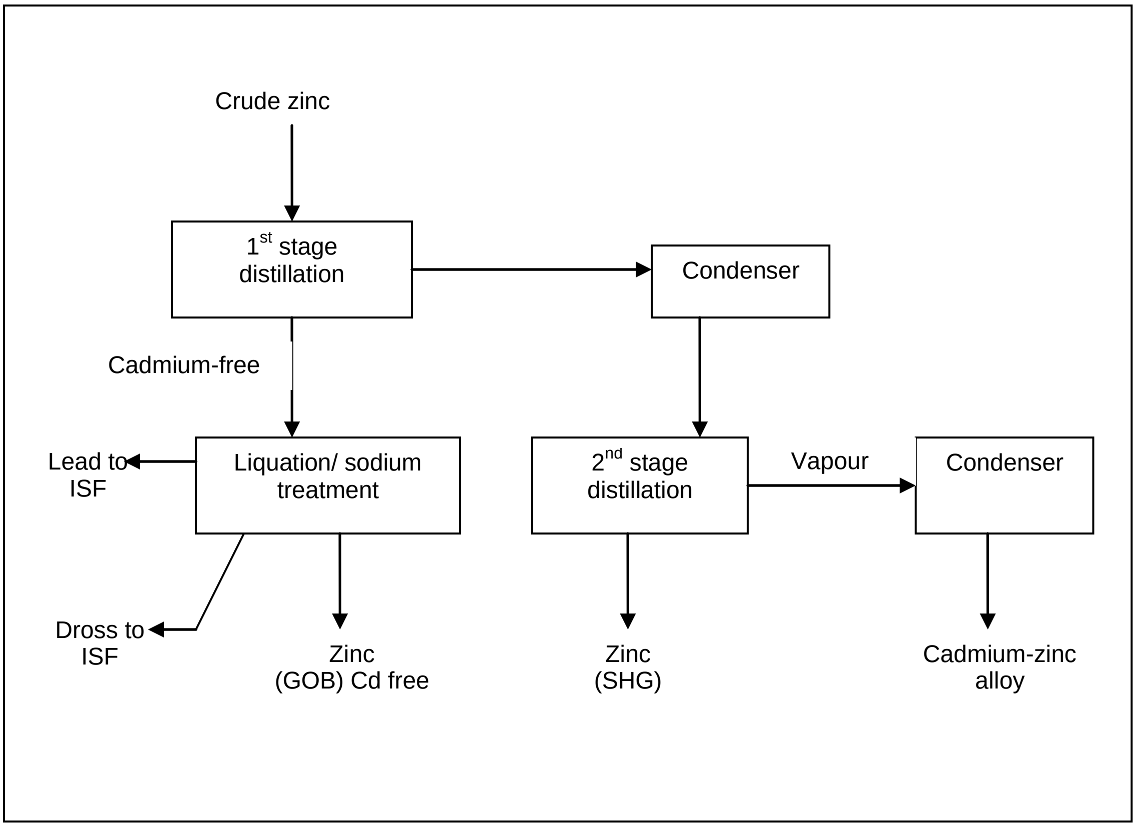


Figure 8: Diagram of Zinc/Cadmium Distillation

The hydrometallurgical route is used for zinc sulphide (blends), oxide, carbonate or silicate concentrates and is responsible for about 80% of the total world output. The diagram of the zinc hydrometallurgical process is given in **Figure 9**.

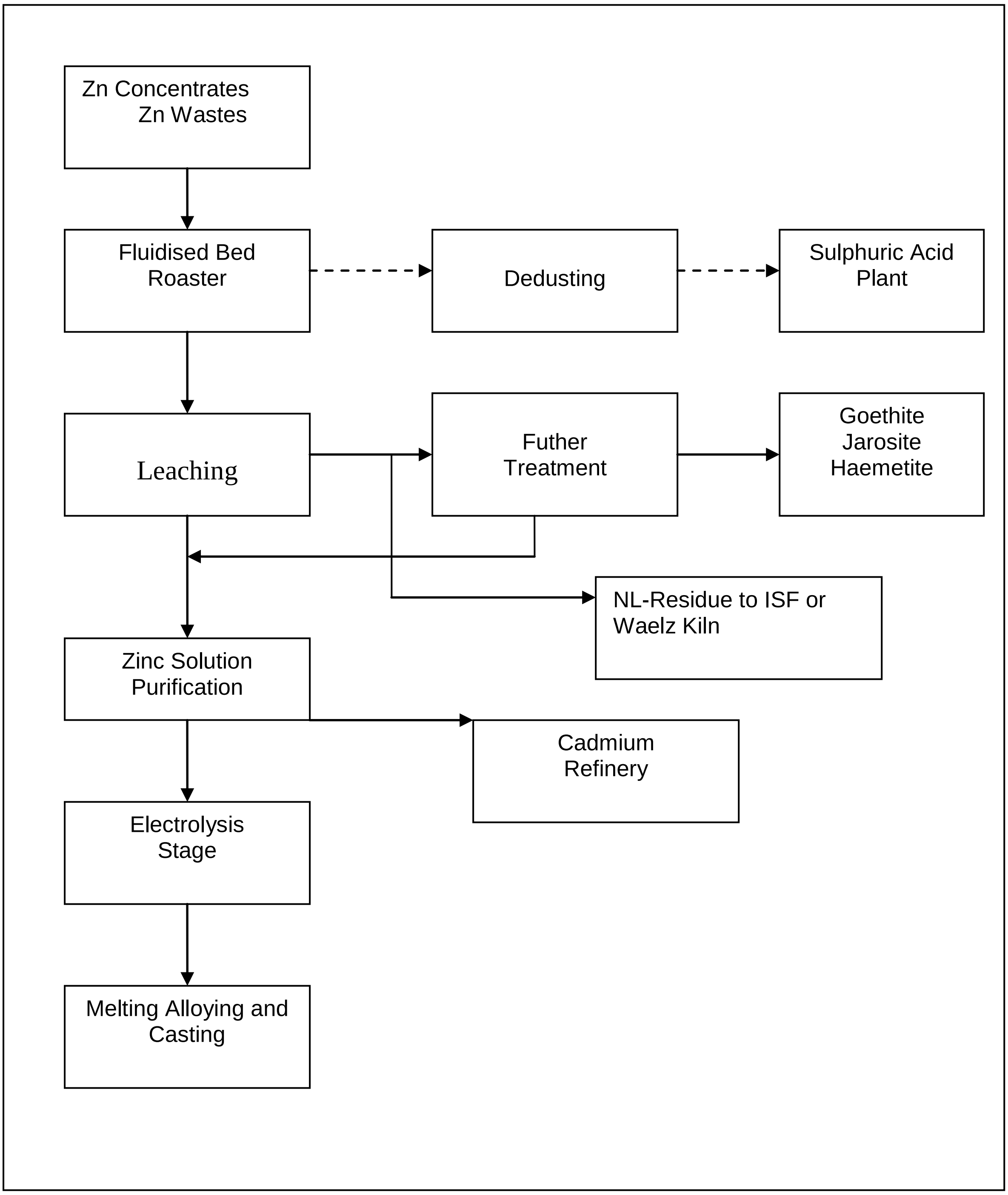


Figure 9: Diagram of the Zinc Hydrometallurgical Process

3.3.2 Secondary Zinc

Residues and scrap, which are relevant and significant to the secondary zinc industry, include: -

- dust from copper alloy making,
- residues from the die casting industry,
- ashes, bottom and top drosses from the galvanising industry,
- old roofing and other sheet materials,
- non-ferrous fraction from the shredding of old cars and of other mainly steel containing
- products,
- dust from electric arc steel making and cast iron making,
- residues from chemical uses of zinc and burnt tires.

The process route used to recover zinc depends on the form and concentration of zinc, and the degree of contamination. A typical process is given in **Figure 10**.

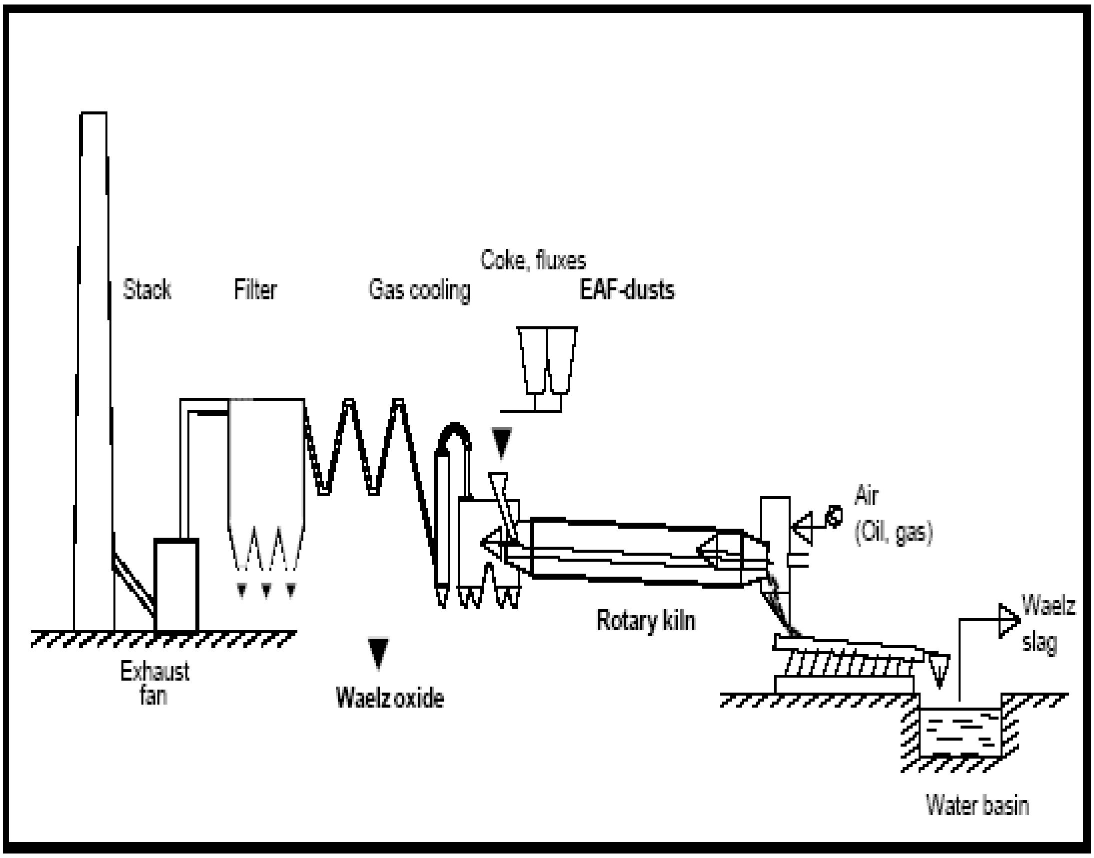


Figure 10: Waelz Kiln

3.4 Processes to Produce Copper From Primary and Secondary Raw Materials

3.4.1 Primary Copper

Primary copper may be produced from primary concentrates and other materials by pyrometallurgical or hydrometallurgical routes. Schematic diagram of primary copper production route is given in **Figure 11**.

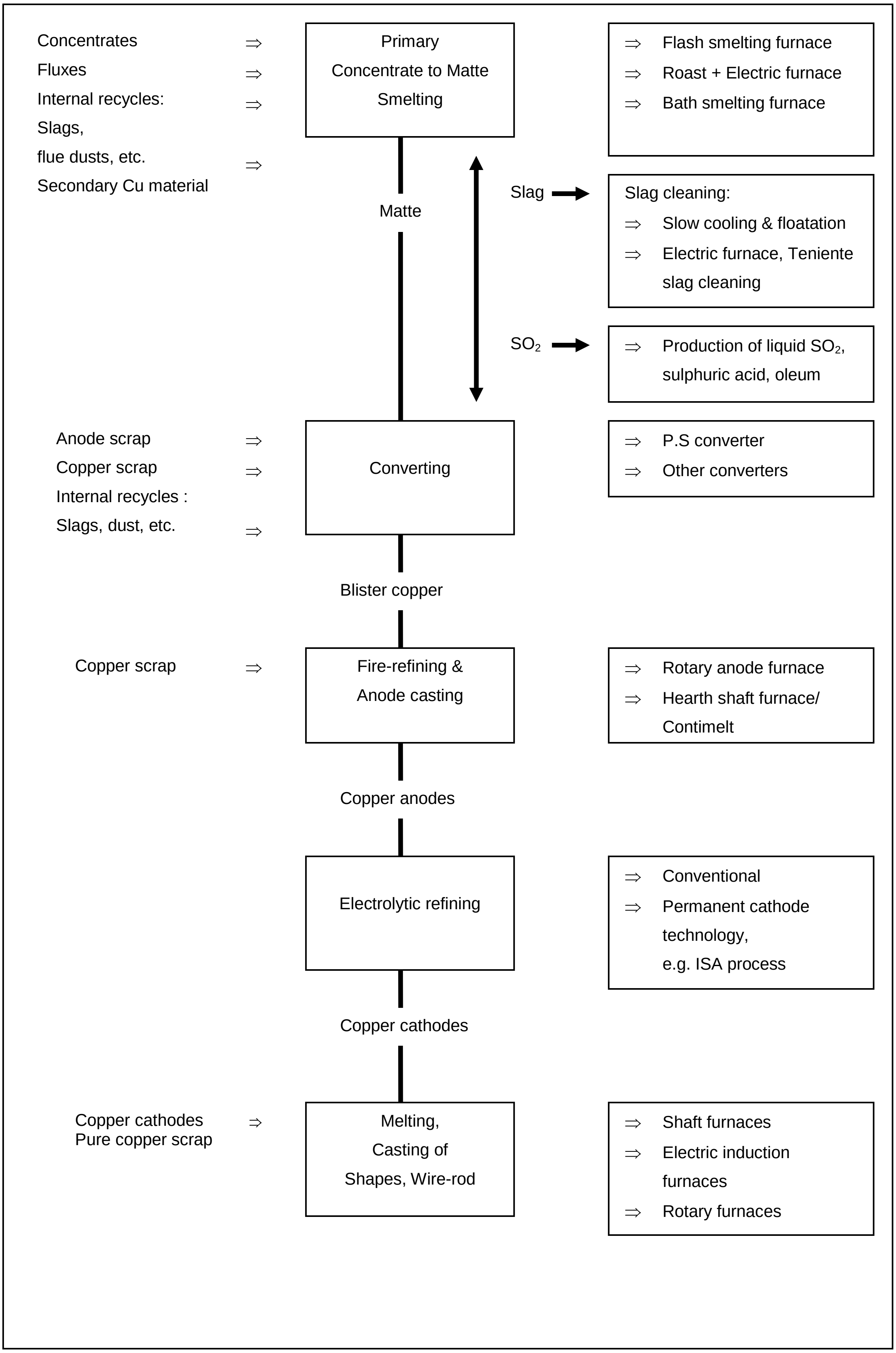


Figure 11: Primary Copper Production Route

3.4.2 Secondary Copper

Secondary copper is produced by pyro-metallurgical processes as shown in **Figure 12**.

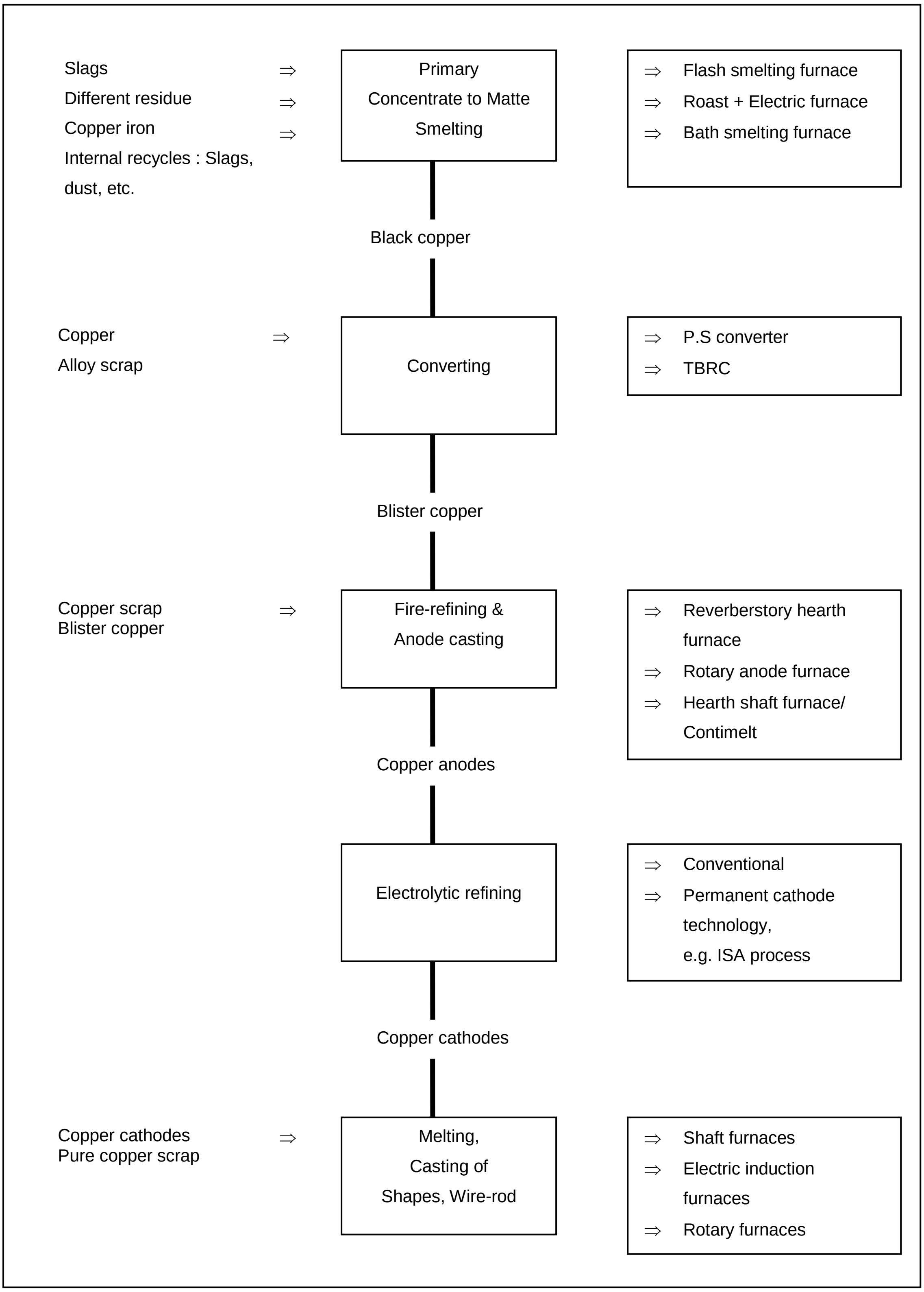


Figure 12: Generic Flow Sheet for Secondary Copper Production

4.0 PROCESS CONTROL AND OPTIMIZATION

Process control techniques that are designed to measure and maintain optimum parameters such as temperature, pressure, gas components and other critical process parameters etc are considered to be BAT.

Sampling and analysis of raw materials to control plant conditions. Good mixing of different feed materials should be achieved to get optimum conversion efficiency and reduce emissions and rejects.

The use of feed weighing and metering systems, the use of microprocessors to control material feed-rate, critical process and combustion conditions and gas additions allow process operation to be optimised. Several parameters can be measured to allow this and alarms provided for critical parameters, which include:

- On-line monitoring of temperature, furnace pressure (or depression) and gas volume or flow.
- Monitoring of gaseous components (O_2, SO_2, CO, dust, NO_x etc).
- On-line monitoring of vibration to detect blockages and possible equipment failure.
- On-line monitoring of the current and voltage of electrolytic processes.
- On-line monitoring of emissions to control critical process parameters.
- Monitoring and control of the temperature of melting furnaces to prevent the production of metal and metal oxide fume by overheating.

Operators, engineers and others should be continuously trained and assessed in the use of operating instructions, the use of the modern control techniques and the significance of alarms and the actions to be taken when alarms are given.

5.0 SOURCES OF AIR POLLUTANT EMISSIONS

Emissions to air arise from the storage, handling, pre-treatment, pyro-metallurgical and hydrometallurgical stages. Transfer of materials is particularly important. Fugitive emissions can be much greater than those that are captured and abated. Potential fugitive emissions must be considered at all stages of process design and development. The potential sources of emissions to air are as follows:

5.1 Aluminium production

5.1.1 Primary Aluminium

5.1.1.1 Bauxite Production Facilities

At the bauxite production facilities, dust is emitted to the atmosphere from dryers and materials-handling equipment, through vehicular movement, and from blasting. The dust can be a nuisance if containment systems are not in place, especially on the dryers and handling equipment. Other air emissions could include nitrogen oxides (NO_x), sulfur dioxide (SO_2), and other products of combustion from the bauxite dryers.

5.1.1.2 Alumina Plant

At the alumina plant, air emissions can include bauxite dust from handling and processing; limestone dust from limestone handling, burnt lime dust from conveyors and bins, alumina dust from materials handling, red mud dust and sodium salts from red mud stacks (impoundments), caustic aerosols from cooling towers, and products of combustion such as sulfur dioxide and nitrogen oxides from boilers, calciners, mobile equipment, and kilns. The calciners may also emit alumina dust and the kilns, burnt lime dust.

5.1.1.3 Smelter Plants

In the aluminum smelter, air emissions include alumina dust from handling facilities; coke dust from coke handling; gaseous and particulate fluorides; sulfur and carbon dioxides and various dusts from the electrolytic reduction cells; gaseous and particulate fluorides; sulfur dioxide; tar vapor and carbon particulates from the baking furnace; coke dust, tars, and poly~~nuclear~~ aromatic hydrocarbons (PAHs) from the green carbon and anode-forming plant; carbon dust from the rodding room; and fluxing emissions and carbon oxides from smelting, anode production, casting, and finishing. The electrolytic reduction cells (pot line) are the major source of the air emissions, with the gaseous and particulate fluorides being of prime concern. The anode effect associated with electrolysis also results in emissions of carbon tetrafluoride (CF_4) and carbon hexafluoride (C_2F_6), which are greenhouse gases, of concern because of their potential for global warming.

A summary of the relevance of the main air pollutants and their emission sources is given in **Table 4**.

Table 4: Significance of Potential Emissions from Primary Aluminium

Component	Flue gases from electrolysis cells	Pot room ventilation (smelting)	Refining
Fluorides – gaseous and total F	•	•••	• (chlorides)
PFCs	•••	•	
Tars and PAHs	•**	••**	
SO_2 (without scrubbers)* and COS	••*		•
Carbon dioxide	••		
Dust	•	•	•

Note. * Wet scrubbers are generally used after dry scrubbing in Scandinavia to remove SO_2 and are usually associated with the use of seawater as the scrubbing medium.

** Tars and PAHs are relevant to Søderberg processes and pre-bake processes that have an integrated electrode production process. They can also be relevant for the small number of plants using paste for anode pin connection protection collars.

••• More significant……………• less significant

5.1.2 Secondary Aluminium

There are potential emissions to air of dust, metal compounds, chlorides, HCl and products of poor combustion such as dioxins and other organic compounds from the melting and treatment furnaces. The formation of dioxins in the combustion zone and in the cooling part of the off-gas treatment system (de-novo synthesis) may be possible. The emissions can escape the process either as stack emissions or as fugitive emissions depending on the age of the plant and the used technology. **Table 5** gives a summary of significant emission to air from secondary production of aluminium.

Table 5: Significance of Potential Emissions to Air from Secondary Production of Aluminium.

Component	Pre Treatment	Melting	Refining and de-gassing
HCl, HF and chlorides	•	••	•••
Metals and compounds	••	••	••
Oxides of nitrogen	•	••	• (combustion gases)
SO_2	• (with suitable fuel)	• (with suitable fuel)	• (combustion gases)
Organic compounds (VOC, dioxins)	•••	•••	
Dust	•••	•••	••
Note. ••• More significant……………• less significant			

5.2 Lead and Zinc Production

The principal air pollutants emitted from the processes are particulate matter and sulfur dioxide. Fugitive emissions occur at furnace openings and from launders, casting molds, and ladles carrying molten materials, which release sulfur dioxide and volatile substances into the working environment. Additional fugitive particulate emissions occur from materials handling and transport of ores and concentrates. Some vapors are produced in hydrometallurgy and in various refining processes. The principal constituents of the particulate matter are lead/zinc and iron oxides, but oxides of metals such as arsenic, antimony, cadmium, copper, and mercury are also present, along with metallic sulfates. Dust from raw materials handling contains metals, mainly in sulfidic form, although chlorides, fluorides, and metals in other chemical forms may be present. Off-gases contain fine dust particles and volatile impurities such as arsenic, fluorine, and mercury.

The emissions can escape the process either as stack emissions or as fugitive emissions depending on the age of the plant and the technology used. Stack emissions are normally monitored continuously or periodically and reported.

The main emissions to air from zinc and lead production are: -

- sulphur dioxide (SO_2), other sulphur compounds and acid mists;
- oxides of nitrogen (NO_x) and other nitrogen compounds;
- metals and their compounds;
- dust.
- VOCs and dioxins.

Table 6 gives the potential emissions to air from lead and zinc production.

Table 6: Significance of Potential Emissions to Air from Lead and Zinc Production

Component	Roasting sintering smelting	Leaching and purification	Electrolysis	Battery Breaking	Casting etc.	Sulphuric acid plant
Sulphur oxides	••*	•	•• (acid mist)	•	•	•••
Nitrogen oxides	•*				•	•
Dust and metals	•••*	•	•	•••	•••	
VOC and dioxins	•(••)**				•*	
Note. ••• more significant …………………..• less significant.						
*The direct emissions from the roasting or smelting stages are treated and/or converted in the gas cleaning steps and sulphuric acid plant; the remaining emissions of sulphur dioxide and nitrogen oxides of the sulphuric acid plant are still relevant. Fugitive or non-captured emissions are also relevant from these sources. Secondary smelting of battery paste is a source of SO_2. ** Dioxins and VOC may be present if secondary materials are used that contain dioxins or are contaminated with organic materials. VOCs may also be present during solvent extraction processes used for the production of Ga, Ge etc.						

5.3 Copper Production

The potential sources and emissions such as dust, metal compounds, organic carbon (which can result in the formation of dioxins) and sulphur dioxide are summarized in **Table 7.**

Table 7: Significance of Potential Emissions to Air from Copper Production

Emission Source	Dust And Metal Compounds	Dioxins	Organic Carbon	Sulphur Compounds
Material Handling	••			
Storage	•			
Drying	•••		•	•
Scrap Treatment	••	••• (secondary)	••• (secondary)	
Smelting	•••	••• (secondary)	•(secondary)	••• (Treated in a recovery plant)
Converting	••	• (secondary)	• (secondary)	••• (Treated in a recovery plant)
Refining	••	• (secondary)	• (secondary)	•
Melting/Casting	• (•• for alloys)		• (secondary) + CO	
Ladle Transfers	•••			•
Electrolysis				
Slag Treatment	••		•CO	

6.0 EMISSION CONTROL OPTIONS

Abatement of dust emissions, in particular fugitive dust, is of major importance for this sector. Details on dust control options are given in **Table 8**.

Table 8: Overview of Dust Abatement Techniques

Abatement Type	Advantages	Disadvantages	Associated emission mg/Nm^3	Reason for choice
Fabric Filters	Most with good sealing and modern fabrics.	Clogging, fires, sealing.	1 - 5	Performance for suitable dusts if well monitored. Potential to recycle dust to process.
Wet Electrostatic Precipitator	Improved performance for wet gases	Wire breakage & shorting.	< 5 Optically clear	Performance for suitable dusts, low pressure-drop but effluent produced.
Electrostatic Precipitator	Most with good control systems and gas distribution.	Variation in particles, wire breakage & shorting	5 - 10 (< 50 as pre-abatement)	Low pressure-drop, reliable, Low maintenance.
Wet Scrubbers	Only some dusts are suitable. Cleaning fuel gases or gases for acid plant.	Lower performance & blockages	< 20	Pre-cleaning of gases prior to other methods. Removal of acid gases and mists.
Ceramic Filters	Higher temperature operation.	Fragility, clogging & sealing.	< 1	Dust must be suitable. Housing material limits upper temperature
Cyclones	Pre-abatement	Poor performance. Limited efficiency for fine particles	< 50	Pre-cleaning of gases prior to other methods.
Emissions are given as daily averages based on continuous monitoring during the operating period.				

Fugitive emissions can be highly significant, therefore if fugitive emissions cannot be prevented or minimised to an acceptable level, secondary fume collection systems can be used. Some furnaces can be equipped with secondary hoods in order to prevent fugitive emissions during charging or tapping as described above. The fan suction is provided directly at the source of fume to optimise the reduction of fugitive emissions. Alternatively, the air could be extracted at the roof ventilator, but a large volume of air would have to be handled which might not be cleaned effectively in a fabric filter. Other disadvantages are high energy consumption, high investment, more waste (used filter media). Secondary fume collection systems are designed for specific cases. Energy use can be minimised by automatically controlling the point of extraction using dampers and fan controls so that the systems are deployed when and where they are needed, for example during charging or during “roll out” of a converter.

The BAT for the treatment and abatement of main air emissions from non-ferrous production plants are summarized in **Table 9**.

Table 9: Summary of Sources and Treatment/Abatement Options

Process stage	Component in off-gas	Mitigation
Materials handling and storage.	Dust and metals.	Correct storage, handling and transfer. Dust collection and fabric filter if necessary.
Grinding, drying.	Dust and metals.	Process operation. Gas collection and fabric filter.
Sintering/roasting Smelting Converting Fire refining	VOCs, dioxins. Dust and metal compounds. Carbon monoxide Sulphur dioxide	Afterburner, adsorbent or activated carbon addition. Gas collection, gas cleaning in fabric filter, heat recovery. Afterburner if necessary sulphuric acid plant (for sulphidic ores) or scrubber
Slag treatment.	Dust and metals. Sulphur dioxide. Carbon monoxide.	Gas collection, cooling and fabric filter. Scrubber. Afterburner
Leaching and chemical refining.	Chlorine.	Gas collection and re-use, wet chemical scrubber.
Carbonyl refining.	Carbon monoxide. Hydrogen.	Sealed process, recovery and re-use. Afterburner and dust removal in fabric filter for tail gas.
Solvent extraction.	VOC. (depends on the solvent used and should be determined locally to assess the possible hazard).	Containment, gas collection, solvent recovery. Carbon adsorption if necessary.
Thermal refining.	Dust and metals. Sulphur dioxide.	Gas collection and fabric filter. Scrubber if necessary.
Molten salt electrolysis	Fluoride, chlorine, PFCs	Process operation. Gas collection, scrubber (alumina) and fabric filter.
Electrode baking, graphitisation	Dust, metals, SO_2, Fluoride, PAHs, tars	Gas collection, condenser and EP, afterburner or alumina scrubber and fabric filter. Scrubber if necessary for SO_2.
Metal powder production	Dust and metals	Gas collection and fabric filter.
Powder production	Dust, Ammonia	Gas collection and recovery. Acid medium scrubber.

High temperature reduction	Hydrogen.	Sealed process, re-use.
Electro-winning.	Chlorine. Acid mist.	Gas collection and re-use. Wet scrubber. De-mister.
Melting and casting.	Dust and metals. VOCs, dioxins (organic feed)	Gas collection and fabric filter. Afterburner (Carbon injection)
Note. Dust arrestment using a fabric filter may require the removal of hot particles to prevent fires. Hot electrostatic precipitators would be used in a gas cleaning system prior to a sulphuric acid plant or for wet gases.		

Best available techniques for the different non-ferrous sectors are given in **Table 10** to **Table 19**.

Table 10: Summary of Handling and Storage Techniques for Aluminium

Material	Storage	Handling	Pre-treatment	Comment
Fuel and other oils	Tanks or drums in bunded areas	Secure pipeline or manual systems	Heated storage and pipelines	Back venting of displaced gases
Fluxes and salt.	Enclosed (Silo) if dust forming	Enclosed conveyors with dust collection		
Fine dust (Skimmings) etc.	Enclosed if dust forming.	Enclosed with dust collection.	Milling and Density separation.	
Swarf	Covered bays if soluble or emulsified oil.	Mechanical loader.	Swarf dryer. Centrifuging	Oil collection if necessary
Coarse dust	Open or covered bays	Mechanical loader.	Swarf dryer if necessary.	Oil collection if necessary
Lump (raw material or slag).	Open	Mechanical loader.		Oil collection if necessary
Whole items, foils and sheets.	Open or covered bays	Mechanical loader.		Oil collection if necessary
Chlorine gas or mixturescontaining chlorine	Approved pressure vessels	Approved methods		
Products – Slab, billets, sheets and ingots	Open storage.		Pre-heating	
Process residues for recovery e.g. skimmings, salt slag and linings	Covered or enclosed depending on dust formation.	Depends on conditions.	Separation by milling and/or dissolution. - Potentially very dusty.	Skimmings and salt slag need to be kept dry. Appropriate drainage system.
Wastes for disposal.	Covered or enclosed bays or covered	Depends on conditions.		Appropriate drainage system.

	containers for transport depending on the material.			

Table 11: Process Stages Considered as Best Available Techniques for Primary Aluminium Production.

Process Stage	Technique	Comments
Production of alumina	Bayer process	Optimised to reduce energy, remove dust and reuse red mud transport water.
Refining	Use of mixtures of chlorine and argon/nitrogen or salt flux (AlF_3).	Addition via an inline cell for Cl_2, Ar, N_2 injection.

Table 12: Furnaces Considered Being BAT for Secondary Aluminium Production

Furnace	Gas Collection	Advantages	Disadvantages	Comments
Reverberatory furnace.	Semi sealed	Large metal capacity	Lower efficiency, restricted feed-stock	Use of sealed charging system (charging car)
Reverberatory furnace with side-well or charging well.	Semi sealed	Charging well allows efficient recovery of fine material. Larger range of feed material	Lower thermal efficiency	Use of sealed charging system (charging car)
Rotary Furnace	Semi sealed	No feedstock restrictions. Good thermal efficiency	Relatively high usage of salt slag.	Targeted fume extraction
Tilting rotary furnace	Semi sealed	Efficient for low grade feed including skimmings. Good thermal efficiency	Restricted metal capacity	Minimum use of salt flux compared to fixed rotary furnace.
Induction Furnace	Open, hooded	No combustion gases	Restricted metal capacity and feedstock	Useful for small loads of clean metal
Shaft furnace (Meltower)	Semi sealed	Charge preheating		For clean metal

Table 13: Other Process Stages Considered as Best Available Techniques for Secondary Aluminium Production

Process Stage	Technique	Comments
Refining	Use of mixtures of chlorine and argon/nitrogen or salt flux (AlF_3).	Inert cover gas or dross press
Skimmings treatment.	Inert cover gas and cooling in a sealed drum or dross press	Ammonia formation if wet.
Holding or degassing.	Fume collection from furnaces and launders, cooling, fabric filter if necessary	

Table 14: Abatement Applications Considered as Best Available Techniques for Primary Aluminium Production

Processing Stage	Fume collection	Fabric Filter	PAH removal	VOC removal
Raw Materials	√ (if dusty)	√ (if dusty)		
Primary Smelting	√	√ (with dry alumina scrubber)	√	
Integrated anode plant	√	√	√	√
Alumina production	√	√ (or ESP)		
Holding and degassing	√	√		

Table 15: Abatement Applications Considered as Best Available Techniques for Secondary Aluminium Production

Processing Stage	Fume collection	After burning	Filter	Acid gas removal	VOC removal
Raw Materials	• (if dusty)		• (if dusty)		
Secondary Smelting	•	• (if needed)	•	• (if needed)	• (if needed)
Swarf drying and de-coating	• (if needed)	• (if needed)	• (if needed)	• (if needed)	• (if needed)
Holding and de-gassing	• (if needed)		• (if needed)		
Salt Slag or Skimmings Treatment	•	• (for hydrogen, phosphine	•		

		etc)			

Table 16: Summary of Abatement Options for Components in the Off-Gas for the Production of Lead and Zinc.

Process Stage	Component In Off - gas	Abatement option
Raw Materials Handling	Dust and metals	Correct storage Dust collection and fabric filter
Raw Materials Pre-treatment (mechanical de-coating/stripping) (thermal de-coating)	Dust and metals Organic material*	Correct pre-treatment Gas collection and fabric filter Process operation, after-burning, carbon injection and correct gas cooling.
Primary Roasting and Smelting. Sintering	Dust, metals and sulphur dioxide. Hg	Process operation, gas collection, gas cleaning (dry and wet EP etc), cooling and sulphuric acid plant.
ISF	CO, metal vapour	Wet scrubbing (to cool gas) prior to use as LCV gas.
Slag granulation	Steam, dust, H_2S, SO_2,	Wet ESP, scrubber
Secondary Smelting	Dust and metals Organic material* Sulphur dioxide**	Process operation and gas collection, cooling and fabric filter. Process operation, after-burning, carbon injection and correct gas cooling. Scrubbing if necessary.
Chemical refining	Mist and metals (As, Sb)	Process operation and gas collection with oxidising scrubber.
Solvent extraction	VOC and Odour	Containment, Condenser. Carbon or bio filter if necessary.
Electro-winning	Acid mists	Gas collection and scrubbing/ de-misting.
Thermal refining	Dust and metals Sulphur dioxide**	Process operation. Gas collection, cooling and fabric filter. Scrubbing if necessary.
Melting, alloying, casting and dust production.	Dust and metals Organic material*	Process operation. Gas collection cooling and fabric filter. Process operation, after-burning, carbon injection and correct gas cooling.
Slag fuming and Waelz kiln processes	Dust and metals Organic material*	Process operation. Gas collection, cooling and fabric filter or wet EP if wet quenching is used. Process operation, after-burning, carbon injection or carbon injection and correct gas cooling.

Note. * Organic materials include VOC reported as total carbon (excluding CO), dioxins and CO, the exact content depends on the organic content of the raw materials used.
** Sulphur dioxide may be present if sulphur containing raw materials (e.g. battery paste) or fuels are used and sulphur is not fixed in a slag or matte.

Table 17: Emissions from Chemical Refining, Electro-Winning and Solvent Extraction for Lead and Zinc Production.

Pollutant	Range associated with the use of BAT	Techniques that can be used to reach these levels	Comments
Acid mists	< 50 mg/Nm³	Demister Wet alkaline scrubber.	A de-mister will allow the collected acid to be reused.
Arsine, stibine	< 0.5 mg/Nm³	Oxidising scrubber	
VOC or solvents as C	< 5 mg/Nm³	Containment, condenser, carbon or bio filter	
Note. Collected emissions only. Associated emissions are given as daily averages based on continuous monitoring during the operating period. In cases where continuous monitoring is not practicable the value will be the average over the sampling period. For the abatement system used, the characteristics of the gas and dust will be taken into account in the design of the system and the correct operating temperature used.			

Table 18: Summary of Handling and Storage Techniques for Copper Production

Raw Material	Storage	Handling	Pre-treatment	Comment
Coal or Coke.	Covered Bays, Silos.	Covered conveyors if non-dusty. Pneumatic.		
Fuel and other oils.	Tanks or drums in bunded areas.	Secure pipeline or manual system		
Fluxes. If dust forming	Open on concrete or similar, floors. Enclosed (Silo) if required	Enclosed conveyors with dust collection. Pneumatic.	Blending with concentrates or other material.	
Concentrates.	Enclosed unless non-dust forming.	Enclosed with dust collection. Pneumatic.	Blending using conveyors. Drying.	
Copper Products – Cathodes, wire-rod, copper billets and cakes.	Open concrete area or covered storage.			
Fine dust.	Enclosed.	Enclosed with dust collection. Pneumatic.	Blending, Agglomeration.	
Coarse dust (raw material or granulated slag)	Covered Bays	Mechanical loader.	De-oiling if necessary	Oil collection if necessary

Lump (raw material or slag).	Open	Mechanical loader.		Oil collection if necessary
Whole Items	Open or Covered Bays	Mechanical loader.		Oil collection if necessary
Swarf	Covered storage	Charge skips	Swarf drying or de-oiling.	Oil collection if necessary
Cable.	Open	Mechanical loader	De-coating.	
Circuit Boards.	Covered Bays	Mechanical loader.	Grinding + density separation.	Plastic content may provide heat input
Process residues for recovery.	Open, covered or enclosed depending on dust formation.	Depends on conditions.		Appropriate drainage system
Wastes for Disposal. (e.g. furnace linings)	Open covered or enclosed bays or sealed (drums)	Depends on conditions.		Appropriate drainage system.

Source: European BAT Reference Document

Table 19: Summary of the Abatement Methods for Components in Off-Gases for Copper Production.

Process Stage.	Component in Off – gas.	Abatement option.
Raw Materials Handling	Dust and metals.	Correct storage, handling and transfer. Dust collection and fabric filter
Raw materials thermal pre-treatment	Dust and metals. Organic material* and carbon monoxide.	Correct pre-treatment. Gas collection and fabric filter. Process operation, after-burning and correct gas cooling.
Primary Smelting	Dust and metals. Sulphur dioxide. Mercury	Process operation and gas collection, gas cleaning followed by gas cooling/final cleaning and sulphuric acid plant or sulphur dioxide recovery (normally followed by sulphuric acid plant). If high in feed: removal after SO_2 gas cleaning.
Secondary Smelting	Dust and metals. Organic material* and carbon monoxide. Sulphur dioxide. **	Process operation and gas collection, cooling and cleaning by fabric filter Process operation, after-burning if necessary and correct gas cooling. Scrubbing if necessary.
Primary Converting	Dust and metals. Sulphur dioxide.	Process operation and gas collection, gas cleaning followed by sulphuric acid plant
Secondary Converting	Dust and metal vapour or compounds. Organic material. * Carbon monoxide. *** Sulphur dioxide. **	Process operation and gas collection, cooling and cleaning by fabric filter. Process operation, after-burning if necessary and correct gas cooling. Scrubbing if necessary.

Fire Refining	Dust and metals Organic material. * Carbon monoxide. **** Sulphur dioxide**	Process operation and gas collection, cooling and cleaning by fabric filter or scrubber. Process operation, after-burning (if necessary during poling) and correct gas cooling. Scrubbing if necessary.
Melting and Casting	Dust and metals Organic material. * Carbon monoxide.	Process operation and gas collection, cooling and cleaning by fabric filter. Process operation, after-burning if necessary and correct gas cooling.
Anode casting and slag granulation.	Water vapour	Wet scrubber or de-mister if necessary.
Pyro-metallurgical slag treatment processes	Dust and metals Carbon monoxide Sulphur dioxide	Process operation and gas collection, cooling and cleaning by fabric filter. After-burning if necessary. Treatment for removal
Note. * Organic materials include VOC reported as total carbon (excluding CO) and dioxins, the exact content depends on the raw materials used. ** Sulphur dioxide may be present if sulphur containing raw materials or fuels are used. Carbon monoxide may be produced by poor combustion, the presence of organic material or deliberately to minimise oxygen content. *** For batch process, CO only at start of the blow **** CO only when not after-burning		

7.0 EMISSION ASSOCIATED WITH BAT

The emission levels associated with abatement systems that are considered to be BAT for the non-ferrous metal processes are shown in **Table 20** to **Table 30**.

Table 20: Emissions Associated with the Use of BAT for Primary Aluminium Electrolysis.

Pollutant	Range associated with the use of BAT	Techniques that can be used to reach these levels	Comments
Dust	1 - 5 mg/Nm^3	Fabric filter.	Depends on characteristics of dust.
SO_2	Not applicable	Control of sulphur content of the anodes.	Aim to minimise SO_2
Poly fluorinated hydrocarbons	< 0.1 anode effects per cell per day	Process control based on active cell databases .	< 0.1 kg/t Al
HF Total fluoride	< 0.2 mg/Nm^3 < 0.5 mg/Nm^3	Alumina scrubber and fabric filter	
Note. Collected emissions only. Associated emissions are given as daily averages based on continuous monitoring during the operating period. In cases where continuous monitoring is not practicable the value will be the average over the sampling period. For the abatement system used, the characteristics of the gas and dust will be taken into account in the design of the system and the correct operating temperature used.			

Table 21: Emissions Associated with BAT for Holding and De-Gassing Molten Metal from Primary and Secondary Aluminium.

Pollutant	Range associated with the use of BAT	Techniques that can be used to reach these levels	Comments
Dust	1 - 5 mg/Nm^3	Fabric filter	
Chlorides, fluorides and acid gases	SO_2< 50 - 200 mg/Nm^3 Chloride < 5 mg/Nm^3 Fluoride < 1 mg/Nm^3	Wet or semi-dry alkaline scrubber.	
NO_x	< 100 mg/Nm^3 < 100 - 300 mg/Nm^3	Low NO_x burner Oxy-fuel burner.	Higher values are associated with oxygen enrichment to reduce energy use. In these cases gas volume and mass emission is reduced.
Note. Collected emissions only. Associated emissions are given as daily averages based on continuous monitoring during the operating period. In cases where continuous monitoring is not practicable the value will be the average over the sampling period. For the abatement system used, the characteristics of the gas and dust will be taken into account in the design of the system and the correct operating temperature used.			

Table 22: Emissions Associated with the Use of BAT for Materials Pre-Treatment (Including Swarf Drying), Melting and Smelting of Secondary Aluminium.

Pollutant	Range associated with the use of BAT	Techniques that can be used to reach these levels	Comments
Dust	1 - 5 mg/Nm^3	Fabric filter	High performance fabric filters can achieve low levels of heavy metals. The concentration of heavy metals is linked to the concentration of dust and contents of the metals in the dust.
Chlorides, fluorides and acid gases	SO_2 < 50 - 200mg/Nm^3 Chloride < 5 mg/Nm^3 Fluoride < 1 mg/Nm^3	Wet or semi-dry alkaline scrubber.	
NO_x	< 100 mg/Nm^3 < 100 - 300 mg/Nm^3	Low NO_x burner. Oxy-fuel burner.	Higher values are associated with oxygen enrichment to reduce energy use. In these cases gas volume and mass emission is reduced.
Total organic carbon as C	< 5 - 15 mg/Nm^3 < 5 - 50 mg/Nm^3	Afterburner. Optimised combustion.	Pre-treatment of secondary material to remove organic coatings.

Dioxins	$< 0.1 - 0.5$ ng TEQ/Nm^3	High efficiency dust removal system (i.e. fabric filter), afterburner followed by quenching. Other techniques are available (e.g. adsorption on activated carbon, oxidation catalyst).	
Note. Collected emissions only. Associated emissions are given as daily averages based on continuous monitoring during the operating period. In cases where continuous monitoring is not practicable the value will be the average over the sampling period. For the abatement system used, the characteristics of the gas and dust will be taken into account in the design of the system and the correct operating temperature used. For SO_2 or total carbon removal, the variation in raw gas concentration during batch processes may affect the performance of the abatement system.			

Table 23: Emissions from Primary Smelting and Converting Associated with the Use of BAT in the Copper Sector.

Pollutant	Range associated with the use of BAT	Techniques that can be used to reach these levels	Comments
SO_2 – rich off-gas streams (> 5%)	> 99.7% conversion factor	Double contact sulphuric acid plant (Tail gas SO_2 content depends on feed gas strength). A demister may be appropriate for the final removal of SO_3.	Very low levels for other air-borne pollutants will be reached due to intensive gas treatment prior to the contact plant (wet scrubbing, wet EP and, if necessary, mercury removal) to ensure H_2SO_4product quality
Note. Collected emissions only. Associated emissions are given as daily averages based on continuous monitoring during the operating period. In cases where continuous monitoring is not practicable the value will be the average over the sampling period. For the abatement system used, the characteristics of the gas and dust will be taken into account in the design of the system and the correct operating temperature used. > 99.9% conversion factor has been achieved in a plant with a high, constant sulphur dioxide feed, sophisticated gas cleaning and inter-pass cooling.			

Source: European BAT Reference Document

Table 24: Emissions from Hydrometallurgical and Electro-Winning Processes Associated with the Use of BAT in the Copper Sector.

Pollutant	Range associated with the use of BAT	Techniques that can be used to reach these levels	Comments
Acid mists	< 50 mg/Nm³	De-mister, Wet scrubber.	A de-mister or water scrubber will allow the collected acid to be reused.
VOC or solvents as C	< 5 - 15 mg/Nm³	Containment, condenser, carbon or bio filter.	
Note. Collected emissions only. Associated emissions are given as daily averages based on continuous monitoring during the operating period. In cases where continuous monitoring is not practicable the value will be the average over the sampling period. For the abatement system used, the characteristics of the gas and dust will be taken into account in the design of the system and the correct operating temperature used.			

Table 25: Emissions from Secondary Smelting and Converting, Primary and Secondary Fire Refining, Electric Slag Cleaning and Melting Associated with the Use of BAT in the Copper Sector.

Pollutant	Range associated with the use of BAT	Techniques that can be used to reach these levels	Comments
Dust	1 - 5 mg/Nm³	Fabric filter.	The characteristics of the dust will vary with the raw materials and affect the value achieved. High performance fabric filters can achieve low levels of heavy metals. The concentration of heavy metals is linked to the concentration of dust and proportion of the metals in the dust.
SO_2	< 50 - 200 mg/Nm³	Alkali semi-dry scrubber and fabric filter. Wet alkali or double alkali scrubbers using lime, magnesium hydroxide, sodium hydroxide. Combinations of sodium or alumina/aluminium sulphate in combination with lime to regenerate the reagent and form gypsum.	Potential cross-media effects from energy use, wastewater and solid residues together with the ability to re-use scrubber products will influence the technique used.

NO_x	< 100 mg/Nm^3 < 100 - 300 mg/Nm^3	Low NO_x burner. Oxy-fuel burner.	Higher values are associated with oxygen enrichment to reduce energy use. In these cases gas volume and mass emission is reduced.
Total organic carbon as C	< 5 - 15 mg/Nm^3 < 5 - 50 mg/Nm^3	Afterburner. Optimised combustion.	Pre-treatment of secondary material to remove organic coatings if necessary.
Dioxins	< 0.1 - 0.5 ng TEQ/Nm^3	High efficiency dust removal system (i.e. fabric filter), afterburner followed by rapid quenching.	Other techniques are available (e.g. adsorption on activated carbon: - carbon filter or by injection with lime/carbon). Treatment of a clean de-dusted gas is required to achieve low levels.
Note. Collected emissions only. Associated emissions are given as daily averages based on continuous monitoring during the operating period. In cases where continuous monitoring is not practicable the value will be the average over the sampling period. For the abatement system used, the characteristics of the gas and dust be taken into account in the design of the system and the correct operating temperature used. For SO_2 or total carbon removal, the variation in raw gas concentration during batch processes may affect the performance of the abatement system. For example converter "blows" will produce peak raw gas concentrations and consequently the number cycles per day influence the associated range (given as a daily average), a similar effect may be seen with other batch process stages. Peak concentrations in the treated gas may be up to 3 times the reported range. For NO_x, the use of highly efficient processes (e.g. Contimelt) requires a balance to be established locally between energy use and achieved value.			

Table 26: Emissions from Secondary Fume Collection Systems and Drying Processes Associated with the Use of BAT in the Copper Sector.

Pollutant	Range associated with the use of BAT	Techniques that can be used to reach these levels	Comments
Dust	1 - 5 mg/Nm^3	Fabric filter with lime injection (for SO_2 collection/filter protection).	Dust re-circulation may be used for fabric protection/fine particle capture. The concentration of heavy metals is linked to the concentration of dust and proportion of the metals in the dust.
SO_2	< 500 mg/Nm^3 < 50 - 200 mg/Nm^3	Fabric filter with dry lime injection into a cool gas. Alkaline wet scrubber for SO_2 collection from hot gases (from dryer gases	There are potentially significant cross media effects using wet or semi-dry scrubbing systems

		after dust removal).	with a cool gas.
Dioxins	< 0.1 - 0.5 ng TEQ/Nm^3	Fabric filter with lime injection for filter protection.	Treatment of a clean de-dusted gas is required to achieve low levels.
Note. Collected emissions only. Associated emissions are given as daily averages based on continuous monitoring during the operating period. In cases where continuous monitoring is not practicable the value will be the average over the sampling period. For the abatement system used, the characteristics of the gas and dust will be taken into account in the design of the system and the correct operating temperature used.			

Table 27: Emissions from Primary Smelting, Roasting and Sintering Associated with the Use of BAT in the Lead and Zinc Sectors.

Pollutant	Range associated with the use of BAT	Techniques that can be used to reach these levels	Comments
Low SO_2 off-gas streams (~ 1 – 4%)	> 99.1	Single contact sulphuric acid plant or WSA, (tail gas SO_2 content depends on feed gas strength)	For low-grade SO_2 gases. Combined with dry or semi-dry scrubber to reduce SO_2 emission and produce gypsum if a market is available.
SO_2– rich off-gas streams (> 5%)	> 99.7% conversion factor	Double contact sulphuric acid plant (Tail gas SO_2 content depends on feed gas strength). A de-mister may be appropriate for the final removal of SO_3	Very low levels for other air-borne pollutants will be reached due to intensive gas treatment prior to the contact plant (wet scrubbing, wet EP and, if necessary, mercury removal to ensure H_2SO_4 product quality
Note. Collected emissions only. Associated emissions are given as daily averages based on continuous monitoring during the operating period. In cases where continuous monitoring is not practicable the value will be the average over the sampling period. For the abatement system used, the characteristics of the gas and dust will be taken into account in the design of the system and the correct operating temperature used.			

Table 28: Emissions from Chemical Refining, Electro-Winning and Solvent Extraction for Lead and Zinc Production.

Pollutant	Range associated with the use of BAT	Techniques that can be used to reach these levels	Comments
Acid mists	< 50 mg/Nm^3	De-mister Wet alkaline scrubber.	A de-mister will allow the collected acid to be reused.
Arsine, stibine	< 0.5 mg/Nm^3	Oxidising scrubber	
VOC or solvent as C	< 5 mg/Nm^3	Containment, condenser, carbon or bio filter	

Note. Collected emissions only.
Associated emissions are given as daily averages based on continuous monitoring during the operating period. In cases where continuous monitoring is not practicable the value will be the average over the sampling period.
For the abatement system used, the characteristics of the gas and dust will be taken into account in the design of the system and the correct operating temperature used.

Table 29: Emissions from the Melting of Clean Material, Alloying and Zinc Dust Production.

Pollutant	Range associated with the use of BAT	Techniques that can be used to reach these levels	Comments
Dust	1 - 5 mg/Nm^3	Fabric filter. (Temperature control of melting kettles or vessels is needed to prevent volatilisation of metals.)	High performance fabric filters can achieve low levels of heavy metals. The concentration of heavy metals is linked to the concentration of dust and content of the metals in the dust.
NO_x	< 100 mg/Nm^3 < 100 - 300 mg/Nm^3	Low NO_x burner. Oxy-fuel burner.	Higher values are associated with oxygen enrichment to reduce energy use. In these cases gas volume and mass emission is reduced.
Total organic carbon as C (if present)	< 5 - 15 mg/Nm^3 < 5 - 50 mg/Nm^3	Afterburner. Optimised combustion.	
Dioxins (if present)	< 0.1 - 0.5 ng TEQ/Nm^3	High efficiency dust removal system (i.e. fabric filter), afterburner followed by rapid quenching. Other techniques are available (e.g. adsorption on activated carbon, oxidation catalyst).	Treatment of a clean de-dusted gas may be required to achieve low levels

Note. Collected emissions only.
Associated emissions are given as daily averages based on continuous monitoring during the operating period. In cases where continuous monitoring is not practicable the value will be the average over the sampling period.
For the abatement system used, the characteristics of the gas and dust will be taken into account in the design of the system and the correct operating temperature used.

Table 30: Emissions from Materials Pre-Treatment, Secondary Smelting, Thermal Refining, Melting, Slag Fuming and Waelz Kiln Operation for Lead and Zinc Production.

Pollutant	Range associated with the use of BAT	Recommended Techniques	Comments
Dust	1 - 5 mg/Nm^3	Fabric filter, wet EP. (A wet EP may be applicable to gases from slag granulation or wet gas quenching.)	High performance fabric filters can achieve low levels of heavy metals. The concentration of heavy metals is linked to the concentration of dust and content of the metals in the dust.
SO_2	< 50 - 200 mg/Nm^3	Wet alkaline scrubber. Alkali semi-dry scrubber and fabric filter	
NO_x	< 100 mg/Nm^3 < 100 - 300 mg/Nm^3	Low NO_x burner. Oxy-fuel burner.	Higher values are associated with oxygen enrichment to reduce energy use. In these cases gas volume and mass emission is reduced.
CO and metal vapour	Not emitted	Wet scrubber	To cool and clean the gases of an ISF prior to use as a fuel.
Total organic carbon as C	< 5 - 15 mg/Nm^3 < 5 - 50 mg/Nm^3	Afterburner. Optimised combustion.	Pre-treatment of secondary material to remove organic coatings if necessary.
Dioxins	< 0.1 - 0.5 ng TEQ/Nm^3	High efficiency dust removal system (i.e. fabric filter), afterburner followed by quenching. Other techniques are available (e.g. adsorption on activated carbon, carbon/lime injection).	

Note. Collected emissions only.
Associated emissions are given as daily averages based on continuous monitoring during the operating period. In cases where continuous monitoring is not practicable the value will be the average over the sampling period.
For the abatement system used, the characteristics of the gas and dust will be taken into account in the design of the system and the correct operating temperature used.
For SO_2 or total carbon removal, the variation in raw gas concentration during batch processes may affect the performance of the abatement system.

8.0 EMISSION MONITORING AND REPORTING

The emission monitoring should be carried out to determine the substances in the clean gas so that they can be reported. In order to control the process and maintain optimum operation with minimum emissions to air, process parameters such temperature, pressure as well as key pollutants concentrations should be monitored online where appropriate.

Frequent sampling may be required during startup and upset conditions. Air emissions should be monitored regularly for particulate matter and fluorides. Hydrocarbon emissions should be monitored annually on the anode plant and baking furnaces. Monitoring data should be analyzed and reviewed at regular intervals and compared with the operating standards so that any necessary corrective actions can be taken. Records of monitoring results should be kept in an acceptable format. The results should be reported to the responsible authorities and relevant parties, as required.

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