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GUIDELINES FOR ENVIRONMENTAL MANAGEMENT OF ALUMINIUM SMELTERS

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Guidelines for Environmental Management of Aluminium Smelters

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FOREWORD

The environmental aspects of aluminium smelting were first brought under review by UNEP by means of a Seminar on the Aluminium Industry and the Environment, held in Paris, 6 - 8 October 1975 (1). The material received in relation to the Seminar has been summarized in UNEP's Overview document on "Environmental Aspects of the Aluminium Industry (2).

In order to provide a continuous forum for consultation and communication to exchange experience amongst Governments, industry and relevant international institutions, UNEP established an Environmental Consultative Committee for the Aluminium Industry, which held its first meeting in Paris in April 1978 (3) and second meeting in Paris in October 1979 (4).

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(1) UNEP Industry Sector Seminars, Aluminium Meeting - Seminar Papers and Documents, Paris, 1975.

(2) Environmental Aspects of the Aluminium Industry - An Overview, UNEP Industry & Environment Office, Paris 1977.

(3) Record of the Meeting of the 1st UNEP Environmental Consultative Committee on the Aluminium Industry, Paris 1978, IEO/CC/Al.1 (Final).

(4) Record of the Meeting of the 2nd UNEP Environmental Consultative Committee on the Aluminium Industry, Paris 1979, IEO/CC/Al.2/4 (Final).

(5) Environmental Aspects of Aluminium Smelting - A Technical Review, UNEP Industry & Environment Office, Paris 1981.

A review dealing with the technical aspects of environmental management in relation to aluminium smelting plants was examined by the Committee and was published as "Environmental Aspects of Aluminium Smelting - A Technical Review" (5), incorporating comments and suggestions made by the Committee.

One of UNEP's goals is to prepare guidelines on reducing the adverse environmental impact of specific industries. In fulfilment of this goal and as a complement to the Overview and Technical Review, these Guidelines for Environmental Management of Aluminium Smelters have been prepared.

The objective of the guidelines is to assist Governments and industry in the development and elaboration of policies adapted to local needs, in relation to environmental management. They are not statutory or mandatory rules. Rather, these guidelines summarize current experience and generally accepted good environmental and resource management practice, and provide a collection of commonly accepted principles to be applied as appropriate, according to circumstances and conditions.

For further technical details and a review of the literature, the reader is referred to the UNEP Technical Review on the Environmental Aspects of Aluminium Smelting (5), which provides many useful details for practical implementation of the present guidelines.

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(5) Environmental Aspects of Aluminium Smelting - A Technical Review, UNEP Industry & Environment Office, Paris 1981.

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- Members of the UNEP Environmental Consultative Committee on the Aluminium Industry;
- Members of the Environment Committee of the International Primary Aluminium Institute (IPAI);
- Members of the Commission on Environment of the International Chamber of Commerce;
- Other partners in the UNEP consultative process on this industry.

Their assistance is gratefully acknowledged. A list of contributors of specific comments is annexed (Annex IV).

The UNEP Secretariat is especially grateful for the assistance given by Mr. Peter Martyn, Secretary General of IPAI, and Mr. Yves Lallemant, Chairman of the IPAI Environment Committee.

The UNEP officer responsible for this activity was Mr. T. Hamada, Senior Industry Liaison Officer.

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INTRODUCTION

The main environmental problem in the aluminium smelting industry is air pollution caused by fluorides emitted from the aluminium reduction cell. Without proper control measures, fluorides have potentially harmful effects on workers' health inside the plant and on flora and fauna in the vicinity of the smelter.

Over the last 30 years, thanks to the development of technology in the field of production and environmental control, great progress has been made in reducing the amount of fluorides emitted from aluminium smelting plants (see Table 1).

TABLE 1

EVOLUTION OF FLUORIDES EMISSIONS FROM ALUMINIUM SMELTING PLANTS

Environmental control facilities	Year	Amount of total fluorides emitted from smelter per tonne of aluminium production
1st Generation (without control system)	1940 - 55	12 - 25 kg
2nd Generation (with control system)	1955 - 75	2 - 6 kg
3rd Generation (with advanced control system)	1975 - present	0,5 - 1 kg

With sound environmental management involving proper control facilities and technology, the aluminium smelter, especially the latest generation, can be operated with minimum environmental problems.

SECTION I POTENTIAL ENVIRONMENTAL IMPACTS

Pollutants: sources and impacts on the environment

1.1 Brief Description of Smelting Process

1.1.1 Primary aluminium is produced by electrolytic reduction of alumina using the Hall-Héroult processes. Alumina, an oxide of aluminium, is dissolved in a molten cryolite bath at approximately 950°C and electrolysed in a reduction cell by direct current. Cells are connected in series and comprise a carbon cathode insulated by alumina or refractory bricks inside a steel shell. Carbon anodes are suspended from above the cells. A direct current passes from a carbon anode through the bath to the cathode and thence by an aluminium busbar to the neighbouring cell. Liquid aluminium is deposited at the cathode in the bottom of the cell and oxygen combines with the carbon anode. Alumina is added to the molten bath and dissolves as electrolysis proceeds. Fluoride compounds are also added to the bath as required to replenish material removed or consumed in normal operation. The solidified crust of the bath is broken regularly to allow additional alumina to enter the cell. The fume emitted from the electrolytic process is collected by a hood or gas skirt and evacuated for treatment. Molten aluminium is periodically withdrawn from the cell by vacuum suction.

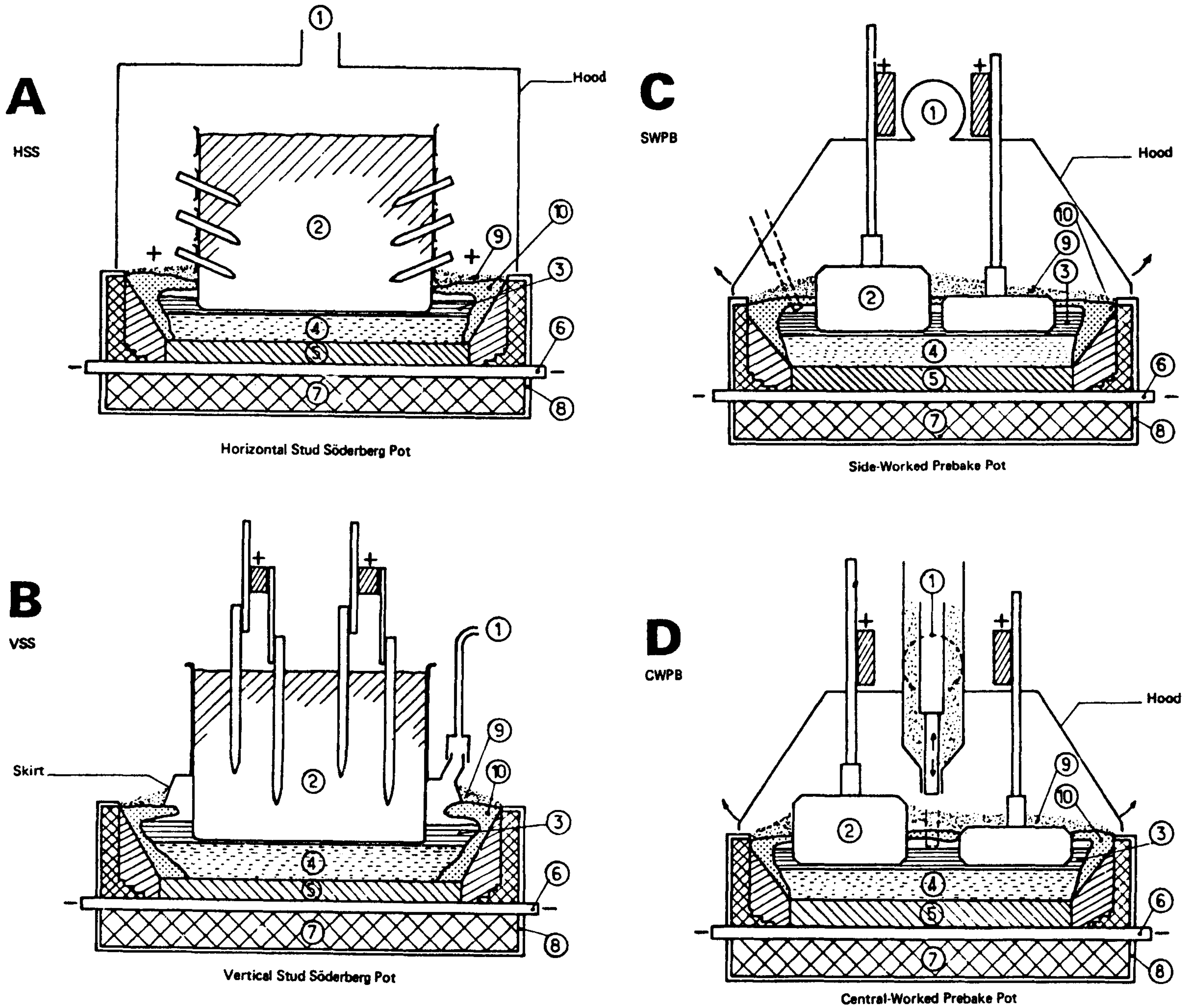
1.1.2 There are several cell systems according to the type of anodes utilized:

(a) Söderberg anodes, made in situ with fresh paste (i.e. a mixture of pitch and coke), are baked by the heat from the molten bath. The current is brought into the Söderberg anode through horizontal studs (Horizontal Stud Söderberg cell - HSS cell), or through vertical studs (Vertical Stud Söderberg cell - VSS cell).

(b) Prebaked anodes are prefabricated and need to be periodically replaced in the cell as they are consumed. There are two designs of cells using prebaked anodes; one in which the alumina is fed into the cells after the crust is broken around the circumference of the entire anode complex (Side Worked Prebake cell - SWPB cell); the other in which the cells are fed with alumina after the crust is broken along the axis or at selected points between the two lines of anodes (Central Worked Prebake cell - CWPB cell). Facilities for the production of prebaked anodes are an important part of this type of plant. Figure 1 illustrates each type of cell system.

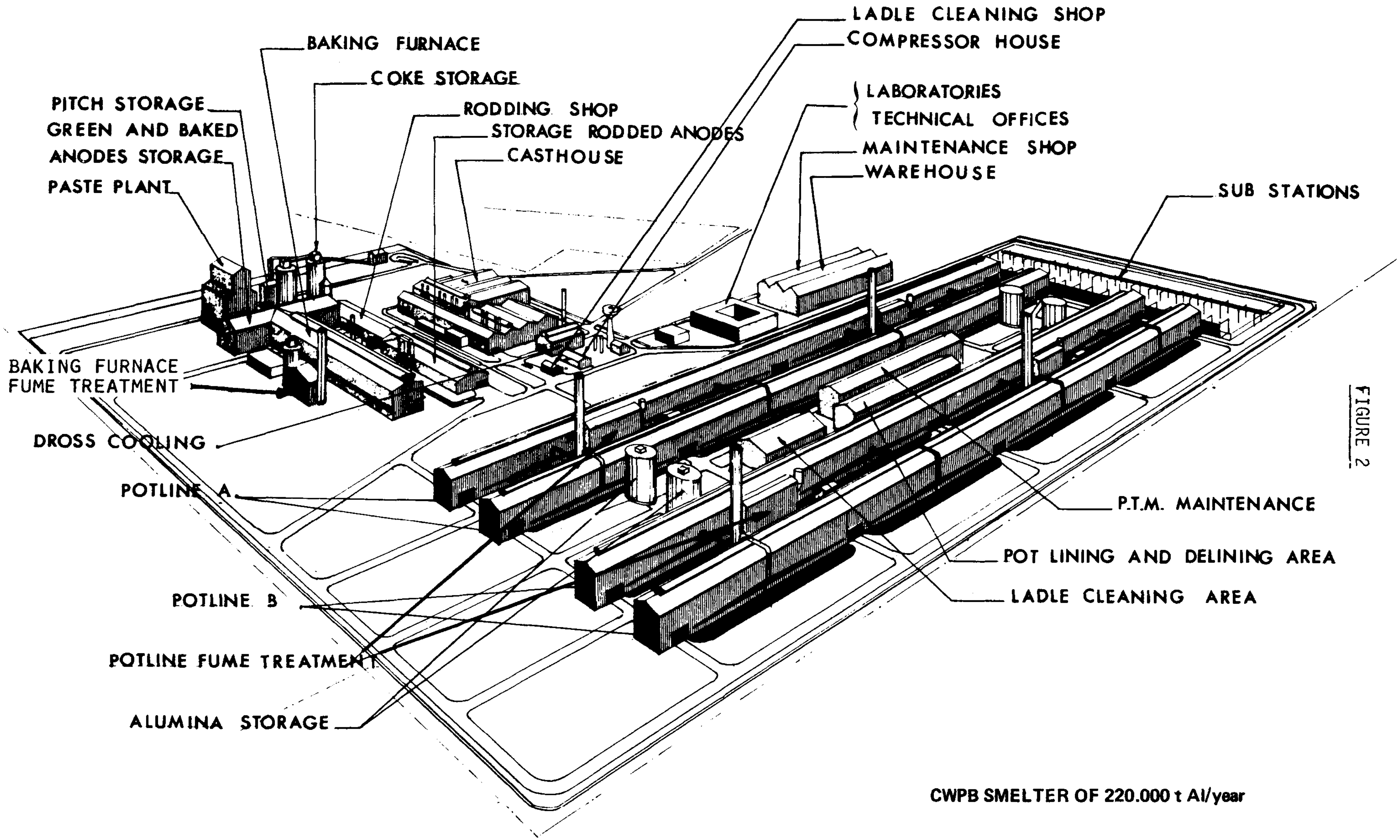
1.1.3 Figure 2 gives by way of illustration the view of a typical modern smelter equipped with two lines of CWPB cells. The cells are connected electrically in series and form a pot-line. For example a pot-line is housed in two buildings, each building being 800 m long and 22 m wide, containing 120 cells arranged side by side in four groups of 30 cells and giving a total annual production of 220,000 tonnes in the two pot-line plants. The plant also includes: a workshop to produce green anodes; an anode bake oven; a cast-house

FIGURE I



1. Fume evacuation pipe
2. Carbon anode
3. Bath of molten cryolite
4. Cathode of liquid aluminium
5. Carbon cathode bars
6. Iron cathode bars
7. Cathode insulation of alumina or refractory bricks
8. Iron shell
9. Blanket of alumina
10. Crust of solidified alumina

FIGURE 2



CWPB SMELTER OF 220.000 t Al/year

to transform the liquid metal into ingots, billets and slabs; and various ancillary workshops.

1.1.4 Figure 3 shows a process flow chart of aluminium smelting from the green anode plant, through the reduction cells to the cast house, with the pollutants that are generated in each stage of the production.

1.2 Air Pollutants

1.2.1 Fluorides

As molten cryolite is utilized as a bath for the electrolysis of alumina, the fume emitted from the electrolytic cell contains gaseous fluoride (mainly hydrogen fluoride) and particulate fluorides.

Gaseous fluoride is also contained in the exhaust gas of the anode baking furnace. This fluoride arises from the recycling of anode butts. The amount of fluoride emitted depends on the cleanliness of the butts. It can make a substantial contribution to the overall gaseous fluoride emission from the smelter if the emission is emitted unscrubbed.

Fluorides are also emitted from the cast-house furnaces when the metal or alloys are treated by fluxes which contain fluoride. However, this emission is minimal.

The excessive intake of fluoride can cause fluorosis (skeletal disorders) in humans[2][3]. No such cases have been reported of workers in modern aluminium smelters or of inhabitants around the smelter.

Farm animals (cattle, sheep, goats etc.) can be affected by fluorosis by ingestion of fluoride in contaminated forage[2][3]. Vegetation is variably susceptible to fluoride[2][3]. Some species may be injured at low concentrations.

1.2.2 Coal tar pitch volatiles

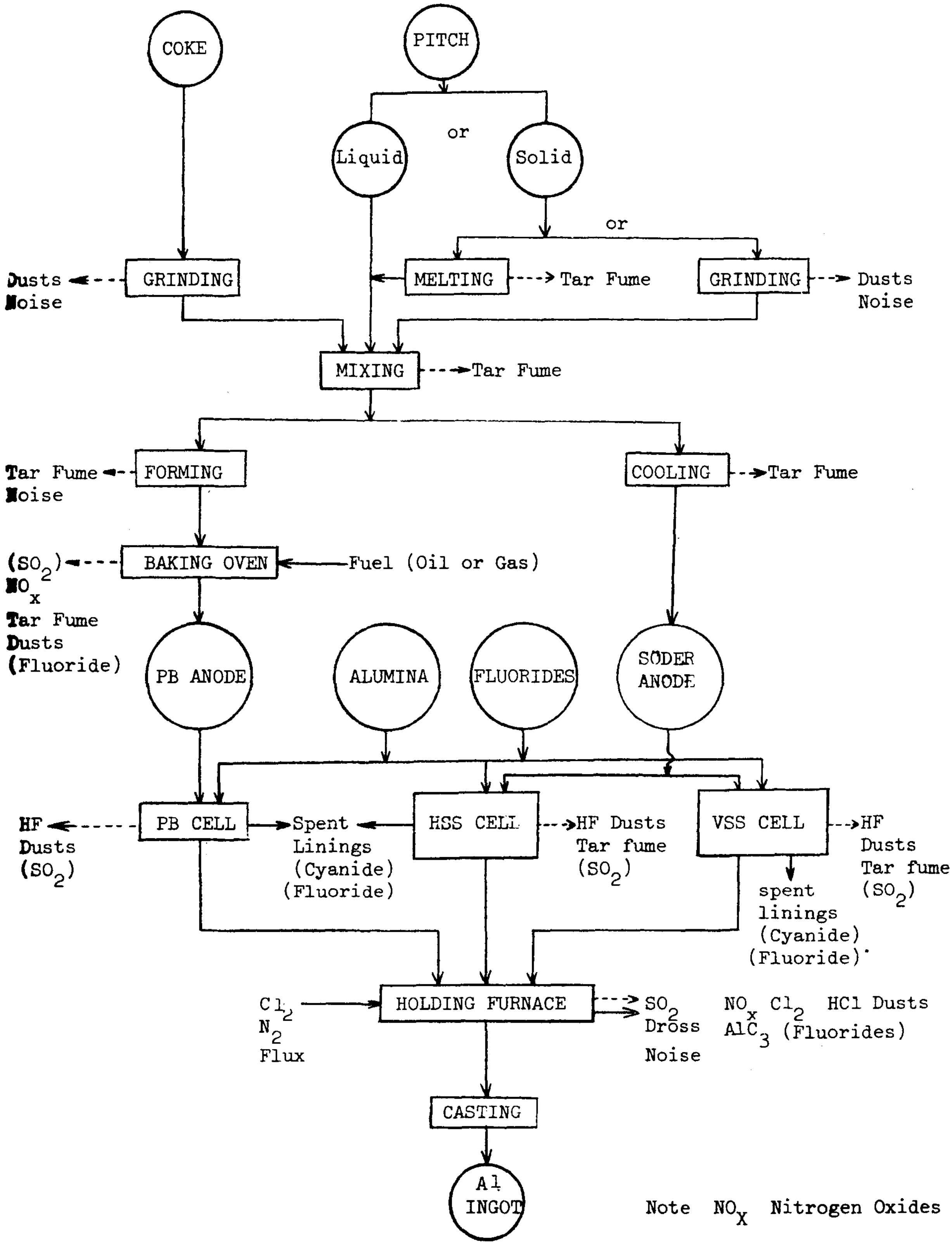
The fume from Söderberg anode cells contains tar fume. Tar fume is also generated from processes in the anode plant such as pitch melting, mixing, cooling of the anode paste, and the forming and baking of the prebake anodes etc.

In cell cathode relining work, the tar fume is given off from the cathode lining mix and carbon ramming mix.

The tar fume contains certain polycyclic aromatic hydrocarbons, some of which are suspected carcinogens, and if they are not adequately controlled, they may have adverse effects on workers' health.

FIGURE 3

POTENTIAL SOURCES OF POLLUTANTS AND ALUMINIUM SMELTING PROCESS FLOW CHART FOR MONITORING AND CONTROL



1.2.3 Dusts

The exhaust gas from the electrolytic cell contains carbon, alumina and fluoride dusts. Carbon dust is also generated from the grinding of coke and pitch, and from anode baking.

The alumina dust is generated as fugitive dust from alumina handling operations.

When the hot metal is treated with gaseous chlorine or fluxed with chloride containing materials in the cast-house furnace, aluminium chloride particulates are generated which creates a white smoke.

These dusts may have certain effects on workers' health and need to be well controlled.

1.2.4 Sulphur dioxide

Although the amount is very small, sulphur dioxide will be emitted from the electrolytic cell when petroleum coke containing sulphur is utilized for anodes[4]. The control of this sulphur dioxide needs to be considered only when the smelter is located in an area where the ambient air concentration of sulphur dioxide is already very high because of other emission sources.

Sulphur dioxide is also emitted from the anode baking furnace and cast-house furnace when sulphur-containing fuels are burnt.

It goes without saying that sulphur dioxide is considered to be an important air pollutant where the public welfare is concerned. However, this is not the specific issue in the case of the aluminium smelter.

1.2.5 Nitrogen oxides

Nitrogen oxides are emitted from anode baking furnaces and cast-house furnaces. This problem is not specific to aluminium smelters either. However, combustion control might be needed according to the local conditions of the plant site.

1.3 Water Pollutants

1.3.1 Fluorides, pH

When a wet scrubbing system is utilized for the cleaning of fumes emitted from electrolytic cells, the scrubbing water contains fluorides that need to be treated before being discharged.

The pH value of the scrubbing water also needs to be controlled.

1.3.2 Suspended solids

The scrubbing water from the wet scrubbing of electrolytic cell gas contains suspended solids such as alumina, carbon, fluorides etc. and should be treated before discharge.

1.3.3 Oil and grease

The cooling water for metal casting may contain oil, grease and additives which need to be controlled.

1.3.4 Cyanide

When spent cell linings are stored in the open air or in pits and come into contact with precipitation or groundwater, fluorides and cyanide are leached. Careful consideration should be given in particular to this area of potential pollution.

1.4 Solid Wastes

1.4.1 Spent pot linings

The major problem relating to solid waste is spent cell linings. Cell cathode linings need to be relined every 4 to 5 years. The spent cell linings are composed of carbon, refractory material, bricks and/or alumina which contain fluorides, sodium and small amounts of carbides, nitrides and cyanides.

1.4.2 Dusts and sludges

Dusts collected from cell exhaust gas contain fluoride and appropriate measures need to be taken in their disposal to prevent pollution.

1.4.3 Skimmings and drosses

Although the quantity is relatively small, skimmings and drosses are generated from cast-house furnaces. These have no significant impact but can, in most cases, be usefully recycled. Fugitive dust losses can be generated during cooling prior to recycling of the material. If wetted, these materials can evolve gases, including ammonia, that can be of concern in enclosed spaces.

1.5 Other Possible Harmful Effects

1.5.1 Noise

Workers should be protected from the noise frequently generated from coke or pitch grinding, forming of prebaked anodes (in case of vibration), crust breaking operation, metal tapping by vacuum siphon, ramming of cathode lining and cast-house furnace burners.

Noise from the large exhaust fans for cell gas capture, compressors, vacuum pumps, crust breakers and other equipment may cause a community noise problem.

1.5.2 Heat

In some areas, measures for prevention of heat stress on cell-room workers will need attention.

SECTION II RECOMMENDATIONS FOR ENVIRONMENTAL CONTROL MANAGEMENT

2.1 Management Policy

2.1.1 The top management of the aluminium smelter should consider environmental protection as one of the company's most important social responsibilities and an important aspect of management. One of the key elements to the proper management of the outside environment lies in the reputation of the smelter with the local community. A smelter should be a good citizen and try to establish a favourable reputation and relationship with the local community in order to avoid any unnecessary environmental conflict: it is essential to create mutual trust among parties concerned. Good environmental management is also essential to the health and safety of employees within the plant.

2.1.2 Past experience has demonstrated that prevention is less costly than remedy where pollution is concerned.

2.1.3 The key to effective protection of the environment is an "awareness" and "consciousness" by top management of the issues at stake i.e. of "potential risks and problems". Top management should have a sound policy and strong conviction to protect the environment and this "conviction" should be put into practice through the works manager and middle management into the daily activity of engineers, staff, foremen and workers in the plant.

2.1.4 Only top management can provide the resources, such as money and manpower, for the protection of the environment. The resources available can be utilized most effectively, and good environmental control can be achieved, only when all the employees in the smelter have the same understanding of environmental issues, and do their best under the management's basic policy to ensure effective environmental protection.

2.2 Siting, Design and Construction of Smelter

2.2.1 Our knowledge of the environment shows that man's way of life leads to a greater or lesser extent to the change of the Natural Environment. Environmental issues are always a question of balance and compromise and the environment cannot be totally shielded from change. However, such change must be managed rationally.

2.2.2 Proper plant site selection, provision of a buffer zone, the use of proper production technology and good design of plant layout and production facilities minimize environmental impact and its control cost.

2.2.3 It is highly advisable, and usually mandatory, to undertake environmental impact assessment(5)(6) in site selection. The results of the study will form a key part of the feasibility study and the proposed plant design.

2.2.4 The surrounding ecosystem (flora and fauna), soil and geological conditions, topography, meteorological conditions, land use etc. of the potential plant site should be surveyed and the potential impact on the physical and socio-economic environment should be assessed.

2.2.5 Annex I provides an example of a check list of questions to which an environmental impact study should respond(6).

2.2.6 The plant site finally selected will be determined according to economic and other basic factors in association with results of the environmental impact assessment. Consideration of the natural assimilation capacity of the whole surrounding area is also an important factor for site selection. Location in an industrial complex may not be advantageous in this respect and the synergistic interaction between different pollutants may also need to be considered.

2.2.7 Before the design stage of plant facilities, a target of environmental control should first be set by the top management of the company. The target corresponds to emission standards, to standards that regulate the quality of the ambient air and water. If government regulations already exist, the target will need to meet these standards first.

2.2.8 The significant environmental component, i.e. air, water, land, plants, flora and fauna, or aesthetic features etc., may vary from country to country and from locality to locality. The relative value of these environmental components also differs according to each specific plant site.

2.2.9 The target should be set in consideration of the results of environmental impact assessment, with regard to the priority of the environmental components to be protected and in relation to the cost-effectiveness of control measures. Subsequently, plant facilities should be designed to meet these requirements. The design itself should be flexible enough to accommodate any changes in the foreseeable future as retrofitting is very costly.

2.2.10 Pollution control technology has become an integrated part of the production process in many industries. It is recommended that pollution control facilities should be designed as an integral part of the production facilities. In the case of primary aluminium production, modern technology makes this possible.

2.2.11 When necessary and feasible, the establishment of a buffer zone around the smelter may be recommended where certain kinds of agriculture, forestry and stock raising ought to be restricted or controlled. The size of the buffer zone should vary in relation to conditions of fluoride emission (concentration, amount, method of discharge etc.), topography, meteorology, land use and other environmental conditions of the plant site.

2.3 Environmental Standards

2.3.1 For the design of plant facilities and the operation of the smelter, environmental standards on the ambient air and water quality, and emission standards on fluorides, need to be established by the government or by the smelter itself.

2.3.2 In some locations, close to farming areas, especially stock farming areas, the amount of fluorides in forage may need to be measured and controlled, and comply with relevant standards (mgF/kg of dry forage is the most common unit). Generally, the emission standard is expressed in terms of concentration of fluorides in exhaust gas (mgF/Nm^3) and compliance with standards of performance expressed as amount of fluorides emitted per tonne of aluminium produced (Kg F/tAl).

2.3.3 These standards should be established preferably after a study of environmental impact assessment, along with the various local conditions of the plant site (topographical, meteorological, geological, land use etc.) and the size of the smelter. Limits set on fluorides therefore cannot be universal and standards may vary from site to site[7].

2.3.4 The standards for working conditions to protect workers' health however can be universal but actually government standards vary considerably in different countries. The principal standards are listed for reference in Annex II.

2.4 Control of Fume Evolved from the Cells

2.4.1 The cells should be furnished with a fume collection system capable of collecting as much fume as possible which is then channelled to cleaning equipment and very little is released into the working atmosphere of the building. The key question in controlling the cell fume efficiently and cost-effectively is how to collect the fume in as high a concentration as possible. For, normally, by minim- izing the volume of fume to be cleaned, initial investment for the scrubbing system and its running cost (especially power cost) can be minimized.

2.4.2 Hooded CWPB cells are the most efficient from this point of view. Even for unhooded SWPB cells, it is recommended that cell fume be collected by some means, such as local hoods.

2.4.3 For HSS cells, the sealing of the hood door and anode casing needs to be kept in good airtight condition for effective fume collection.

2.4.4 In the case of VSS cells, the cell fume is collected by a gas skirt and is sent to the cleaning equipment after the major part of the carbon monoxide and tar fume has been burned in burners. Good maintenance work on the gas skirt and duct works, careful cell operation to keep all burners lit, together with a good alumina blanket on the end of the gas skirts and gas holes on the crust, all contribute to high fume collection efficiency.

2.4.5 Fume collection efficiency is an essential part of overall effectiveness of the fume cleaning system and its operation.

2.4.6 Good fume collection is an important factor where favourable working conditions in the cell room are concerned.

2.4.7 Cleaning devices for the collected fume can be either wet or dry. Both systems give a high fluoride scrubbing efficiency, although some wet scrubbers are less efficient for sub-micron fluoride particulate fume.

2.4.8 In the dry scrubbing system, the cell fume comes into contact with alumina in the duct or in the fluidized bed. The alumina with the adsorbed fluoride is then filtered. The filters retain both the alumina which has adsorbed HF and the fluoride particulate. The alumina and the fluorides are recycled to the pots. By employing the dry system, the waste water treatment is avoided.

2.4.9 In the case of a wet scrubbing system, caustic soda, lime or soft water etc., may be used as scrubbing media. The scrubbing water needs to be treated before being discharged to the external water systems. Generally, fluorides are recovered as cryolite or removed as CaF_2. One advantage of the wet system is that sulphur dioxide in the cell fume is removed to some degree at the same time depending on the pH of the scrubbing media used.

2.4.10 In some existing plants, when the cell fume collection is not high enough, the ventilation air from the cell room may need to be cleaned before being exhausted to the atmosphere outside (roof scrubbing system). However, this type of scrubbing is very expensive both to install and in running costs. It is therefore recommended that an effort be made to gain higher collection efficiency of cell gas rather than to install a roof scrubbing system and this is possible with modern technology.

2.4.11 For the unhooded cell, the use of alumina with the proper physical properties is also a key factor in reducing the generation of fluoride and fugitive alumina dust from the cells to the working environment.

2.4.12 An example of airborne emissions from a modern CWPB plant is shown in Annex III.

2.5 Control of Emissions from the Green Anode Plant

2.5.1 All grinding and screening equipment should be efficiently enclosed and dust should be exhausted through dust collection equipment.

2.5.2 The pitch melter, paste mixer and green anode forming machine should be efficiently enclosed and the tar fume needs to be collected, cleaned and exhausted. Wet or dry scrubbing can be utilized to clean the tar fume.

2.6 Control of Emissions from the Anode Bake Oven

2.6.1 In addition to products of combustion i.e. NO_x and SO_2, the exhaust gas from the anode bake oven contains burned or unburned tar fume, carbon dusts and a small amount of fluorides originating from recycled anode butts.

2.6.2 Carbon dusts and tar fume can be cleaned by an electrostatic precipitator, wet scrubbing or dry alumina scrubbing, depending on the composition of the gas, but NO_x and a certain fraction of the SO_2 are difficult to control.

2.7 Control of Emissions from the Cast House

2.7.1 When excess chlorine gas is utilized for the degassing and fluxing operation of liquid metal, fluxing fumes may better be treated by an alkaline wet scrubber before being exhausted to the atmosphere. However, it is recommended, if possible, to substitute chlorine by inert gases such as nitrogen, argon etc., in order to eliminate the scrubbing system, or to use equipment which limits evolution of excess chlorine.

2.7.2 Solid flux may contain some fluorides. The fluxing operation is carried out intermittently and the amount of emitted fluorides is not very great. The fluxing fume, however, contains a rather high concentration of fluorides and a lot of dust, and some attention should be paid to maintaining good working conditions.

2.7.3 NO_x in the exhaust gas of the cast house furnace, can be controlled by combustion control and SO_2 by selection of fuel when necessary.

2.7.4 Dusts contained in the exhaust gas of the cast house furnace can be collected by bag house or electrostatic precipitator according to needs.

2.8 Solid Waste Disposal

2.8.1 Great attention should be paid to the storage and disposal of spent cell linings (carbon and refractory). Fluorides, sodium, and cyanides in spent cell linings can be partly leached out by rain- or groundwater and contaminate the surrounding soil and water. It is desirable to transform spent cell linings to non-hazardous waste and then dispose of them. Studies of numerous techniques for decontamination of cyanide or recovery of fluorides on spent cell linings have been made. However, no universally economically feasible technology has been developed yet. The necessity and feasibility of treatment of spent cell linings before disposal are dependent on the specific local conditions of each plant. The minimum precautions to prevent pollution in storage or disposal are to keep or dump the spent cell linings on an impermeable site, under cover or treat the rain-water which comes into contact with them.

2.8.2 Dusts (or sludge in the case of wet scrubbing) which are collected from cell fume, contain fluorides and sodium, leachable by rain-water. They can be recycled or should be disposed of with proper precaution.

2.8.3 It should be noted that the rehabilitation of an unsuitable disposal site for land use which has been used for untreated contaminated waste disposal is costly. It is recommended that future land use and the hydrology and geology of the site be taken into consideration before a decision is made on the method and site for disposal.

2.8.4 The method of disposal and the disposal site are important factors to be considered in plant site selection.

2.8.5 Most of the dross from the cast house furnace can be usefully recycled.

2.9 Liquid Effluent Treatment

2.9.1 Recycling of used water is highly recommended.

2.9.2 Liquid effluent from wet scrubbing of cell fume is the major source of potential water pollution. It contains fluorides, sodium sulphate and, in the case of the Söderberg cell plant, hydrocarbons. This effluent should be treated before being discharged to external water systems. Fluorides can be recovered from this effluent, generally as cryolite.

2.9.3 The scrubbing water from wet scrubbing in the anode plant and anode bake oven contain hydrocarbon (tarry matter) and should be treated before being discharged. Separated tarry matter should be disposed of properly.

2.9.4 Caustic scrubbing water from the scrubber to wash chlorine gas after the fluxing operation of metal in the cast house, should be treated before being discharged to the outside water body.

2.10 Health Protection and Safety for Workers

2.10.1 Protection of workers' health and safety should be considered as the first priority in the design of plant facilities and their operation[8, 9, 10].

2.10.2 In order to protect workers' health and safety it is essential that the workers themselves should be aware and conscious of "risks". Prior to the start of operation, workers should be given sufficient knowledge and information on "potential risks" and be trained and accustomed to acting in accordance with established norms and procedures. It is essential that a safety manual be drawn up and distributed to the workers. An appropriate and continuous safety promotion campaign is indispensable.

2.10.3 Principal airborne contaminants for cell room workers are:

- Gaseous and particulate fluorides, emitted from cells.

- Dust, consisting mainly of alumina and some fluorides and carbon, released from multiple sources as a result of handling materials.

- Coal tar pitch volatiles emitted from Söderberg cells.

- Tar fume emitted for a short period during initial baking of new potlinings.

- Heat from cell operations.

The following precautionary measures against excessive exposure of workers are recommended.

- Ensure good ventilation of the pot room building;
- Try to increase and keep the fume collection efficiency as high as possible (see section 2.4).
- In the case of the VSS cell, the anode surface should be well controlled to minimize the evolution of tar fume. In addition, the stud pulling (changing) operation should, if possible, be carried out under special precautions, to protect workers from excessive exposure to the tar fume.

2.10.4 In the green anode plant, workers should be protected from exposure to coke and pitch dusts and coal tar pitch volatiles. Carbon dust and coal tar pitch volatiles should also be controlled in the working environment of the anode baking plant.

2.10.5 Workers should be protected from coal tar pitch volatile, noise and vibration in the cathode re-lining works.

2.10.6 Possible exposure in the cast house would be to fluorides, chlorine, chlorides, ammonia, nuisance dust, oil mist, asbestos and alloying elements. Asbestos can present a major health hazard and it must therefore be handled very cautiously or, preferably, alternative materials substituted where possible.

2.10.7 In the cast house, asbestos containing products may be used in molten metal transfer troughs, headers, floats, etc. Where the marinite has to be machined and sized for each individual casting operation, this generates asbestos dust. It is essential that this operation be carried out in defined areas with exhaust ventilation and dust collection. Proper disposal of dust and wastes from this facility must be given consideration.

2.10.8 Sometimes fuel combustion in the cast house furnaces generates high noise levels.

2.10.9 Molten metal explosions are possible. Extreme care should be taken when charging metal or scrap material to the cast-house furnace to ensure no entrapped water is present. It is essential that some form of preheating is carried out prior to charging into liquid metal. Casting should be controlled to avoid the possibility of hot metal "run-outs" into the cooling water and to avoid risk of explosion in case these "run-outs" occurred.

2.10.10 Repair and maintenance workers are more likely to be exposed to contaminants and to higher concentrations of those contaminants. Special attention should be paid to the monitoring of conditions of work in this area.

2.10.11 Wearing of respiratory and ear protection should be mandatory in areas of the plant where personal exposure exceeds the published legally enforceable occupational exposure limit for the contaminant or noise,.and encouraged in other areas.

2.10.12 A health protection programme should be developed and implemented including periodic monitoring of workers' exposure and health condition (fluorine content in urine, lung function, hearing acuity etc.)[8,9,10].

2.10.13 Standards for occupational exposure limits for airborne contaminants in various countries are quoted in reference[10].

2.11 Monitoring

2.11.1 Environmental monitoring is very important to verify whether the smelter is being operated with the appropriate environmental controls and without any adverse effects to the environment.

2.11.2 Subjects, methods and frequency of measuring depend on the conditions at each plant site. Emission of air and water pollutants (concentration and amount), ambient air quality in the work place and around the smelter should be monitored at most plants, as should the quality of the groundwater around the solid waste disposal site. In some locations, vegetation and animals may need to be monitored. In any case, the installation of a monitoring network around the plant is recommended. Measuring methods and equipment are well developed.[3,11,12]

2.11.3 In some plant locations, where the waste water is discharged into a public water body, which is to be utilized for fishing or as a source of industrial, farming or drinking water, continuous monitoring (24 hours/day) and an alarm system on effluent water quality (at least of pH and oil) is highly recommended.

2.12 Emergency Planning

2.12.1 The smelter should be prepared for the accidental leak of hazardous gas (Cl_2), caustic and oil spill, etc. or the break-down of the scrubbing system of cell fume.

2.12.2 Any accidental leak or spill should be reported immediately to the designated key personnel in the plant and also to the local authorities such as the municipality, police station, or whoever has been appropriately designated, and proper counter-measures should be taken promptly. An immediate report to the local authorities is indispensable in minimizing the impact of the accident on the surrounding environment and also to maintain an atmosphere of mutual confidence with the local community.

2.12.3 A communication channel to the designated key personnel in and outside the plant in an emergency should be established and the role and action of each of the key members of staff should be stated clearly and precisely in an "Emergency Manual".

2.12.4 The implementation of the emergency plan must be rehearsed and practised frequently and at regular intervals to ensure smooth and effective action when actually needed.

2.13 Education and Training

2.13.1 Education and training should be provided for the whole of the workforce in the plant, including staff and managers, to inform them of the potential risks and problems associated with the plant facilities, operations and their jobs, which might impinge on the environment and on their own health and safety.

2.13.2 Satisfactory environmental control can only be achieved through proper operation and maintenance of well designed production and environmental control facilities, together with the effort and collaboration of the whole of the workforce in the plant.

2.13.3 Disciplined behaviour on the part of the workforce is essential if their health and safety is to be ensured. In order to cultivate this necessary discipline, it is highly recommended that a periodical and consistent programme of education and training be established in each plant.

2.13.4 Environmental control cost can be minimized by proper operation of production facilities and good housekeeping. These are also essential elements in ensuring the workers' health and safety.

2.13.5 The workforce should be aware that the reputation of the smelter with the local community is a key element in the proper management of the outside environment. The necessity of establishing a good reputation for the smelter in the local community is a goal towards which the employees as a whole should be encouraged to work.

SECTION III CONCLUSIONS

3.1 Top management should have a sound policy regarding the protection of the environment and workers' health and safety. This policy should be integrated into the activities of the whole workforce with an appropriate allocation of resources and be monitored periodically.

3.2 A target or standard for environmental control should be developed jointly by the government or control authority with senior management of the company according to the characteristics of the smelter and specific local environmental conditions of the plant site. These standards should be site specific.

3.3 Environmental impact assessment is indispensable for the final selection between possible alternatives of the plant sites and the designs of plant facilities.

3.4 Technologies for environmental control have been well developed and are available. It only remains to select the right technology to suit the specific conditions. Pollution control facilities should be designed as an integrated part of the production facilities.

3.5 Proper attention needs to be paid to the disposal of solid wastes.

3.6 The environment should be monitored regularly to ensure the efficient operation of control methods.

3.7 Satisfactory environmental and health and safety control can only be achieved through the correct operation and good maintenance of production and pollution control facilities.

3.8 Disciplined behaviour on the part of the workforce is also an essential element in achieving good environmental and health and safety standards. Continuous education and training of staff and workers is therefore indispensable in order to establish and maintain these standards.

3.9 The aluminium smelter can be operated without detrimental effects upon the environment.

ANNEX I

CHECK-LIST FOR AN ENVIRONMENTAL COMPATIBILITY SURVEY: AN EXAMPLE

1 Physical environment

a Present land use

1 Population density.
2 Natural vegetation.
3 Agricultural crops and their growth season.
4 Livestock.
5 Ground water uses and soils stability.
7 Existing industry.

b Future land use

1 Population growth projections.
2 Regional agricultural needs.
3 Regional livestock needs.
4 Recreational potential.
5 Silvicultural potential.
6 Future industrialization.

c Water availability and use

1 Quantity available.
2 Surface water quality.
3 Ground water quality.
4 Present and future water requirements for:
 a Industry.
 b Residential.
 c Recreational.
5 Relationship between water quality and vegetation cover.
6 Flood plain location and flood frequency.
7 Receiving stream chacteristics and availability of dilution water.
8 Present and future discharge inventory into river basin.
9 Water quality impacts of present and projected discharges.

d Meteorological factors

1 Climate - humidity, temperature range, rainfall, seasonal variations, prevailing wind patterns, wind speed, wind variability, inversion conditions, sea breeze effects, valley downwash conditions, ventilation potential.
2 Surrounding topography - ground cover, terrain, orographic effects, channelling effects, surface roughness, effects of water bodies.
3 Atmospheric dispersion characteristics, terrain characteristics, typical lapse rates, nocturnal and subsistence inversions, wind variability.

e **Ambient air quality - background levels**

1 Ambient air monitoring data available.

2 Air emission inventories for the surrounding area, air quality impact predictions for present and projected emissions for all sources in the area.

3 Fugitive emission air quality impacts, i.e. roads, ploughed fields, forest, bulk loading and handling facilities, mining operations, transportation.

f **Solid waste disposal potential**

1 Soil permeability conditions.

2 Ground water location and use.

3 Vegetation cover characteristics.

4 Aesthetics of land fills in the area.

5 Proximity to coastal areas.

6 Requirements for top soil segregation.

g **Coastal management**

1 Estuarine water flow and quality.

2 Beach erosion from dock, pier or breakwater construction.

3 Water quality and recreational impacts from construction runoff, plant runoff, waste water disposal.

2 Social environment

a Demography

1 Population location.

2 Indirect impact of transportation requirements.

a People.

b Raw materials.

c Products.

3 Impact on population growth in urban and rural areas.

4 Housing needs resulting from plant operation.

b **Aesthetics and economics**

1 Impact on property values.

2 Aesthetics of the plant.

3 Need for professionals, i.e. medical, legal, governmental, educational, commercial, etc.

4 Impact on tax base and public spending requirements.

c **Impact on historical, cultural and archaeological or sacred sites in the area**

3 **Economic environment**

1 Plant impacts on wages and wage rates.

2 Plant impact on cost of living for plant employees and non-employees.

3 Plant impact on community growth and commercial development.

4 Plant impact on tax base, tax rates and tax requirements.

5 Plant impact on spin-off development and subsequent secondary impacts on regional economy.

4 **Construction phase**

1 During the construction phase, specify impacts may have to be considered such as: traffic congestion, noise, temporary workforce requirements, etc.

ANNEX II[(10)]

Threshold Limit Values concerning Health Protection of Workers

A. Fluoride (USA, NIOSH)

HF as F	2 mg/m^3
Particulate Fluorides as F	2.5 mg/m^3
Total HF as F and Particulate Fluorides as F	2.5 mg/m^3
F^- in urine (+)	4 mg/l preshift after 48 h. of non-exposure
and	7 mg/l postshift taken on 4th or later day of the workweek

(+) Not an official TLV, but applied at all smelters. Both of these values of 4 mg/l and 7 mg/l are applicable to work groups (e.g. anode changer, spike setters, etc.) and the number represents geometric mean values for each of these individual job groups.

B. Other Contaminants (USA)

SO_2	5 mg/m^3
Total Suspended Particulates	10 mg/m^3 (respirable 5 mg/m^3)

C. Coaltar Pitch Volatiles (USA)

Benzene soluble Organics	0.2 mg/m^3

This TLV is still applied, but research has shown that the dangerous Particulate Aromatic Hydrocarbons (PAH) are found in varying concentrations. Research is under way to develop a simple chromatographic method which would allow several specific PAHs to be measured. It is not possible to be satisfied with monitoring only B-3-4-P (Benzo-3-4-Pyren) which is not sufficiently significant as a carcinogen.

There is a tendency to replace benzene by the less toxic cyclohexane as solvent.

D. Polycyclic Aromatic Hydrocarbons (Thin Layer Chromatography)

Norway - Total PAH	40 ug/m^3
Sweden - B-3-4-P alone	5 ug/m^3

E. Noise

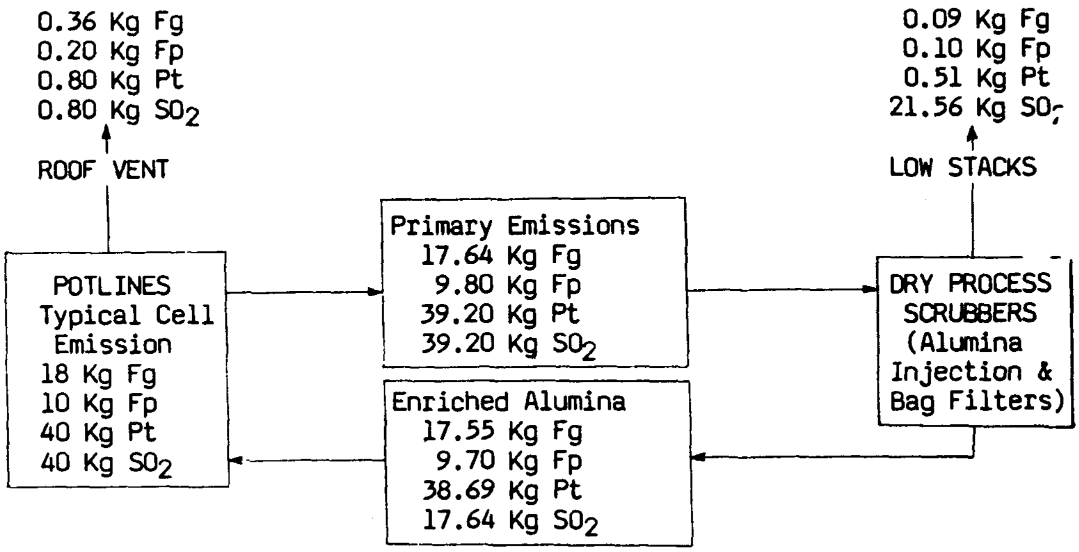
USA - OSHA	90 dBA
USA - ACGIH	85 dBA

These values are time weighted average concentrations for a normal 8-hour workday or 40-hour workweek.

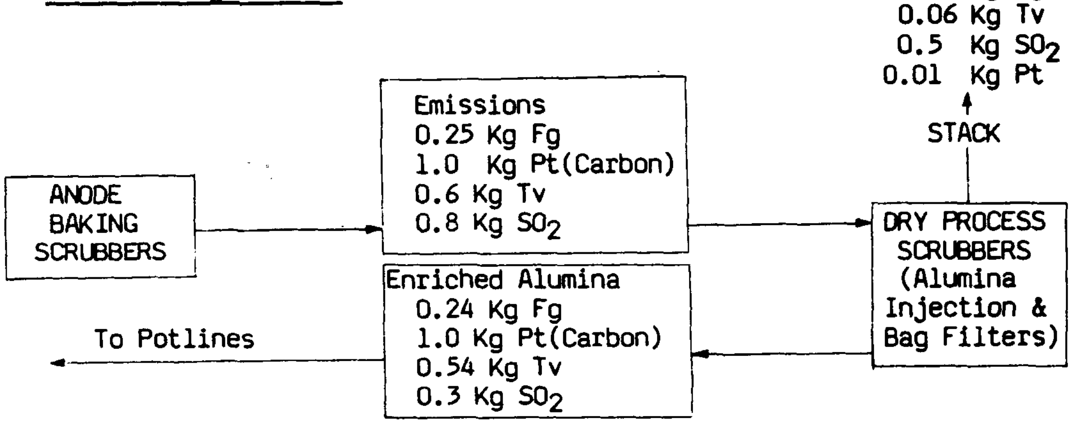
ANNEX III

Airborne Emissions from a Modern CWPB Plant (Long term average) - AN EXAMPLE

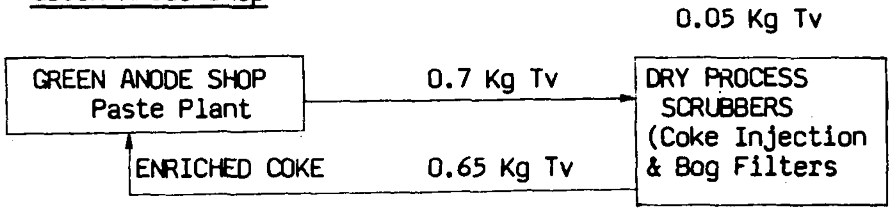
Source 1 : Potlines



Source 2 : Anode Baking Furnace



Source : Green Anode Shop



NOTE :

1. Emission Levels Shown are the Quantity Emitted per Tonne of Aluminium Produced
2. Fg Gaseous Fluorides; SO_2 Sulphur Dioxide
   Fp Particulate Fluorides; Tv Tar Vapour
   Pt Particulates, including fluorides and excluding particulates from other sources than cell. When including particulates from other sources than cell, the actual amount to roof vent will be about 3,0 kg Pt.
3. Based on 2% S in coke.

Bibliography

1. "Environmental Aspects of Aluminium Smelting", Technical Review UNEP, IEO, 1981.

2. Journal of Occupational Medicine (J.O.M.) Jan. 1977 Vol. 19, Nº 1
   (a) Fluorides: A New Critical Review: James P. Hughes, M.D. p 11
   (b) Occupational Fluoride Exposure: Harold C. Hodge, Ph.D. p 12-39
   (c) Effects of Fluoride on Livestock: J.W. Suthie, Ph.D. p 40-48
   (d) Fluoride and Plant Life: Leonard H. Weinstein, Ph.D. p 49-78

3. Fluorine and Fluorides, Environmental Health Criteria 36, IPCS (International Programme for Chemical Safety), WHO, Geneva, 1984.

4. "Review of the Petroleum Coke Situation and its Potential Impact on Sulphur Dioxide Emissions from Primary Aluminium Plants". IPAI (International Primary Aluminium Institute), December, 1978.

5. "Guidelines for Assessing Industrial Environmental Impact and Environmental Criteria for the Siting of Industry". UNEP Industry and Environment Guidelines Series, Vol. 1. 1980.

6. "Environmental Recommendations for Siting and Operation of New Primary Aluminium Industry Facilities". IPAI Dec. 1977.

7. "Environmental Legislation Survey", IPAI 1981.

8. "Health Protection in Primary Aluminium Production", IPAI, Proceedings of a Seminar, Copenhagen, 28-30 June 1977.

9. "Health Protection in Primary Aluminium Production", Volume 2, IPAI Proceedings of a Seminar, Montreal, 22-24 September 1981.

10. "The Measurement of Employee Exposure in Aluminium Production", IPAI July 1982.

11. "The monitoring of Emissions from Aluminium Production, Sampling and Analytical Techniques, with Particular Reference to Fluoride Emissions", IPAI August 1978.

12. "Sampling and Analysis of Fluoride: Methods for Ambient Air, Plant and Animal Tissues, Water, Soil and Foods". J.S. Jacobson, Ph.D. and L.H. Weinstein, Ph.D. Journal of Occupational Medicine, Volume 19 N°1, p 79-87, January 1977.

ANNEX IV

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