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FERROALLOY PRODUCTION
AP-42 Section 12.4
Reference Number
26

Trondheim October 7th, 1968.
21/IN/EA/

Dr. John H. Ludwig,
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Ohio 45 226, U.S.A.

Dear Dr. Ludwig,

Pollution Problems by Electric Furnace Ferro-Alloy Production.

/. For your information we enclose a copy of a report prepared by SINTEF on behalf of the Royal Norwegian Department of Industry.

Sincerely yours
SINTEF
Ivar Nestaas

Enclosure.

United Nations

Economic Commission for Europe

Steel Committees ad hoc Group of Experts on Air and Water Pollution Arising in the Iron and Steel Industry

Note Presented by Norway

Pollution Problems by Electric Furnace Ferro-Alloys Production.

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SUMMARY.

Fumes emitted from furnaces producing ferro-alloys are probably not harmful to people, animals or vegetation. The fumes are objectionable from an esthetical and psychological point of view, and deposition of coarse particles in the immediate vicinity of the plants is a problem in some cases.

The fume- and dust-problems in the metallurgical industry present many difficulties. Their solution demands intimate knowledge of gas cleaning technology, chemistry and metallurgy. The formation of fumes represents a loss of energy and valuable material from the process. It is thus of great importance to reduce these losses to a minimum.

Open sub-merged arc furnaces are widely used in the production of ferrosilicon, ferrochromium and silicomanganese. The volumes of gas emitted from the stack of these furnaces are very large. Only 0.5-3 % of the gases are produced in the furnace itself, the rest is infiltrating air. Cleaning of these very dilute gases is expensive, especially because the large number of very small particles demands very effective cleaning to make the plume invisible.

The gas volumes emitted from closed furnaces, widely used in the production of ferromanganese, are relatively small and their cleaning presents relatively few technical problems, expecially when the gases are collected in the unburnt state. The unburnt gas, containing a high percentage of carbon monoxide, is poisonous and forms explosive mixtures with air. This makes the reliability of the gas cleaning equipment a very important feature. Wet cleaning systems are most widely used, giving rise to problems associated with the disposal of sludge and contaminated water.

It is likely that closed and semi-closed furnaces for the manufacture of alloys which are now being manufactured in open furnaces will be developed in the future. Careful preparation of raw materials will favour this development. Classified raw materials will for instance give better operation of the furnaces, higher yield and less fume.

The remainder of this summary presents a brief survey of published information regarding air pollution problems associated with the most important ferroalloys: ferrosilicon, ferromanganese, silicomanganese and ferrochromium.

Ferrosilicon.

Ferrosilicon is predominantly produced in open, 3-phase electric furnaces. Some semi-closed furnaces for production of alloys containing 45 % silicon or less are however in operation. An increasing content of silicon in the alloy increases the formation of fume, and consequently the consumption of quartz, more than proportionally to the silicon content of the alloy. An open 6000 kW ferrosilicon furnace ventilated by natural convection is reported to emit 150-200 000 Nm^3 of stack gas per metric ton of 75 % ferrosilicon produced. The particulate emission is then 100-200 kg per metric ton of 75 % ferrosilicon. It can for practical purposes be considered as consisting of two fractions, a coarse one (10-20 %) composed of particles from the charge and a fine one composed of sub-micron amorphous SiO_2. The finer fraction is forming the characteristic plume associated with the production of ferrosilicon.

A complete elimination of the visible plume will demand removal of more than 95 % by weight of the solid material. This can only be obtained by means of gas-cleaning equipment of very high efficiency. The coarse fraction can be removed by less expensive equipment at lower cost.

The report mentions some of the more recent installations, a dry electrostatic precipitator in Norway, a wet precipitator in Switzerland and a baghouse in France. Published cost-data are included, but no attempt has been made to compare the economics of different systems.

Ferromanganese.

The emission of poisonous manganese compounds during production of ferromanganese has been drastically reduced after the shift from open to closed furnaces. The gases from closed furnaces can be collected in concentrated form and cleaned for subsequent use as a fuel. Different types of high-energy scrubbers are still the most widely used type of gas-cleaning equipment in this connection.

1. INTRODUCTION.

Ferro alloys is a common name for alloys consisting of iron and one or more other metals, being used by the steel industry as desoxidants and as sources of alloying elements to obtain desired properties in the steel. Most of the alloying metals are less noble than iron, indicating that the process temperature during smelting of the alloys must be higher than during the reduction of iron and higher the more stable their oxides are. The practical consequence of this is that only a few of the ferro alloys can be manufactured by carbothermic reduction in furnaces of the blast-furnace type. Production of ferro alloys is thus particularly well suited for electric smelting.

2. THE DIFFERENT FERRO ALLOYS.

2.1. High silicon containing alloys.

Ferrosilicon is an alloy consisting of iron and silicon, the composition is indicated by its silicon content in %. Alloys containing more than 15 % silicon are termed high-percentage alloys. The common alloys produced in electric furnaces contain approximately 25, 45, 75 and 90 % of silicon. Silicon metal containing approximately 98 % of silicon is manufactured in the same type of furnace.

2.2. Manganese alloys.

These alloys contain Mn, Fe and smaller amounts of C and Si. The most important process is carbothermic reduction of manganese ore in blast furnaces or electric furnaces. Aluminothermic and silicothermic reduction is to some extent used in production of alloys with low carbon content.

Alloys having a low manganese content, like spiegeleisen (5-20 % Mn, 3.5-5.5 % C), silico-spiegel (15-20 % Mn, 10 % Si and 5 % C), and ferro-manganese having a high carbon content (78 % Mn, 7 % C, 2 % Si and 13 % Fe) are produced in ordinary blast furnaces.

Ferromanganese having both high, medium (1-1.5 % C) and low (0.1-0.3 % C) contents of carbon, as well as several qualities of silicomanganese (15-25 % Si), are produced in [illegible]

2.3. Chromium alloys.

Ferrochromium alloys are usually containing 60-70 % Cr, 4-6 % C and less than 2 % Si. Alloys of differing compositions are, however, produced according to demand. Ferrochromium alloys having a low content of carbon were most widely used some years ago. The introduction of oxygen-blown furnaces in the steel industry has to an increasing extent shifted the demand towards the significantly less expensive alloys having a high carbon content.

2.4. Other alloys.

In addition to the main types mentioned earlier, there is also a limited production of other alloys. Among these is a series of alloys containing aluminium and calcium.

3. ELECTRIC SMELTING.

3.1. Metallurgy.

The raw materials for the production of the common ferro alloys are iron in the form of scrap or iron ore and, according to the specific alloy to be produced, quartz and oxidic manganese or chromium ores. The reduction material is carbon, in the form of coke, coal or charcoal, or silicon. Fluorspar, limestone, bauxite and other additives are used to form slag, and in some cases as sources of aluminium or calcium for the alloys.

The general equation describing the carbothermic reduction taking place in the electric furnace is:

$$Me_xO_y + y\,C = xMe + yCO$$

The equilibrium will in presence of iron or easily reducable iron ore be strongly shifted to the right. The heat released during dissolution of for instance silicon in iron essentially promotes the reduction of the quartz by contributing to the energy of reaction.

Reduction of oxides of manganese and chromium leads to the formation of ferro alloys having a high content of carbon:

$$Fe + MeO + 2\,C \longrightarrow [Fe - Me - C] + CO \qquad \text{(Reduction)}$$

The carbon content depends upon the temperature during the reduction, the contents of metal oxides and the alkalinity of the slag. The carbon may be partially removed by a successive refining causing a substantial loss of metal oxides. The loss of metals increases rapidly with decreasing carbon content of the alloy.

High-quality ferrochromium and ferromanganese having a low content of carbon are for this reason produced by means of a combined carbothermic-silicothermic process:

1. $MeO + SiO_2 + 4\,C + Fe \longrightarrow [Fe - Me - C - Si] + 3\,CO$
2. $[Fe - Me - C - Si] + 2\,MeO + CaO \longrightarrow [Fe - 3\,Me - C] + CaO \cdot SiO_2$

The first step consists of making an intermediate alloy containing silicon and a small amount of carbon. This alloy is made by carbothermic reduction in an electric furnace, its carbon content depends upon its content of silicon. The second step consists of the intermediate alloy being desiliconized with ore in a Héroult furnace during addition of limestone.

3.2. The mechanisms of smelting and fume formation.

Development of energy during smelting of ferro-alloys in electric furnaces is partly occuring in the electric arc and partly by electric resistance in the charge. There is a great number of small electric arcs between the electrodes and the charge. The smelting takes place rapidly at high temperature in a comparatively narrow region surrounding the lower end of the electrodes. This mechanism of smelting is usually leading to evaporation of metals and oxides of metals having an appreciable vapour pressure in the temperature region from 2000 to 2500°C. It is assumed that metals like for instance Mn, Fe and Si have a trend to evaporate in the region of the electric arc. SiO as well as several alkaline compounds do also have a significant vapour pressure in this region.

The process gases rising through the charge consist of CO and evaporated oxides and metals. If combustion takes place on the surface of the charge, the vapours react to form the characteristic metallurgical fume consisting of sub-micron oxide particles.

In a closed furnace where no combustion takes place due to lack of oxygen, the metal vapour may during the cooling period react with CO to form finely divided carbon particles and low-valence metal oxides like FeO, MnO and possibly SiO. [illegible]

3.3. Electric furnaces.

The open electric furnace represents the oldest and simplest design, and is still the one most widely used. The closed furnaces are however to an increasing extent being used when the raw materials do not form cavities and bridges in the furnace but sink uniformly. Production of pig iron, calcium carbide, and to some extent silico manganese are examples of processes of the latter kind. Open furnaces are still required in the so-called high-temperature processes for production of alloys having a high content of silicon. The reason is that quartz, the main component of the charge, at temperatures below its smelting point tends to become pliable and form a sticky mass.

Modern open furnaces are usually equipped with a hood for the collection of gases which are released to the atmosphere through a stack mounted on the roof of the building. Large amounts of air are flowing into the hood, the gas emitted to the atmosphere contains only 0.5-3 % of gases produced in the furnace itself. Reducing the volume of secondary air by decreasing the distance between the hood and the furnace, or by designing a nearly closed hood with small openings to be used by the operators,has proved difficult. The primary difficulties have been to provide access to the furnace for the operators and to avoid damages because of high gas temperatures.

Closed and semi-closed furnaces emit relatively small volumes of gases to be cleaned, and the cleaning does not present technical problems provided no combustion takes place. The gas contains a high percentage of CO and is a valuable fuel. Cleaning of the gas followed by combustion may be a profitable process. Installation of gas cleaning equipment in connection with closed furnaces demands special precautions to be taken because the gas i poisonous, explosive if mixed with air in certain proportions and containing a high and varying amount of finely divided particulate material. The cleaned gas will frequently have to be transported in long ducts to the place of consumption, this calls for high-efficiency cleaning. Wet cleaning systems are for reasons of safety and simplicity of operation most widely used. Providing the large amounts of water needed and the disposal of sludge may however present serious problems.

Complete collection of gas from the closed furnaces is usually not achievable. Some gas will escape during charging and around the electrodes, this gas will burn in the same manner as the gases emitted from the open furnaces. It will mix with large volumes of air before it is collected by the hood and [illegible] cleaning of this gas would because of the large volumes involved be very expensive. This indicates the importance of preventing leakages from closed furnaces. Air pollution problems caused by fumes escaping from closed furnaces could, however, in most cases be solved in a satisfactory manner by means of tall stacks.

3.4. Raw materials and emission of fumes.

The particle size of the raw materials has a very pronounced effect upon the operation of electric furnaces and the formation of fumes. It determines the porosity of the charge and the possibilities of obtaining a steady and uniform emission of gases. A porous charge will give a good distribution of gas across the furnace, while in a dense charge containing a large proportion of fines the gas will be emitted from a few passages close to the electrodes. The temperature and the velocity of the gas will in this case increase and the typical eruptions occur. They lead to an increase in gas temperature and an increased loss of material due to vapourization and to charge material being carried away.

The ideal size of the coke is approximately 5-15 mm. The industry is presently to a great extent using as a reductant unscreened coke having a size of 0-25 mm. As much as 50-60 % of the material may be smaller than 4 mm. It is evident that a classified fraction of coke, say 5-15 mm, will give an essential increase in porosity of the charge and thus improve the operation of the furnace and reduce the amount of particles and fumes emitted. Classifying the raw materials is, however, an economic as well as a technical problem. Special installations for screening and drying are required as well as facilities for storage of the different fractions. The fines will have to be sintered or briquetted to make further use possible, and represent a special problem.

Available experience seems to indicate that quartz having good thermal stability increases the yield during smelting of ferrosilicon, thus reducing the amounts of fumes emitted.

[illegible]TION PROBLEMS AND TECHNICAL MEANS OF THEIR ABATEMENT.

[illegible] Ferrosilicon.

[illegible] The process.

3-phase furnaces are the dominating type for production of ferrosilicon, [illegible] newer ones have the electrodes placed in a triangle. The size of the furnaces varies from 6-8000 kVA in the older upwards to 40 000 kVA in the largest of the newer ones.

The raw materials are quartz, iron (usually iron ore or scrap) a reductant (coke, coke-breeze, charcoal or coal) and electrodes. The process is chemically to be considered as a carbothermic reduction of quartz according to the stoichiometric equation:

$$Fe + SiO_2 + 2\ C = FeSi + 2\ CO$$

The special nature of the air pollution problems connected with the production of ferro silicon is caused by the open furnaces. Work has been going on for a long time to build closed furnaces, and a few semi-closed furnaces for the production of qualities containing up to 45 % Si are operating today. These furnaces do, however, demand classified coke and good quality scrap iron. Operation of these furnaces become more difficult with an increasing content of silicon in the product. Experiments are also being made with fully closed furnaces, the results indicate that the problems connected with their operation will not be solved in the near future.

The eruptions represent a considerable loss of material. Satisfactory operation of a ferro silicon furnace does then demand that the eruptions are counteracted efficiently. Careful attention from the operators is very important. The general operating conditions of the furnaces have a strong influence upon the energy consumption and the yield of silicon during the process, and consequently also upon the amount of silicon dioxide in the fume. An increasing content of silicon in the alloy increases the frequency of eruptions and the emission of fumes. The consumption of quartz increases more than proportionally to the content of silicon in the alloy.

[illegible] The quantities emitted.

The fumes in the gases emitted are mainly consisting of amorphous SiO_2, formed by reaction between evaporated SiO and atmospheric O_2. The loss of [illegible]

4.1.3. Gas cleaning.

A series of attempts to clean the burnt gases from open FeSi furnaces have been made. The coarse fraction causing dustfall in the vicinity of the plant can be removed by means of cyclones or multicyclones. Even simple gas cleaning installations are, because of the large volumes of gas involved, expensive in installation and operation. A combination of cyclones and a tall stack will, however, in many cases eliminate much of the nuisance. The fine particles of SiO_2 have for practical purposes no velocity of sedimentation, their movement is determined by the circulation of the surrounding atmosphere. Local meteorological and topographical conditions are thus controlling the dispersion of the plume, and should be given careful consideration whenever a site for a new plant is being selected.

Cleaned gas effluent from the production of silicon metal and 75 % ferro silicon has been described as follows[4]:

- slightly blue and nearly invisible at a dust content of 0.05 g/Nm^3
- 0.1 g/Nm^3 already shows the existence of a furnace
- 0.15 g/Nm^3 yields a gas of whitish-grey colour and the fumes disperse at a distance of some hundred meters from the stack.

This means that complete elimination of the very evident plume from a ferro silicon furnace requires a cleaning efficiency in excess of 95 % by weight. High-efficiency gas cleaning equipment as electrostatic precipitators, fabric filters or high-energy scrubbers will be required to obtain this. Pilot-scale experiments have indicated that a scrubber to obtain a sufficient efficiency would require an energy consumption of 1000-1500 kWh per metric ton 75 % FeSi, or 10-15 % of the energy required during the smelting.

Two examples of recently installed gas-cleaning plants shall be described in more detail. A Norwegian plant has installed a dry electrostatic precipitator in connection with a 9000 kW furnace producing silicon metal. Due to the high resistivity of the fume particles, the gases are initially cooled with water in a conditioning tower. The installation has been in operation for a little more than a year. Some difficulties encountered during the running-in period seem to be essentially overcome by now. The installed cost was 4.5 mill.N.kr. Operating costs have been reported to be 100.000 and capital costs to be 450.000 N.kr. per year, making the total costs of gas cleaning 83 N.kr. per metric ton of 75 % FeSi [5]. 10 metric tons of dust having a volume of 50 m^3 are produced every 24 hours. No profitable use of the dust has been found yet.

A Swiss company has recently published an account of their experiences in cleaning gases from ferro silicon furnaces [4]. Originally they installed a venturi scrubber, but the efficiency obtained was far below expectations. "The hopes with respect to the efficiency of the cleaner broke down, only a maximum of 30 % dust was intercepted. Instead there was an enourmous development of water vapour which worsened the visual situation [4]." Installation of 2 wet electrostatic precipitators was, however, a success. The gases are then cooled and pre-scrubbed by passing through a 15 cm thick layer of glass balls flushed with water before they enter the precipitator. The average dust content of the gas is 1.7 g per Nm^3, corresponding to 150-160 kg dust per metric ton 75 % FeSi. The extreme values encountered during a 24 hours period are 0.6 and 4.5 g/Nm^3. The dust content of the cleaned gas was, according to the guarantee, 0.1 g/Nm^3. It is usually 0.05-0.08 g/Nm^3 except during short periods when the collecting electrodes are washed with water to remove dust deposits. The average dust content is then 0.15 g/Nm^3. ← .07 T/SCF The total amount of water effluent from the 2 precipitators is 130 m^3 per hour, the cleaning of this water has turned out to be a problem. Several experts assured that the slurry could easily be cleaned in settling basins, but the problem of water pollution was underestimated. A very important part of the gas cleaning costs is the "flocculant" used to treat the waste water.

The Swiss company reports that the total installed cost of their gas cleaning installations is 1.2 mill.U.S. dollars. This sum includes the unsuccesful installation of scrubbers, 2 wet electrostatic precipitators with [illegible] facilities for cleaning of water effluents and a baghouse. These installations clean the gases from 2 9000 kVA furnaces producing 75 % FeSi or silicon metal, 2 2500 kVA furnaces producing various other ferro-alloys and 1 4000 kVA furnace producing steel. Having acquired their present know-how, they assume that a satisfactory installation can be built for 700.000 U.S. dollars. The operating costs for the entire pollution control system amounts to 140 U.S. dollars per 24 hours, but they hope to cut it to 90 U.S. dollars per 24 hours.

Several furnaces in France are equipped with baghouses [6], among them are 3 10 000 kVA furnaces producing 40-75 % FeSi and 1 10000 kVA furnace producing 75-90 % FeSi. The results obtained are reported to be favourable, the dust content of the cleaned gas is less than 20 mg/m^3. ← .01 T/SCF The cost of the filter installation, including gas cooler and pre-cleaner, is reported to have been approximately 23 % of the cost of the furnace. Operating costs excluding capital costs were approximately 15 N.kr/metric ton FeSi in [illegible]

4.2. Ferromanganese.

4.2.1. The process.

During reduction and smelting of manganese ore, some of the manganese will evaporate because of its low boiling point. The vapour pressure of manganese is reduced when alloyed with iron, but the trend of the metal to evaporate does even then lead to formation of manganese fumes. As the reduction takes place in molten state, the use of closed furnaces presents few operational difficulties. The closing makes it possible to recover concentrated CO and valuable dust containing a high percentage of manganese.

The first closed furnaces had an installed effect of 7-9000 kW, while the newest furnaces built in Norway have a transformer capacity of 40 000 kVA.

Open furnaces for the production of ferromanganese are to our knowledge not built any more.

4.2.2. The quantities emitted.

Percentual loss of materials with the fumes varies highly according to the amounts of fumes in the raw materials and operating conditions. The literature reports the evaporative losses to be 10-20 %. Modern smelting practice has probably reduced the evaporative losses to approximately 5-10 %.

Published data regarding emissions from open and closed FeMn furnaces are unfortunately scarce. It is, however, likely that the fumes from closed furnaces have properties similar to the fumes from manganese blast furnaces. The coarse fraction constituting approximately 20 % of the solids emission consists of coke breeze and small particles of manganese ore from the charge. The fine fraction is typical metallurgical fume having a particle size of 0.1-1.0 µm.

Measurements on closed 35-40 000 kVA furnaces have shown average dust contents of 15-40 g/Nm^3 in the gas [3] [7]. Solids concentrations of up to 200 g/Nm^3 have been reported. The volume of gas emitted from a closed furnace is usually 700-800 Nm^3 per metric ton of FeMn. The bulk weight of the dust is reported to be 450-500 kg/m^3, or twice the weight of dust from FeSi furnaces.

.2.3. Gas cleaning.

The first closed furnaces for smelting of ferromanganese were equipped with dynamic scrubbers, and scrubbers of various types are still the most widely used type of gas-cleaning equipment. Two recently installed Norwegian furnaces of 36 000 and 39 000 kVA transformer capacity are equipped with a 2-step injector-venturi scrubber and a conventional venturi scrubber. Average solids concentration after the injector venturi is about 20 mg/Nm^3. ← 101 gr/SCF

A French publication [6] describes a baghouse installed in connection with a FeMn-furnace. Experience shows that the gases are considerably easier to clean than the gases from FeSi-furnaces.

Cost data regarding the cleaning of gases from closed FeMn-furnaces have not been found in the literature. The installations will, however, because of the much smaller volumes of gas be far less expensive than the ones used in connection with FeSi-furnaces. The costs of the scrubber installation on two furnaces in Norway are reported to have been 3.5-4.0 % of the costs of the total installations. Operating cost including capital costs is approximately 3-4 N.kr. per metric ton of FeMn [7].

Manganese compounds are poisonous, and the authorities are for this reason frequently imposing restrictions upon the emissions. The shift from open to closed furnaces has led to radical improvements of the atmospheric conditions in the vicinity of plants producing ferromanganese. Some gas is, however, escaping even from the closed furnaces. Cleaning of this gas is very expensive, and tall stacks are recommended as an alternative to cleaning.

.3. Silicomanganese.

.3.1. The process.

Silicomanganese is besides its main use as a desoxidant in the production of steel also used as a reductant in the production of ferromanganese having a low content of carbon (ferromanganese suraffiné). It is usually produced from manganese slag, quartz and coke-breeze in an electric furnace. Low-grade manganese ore can also be used as a raw material.

Open furnaces are still the ones most widely used in the production of silicomanganese, but closed furnaces are used to some extent. It is claimed that open furnaces offer some technical advantages.

4.3.2. The quantities emitted.

Published data regarding the emissions from silicomanganese furnaces are rather scarce. A few measurements on an older, open furnace of 6000 kVA transformer capacity [3] showed that the volume of gas collected by the hood was approximately 70 000 Nm^3/h, 40-50 kg of particulate material containing about 20 % of manganese were emitted per hour. The particulate emission from another Norwegian furnace of 10 000 kVA is reported to be somewhat higher [7], about 170 kg per hour.

The gas from 3 open furnaces in a plant in Italy is reported to contain 1-2 g/Nm^3 of particulate material.

The volume of gas emitted from closed SiMn-furnaces seems to be of the same order as for closed FeMn-furnaces.

4.3.3. Gas cleaning.

Cleaning of the gas from open SiMn-furnaces involves the same problems as the cleaning of gases from open FeSi-furnaces. Large volumes of gas makes the costs of gas cleaning high. The manganese gives the fume a reddish-brown colour, making a high efficiency of collection necessary if the plume is to become invisible. SiMn-dust is easier to collect than FeSi-dust because of its higher specific weight and lower electric resistivity. The gas from the 3 Italian furnaces mentioned above is cleaned in a common electrostatic precipitator of the dry type. Experiments with bag-houses have been made in France. None of the open furnaces producing SiMn in Norway is to our knowledge equipped with gas cleaning installations.

The methods and costs of cleaning the gases from closed SiMn-furnaces are the same as for FeMn-furnaces.

4.4. Ferrochrome and ferrosilicochrome.

4.4.1. The process.

Chromium is less noble than iron, but slightly more noble than manganese and does during the production behave similarly to this metal. Chromium has got a low vapour pressure, making loss of metal through vapourization insignificant. The production consists of carbothermic reduction in open furnaces.

..2. The quantities emitted.

Chromium will because of the low vapour pressure be emitted as comparatively large particles of raw material carried away by the gas stream. Only traces of chromium are found in the fraction below 1 µm, making this fraction similar to the particles in the fumes from FeSi furnaces.

..3. Gas cleaning.

Very little information regarding existing installations is published. Cyclones not capable of removing the fumes are installed on several furnaces in France [6].

A bag-house which was installed on a 5000 kVA-furnace has been troubled by operational difficulties. One of the causes of the trouble was the addition of fluorspar during the smelting. Severe corrosion took place because of the acidic gaseous compounds formed.

The costs of cleaning the gases will for reasons explained before be high. Gas cleaning equipment is to our knowledge not installed on any furnace in Norway.

Trondheim, September 28th, 1960.

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