COMMISSION
OF THE EUROPEAN COMMUNITIES

Technical measures of air pollution control in the iron and steel industry

Reports and information on research work subsidized by the ECSC

as at June 1968

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FOREWORD

During the past 20 years, air pollution has jeopardized man's health to such an extent in many Community areas that some member States have been obliged to introduce new legislation with a view to limiting the discharge of dusts, fumes, gases and vapours.

In many work locations, air pollution is often a very great health hazard owing to the concentration of harmful elements, particularly at the source.

If any kind of contamination of the atmosphere with foreign matter calls for preventive measures, it follows that particularly stringent precautions must be observed at work locations so as to afford adequate protection to the people working there.

It must be admitted that in the past much doubt unfortunately existed regarding the nature and extent of air pollution and the most effective steps of preventing it—doubts which have sometimes persisted to the present day. But, in this sphere, the protection of workers' health is entirely dependent on the answers given to these questions, as does at least a substantial proportion of the industry's profitability.

In view of this, the High Authority, until mid-1967 the executive body of the European Coal and Steel Community, headed a campaign for the control of dust and waste-gas pollution in the sectors for which it was responsible.

The ECSC Treaty particularly charged the High Authority with promoting production and safe working conditions in the coal and steel industries and improving the living and working conditions of labour; accordingly from 1957 onward, it set up research programmes for the technological control of dusts in mines and the iron and steel industry and has since subsidized many studies in this field. One of the High Authority's last decisions was to adopt a new draft research programme for the prevention and technological control of air pollution caused by the iron and steel industry (14 June 1967).

It is the Commission of the European Communities which is now responsible for the implementation of this research programme, now almost ready for the go-ahead signal. The Commission believes the present moment to be an opportune one for providing interested parties with a conspectus of work done in this field since 1958—a decade of research promoted by the ECSC. It also wishes to express its gratitude to all the members of committees and study groups appointed to discuss and follow this work, and also to all others who helped to ensure its success.

In addition to merely summarizing the results achieved by Community-aided research, the present report sets out to give the reader an idea of the iron and steel industry's difficulties in controlling dusts and waste gases with particular reference to the technological and economic aspects of air pollution control. These are difficulties which can only be overcome step by step, by the vigorous and concerted efforts of all concerned, thereby helping to solve the urgent and essentially human problem of adequately protecting the health of workers and their families.

Lionello Levi Sandri

LIONELLO LEVI SANDRI

Vice-President of the Commission
of the European Communities

1. INTRODUCTION

1.1 Sources of air pollution in the iron and steel industry

Whenever reference is made to air pollution caused by the iron and steel industry, this relates often only to the contamination of the outdoor atmosphere with which the general public is familiar in the form of dust and gas emitted by chimneys of converters, open-hearth furnaces, sintering plants, power stations, etc. (Fig. 1).

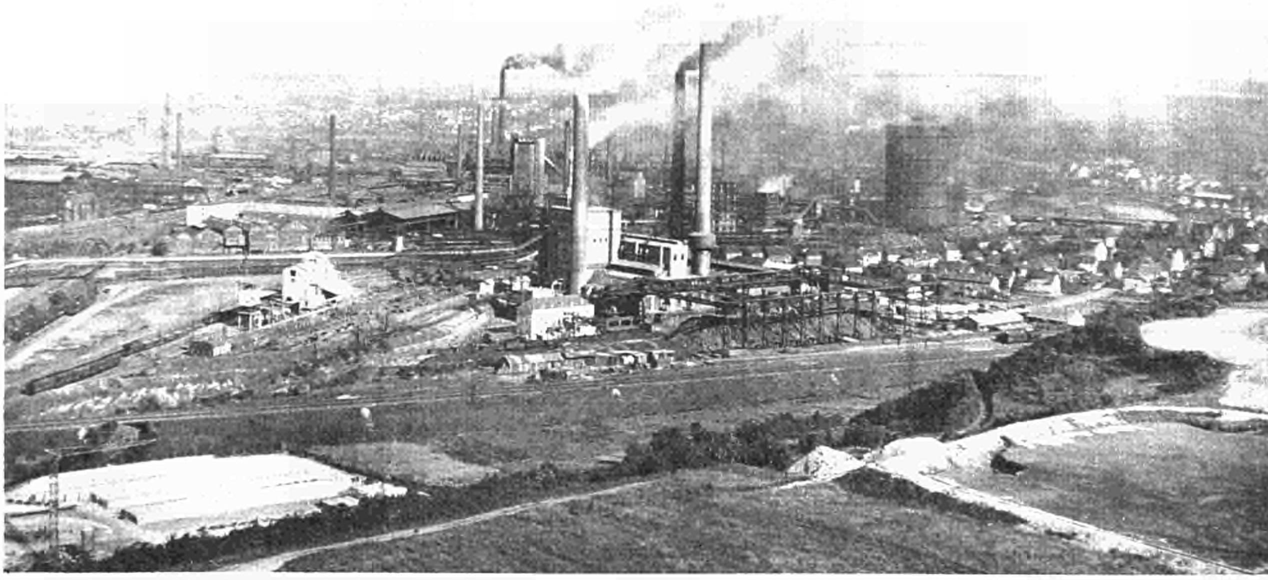

Fig. 1

Dust pall overhanging an industrial area

Despite all air pollution control measures applied to date, there are residential areas near industrial centres where the daily deposition of dust exceeds 1 g per square metre of surface area and where under certain atmospheric conditions the content of SO_2 and other gaseous contaminants attains values which cannot be considered as constituting a source of danger to sensitive plants only.

It should not be forgotten that there are many working areas in which air pollutants are to be found in concentrations that often far exceed those measured in the outside atmosphere and cause considerable annoyance to working personnel whose health is thereby affected. The diagrams in Figures 2a-d give a review of the chief sources of atmospheric pollution in iron and steelworks in regard to both working areas and outside atmosphere.

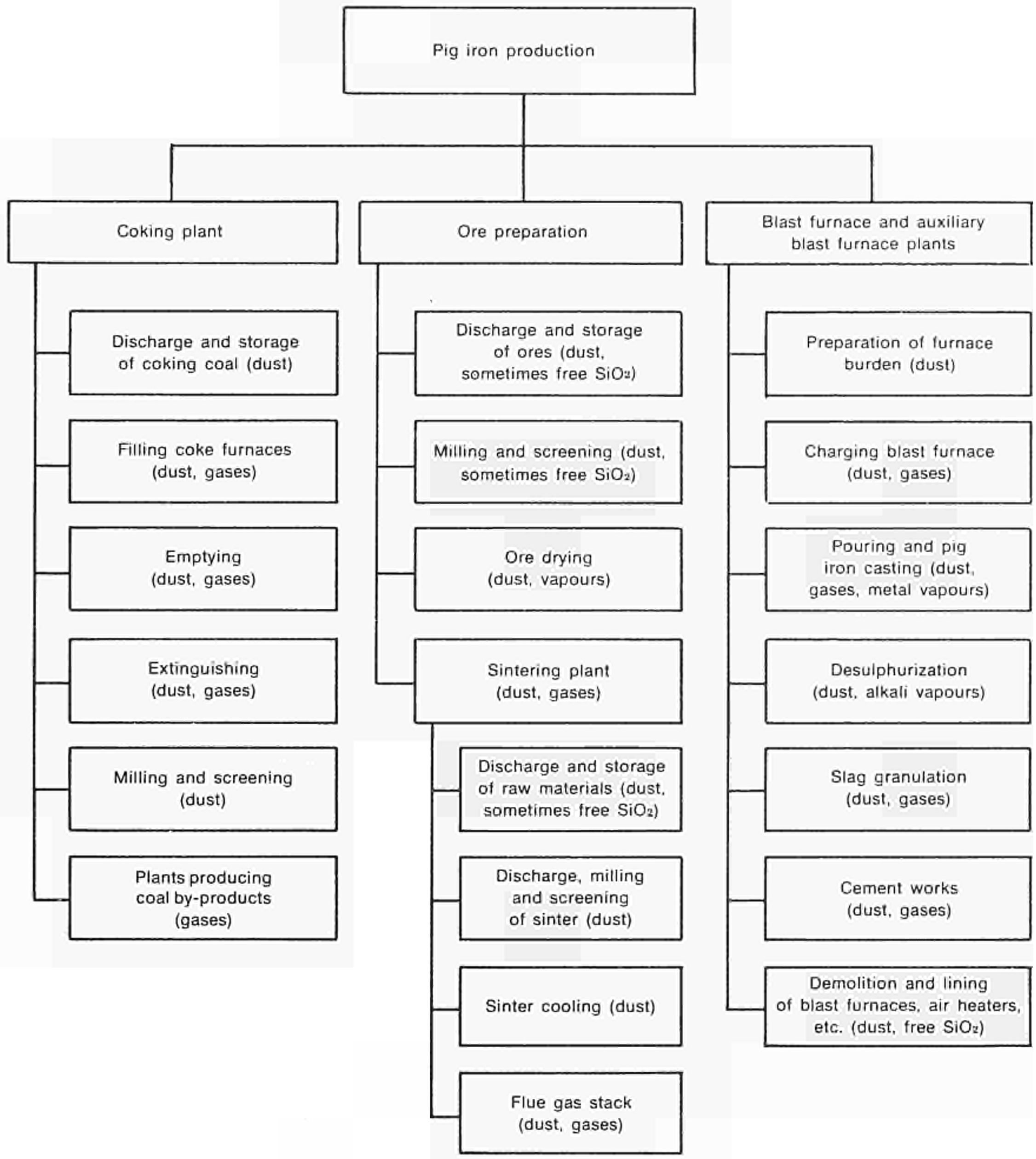

Fig. 2

Sources of air pollution in the iron and steel industry
a) Pig iron production

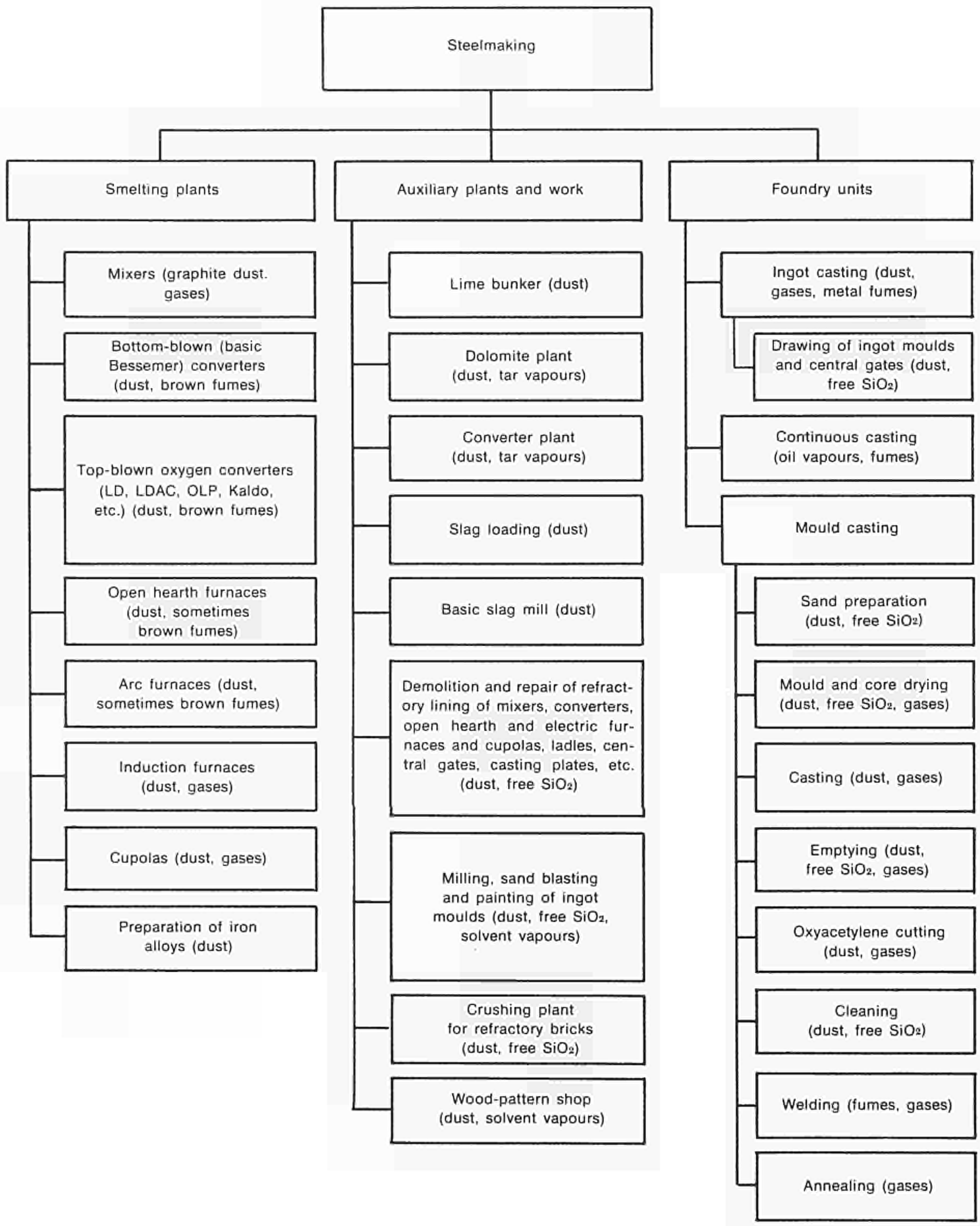

Fig. 2

Sources of air pollution in the iron and steel industry
b) Steelmaking

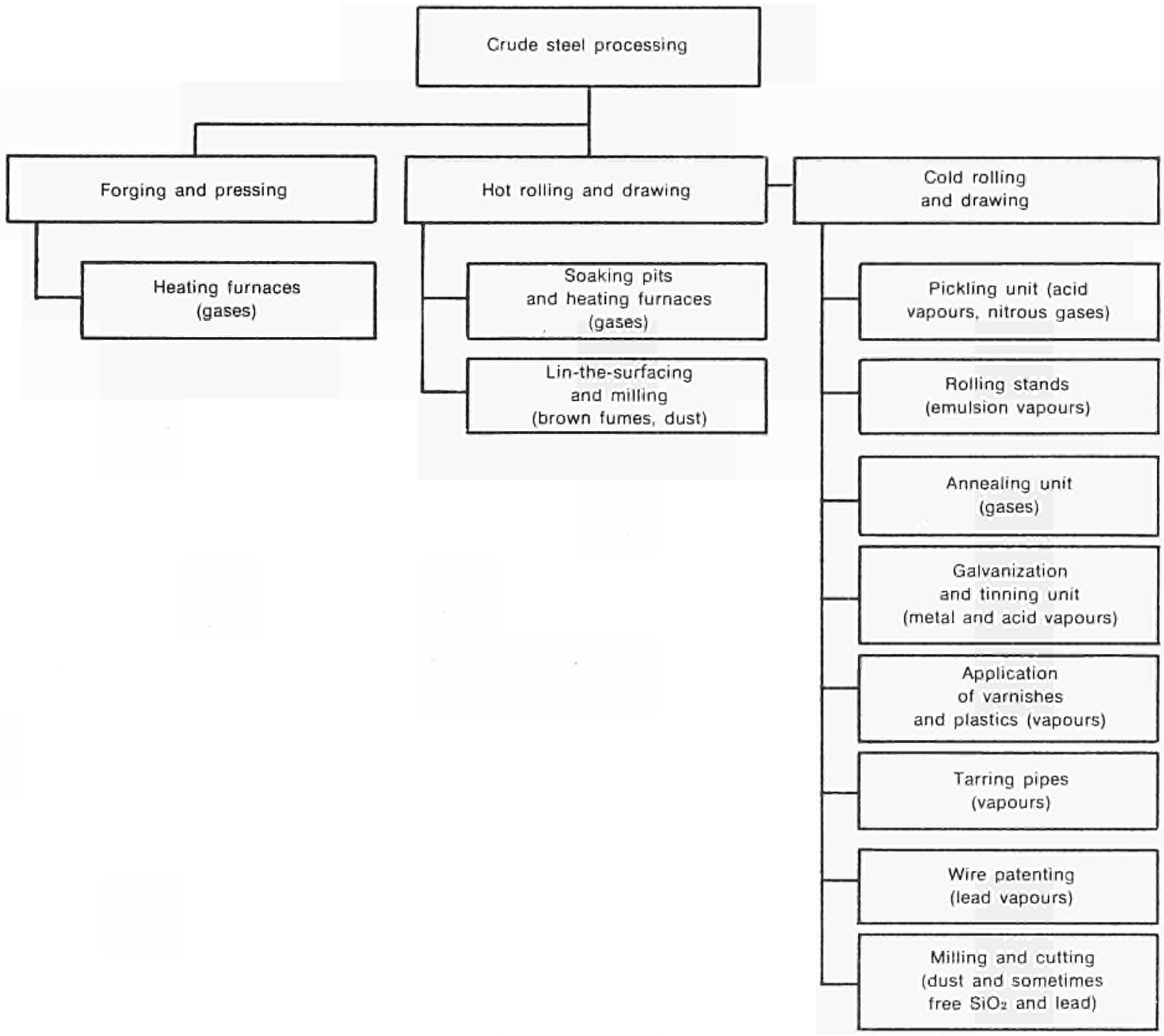

Fig. 2

Sources of air pollution in the iron and steel industry
c) Crude steel processing

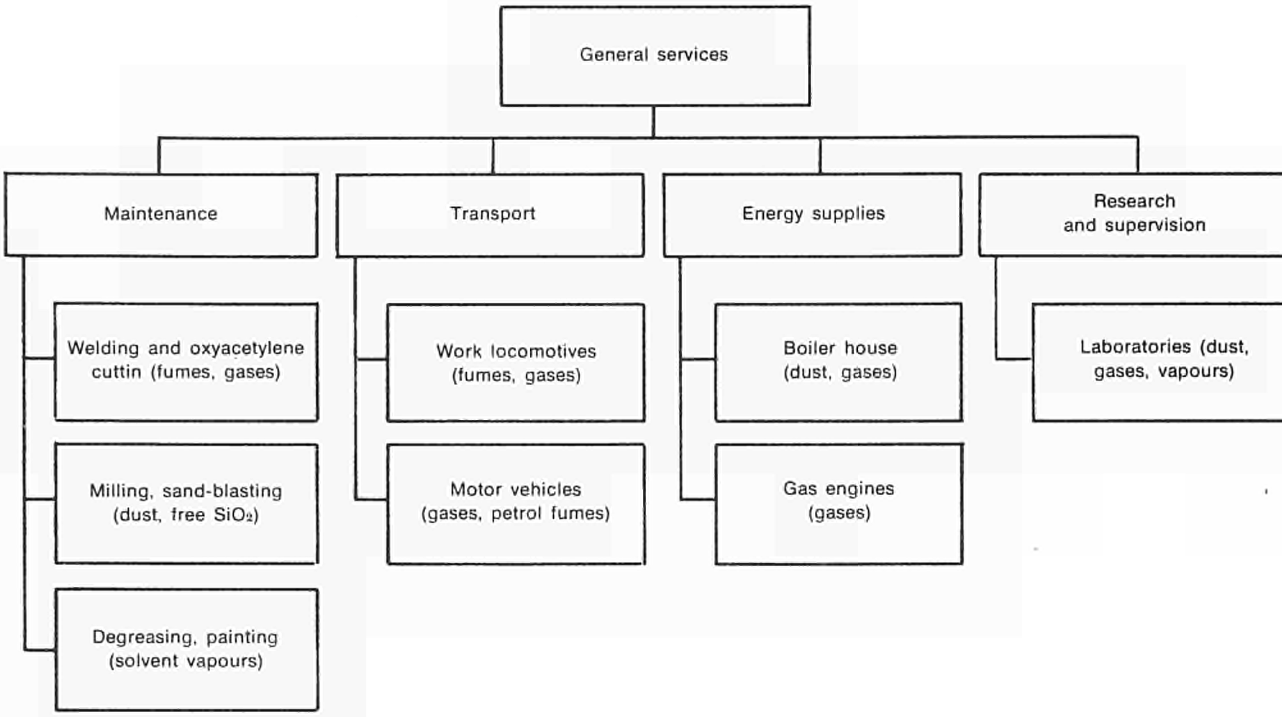

Fig. 2

Sources of air pollution in the iron and steel industry
d) General services

1.2 ECSC activity in the field of air pollution control

Having regard to this situation, the ECSC has for ten years been making considerable grants towards research aimed at increasing knowledge on the nature and extent of such air pollution and developing practical control methods. In the iron and steel industry sector, these grants amount to about 3m. units of account.(1)

These grants come out of levy revenues and are made in accordance with section 55 of the ECSC Treaty. They cover both individual studies and entire research programmes.

For the examination of requests for grants and the drafting of research programmes, the ECSC calls on qualified scientists and technologists of the relevant professional organisations and the governments of the Community countries.

For every research subsidized by the ECSC a research contract is concluded in which the mutual obligations of the research partners are set out in detail.

The results of these researches, continuously supervized by the specialists, are made available to all interested parties in the Community by suitable means such as publications.

Readers interested in these matters may find further information in previous ECSC publications.(2),(3)

1.3 Research and information groups

For the implementation of the first general research programme on technical methods of dust control in the iron and steel industry, the following three headings were considered to be convenient for the preliminary

(1) The unit of account = US $1.
(2) ECSC Bulletin No. 41 (1963) "The High Authority's Research Policy in the technological sphere".
(3) ECSC Bulletin No. 60 (1966) "The High Authority's Policy in the field of Promoting Studies and Research on Industrial Health, Medicine and Safety".

examination of requests for grants, [4], [5] the pursuance of ECSC-aided research work and the mutual exchange of experience in this subject:

(a) dust and gas measurement,
(b) control of brown fumes,
(c) control of other dusts and waste gases.

This is the arrangement followed in the present account of the results of these researches.

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(4) Official Gazette of the ECSC, Vol. 6, No. 37, p. 610, of 16.12.1957.
(5) Official Gazette of the ECSC, Vol. 1, No. 16, pp. 379/80 of 20.9.1958.

2. RESEARCH IN THE FIELD OF DUST AND GAS MEASUREMENT

2.0 Scope and problems

The successful control of dusts and waste gases essentially depends on the proper understanding of their chemical and physical nature and of the amount and concentration with which they occur at the working area, in the outside atmosphere or at the source of emission.

For example, accurate *measurements of the air pollution of a work location* are a *sine qua non* whenever:

(a) the dust nuisance to personnel has to be appraised, or the work location monitored to ensure observance of the maximum acceptable concentrations (MAC) or threshold limit values (TLV),(6)

(b) an exhaust ventilating system is being planned or its operating efficiency has to be checked after installation,

(c) the desirability of purchasing protective apparatus such as dust and gas-masks is under consideration,

(d) it is necessary to study the ambient air pollution caused by a change of method of working, production switch, or the use of alternative primary or auxiliary materials.

On the other hand, the emissions from the various sources of air pollution(7) that concern us here, e.g. a sintering plant or boiler-house, must be measured with a view to:

(a) appraising possible hazard, damage or nuisance caused to ambient environment by waste gases,

(b) determining the stack height required for adequate atmospheric dilution of waste gases,

(c) selecting, dimensioning and designing any air-cleaning equipment required,

(d) supervising the operation of air-cleaning equipment already installed (e.g. for the purpose of ensuring compliance with official regulations limiting emission),

(e) the choice of suitable fuels and raw materials and early detection of variations in the normal process.

Measurements of the ground level concentration(8) of dusts and gases are also required when, for example,

(a) it is necessary to ascertain the causes of damage to vegetation in the neighbourhood of industrial plants,

(b) the efficacy of dust and stack gas control measures (e.g. changing the production process, conversion to other fuels and raw and auxiliary materials, installing air-cleaning equipment) has to be demonstrated.

All these measurements essentially consist of two separate procedures, viz.

(i) sampling and
(ii) analysis.

But often they are not differentiated in ordinary speech, or even in the literature, so that instruments solely used for dust sampling are frequently designated "dust meters".

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(6) The "maximum acceptable concentration" of a gaseous, a fume or dusty pollutant is the concentration in the atmosphere of a work space (measured at the respiratory level) which in general is unlikely to affect the health of persons working in the said space even when they are exposed to it for 8 hours a day.
The maximum acceptable concentrations of gases and vapours are usually specified in ppm (cc gas per cm air) for a temperature of 20°C and a barometric pressure of 760 mm Hg, and that of aerosols (dust, smoke or mist) in mg/m^3 (1 mg material per m^3 air). They are compiled and published in tables regularly brought up-to-date by the competent ministries or organisations of the various countries. These values substantially correspond in western countries and are known as *Valeurs limites de concentration des substances toxiques dans l'air* in French-speaking countries, *Maximale Arbeitsplatz-Konzentration* in the German-speaking area, *Valori limite di concentrazione media nell'aria di sostanze tossiche industriali* in Italian, and as *maximaal aanvaardbare concentratie (MAC)* in the Dutch-speaking area.

(7) By "emission" is meant solid, liquid or gaseous pollutants of any kind or origin which are discharged to the air (e.g. fumes from a chimney or emissions from motor vehicles).

(8) By "ground level concentration" is meant the concentration of solid, liquid and gaseous air pollutants permanently or temporarily found near the ground. Depending on their chemical and physical characteristics and the prevailing atmospheric conditions, ground level concentrations may either constitute a nuisance only or else may cause damage to men, animals and plants and also to buildings, steel structures, etc. Such damage may arise through inhalation, irritation of the skin, chemical attack of the surface of plants or artefacts. Indirect consequences such as reduced radiation from the sun (the smoke pall overhanging many industrial regions) also deserve mention. The term, "ground level concentration" may be compared with F. "immission" or G. "Immission".

Both for sampling and analysis, there already exist many methods and considerable equipment invariably calling for properly trained, reliable and experienced personnel and usually requiring a great deal of time and technical effort, but not always yielding satisfactory results.

In this situation it is understandable that despite research workers' efforts to date:

(a) some uncertainty exists about the reliability or comparability of the results obtained with various types of apparatus and methods for determining air pollution,

(b) there are still many gaps in our knowledge of air pollution in various working locations in different iron and steel plants,

(c) generally speaking there is still too little known about air pollution in the vicinity of iron and steel works (ground level concentration),

(d) hitherto there have only been few practical possibilities of monitoring the dusts and gases (effluents) discharged by the steelmaking industry.

Thus may be defined as the scope of ECSC research on dust and gas measurement:

(a) the comparison and improvement of existing measuring instruments and methods and the development of new ones,

(b) research on air pollution in different work localities,

(c) research on waste gas emissions and ground level concentration.

2.1 Comparison and improvement of existing measuring instruments and methods and development of new ones

2.11 *Comparison of sampling instruments and methods* (Study PS 150)

In view of the reasons stated above, a *comparative study of sampling instruments and methods* should be given high priority.

Undoubtedly some extremely interesting results and experience have been obtained from this study in which 7 institutions from 5 different countries took part, using altogether 10 gravimetric dust-sampling instruments and 12 instruments for the determination of particle size.

The tests were conducted both under practical and laboratory conditions, i.e. once in the sintering plant of a German and in that of a Dutch iron and steel works and twice in the IRCHA's large dust sphere at Le Bouchet, which has a capacity of over 2,000 m³ (Fig. 3).

The first studies carried out in 1961 revealed very few substantial differences in the gravimetric determination of dust concentration, but on the other hand the particle count results showed considerable discrepancies which in particular were due to the limit of perceptibility of the various measuring methods.

In later studies in 1963, 194 mean particle concentration values were determined, and one highly important conclusion was that for any instrument the results obtained in the dust sphere could be compared with those from any other instrument, the standard deviation being 15%.

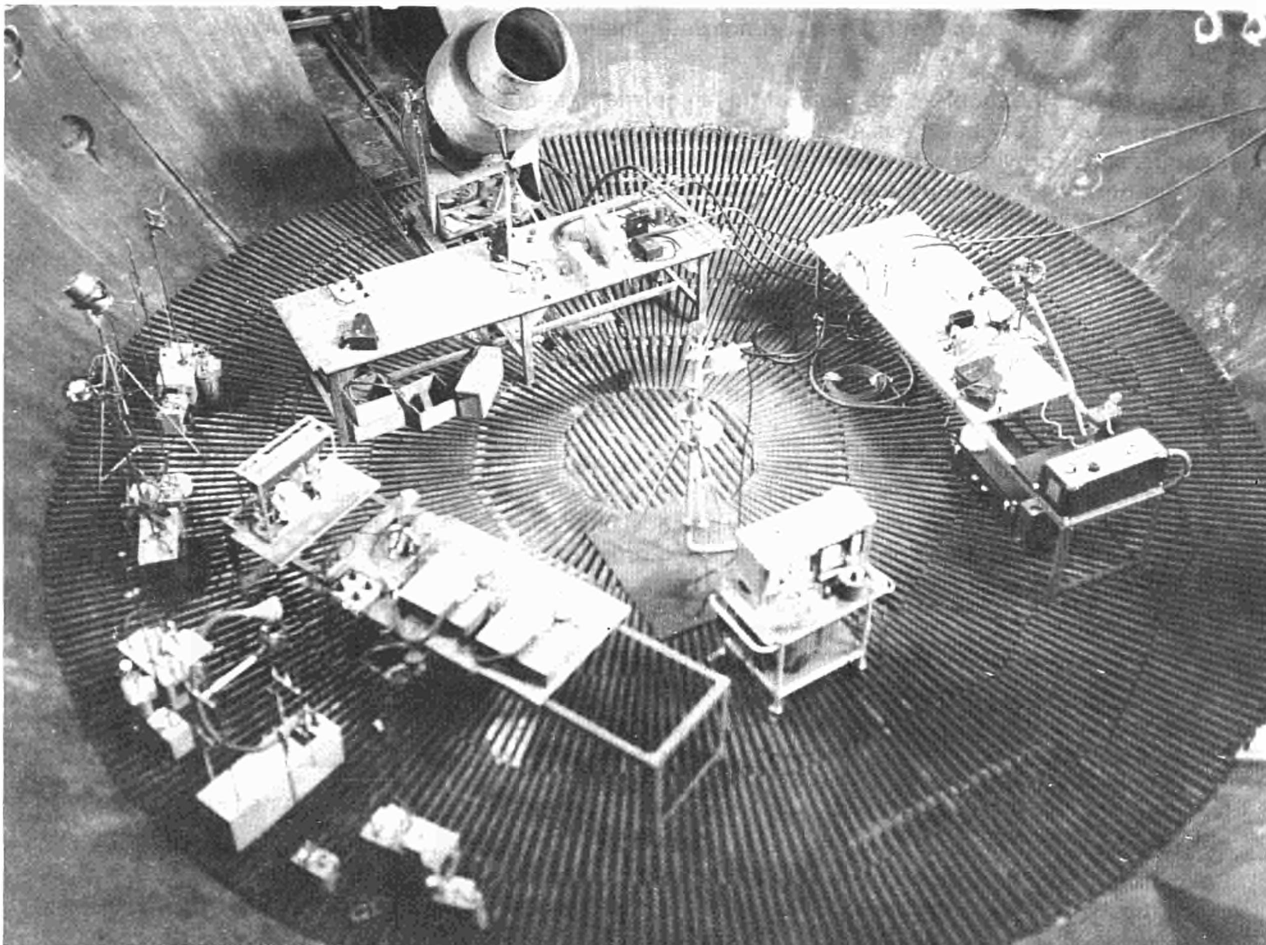
It was found that in general the same comparison could be applied to measurements in the iron and steel works. Since dust concentrations in the industry are known to be subject to random fluctuations, the extrapolation can only be applied to mean or long-term values, not to short-term ones.

It must be admitted that in this Community study one basic drawback inherent in all these instruments could not be overcome, namely that although they enable dust concentrations to be measured at a given point, these dust concentrations do not necessarily correspond to the actual dust exposures of workers in their occupational environment.

2.12 *Development of a portable dust-measuring instrument with a large air sample capacity* (Study PS 139)

Steelworkers are usually not sedentary but move about over areas of varying size in which the dust conditions fluctuate widely from place to place and from time to time.

But the instruments previously used for determining the dustiness of a work locality do not take sufficient account of these factors; either their size, weight and power supply reduce their mobility or they operate intermittently and usually trap so little air that their results cannot be considered as generally valid.



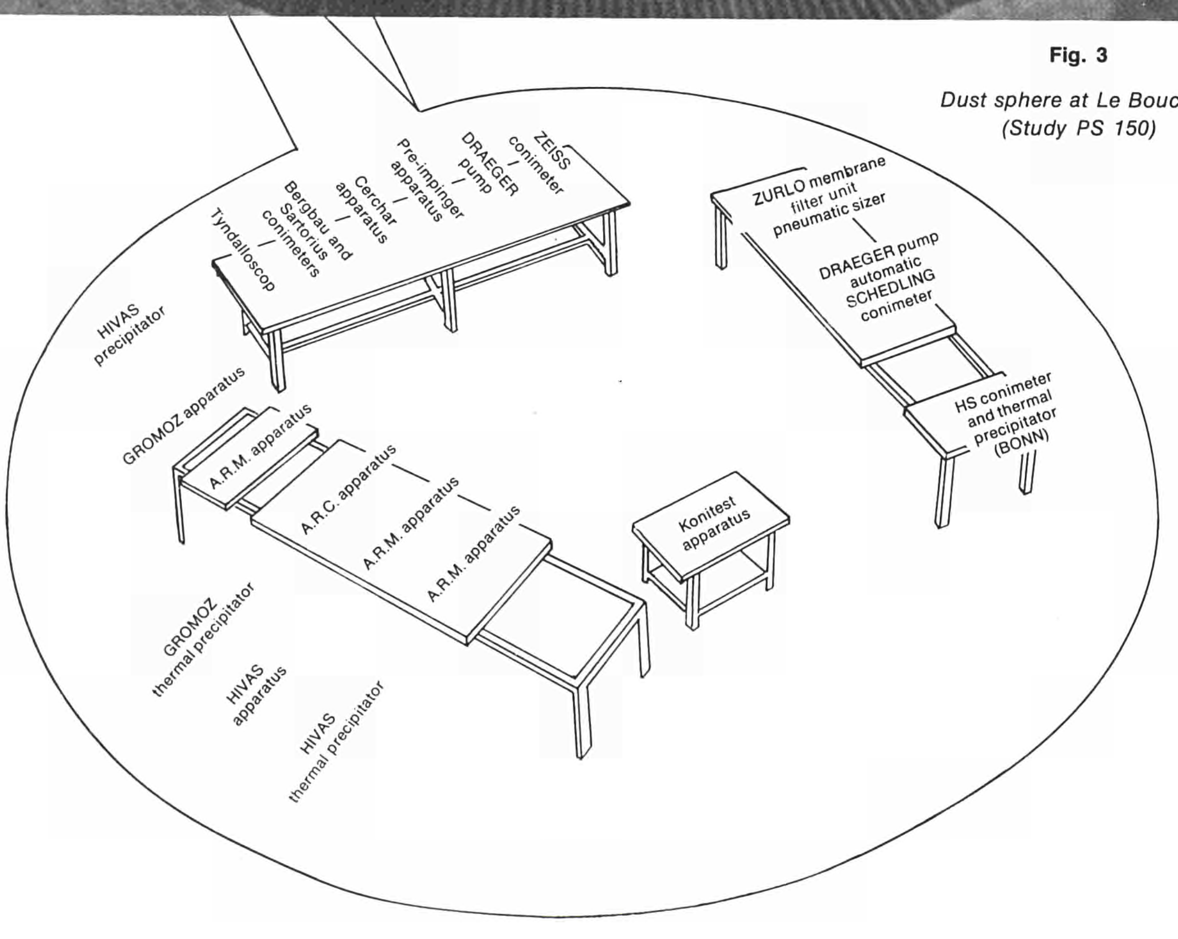


Fig. 3

Dust sphere at Le Bouchet (Study PS 150)

The following study has to led to a considerable improvement. It related to the *development of a small dust collector carried on the back* with a suction nozzle in the immediate vicinity of the wearer's mouth and nose (Fig. 4).

This instrument is about 24 cm high, of the same width, about 14 cm deep, weighs somewhat more than 8 kg, has an electric fan run off a lead storage battery and operating at 10 m^3/h against a resistance of 190 mm, water gauge, and is provided with a flowmeter and a flexible suction nozzle. In this way it is possible for the dustiness in the worker's respiratory zone to be determined very accurately even when his work involves constant movement from place to place.

So great was the demand for this instrument that it is now being manufactured on a commercial scale.

2.13 *Micropore membranes* (Study PS 10)

In many cases dusts precipitated on the filters of dust collectors not only have to be weighed and compared with the amount of the induced air stream, but also subjected to a further chemical, physical and especially microscopic examination.

In recent years the micropore filter has often been used for this purpose. It consists of cellulose acetate or cellulose nitrate membranes 1/10 to 2/10 mm in thickness which are rendered transparent or even completely soluble by certain fluids. But the use of these very practical filters soon created a number of problems, for example how to fix the particles retained on the membranes (in order to prevent losses in the transport of dust samples) or how to assess the errors arising when the particles overlie each other and cannot be counted separately.

Both these and other problems were solved by a study relating to the *use of micropore membranes for the determination of dust concentration in the iron and steel industry.*

The object of the study was the development of a definitive method of counting air-borne dusts by means of membrane filters, the following factors being investigated:

(i) The effect of air humidity and speed.
It was found that the humidity of the air has no influence and that the air speed is negligible when it does not exceed 3 m/sec;

(ii) Solubilization of the membranes.
Since the membranes could be solubilized, all the dust was seen in a single microscope field instead of in several layers;

(iii) Counting by microprojection.
It was found that dark dusts, e.g. iron oxide and carbon, give the same results as those obtained with direct light-field counting, whereas transparent dusts give 10%-15% lower results;

(iv) Fixation of particles settling on the membranes.
The method developed prevented losses during the transport of dust samples;

(v) Errors arising when the particles overlie each other and cannot be counted separately.
It was shown how the errors could be theoretically calculated and how the range of error could be established in practice by means of two simultaneous analyses.

2.14 *Research on the development of a simple method for determining free SiO_2 content* (Study PS 37)

From an *investigation into the utility of a simple method for determining the free SiO_2 content,* it became apparent that the result obtained by counting dust particles retained by filter membranes was always greatly influenced by the immersion oil used.

It was also demonstrated that, contrary to what had been assumed from previous research results, there is no correlation between the chemically determined free silica content of dusts and the ratio between the number of particles less than 5 μm ([9]) counted under polarized light and then in clear field illumination.

2.15 *Establishment of an international microscopic counting standard* (Study PS 135)

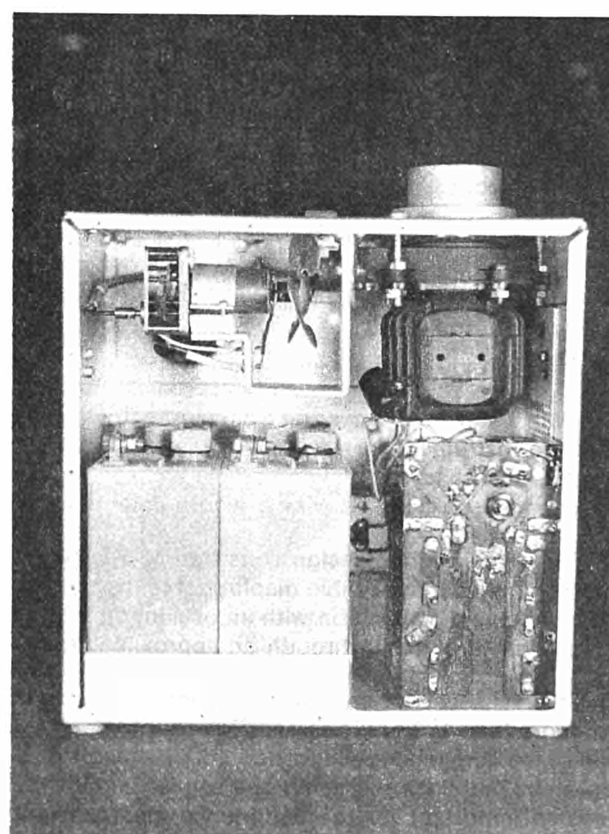
The important part played by the dust particle count will be apparent from the various studies referred to above. The considerable discrepancies in counter results repeatedly found in comparative dust measurement (differences of a ratio of 1 : 10 and over are quite common) are mainly due to the system of microscopic determination employed and also in part to differences in the selective separation factor of the various sampling instruments.

([9]) 1 μm = 1/1,000 mm.

Fig. 4

New portable " Portikon " dust collector (Study PS 139)

a. In use during the demolition of an open hearth furnace



b. The interior of the device

The lower particle size which is still countable primarily depends on the optical system of the sampling apparatus, although the physiological-optical and psychological effects to which the observer is subject are also a very important factor in the proper evaluation of small particles.

To enable such optical system and subjective effects to be allowed for in count results, an ECSC study was made with a view to discovering a suitable *gauge for the microscopic visibility and counting of dust particles* which:

(a) gives a constant point of reference for counting and measuring,

(e) has accurately defined manufacturing specifications,

(c) enables a sufficient number of secondary strong and handy gauges to be produced having a known deviation from the primary standard.

Apparently the study groups has succeeded in devising a simple and effective method of manufacturing such a gauge.

Thirty glass tubes with an inside diameter of 1 to 3 mm and a wall thickness of 0.25 to 0.50 mm are inserted in a glass tube with an inside diameter of about 5 to 6 mm. This nest of tubes is drawn in a small electric furnace into multiple capillary tubes with an outside diameter from 0.2 to 0.5 mm.

Some 30 such multiple capillary tubes are again inserted into a glass tube with an inside diameter of about 3 mm , and this nest of tubes, now containing about 30 × 30 capillary tubes, is again drawn in the furnace into a capillary tube with an outside diameter of 0.2 mm.

The drawn glass tube consists of a more or less cylindrical centre-piece and two conical ends. A piece is cut out of these two ends with a glass cutter and microphotographed. If, as in most cases, the two parts are found to be entirely homothetic, the cylindrical centre-piece is cut up into 6 to 8 mm sections which when mounted act as a counter gauge.

When used with incoherent, oblique illumination (a condensor with a large numerical aperture), the glass acts as a light guide and is brightly illuminated, whereas the tubes containing air are completely in the dark. (Fig. 5).

The cross-sections of the ends represent a physical (non-optical) magnification of the most drawn-out centre piece. The numerical value of this physical magnification is determined by the microscopic measurement of the outside diameter of each section. (In the first of these gauges made by IRCHA the ratio of the diameter of the ends to that of the centre piece was 2.25 : 1).

The gauge can be used:

1. for determining the limit of visibility of a microscope-observer system,
2. for determining as a function of the particle diameter the counting errors of a given observer using a given microscope.

2.16 *Experimental electro-acoustic particle-size measurement* (Study PS 141)

The conventional methods of characterizing dusts by reference to the important particle-size factor are unfortunately fairly complex and laborious.

With a view to discovering a simpler technique, aid was given to a research on the *development of an electro-acoustic instrument for the particle-size measurement of aerosols*. It was planned to develop a dust collector which would react to a single particle and even record the individual reaction stages depending on the mass of the separate particle, i.e. which would determine particle number and size.

The experimental design consisted of a large evacuated vessel in which was mounted an electro-dynamic microphone with a movable diaphragm resting of foamed plastic (for maximum exclusion of extraneous noise). After suitable amplification with an oscillograph the instrument was arranged to detect dust particles carried by the air into the vessel through an approximately 0.5 mm aperture and impinging on the microphone.

The sensitivity of the new instrument was such that single particles of 5 μm diameter could be detected but not more than 100 particles/sec. For counting the separate particles the instrument depends on controlled dilution of the aerosols, which makes it difficult to produce a dust collector for this type of measurement in the working area. But since the technique can be employed at higher temperatures it might, under certain conditions, become important for the continuous measurement of a relatively high overall dust concentration of about 100 mg/m^3, for example in stacks.

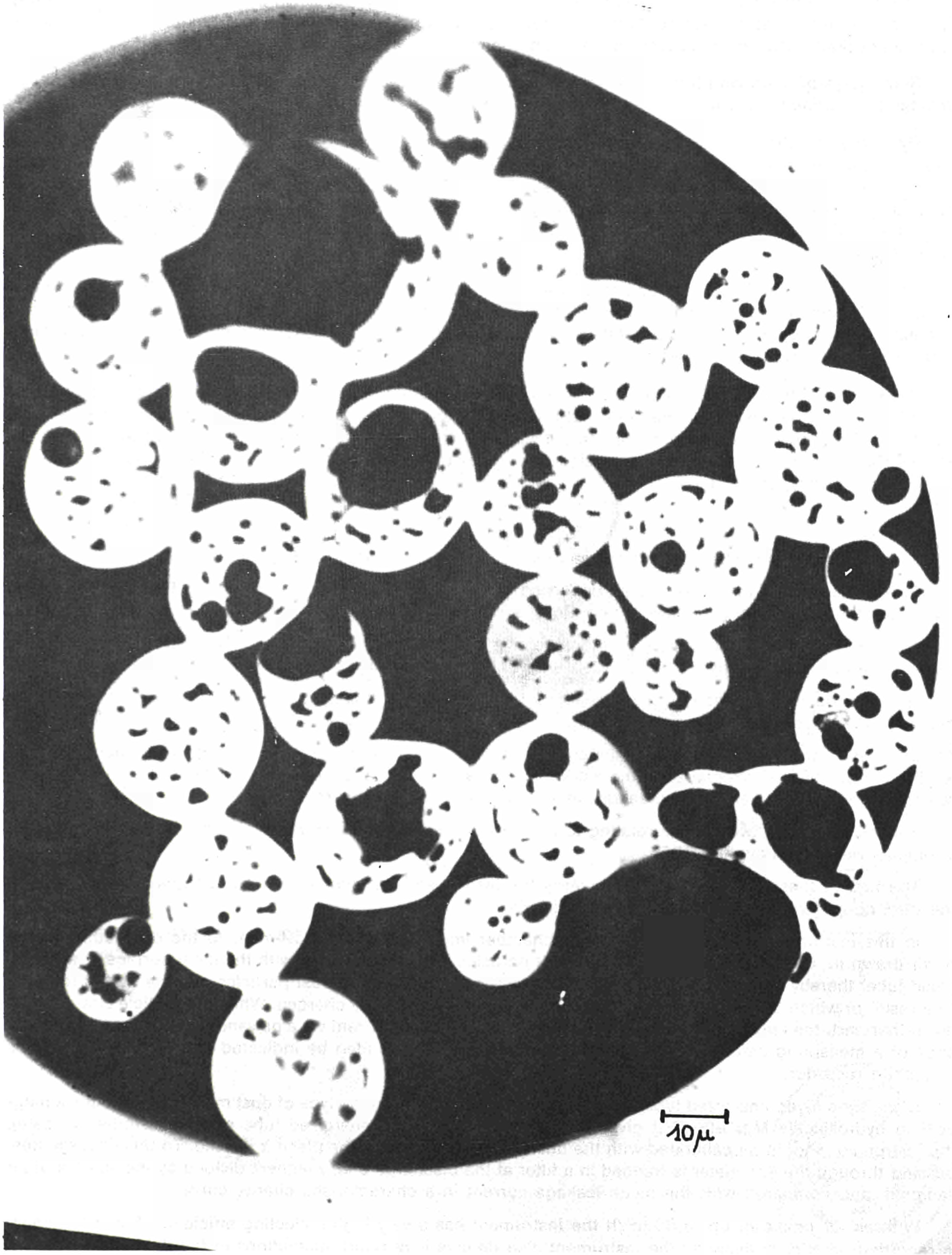


Fig. 5 – *Gauge for dust particle counting (Study PS 135)*

2.17 *Establishing the source of dusts* (Study PS 35)

Owing to the great number of different sources of dust and gas emissions in industrial centres the wrong party may easily be suspected of causing damage or nuisance by air pollution while the real, unknown offender continues unchecked because the source of pollution cannot be detected.

Some ways of improving this unsatisfactory situation are revealed by the results of a study on *dust-source detection in connection with an investigation into dust concentration in the ore sintering sector.*

By improving the analytical methods, especially by means of microscopic examination under reflected, direct or polarised light, it proved possible to establish the source of separate particles in samples of mixed dusts of the type commonly found in steelworks. Thus it was possible to distinguish different iron oxides in dust samples and to say whether they originated from Swedish or Lorraine ores or steelmaking processes. The coke particles from a coke oven could also be distinguished from those emanating from a pulverised coal-fired installation.

The electron microprobe method proved very useful for identifying fine dusts which are often carried great distances. In this new method an electron beam impinges on the dust sample, the x-rays produced at the point of impact being caught by a detector. Stated briefly, the separate pieces of dust are analysed by the detector into their constituent chemical elements.

In a study of the crude gas composition of two cyclone separators a 92.5% retention was obtained in one case and 84% in the other. It was pointed out that theoretically the retention by the same separator is not identical for every particle size but varies according to the type of dust. The research workers concluded from their observations that it is sometimes better to consider the qualitative performance of a separator rather than its efficiency on a purely weight basis.

2.18 *Development of dust-measurement recording instruments* (Studies PS 15 and PS 138)

Provided we know the types of dust occurring at certain strategic points, a simple method of determining their concentration usually suffices for continuous control.

But one drawback of the conventional methods is that a very great number of separate measurements have to be taken to obtain a fairly accurate idea of the variation in dust concentration per unit of time.

Not only do these numerous measurements call for considerable staff and facilities, but the results are only available after a fairly long delay.

But rapid recognition of the time-dependent changes in dust concentration may be very important both for the control of dust exposures at the work location and, for instance, ensuring efficient operation of separators and the early detection of breakdowns in many production processes.

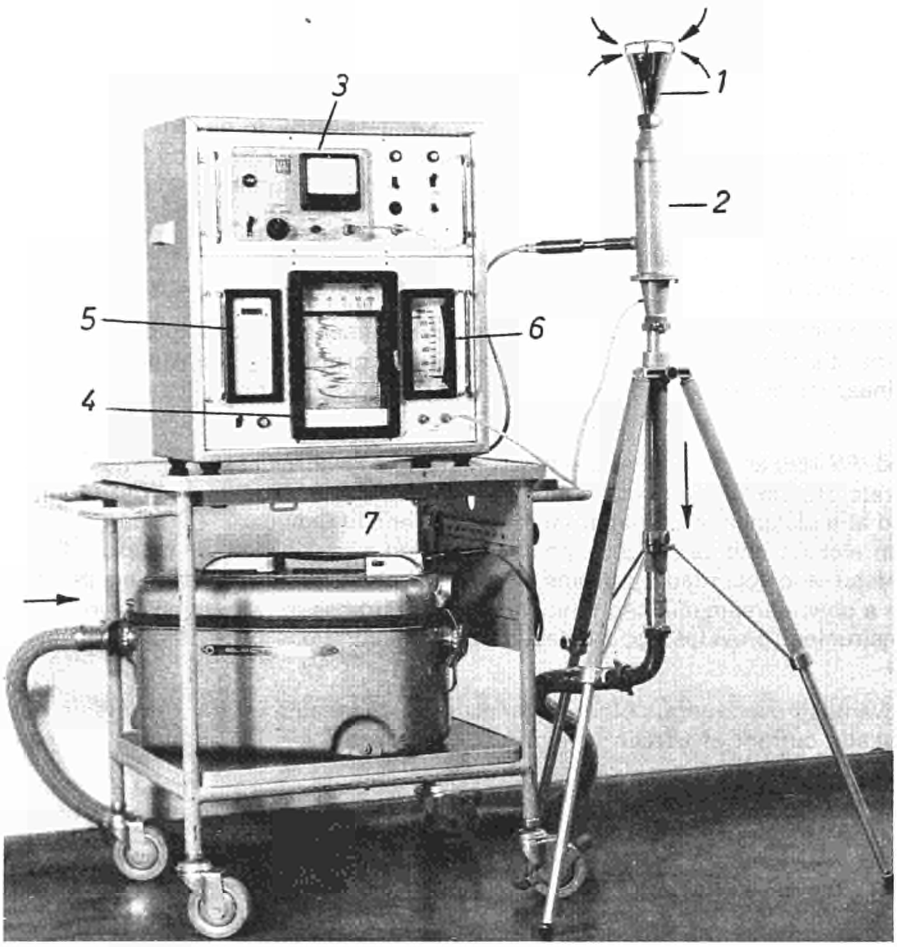
For these reasons two studies relating to the *development of continuous dust-measurement recording instruments* were aided by the ECSC.

The first of these studies (PS 15) concerns the testing and development of an instrument for measuring the dust concentration by electric contact (Fig. 6).

In this instrument, a distributor-entrance chamber imparts a rotary movement to the dust-laden stream of air drawn in. Centrifugal forces bring the dust particles into close contact with the inner surface of an energised tube, thereby causing an electric contact interaction between the dust particles and the wall of the tube as a result of which both the particles and the tube become electrically charged. While the particle charge plays no further part, the energized tube charge is earthed as a leakage current via a galvanometer or the input resistance of a measuring amplifier. The amplified leakage current can then be indicated and recorded by means of a chart recorder.

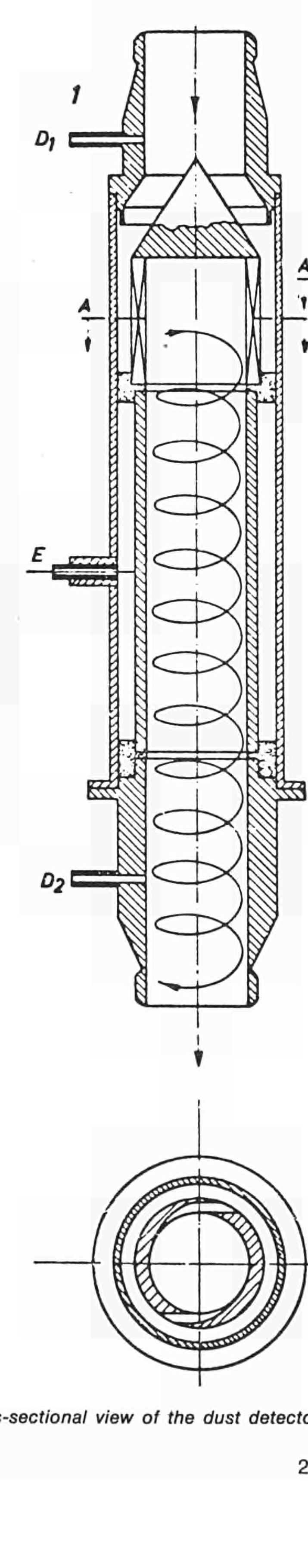
Since for a given energized tube the leakage current depends on the type of dust measured (steatite, a magnesium hydrosilicate $Mg_3H_2(Si_4O_{12})$ gives the best response of all energized tube materials studied to date), the instrument should be calibrated with the dusts to be measured at the place it is used. To this end, the dust passing through the konimeter is trapped in a filter at the discharge end, weighed, divided by the volume of air sampled, and compared with the mean leakage current in a characteristic charge curve.

With an air intake of up to 50 m^3/h the instrument has a very high collecting efficiency. Since the count is recorded practically instantly the instrument also detects very rapid fluctuations in the dust concentration. Within the measuring range of 0 to about 3 g/m^3 (the only one of practical importance) there is a linear and reproducible relationship between the measured value and the gravimetrically determined dust concentration.



a. General view

1 Suction funnel with roof-shaped cover and annular slot
2 Cyclone tube embodiment of the "Konitest" dust detector
3 D.C. meter amplifier
4 Continuous-line recorder
5 Integrator
6 Differential manometer for measuring air flow
7 Aspirator



b. Cross-sectional view of the dust detector

Fig. 6

"Konitest" contact-electrical dust-measuring recording instrument (Study PS 15)

As the research work progressed, it proved possible to increase the instrument's sensitivity still further until it even records dust concentrations of only 1 millionth of a gramme per cubic metre and responds to finely divided iron oxide aerosols of less than 0,3 μm (primary particles in brown fumes). It can be adjusted by a handle to different ranges of sensitivity.

The development of a structural variant of a separating cyclone in which 5μ fractions are continuously separated provided a means of simultaneously recording and measuring the concentration of fine dust inhaled by the lungs and the overall dust concentration; this technique may prove extremely useful for the appraisal and control of silicosis hazards in working areas.

Another new embodiment (the use of a Venturi nozzle made of material sensitive to electric contact) led to a substantial reduction in the instrument's size and weight. This embodiment can be carried on a workman's back and used for measuring the dustiness of working areas and continuously recording the dust concentration prevailing in the respiratory zone at any given time.

A grid probe has been developed for recording and measuring heavy dust loadings, e.g. on the crude gas up-stream side of separators. It consists of several round rods made of material sensitive to electric contact.

It was used in preliminary experiments with pulverized coal burners, and a linear relationship between dust loading and measuring current was still found at dust concentrations of 500 g/m^3. With the usual energized tube and the Venturi nozzle this linear relationship is only in the range of 0 to about 8 g/m^3.

In the second study of this kind *(PS 138)* an instrument was developed (Fig. 7) with a measuring head through which an air stream flows at the rate of 6 m^3 N.T.P./h and is passed to a nozzle at a velocity of about 130 m/s. A 0.5 mm filament probe is located at a distance of 2.5 mm from the slotted end of the nozzle. Dust particles impinging on this probe generate an electric charge which is continuously led away, its voltage measured with an oscillating condenser electrometer and recorded by means of a chart recorder. All dust passing through the measuring head is captured in a down-stream microsorbant filter for the purpose of calibration curve classification and dust analysis. The instrument provides good detection of concentrations of 0.1 mg/m^3 of dusts smaller than 5μm.

The filament probe has an advantage over various other materials such as steatite in that there is no risk of any polarity reversal of the leakage current of certain mixed dust components leading to errors in measurements.

2.2 *Measurements of the dustiness of working areas*

In order to obtain information on the dust conditions prevailing in different working areas in the iron and steel industry, the ECSC has promoted suitable research work in four Community countries.

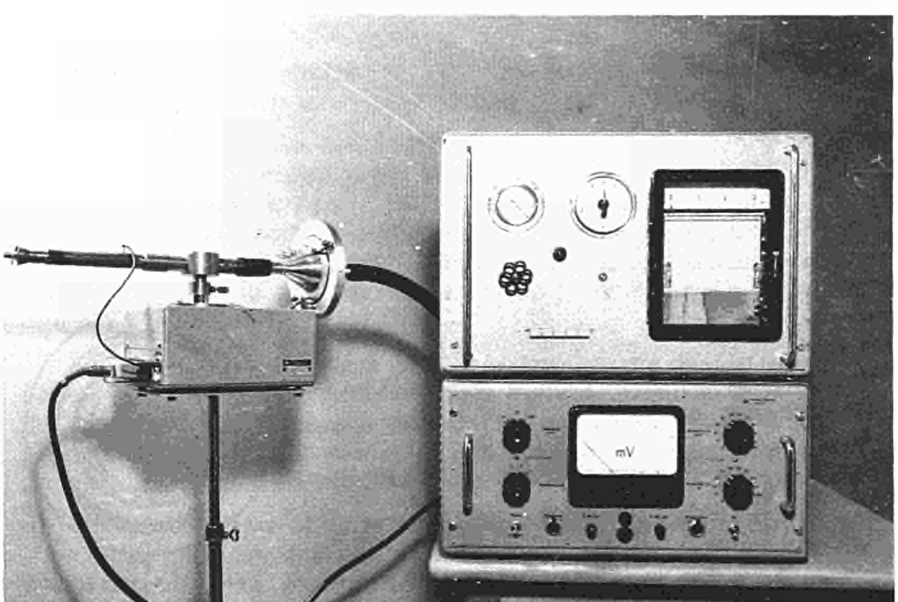


Fig. 7

Contact-electrical dust-measuring recording instrument (Bonn) (Study PS 138)

Owing to their limited size and set-up they were only primarily intended as pilot studies, so that the results obtained, however interesting in detail, must not be regarded as being universally applicable. They are rather parts of a mosaic which is still far from complete.

2.21 *Dust survey in German steelworks* (Study PS 20)

The survey carried out by the *Staubforschungsinstitut des Hauptverbandes der Gewerblichen Berufsgenossenschaften,* Bonn, was focussed on working areas exposed to dust capable of producing silicosis. For instance, in steelworks, dust measurements were made during the demolition of open-hearth furnaces, the cutting, buffing and laying of refractory bricks, and the cleaning of ladles; in foundries, measurements were made of the dust exposure associated with sand processing and the moulding, knocking out, buffing and fettling of castings. The study examines critically the dust conditions encountered, some of which were extremely disconcerting, and puts forward suggestions for further research.

For appraisal of the silicosis hazard the *Staubforschungsinstitut* makes use of its own formula:

$$C\ (SiO_2 < 5\ \mu m) \times C_{total}\ \ < 5\ \mu m) = Z$$

In this formula, the first factor denotes the concentration of free crystalline silica having a respirable particle size less than 0.5 μm, and the second the respirable fine dust concentration less than 0.5 μm of all types of dust in the sample, the concentrations being invariably expressed in mg/m^3.

If the product Z, i.e. the criterion, does not exceed 0,5 ([10]), no silicosis hazard is assumed to be present.

In order to measure these dust concentrations a given volume of air was drawn through a filter (i.e. a microsorbant filter, and in very hot working areas a paper filter). The respirable dust was determined by elutriation.

Silicogenic mineral particles were identified by the x-ray method which has a lower detection limit of 1%.

The basic criterion for the entire dust concentration is that C_{total} must not exceed 15 mg/m^3 even in the absence of silicogenic components.

When the duration of the work was so short that a particle-size measurement failed to give a sufficient amount of dust for practical use (e.g. when refractory bricks are occasionally cut by hand) particle concentration measurements were made with a HS (Hasenclever-Sartorius) konimeter and a projection microscope with a total magnification of 370. An average particle concentration of 200 per cc of silicogenic dusts (after removal by ignition) was considered dangerous in continuous work.

It should be added that the resulting criteria vary within the range of from 0.035 (moulding work in a steelworks foundry) to 442 (cleaning the inside of ingot moulds with a grinding machine).

The final reports on the results of this study and the Italian study discussed below made it clear to the research committee that the silicosis hazard is calculated by different formulas in different countries. It suggested that this question should be examined in future studies within the framework of the exchange of know-how to see whether the formulas derived from theoretical considerations and practical experience can be simplified.

2.22 *Dust survey in Italian steelworks* (Study PS 11 + 12)

The report submitted by the *Clinica del Lavoro,* Milan, deals first with the dust measurements made during the operation of 11 electric furnaces in 5 Italian steelworks. Under unfavourable atmospheric conditions a fume concentration exceeding 5,000 particles of from 0.7 to 5 μm per cc was found 2 metres above the ground in an older type of steelworks using hoodless furnaces. Visibility was limited to a few metres. No substantial air pollution was found in the other steelworks.

Investigation of the refractory bricks used for relining furnaces and ladles showed that the high percentage of free silicic acid in the respirable dust fraction of less than 5 μm was only about 20% less than the average for all dust fractions. But in most other materials the less than 5 μm dust fraction contains only a half to one-third the percentage of free silicic acid.

Investigation of the silicic acid content of the atmosphere of dust in steelworks showed that generally speaking no substantial difference exists between one works and another.

([10]) According to the final research report 1964. The criterion z was subsequently amended as follows:
(a) below 0.2, no apparent silicosis hazard,
(b) from 0.2 to 1.0, silicosis hazard possible,
(c) above 1.0, serious silicosis hazard.
(Cf. Staub-Reinhalt, *Luft* (26) 1966, pp. 2-8).

With the use of the formula employed by the *Clinica del Lavoro* for estimating the degree of silicosis hazard it was found that by and large steelworks operations are not silicogenic, although in some jobs (particularly in the demolition and relining of furnaces) a very considerable silicosis hazard may occasionally be present.

The above-mentioned formula is as follows:

$$\text{silicosis hazard } R = \frac{N \cdot q}{500} \left(1 + \frac{2}{1 + q}\right)$$

where

N = total number of particles of atmospheric dust varying from 0.7 to 5 μm

q = numerical percentage of particles of silicogenic free silicic acid in the less than 5 μm dust fraction of atmospheric dusts

$\frac{2}{1+q}$ = Coefficient of the silicogenic capacity of inert dusts which is especially high with low contents of silicogenic free silicic acid.

No silicosis hazard is assumed to be present with values of R = 1. The hazard increases with increasing values of R exceeding 1.

In this connection the *Clinica del Lavoro* also distinguishes between specific hazard and effective hazard. If, for instance, the actual work performed by a workman relining ladles is limited to 65% of the shift, then the actual hazard is only considered to be 65% of the dust hazard peculiar to the job and calculated by means of the formula. As stated earlier, it is necessary to clarify the reasons for the different methods of calculating silicosis hazard in Community countries.

2.23 *Dust survey in Luxembourg steelworks* (Studies PS 49 and PS 144)

Two studies on dust concentrations in the iron and steel industry relate to Luxembourg.

The first of these, which was carried out by the Directorate of Public Health of the Grand-Duchy of Luxembourg (PS 49) aimed at obtaining a general survey of the dust concentration found at various work locations so as to establish which were the most highly exposed locations to which subsequent more detailed research work could be devoted.

Both particle-size and particle-number determinations were made with a view to establishing the dust concentration. The electrostatic sampler was chiefly used for particle-size measurements, and the Hasenclever-Sartorius konimeter for particle-number counts.

It proved difficult, if not impossible to compare these instruments with others used (e.g. the Dräger dust trap and the Ernst Haage dust sampling apparatus), so that the report recommends the use of one instrument for all comparative measurements.

The highest concentrations by particle number and size of SiO_2—containing respirable dusts less than 5 μm were recorded in blast-furnace plants, followed by basic steelworks, basic slag mills, rolling mills and foundries.

Appraisal work was made difficult by the great fluctuations in dust concentration from one location to another, for instance, scatter of from 50 to 3,000 particles per cc in different operations performed by one workman at a given location. The report accordingly points out that a continuously recording meter would be especially valuable for such cases as this.

The second study made at the *Laboratoire de minéralogie* at the *Musée d'histoire naturelle,* Luxembourg (PS 144), was chiefly concerned in determining the crystallographic properties of the different types of minerals found in dusts occurring in the Luxembourg iron and steel industry, this determination being important for identification. To this extent it has certain parallels with the Belgian study PS 35 referred to in section 2.17.

120 dust samples collected with the electrostatic sampler from different work locations could be classified according to their mineralogical composition, colour and particle shape in a card-index system of microphotographs and radiographs. From these results, the kinds of dust found were classified into 12 different types. For instance, 3 types of dust could be distinguished in the blast-furnace field, viz. dusts found:

1. during the tàpping of pig iron,
2. during the tapping of slag,
3. during the removing of flue dust.

With a view to readier comparison of unknown dust samples and determination of their main constituents, a series of substances frequently occurring in the iron and steel industry, e.g. magnetite, hematite, siderite, quartz, cristobalite, tridymite, lime, calcite, dolomite, are shown separately.

The different dust samples were microphotographed:

(a) under natural light: in order to distinguish the opaque constituents from the transparent ones,

(b) under polarized light with red I wave plates: in order to distinguish the optically isotropic from the optically anisotropic constituents,

(c) by interferometry: in order to determine the transparent constituents and to observe the surface condition.

The research report concludes that it would be useful to add to the card-index system and that the latter could be particularly valuable in studies on the contribution of the various dust sources to air pollution in the neighbourhood of iron and steelworks.

2.24 *Dust survey in Dutch foundries* (Study PS 17)

The most extensive study in the present group of investigations was carried out in the Netherlands by the *Gezondheidsorganisatie T.N.O.*, Delft.

Its objects was to determine the dust concentration at different work locations in steelworks and to study the relationships between dust concentration and pulmonary lesions. At the time of writing results of research work extending over several years had not been completely analysed.

As regards the dust research, in this study it was necessary to:

(a) determine the weight, particle number, particle-size distribution and chemical and physical composition of the dusts at the work location, especially the respirable dust particles,

(b) carry out the measurements so as to give a representative picture of the volume of dust inhaled during a fairly long period (approximately twelve months) with an accuracy revealing any differences existing between different groups of workers.

In this study some 7,000 dust measurements were made in nine foundries, so that statistical processing was necessary.

Since the dust concentration varied extensively from place to place and from time to time it was extremely difficult to determine the mean dust concentration, and owing to the very large number of samples that had to be examined it proved very difficult to determine their composition.

It was found that a plan based on statistical data is needed for the determination of the mean dust concentration relating to different groups of workers. Thus six series of measurements spread over six months were required to distinguish between the dust exposures of moulders and strippers.

No correlation exists between the different units of measurement, e.g. weight and particle number. It did not prove possible to determine the number of quartz particles approximately less than 2 μm. The number of quartz particles varying from 2 to 5 mm was determined by means of the phase-contrast technique. The determination of the weight of quartz in dust particles less than 5 μm presented no difficulty, but there was no correlation with the number of quartz particles.

A very large number of small dust particles are often encountered in steel foundries, most being soluble in hydrochloric acid. In iron foundries the percentage of dust particles soluble in hydrochloric acid was usually smaller. Cristobalite was almost entirely confined to steel foundries.

2.3 **Research on dust gas emissions and their ground level concentration**

Damage to agricultural and forestry areas is often attributed to the effect of fluorine compounds and SO_2 discharged by iron and steelworks.

Two studies relating to these areas were therefore carried out with the financial aid of the ECSC.

2.31 *Research on fluorine— and SO_2—containing waste gases discharged by steelworks* (Study PS 129)

The first of these studies dealt with the *discharge of fluorine— and SO_2—containing waste gases discharged by a single plant centrally situated in a rural locality.*

It was particularly concerned with the effect and volume of the various materials involved in the smelting process, and with the effect of the stacks and atmospheric conditions on the volume and composition of the dusty waste gases and deposits inside and outside the plant.

The fluorine and SO_2 point sources were the open-hearth furnaces and a detached electric furnace not connected to a chimney. Some very interesting results were obtained on the values of dust emissions and the ground level concentration.

It was found, for example, that the effluents from an electric furnace bath without fluorite additive contained 16% of the sulphur introduced and 4% of the fluorine; the values for an electric furnace bath with fluorite were 15% and 38% respectively.

An open-hearth furnace containing no fluorite (the plant no longer uses fluorite in this type of furnace) gave a discharge of 45.6% of the sulphur (S) introduced and 70.6% of the fluorine (F).

The ground level concentrations found in the air discharged by the steelworks at a distance of from 2 to 400 metres varied from 2 millionths g F/m^3 to a maximum of 12 millionths g F/m^3, and from 0.05 to 1.0 mg SO_2/m^3.

Fluorine measurements made at a distance of 600 to 3,000 metres from the steelworks, i.e. including the effluents of other plants, gave a blank value of about 2 millionths g F/m^3, while the waste gases discharged by the works reached values of 5 to 8 millionths g F/m^3.

Vegetation samples taken from points at varying distances and in different directions from the works showed that the sulphur and fluorine content of crops grown near the works and oriented along the prevailing wind (west) were higher than in the same species grown further away or not oriented along the prevailing wind.

Of the analytical methods employed special mention should be made of the recording SO_2 measurement of stack gases and atmosphere with the Wösthoff instrument and the recording measurement of gaseous fluorine compounds with the MINI-ADAK instrument.

Analysis of the stack gases discharged by a 250 ton open-hearth furnace with these instruments showed that the amount of SO_2 effluent is invariably increased with additions of liquid pig iron, bauxite or iron ore, but not with charging. An SO_2 peak was found with each reversal of the burners. A more intense discharge did not occur until the bath temperature was increased during boiling. A sudden rise in the fluorine content of the stack gases is attributed to the movement of the bath. When no fluorite was added, significant amounts of fluorine could find their way into the bath from the ore.

2.32 *Detection and removal of fluorine in waste gases* (Study PS 149)

The second study carried out some years later by a steelworks in an industrial centre was concerned with the *detection and removal of fluorine in waste gases.*

The analytical methods of determining fluorine were first checked and, in this connection, certain important discoveries were made, most of which have now become accepted in the chemistry of fluorine. It was concluded that fluoride concentrations cited in the literature should be accepted with reservation. For instance, if dust samples are taken from acid gases for fluorine analysis, the sample should be immediately alkalinised as otherwise the fluorine values found will be far too low. The choice of filter is also of paramount importance.

A large number of Bergerhoff and Hibernia instruments were used over a considerable period of years for measuring ground level concentrations in the neighbourhood of a large steelworks; they showed that under certain conditions the instrument's position can have a marked effect on the results. If the operator works in accordance with VDI * code 2119 (dust deposit measurements) and the top of the instruments placed 150 cm above the ground, they can, for instance, also record iron ore dust raised near the ground by traffic or during charging and which on account of its weight is only found within a very narrow compass. After elimination of this type of error a fluoride ground level concentration of 2-6 mg/m^2 per diem was measured. Only a small part of this is soluble and hence physiologically active.

Parallel measurements made in the *entire* town of Duisburg with a view to determining the fluoride content of the atmosphere gave values varying from 1 to 3 millionths g/Nm^3; there are, therefore, no significant concentrations in the neighbourhood of the steelworks.

Free fluorine is such a highly reactive material that it is hardly met with in waste gases even in steelworks where the fluorine compounds that can be measured occur in very variable concentrations. It was found that down-stream of all steelmaking furnaces, especially at points where brown fumes occur, the fluorine compounds are nearly all adsorbed by the solid waste gas constituents; this means that separation into "gaseous" and "solid" fluorides is no longer possible. If the dust is subsequently caught in any type of air cleaning plant, correspondingly few fluorides are discharged. When even very large amounts of fluorite are added, as in the 90 ton L-D converter (900 kg) and the 80 ton electric furnace (500 kg) there are no fluoride emissions down-stream of good air cleaning plants.

* *Verein Deutscher Ingenieure,* Düsseldorf.

Fortunately, only small amounts of fluorine compounds are discharged in the sintering process. But since the waste gases discharged by the sintering plant are acidic, only a part of this fluoride is adsorbed by the dust and separated again during cleaning. Some improvement was effected by adding alkaline dusts, e.g. MgO, but the problem will be automatically solved once desulphurisation plants are introduced. The problem has been deferred since fluorine contents are only of minor significance owing to the great stack height.

Fluoride discharges from coal-fired plants mainly depend on the basicity of the ash. Ground level concentrations of fluoride may also be encountered in residential districts when slag only combines with a minor amount of fluoride. In any case the fluorine discharges of large plants are greatly reduced by air cleaning installations.

3. CONTROL OF BROWN FUMES

3.0 Scope and problems

Undoubtedly the most noticeable of the effluents discharged by the iron and steel industry are the brown fumes produced in vast quantities when oxygen-enriched air is blown in Bessemer converters, pure oxygen is blown in L-D and L-D AC converters, oxygen is added in open-hearth and electric furnaces, and in the scarfing of ingots (Fig. 8). Although not constituting a direct health hazard they are capable of intensifying the smoke pall overhanging industrial areas and which causes damage to human, animal and plant life by preventing solar radiation.

From the physical viewpoint these effluents are waste gases in which are dispersed minute iron oxide particles (Fig. 9), of a size comparable to, say, particles of tobacco smoke. Their fineness is due to the manner in which they are produced, viz. as a result of the reaction of oxygen with molten iron, the melts are locally heated to such high temperature as to create considerable evaporation at these points. The iron vapour combines with oxygen from the waste gas or present in the air stream and is then condensed to form countless minute iron oxide particles, which impart the marked brownish-red tinge to the waste gases even when their dust concentration is scarcely 0.15 g (150 mg) per cubic metre at N.T.P.

There are a number of difficulties preventing technically sound and economic cleaning of these fumes. Of these we may mention:

(a) the extreme fineness of the solid particles,
(b) the high temperature, and
(c) the great volume of waste gas produced per second.

Some figures will make this clear.

About 95% of brown fumes consist of particles having diameters of about:

(a) 100 to 800 nm [11] in top-blown oxygen converters, and
(b) 15 to 80 nm in bottom-blown converters.

At the converter outlet the waste gas temperature is at a temperature of about 1,600°C and in its subsequent course it may rise to 2,000°C, depending on the conditions with which it is mixed with the air stream. (The theoretical temperature for a combustion-air factor $n = 1$ would be about 2,700°C).

The capacity of the air cleaning plant should be in accordance with the maximum volume of waste gas passing per second. This volume is in turn dependent on the size of the converter and the charge, the maximum fuel combustion rate, and on the amount of air and water vapour mixed with the converter gases proper during their subsequent course.

In pig iron refining, 1 kg of carbon burns 0.93 m^3 N.T.P. of oxygen, producing 1.86 m^3 N.T.P. CO. Hence at a combustion rate of 0.4% C/min, 67,000 m^3 N.T.P. CO/h are discharged from a 150 ton top-blown oxygen converter. To this amount of gas, which at a temperature of about 1,600°C actually occupies about six times the volume expressed in cubic metres at N.T.P., the entraining air adds an amount of gas whose volume depends on the given conditions; this gas is mixed with the converter gas proper or goes into reaction with it (combustion), thus considerably increasing the volume of waste gas to be treated.

For instance, a 150 ton oxygen converter operating with a decarbonisation rate of 0.4% per minute and complete combustion of the converter gases with 50% excess air (air factor $n = 1.5$), requires an air cleaning plant having a capacity of about 275,000 m^3/h N.T.P. of waste gas.

Owing to its greater decarbonisation rate of about 0.8% C/min and additional nitrogen ballast, a bottom-blown Bessemer converter discharges practically the same specific amounts of waste gas with a pig iron charge of only 50 tons.

For cleaning purposes the gases must first be cooled down to temperatures varying from 50° to 300°C, according to the cleaning method selected.

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[11] 1 nm = 1 millimicron = 1 millionth of a millimetre.

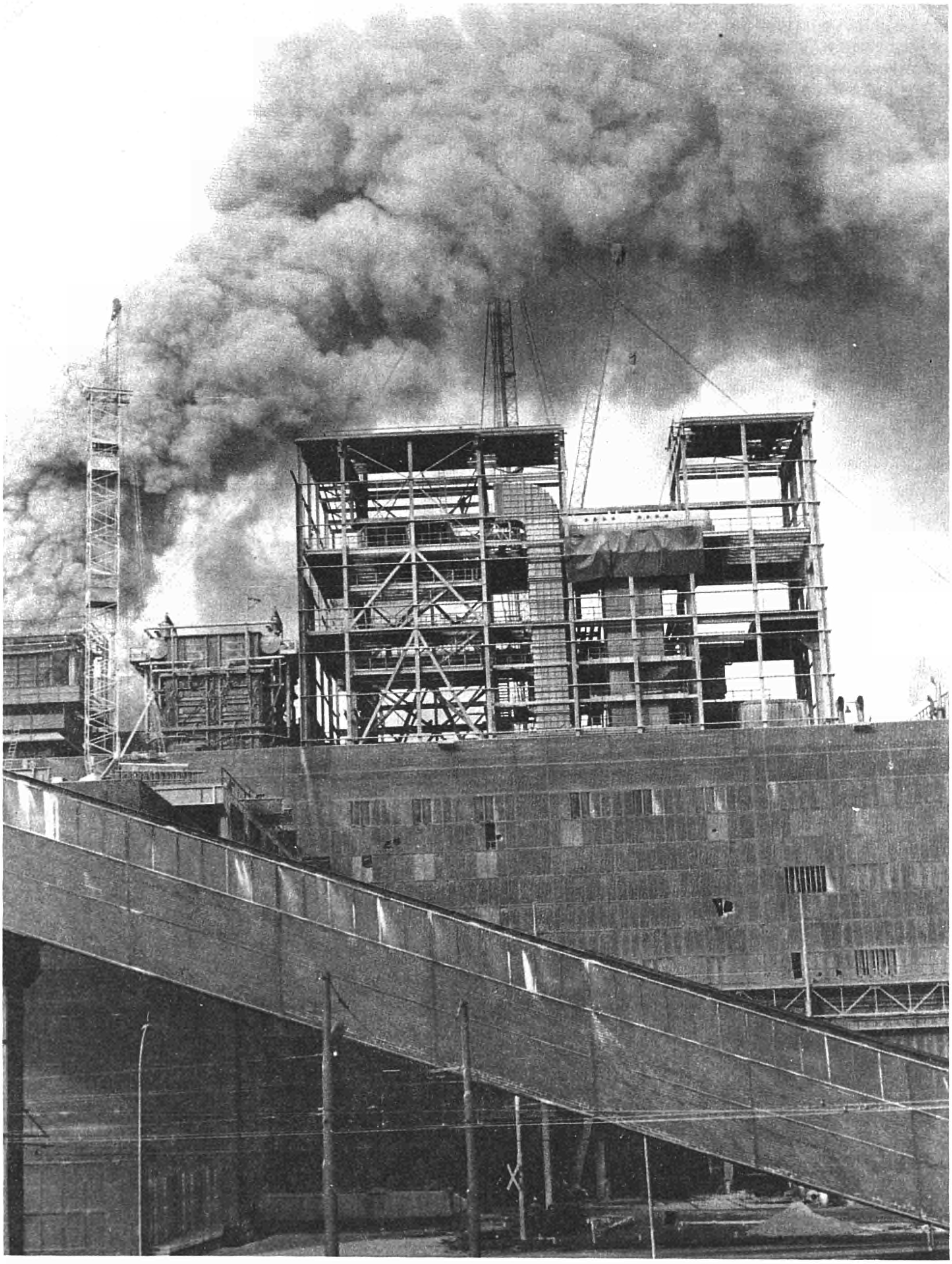


Fig. 8

Discharge of brown converter fumes

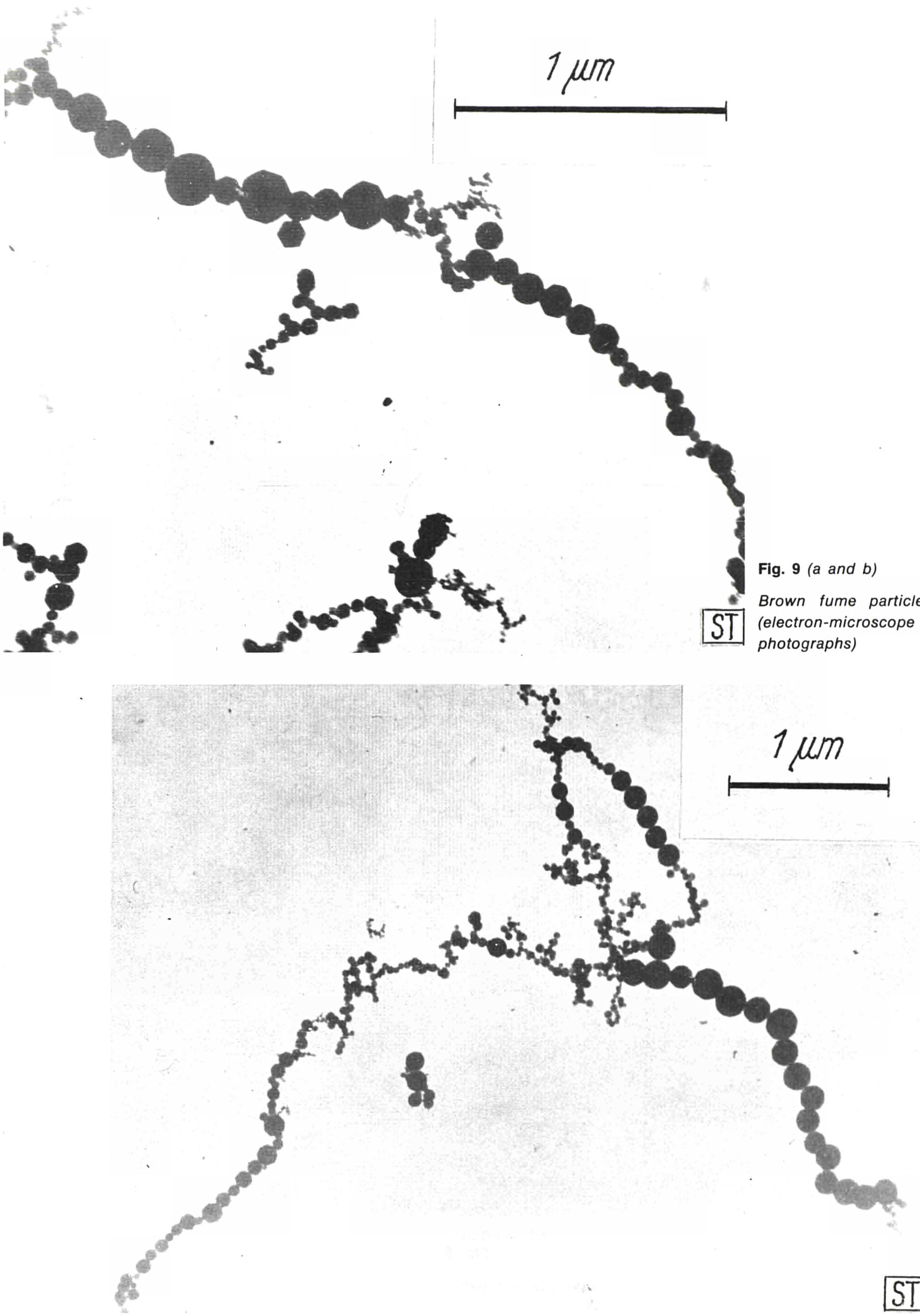


Fig. 9 *(a and b)*

Brown fume particles (electron-microscope photographs)

The 275,000 m³ N.T.P. assumed in the example given above would entail treating about 240 to 220 million kcal/h. In general, about half is lost by indirect cooling in a waste-heat boiler or cooling vent, the residual heat being reduced to the required low temperature by water-spraying. When cloth filters are used, water-spraying is avoided as far as possible and most of the heat drawn off by indirect cooling. But to ensure good separating efficiency, waste gases passing through dry electrical precipitators require wetting or conditioning, and those passing through wet electrical precipitators or Venturi scrubbers need saturating, depending on the amount of water vapour absorbed. The result is that the amount of gas actually passing through the blower is as much as three times that required under normal operating conditions (i.e. about 550,000 to over 800,000 m³/h instead of the above mentioned 275,000 m³/h N.T.P.).

The dust content of the waste gases is not constant during the period of the charge. In undiluted gas it is about 150 to 200 g/gm³ N.T.P. and depending on circumstances, particularly the amount of infiltrating air, it falls to 15 to 40 g/m³ N.T.P. of consumed waste gas. Brown fumes account for about 1-2% by weight of the blast-furnace steel.

Hence converter steelworks produce very substantial amounts of fine dusts having a high iron content; these dusts, either dry or in slurry form, must be removed from the air cleaning plants, stored, transported and further problems specific to the air-cleaning method employed.

3.1 **Cleaning brown fumes from Bessemer converters by means of electrical precipitator** ("Huckingen" study)

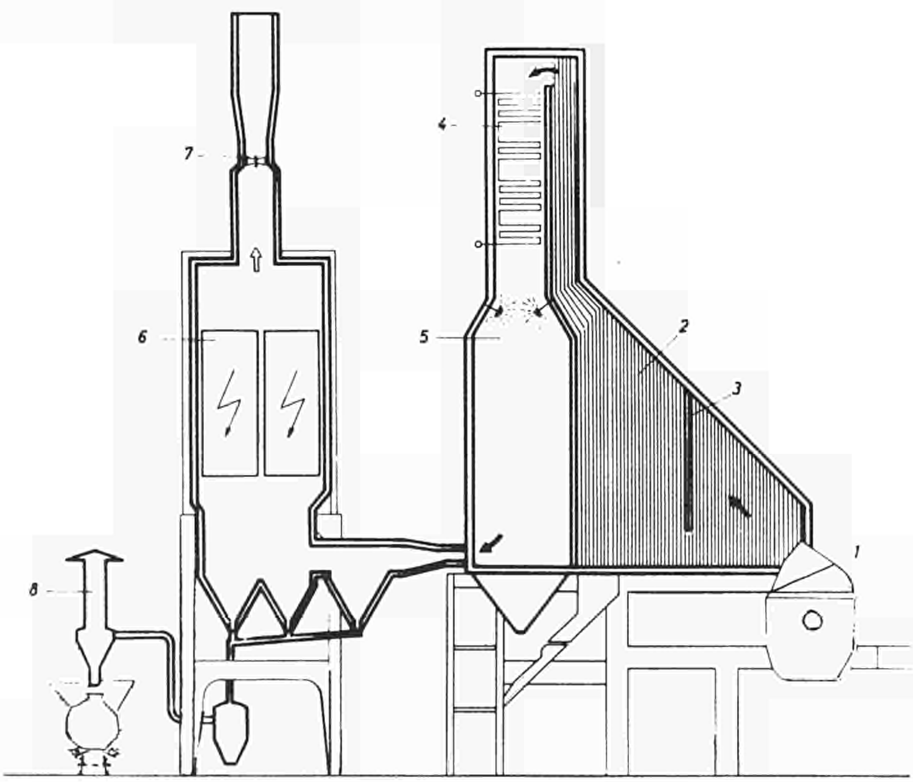
The first ECSC-subsidized study on the technical control of air pollution related to the cleaning, by means of an electrical precipitator, of the brown fumes discharged by a bottom-blown 40 ton Bessemer converter (Figs. 10 and 11).

The air cleaning plant consisted of three parts, viz.:

(a) a waste-heat boiler in which the waste gases are cooled and their heat exploited,

(b) a stabilizer in which a water and vapour pulveriser cools the waste gases still further and wets them sufficiently, and

(c) an electrical precipitator for dust separation.



1 Converter
2 Radiation heating surface
3 Tubular screen
4 Convection heating surface
5 Stabilizer
6 Electrical precipitator
7 Fan
8 Pneumatic dust exhaustion

Fig. 10

Cleaning a Bessemer converter by means of an electrical filter (schematic diagram) (Huckingen Study)

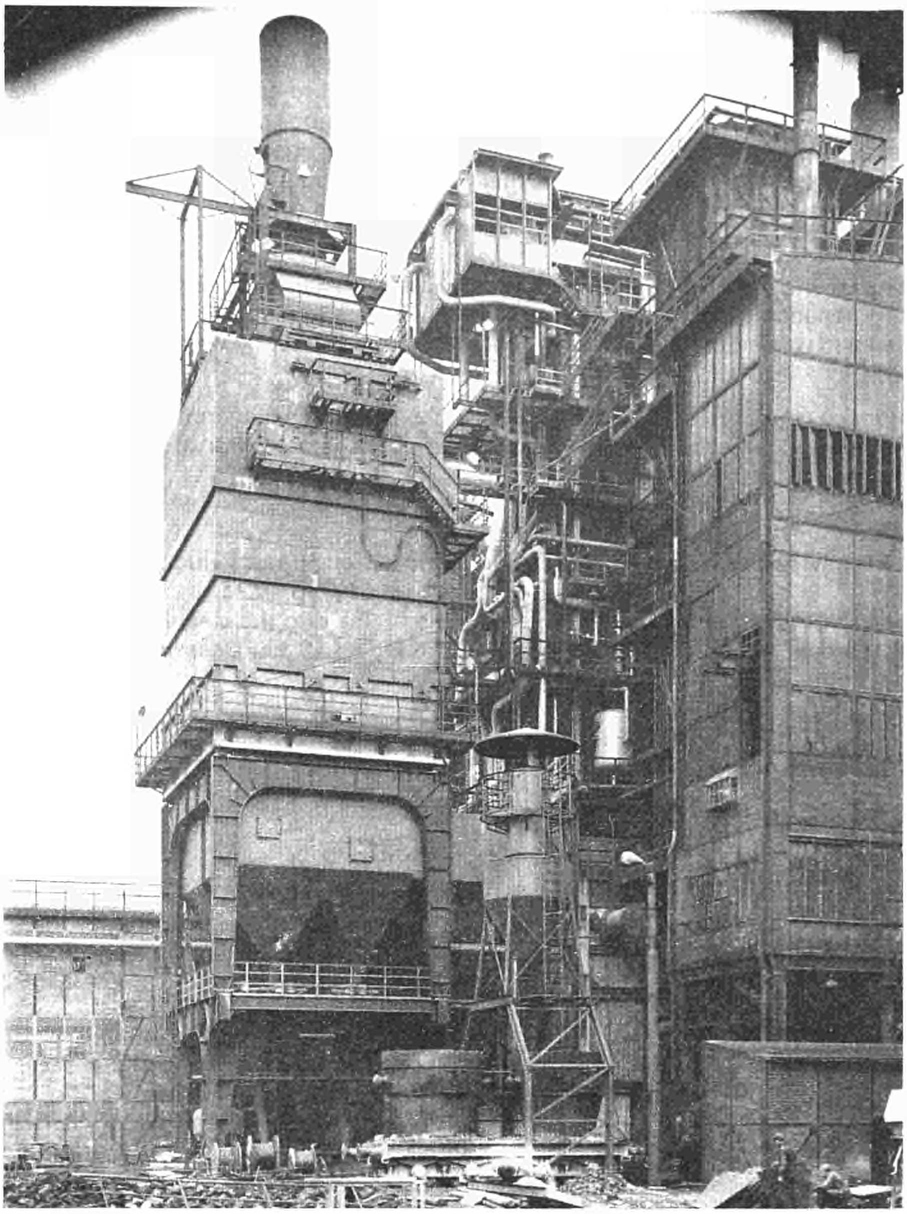


Fig. 11

Cleaning a Bessemer converter by means of an electrical filter assembly
(Huckingen study)

The saturated vapour produced in the waste-heat boiler was passed to an evaporation drum in the form of a Ruths accumulator and then led to the thermal power station. A superheater fed by blast-furnace gas was installed and special control measures observed to ensure that the steam generated was supplied to the plant network as uniformly as possible.

The steam generated in the waste-heat boiler was an asset which offset the cost of operating the air cleaning plant.

Since so little space is usually available in Bessemer steelworks, the space-saving vertical form of precipitator was selected for the experimental plant. Compared to the horizontal precipitator it has, however, the drawback that operation with several voltage fields is difficult and that during precipitation it cannot be cleaned of accumulated dust by rapping.

The precipitated dust was dried, removed from the screens by a pneumatic conveyor, and then conveyed to the steelworks' filter plant in a closed screen waggon. Here it was mixed with dry flue dust and wet slurry deposited on the precipitator basin to produce recovered material suitable for immediate agglomeration. But it was then found much easier to work up the dust into pellets of adequate consistency by passing in through a newly developed unit in the immediate vicinity of the hopper, while adding water, the pellets then being used in the converter or ladle.

This study opened up an entirely new field, and after all research workers concerned had exerted themselves to the utmost and countless modifications and improvements had been made, it showed that there is no real reason why a Bessemer converter cannot be cleaned with the means employed. It must be said, however, that the extensive technical facilities and space required for an air cleaning plant preclude the general introduction of this technique in present-day Bessemer steel works.

3.2 Removal of particles from brown fumes at elevated temperatures in new types of electrical precipitators
(Studies PS 18, 43, 131)

In the conventional type of electrical filter operating with ionising electrodes, increasing deposition of brown fume particles on the discharge electrodes may result in a corona discharge of reversed polarity which reduces precipitator efficiency, particularly when the dust has such a high resistance that the electric charge conferred on it is neutralised too slowly. Depending on the size of this resistance, the construction or technical arrangements employed in conventional electrical filters have to be modified to ensure adequate collection efficiency, e.g. by humidifying according to the temperature of the waste gases.

No serious precipitation difficulties are to be expected in the 10^4 - 10^{11} ohm. cm dust resistance range. The conventional type of electrical filter also requires certain exposure times, and this may affect the size and cost of the electrostatic precipitator.

Observations have shown that iron oxide aerosols have properties enabling *brown fumes to be precipitated in electrostatic fields* (i.e. in electrical filters operating without ionising electrodes or the above-mentioned drawbacks of the conventional method of electrical filtration).

Three consecutive studies were subsidised with a view to testing the accuracy of these observations and their practical possibilities.

The first *study (PS 18)* concerned laboratory tests of an installation with a flow rate of slightly more than 5 m^3/h N.T.P. of dusty air (brown fumes). The second *study (PS 43)* was carried out with a 2,000 m^3/h N.T.P. unit placed on the roof of a basic Bessemer steelworks.

The following results were obtained from these two studies:

In the new method operating with electrodes without corona discharge, i.e. current flow:

(a) the brown converter fumes collect spontaneously as flocs (Fig. 12) of good precipitation efficiency,

(b) increasing deposition of dust particles on the electrodes does not reduce the precipitation efficiency,

(c) the fumes can also be precipitated at temperatures of over 200°C, which means that the waste gases need not be wetted, a technique involving the laborious task of regulating the converter gas flow and finding room for the stabiliser,

(d) once the precipitated gas has been dried it flows readily and can be easily removed from the filter, which is a great advantage when the dust is returned to the steelmaking process,

(e) dust loads of less than 100 mg/m^3 N.T.P. could be dealt with.

The third *study (PS 131)* was concerned with solving the problems anticipated when passing from the small pilot plant to the large-scale unit.

It related to the development and testing of experimental filters capable of handling 25,000 m^3/h N.T.P. waste gas and equipped with electrode systems of the size used in large installations, and again placed on the roof of the above-mentioned basic Bessemer steelworks. (Figs. 13 and 14).

The 1.7 × 4.5 metre electrodes were designed to set up a non-uniform electrostatic field while remaining below the dielectric strength.

This means that so far as possible the distance between the electrodes must be kept the same. A distance of 30 mm ± 3 mm was guaranteed by the suppliers both for the experimental filter subsidized by the ECSC and a second filter of this type of which the entire cost was defrayed by the steelworks.

The sole difference between the two units is in the design of the electrode plates. In one instance these consisted of 0.7 mm stamped plate, and in the other of wirenetting 2.2 mm thick with a 8 mm mesh.

The electrostatic systems were so designed that at a nominal volume of 25,000 m^3/h N.T.P. the gas had a residence time of 1.25 secs in each field, or a total time of 2.5 secs. With due observance of the tolerances, the maximum charge possible at normal temperature without spark-over should be at least 27 kV, which would be equivalent to a field intensity of $E = 9$ kV/cm.

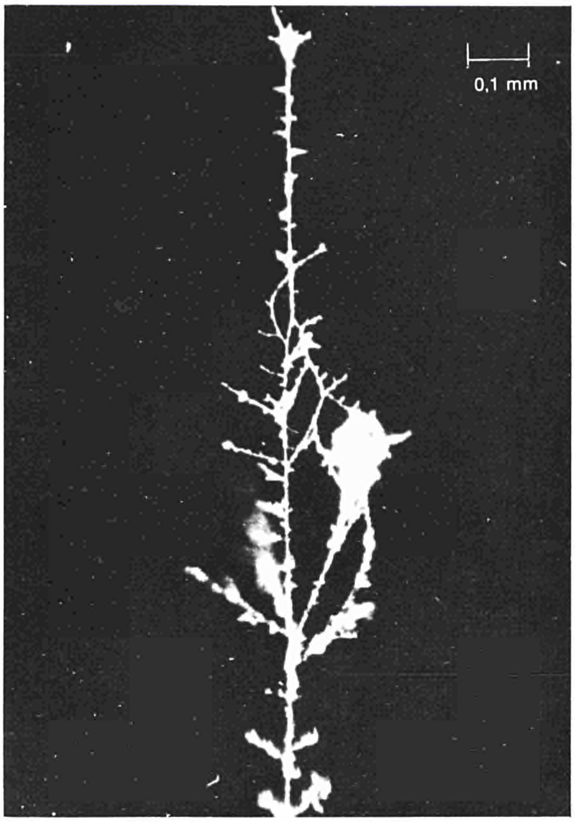


Fig. 12

Brown fumes in an electrostatic field (Study PS 18)

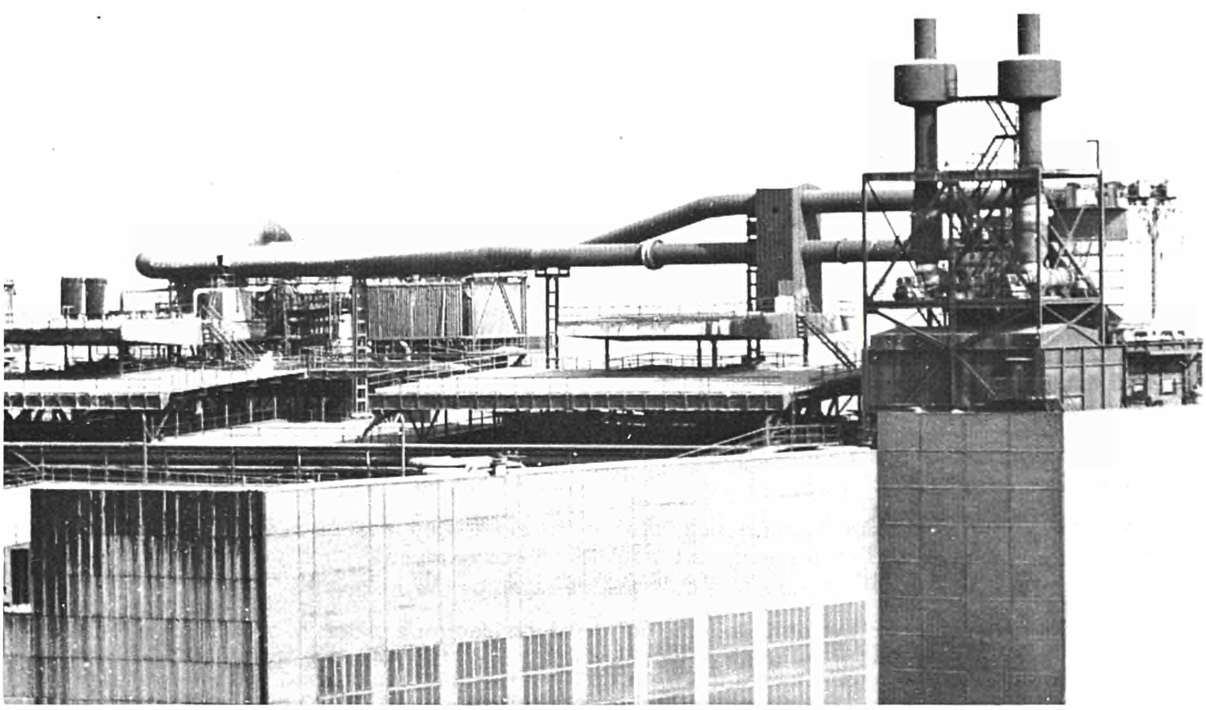
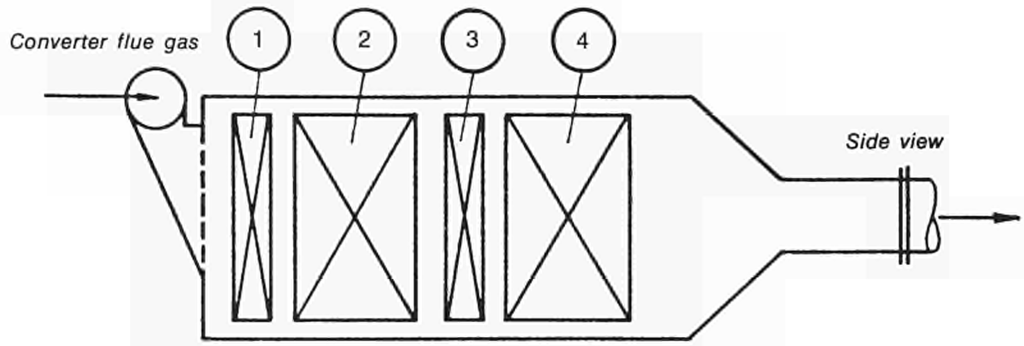


Fig. 13

Pilot plant with electrical precipitator and line connected to the converter stack. (Study PS 131)



1) 1. Ionizing system, about 0.3 m in length
2) 1. Electro-static field, about 1.7 m in length and 4.5 in height
3) 2. Ionizing system, about 0.3 m in length
4) 2. Electro-static field (as for static field 1.)

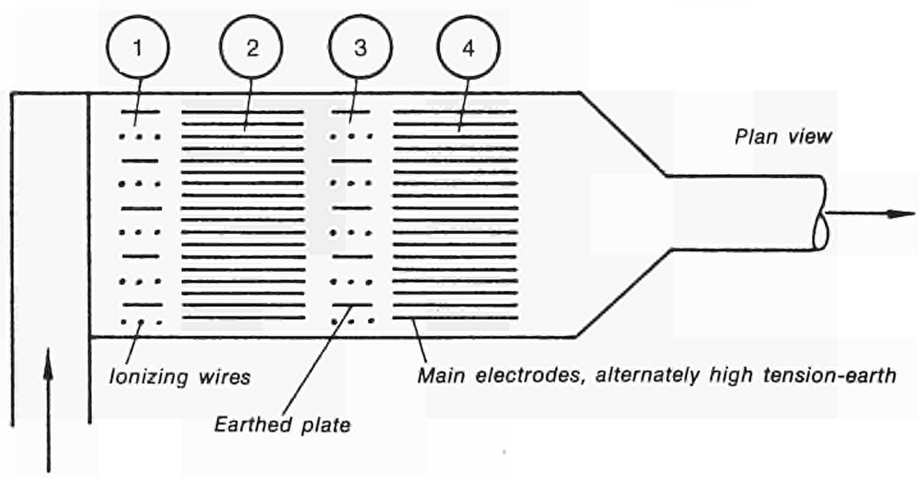


Fig. 14

Principle of internal design of experimental electrical precipitator (Study PS 131)

In both filters a short corona discharge system was also provided upstream of the electrostatic systems with a view to studying the effect of additional corona discharges on the precipitation in the electrical field. The residence time of the gas in the corona discharge fields was about 0.3 secs. The ionising wires consisted of serrated sheet-metal strips or square wires.

Gas distributors were fitted to both filters to ensure uniform gas entry. The suppliers guaranteed a uniform gas distribution with a maximum variation of ± 10% from the average velocity, but after the unit had been installed it was found that occasionally both gas distribution and electrode distances were considerably in excess of the guaranteed tolerances.

Despite various attempts at improvement these structural defects could not be subsequently overcome.

Although the precipitation tests carried out with these defective units essentially confirm the previous results, the dust concentrations in the purified gas still exceeded the stipulated maximum values of 150 mg/m³ N.T.P.

Unfortunately the official time limits allowed for cleaning the steelworks precluded further tests with basically different electrode arrangements, e.g. cylindrical electrodes. As a result the company concerned was unwilling to continue its investigations despite the fact that their potentialities were by no means exhausted, and it was decided to convert the basic Bessemer steelworks to top-blown oxygen converters and to clean the converter fumes with conventional electrical precipitators. These were put into operation in February 1966, but even at the time of writing (June 1968) they were still not entirely satisfactory.

3.3 **Cleaning of L-D converter fumes with bag filters** (Study PS 128)

Another study related to the *cleaning with bag filters of waste gases discharged by an 18 ton L-D converter processing phosphorus-rich pig iron.*

It has long been known that cloth filters have a high collecting efficiency but they soon become clogged up when the temperature falls to below 100°C, so that the dust particles are moistened by adsorption of water vapour. But plastic, cotton and similar cloths are soon destroyed at temperatures exceeding about 100°-150°C. Consequently these have hitherto been deterring factors to the effective use of such cloth filters for cleaning brown fumes.

In the present study these hazards were very successfully overcome mainly by providing a Cowper-type heat exchanger down-stream of the converter stack. In this exchanger the converter gases are precooled in double-walled suction hood with circulating water, thereby losing most of their residual heat. If still necessary, the dust-laden gases are then cooled to the required temperature of 85°-130°C by spraying them with water in a cooling tower arranged down-stream of the heat exchanger. The gases then enter the bag-filter installation which they leave with a residual dust volume of just under 6 mg/m³ N.T.P.

Efficient operation in ensured by a series of measuring, control and safety devices (Figs. 15-16).

The suction hood consists of an ordinary boiler with natural water circulation. Waste steam was vented to the air, the use of a waste-heat boiler being considered uneconomic under the circumstances.

The bag filter consisted of 22 cells each containing 24 filter bags, or a total of 528 bags.

The cells were shut down every 7 minutes in a controlled sequence and the filter bags cleaned by transverse shaking and a simultaneous countercurrent air stream.

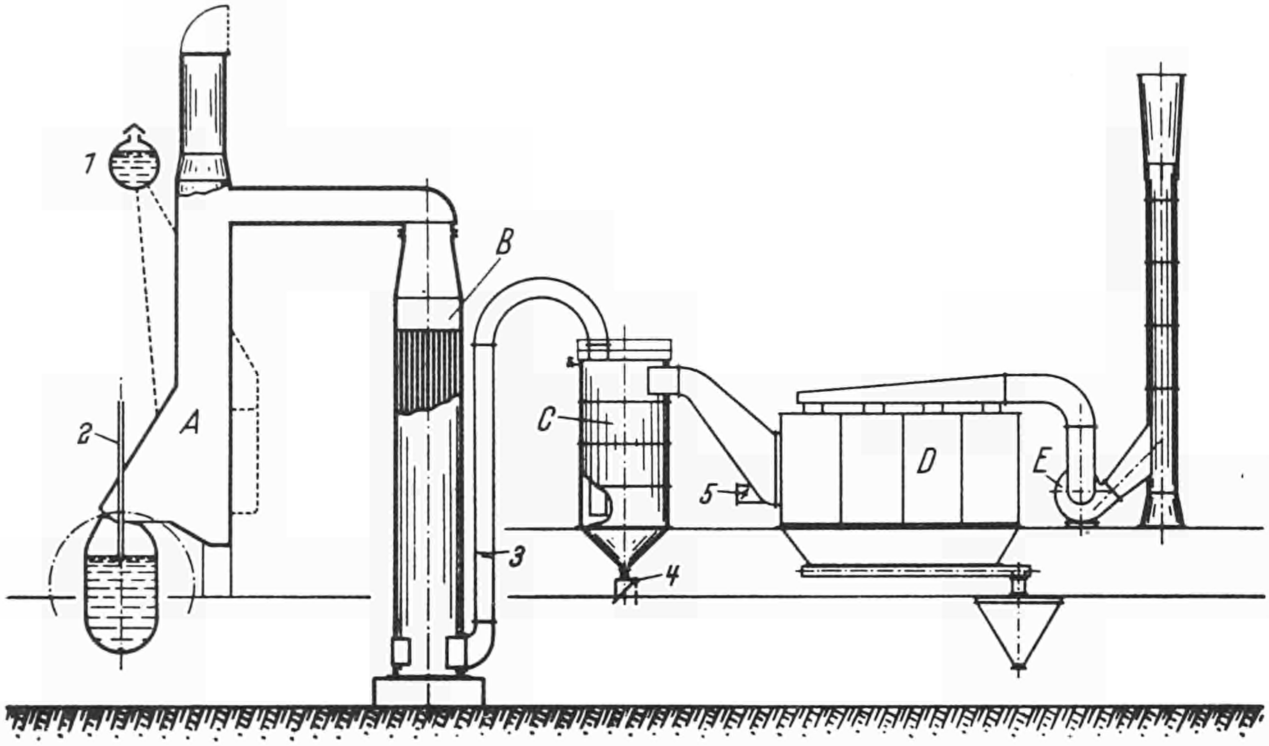
The dust was collected in hoppers arranged at the bottom of the cells, carried by a screw conveyor to an automatic bagging device and returned to the converter in 50 kg paper bags.

After 18 months or about 3,500 operating hours the tergal filter bags still showed no sign of wear and tear.

This installation was later enlarged and has since been cleaning a 60 ton converter instead of the 18 ton unit. The dusts deposited are now supplied to a sintering plant.

Meanwhile several other air-cleaning units for converter and electric furnace waste gases have been installed both inside and outside the Community, and so far as is known they all seem have given good results.

In one of these units, in which the converter gases were burnt with only 25% excess air, a carbon monoxide explosion occurred owing to an unfortunate combination of mishaps and air cleaning was halted for several months. The additional safety precautions now taken preclude a repetition of this accident which was luckily limited to damage of materials.



A = double-walled suction hood with natural water circulation
B = heat exchanger
C = cooling tower (water jet)
D = bag filter
E = fan

1 = expansion tank
2 = oxygen lance
3 = governor slide-valve
4 = slurry discharge
5 = infiltration air inlet

Fig. 15

Cleaning an L-D converter with bag filters (schematic diagram)
(Study PS 128)

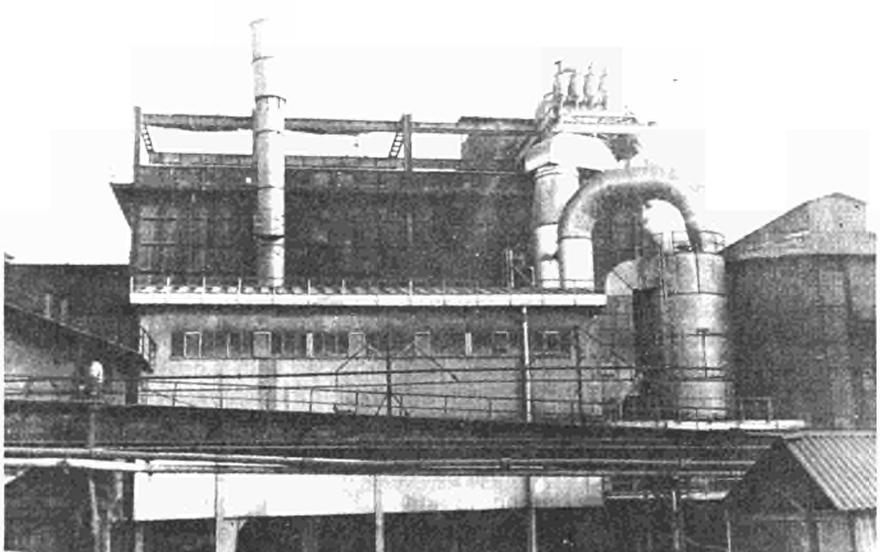


Fig. 16

Cleaning an L-D converter with bag filters (assembly)
(Study PS 128)

3.4 **Scrubbing of converter gas without subsequent combustion** (Studies PS 130 and PS 132)

As stated earlier, the dust-laden gas issuing from the converter is greatly increased in volume by the infiltrating air. The installations requirements for collecting, transporting, cooling and cleaning such waste gases are correspondingly dearer and take up more space.

Two studies were concerned with solving this difficult problem of combustion air and infiltrating air. Their basic principle, although not the method adopted, was the same, viz. to collect the CO-containing converter gases in a substantially unburnt state, clean them and then burn them in a torch flare.

In view of the possible formation of explosive mixture with CO-contaning gases, different types of scrubbing methods were employed in each study.

3.41 *Scrubbing of L-D converter waste gases without subsequent combustion* (Study PS 130)

The first *study relating to the scrubbing of converter gases without subsequent combustion was undertaken in a steelworks operating with 130 ton L-D converters.*

Two different methods of dust collection were tested in this study. One of these uses a water-cooled suction hood with a movable, likewise water-cooled "sleeve" mounted on the converter neck, this sleeve being sealed off by a steam screen at the point of contact with the converter neck.

The second method uses the same suction hood but, instead of a sleeve, has a movable device "skirt" resembling a lampshade, arranged at a distance of about 50 cm from the mouth of the converter.

The advantage of the first method is that it precludes infiltrating air. On the other hand the second method permits direct observation of the converter flame, this being useful for control purposes. Moreover in this method, the hood is less damaged by the converter ejections than the sleeve would be.

In both cases a tubular boiler at an angle of 20° to the ground was connected to the collecting hoods. The gases flow from this boiler into a tower with a vapour superheater which they afterwards leave at a temperature of 450° after being further cooled by water spraying and evaporation. They are supersaturated by further water atomisation in the adjoining horizontal "Granivore" saturator, and then again cleaned in the vertical "Solivore" scrubber. The latter is in four stages equipped with a considerable number of Venturi nozzles. The fan then draws the scrubbed gases into a flare stack, at the end of which they are ignited. (Figs. 17, 18, 19).

A cooling plant, flocculation plant and filter plant are used for processing the water from the scrubber.

To prevent the converter gases from spreading to the steelmaking shop and outside air from penetrating into the suction hood, a throttle valve mounted upstream of the fan automatically regulates the flow of waste gas by continuously measuring the pressure prevailing in the suction hood.

The CO content of the aspirated gas averages from 60% to 80%, so that the plant intends to go back to its former plans for utilising this gas for heating soaking pits, etc.

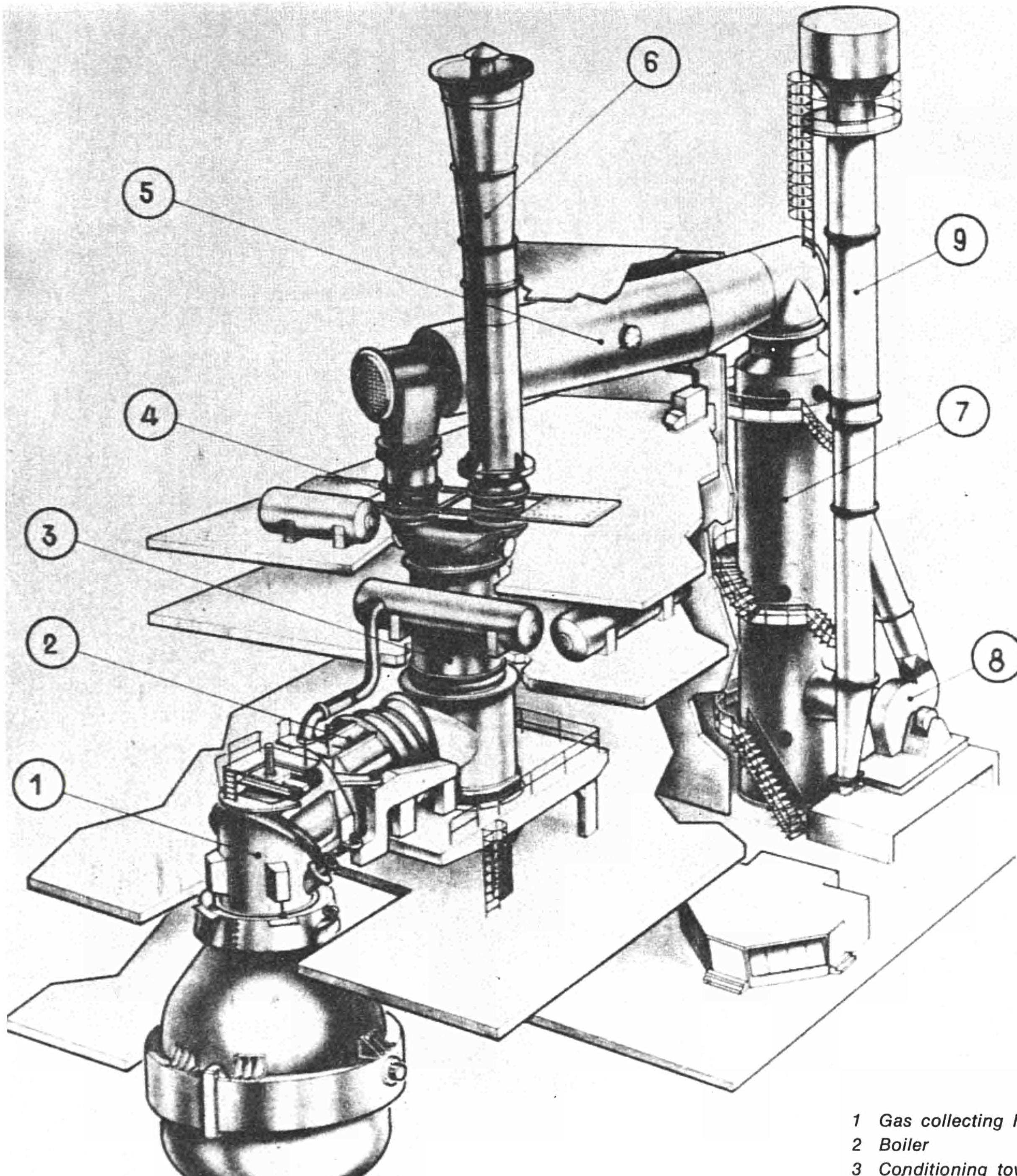
At first, great difficulties were caused by repeated heavy accretions in the hood and fouling of the boiler causing frequent and prolonged stoppages. A provisional solution was provided by replacing the boiler with a slag catcher and a reserve hood, and although this was not entirely satisfactory it did at least permit normal operation of the steelworks. Metal and slag deposits ceased when the blowing method was changed (triple-jet lance), so that no further adhesive accretions were formed.

Since the sleeve mounted on the converter neck caused constant trouble, an open hood is now employed.

At first, cleaning of the waste water was often greatly hindered by clogging of the channels, lines and cooler. The dusts collected in the cleaning of the converter were of a different type and grain size than was assumed.

One source of danger which was soon detected and overcome consisted of the open water-seals of the atomiser tower, saturator, etc., carbon monoxide bubbles escaping via this route and causing high CO concentrations in the air near the steelworks floor. As a result all water seals were provided with a cover and a discharge line running over the roof. The waste-water channel was provided with a tight-sealing cover and an exhauster.

The safety of the system in ensured by establishing a plug of neutral gas (CO_2 and N_2), equivalent to a given volume of completely burnt gas, in the waste-gas circuit at the beginning and end of each blowing period; this plug insulates the CO-containing gas of the refining period from the air which fills the waste-gas system during shut-down periods.



1 *Gas collecting hood*
2 *Boiler*
3 *Conditioning tower*
4 *Regulator*
5 *Saturator*
6 *Emergency stack*
7 *Solivore scrubber*
8 *Fan-extractor*
9 *Flare stack*

Fig. 17

Wet-scrubbing of unburned L-D converter gases (schematic diagram)
(Study PS 130)

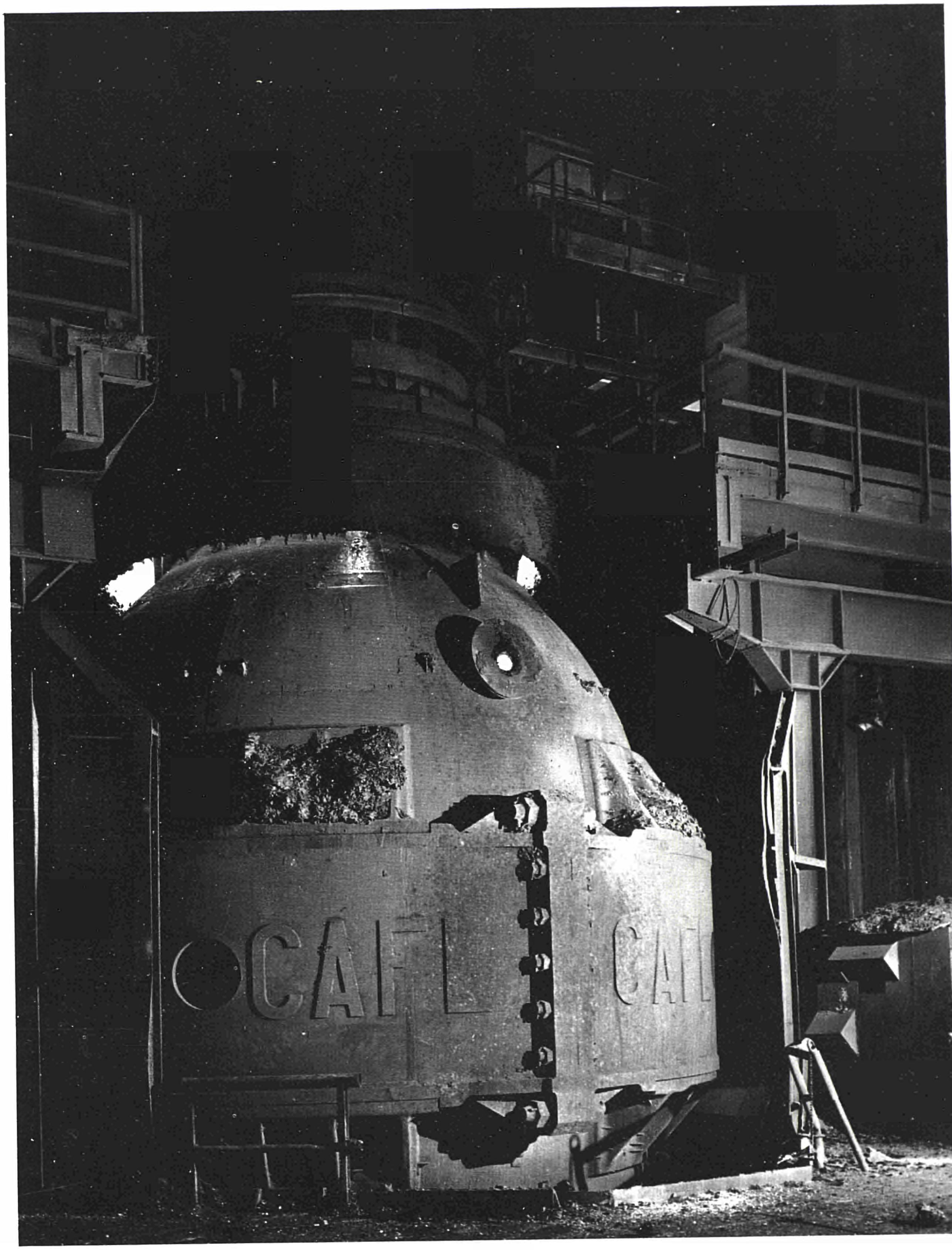


Fig. 18

Converter with gas-collecting hood
(Study PS 130)

Fig. 19

Stack flares
(Study PS 130)

Despite these precautions a number of explosions occurred, but these only caused minor damage to the system, the explosion valves working well.

One explosion took place during a period when two-stage conversion was frequent practice, i.e. at the beginning of the second blowing period following a particularly long ignition delay. Improved operating instructions and an increase in the minimum throughput from 15,000 to 35,000 m^3/h prevented a repetition of this incident.

The other explosions were either due to a considerable leakage of water into the converter during blowing (lance, suction hood) or to deposits of liquid slag on the floor of the conditioning tower where water accumulated owing to clogging of the discharge line. These defects were substantially overcome by an improved lance design, widening the discharge line of the conditioning tower, and replacing the boiler with a slag catcher. During a leakage from the water-cooling jacket to the inside of the slag catcher it was essential to shut down the converter.

A nozzle increasing the gas velocity and preventing flareback was also fitted to the top of the flare stack.

A safety valve was also provided on the fan housing. Lastly, to prevent corrosion the zinc explosion flaps were replaced by stainless steel safety flaps and some of them displaced.

Despite repeated attempts and alterations in the cleaning system over a long period, it was found impossible to reduce the dust content in the cleaned gas to below 200-250 mg/m^3 N.T.P. Ultimately considerable help was afforded by the installation of new 290 kW exhausters having an exhaust-ventilation rate of 100,000 m^3/h previously 110 kW and 70,000 m^3/h). The average dust content of the waste gases down-stream of the unit for a single loading was then 160 mg/m^3 in one measurement and 85 mg/m^3 N.T.P. in another.

3.42 *Scrubbing of L-D AC converter waste gases without subsequent combustion* (Study PS 132)

The second *study has been in progress for several years in a steelworks operating with 160 ton L-D AC converters.*

Steam generation by waste heat not considered worth while. It was therefore planned to aspirate the converter waste gases as far as possible in an unburned state and to clean them by mechanical scrubbing. Since owing to the two blowing periods and the low carbon content of pig iron the waste gases could not be put to any economic use it was decided to flare them. The arrangement of the entire waste-gas cooling and cleaning system can be seen in Figure 20 a.

To prevent air entering the waste-gas system and on the other hand from leaking over the cages of the hood, a second hood was arranged concentrically around the first, a constant amount of gas mixture being aspirated from it by a secondary blower. A vane controller regulated by the pressure in the waste-gas hood ensured that the primary exhaust only aspirated the amount of gas actually produced.

Since this system had not yet been tried out on the L-D AC converter, both the boiler unit and the cleaning unit were so designed that even with a low carbon combustion rate not exceeding 0.3%/min it would have been possible to operate the system with complete combustion of the waste gases. For this reason, each converter was provided with two blowers each having a capacity of 175,000 m^3/h.

When the steelworks started operating, a fairly low rate of combustion was employed. But since the lance first used for the L-D AC process was unsuitable, steei and slag accretions were continually deposited on both the air screen of the hood and the converter stack. In addition, a great deal of lump lime was used at the start and combination of its fine component with the CO_2 in the waste gases caused heavy deposits in the scrubbers.

In conclusion, after flarebacks and sparks flying from the converter had caused a few minor detonations in the waste-gas system, the cylindrical hood with air screen was replaced by a single conical hood and the amount of gas aspirated during blowing was adjusted to a fixed value of 135,000 m^3/h, which is equal to about 65,000 m^3/h N.T.P. The great nuisance of accretions in the converter stacks was prevented by the use of a new type of triple-hole lance with parallel nozzle axes, while deposits in the scrubbers were overcome by the exclusive use of powdered lime.

The steelworks continued operating without trouble for two years, until in 1966 a violent explosion occurred in the cleaning plants of the first two converters. In one case both the washer to the annular slot and the exhaust system were destroyed. Both explosions took place during the interval between the first and second blowing periods after the pig iron had been added. They were clearly due to the cross-sections and the variations between the cross-sections of the waste-gas system being too large for the low rate of combustion.

Since a changeover to complete combustion of the waste gases was uneconomic (in any case the second blower had already been dismantled in 1965) the converter cleaning units were redesigned. The diameter of the

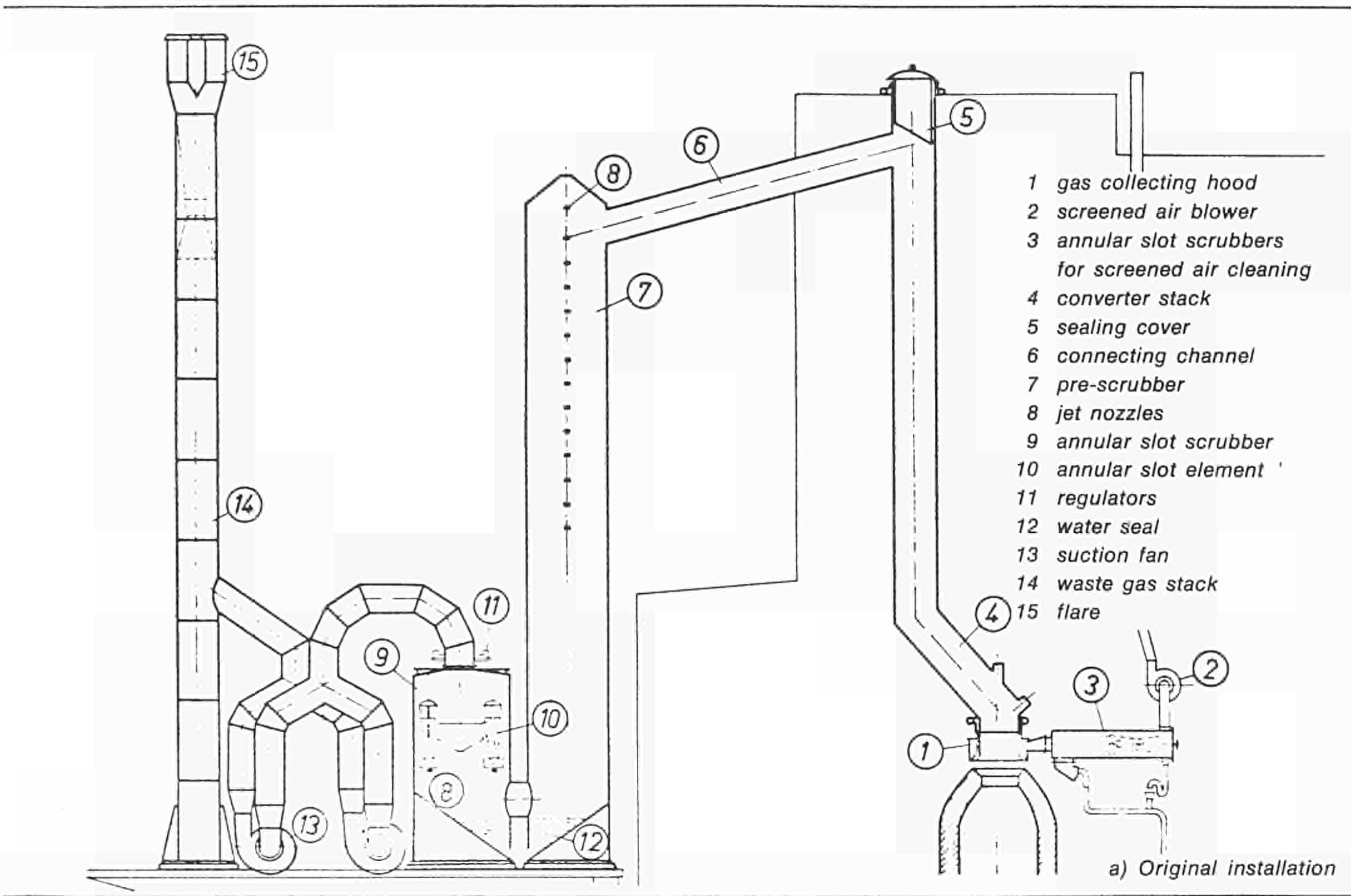


Fig. 20 a

Wet-scrubbing of unburned LDAC-converter gases (schematic diagram)
(Study PS 132)

first scrubbers was reduced from 5 to 2 metres and the washer to the annular slot converted to a water separator with a greatly reduced volume. At the same time a new fine-scrubbing system was put into operation; in this system a single rotating nozzle blowing countercurrently to the waste gas gave pure gas dust contents of well below 150 mg/m^3 N.T.P. of waste gas. (Fig. 20 b).

It is also planned to seal the gap between the converter and the hood with a drop-type sleeve so as to again ensure operation with almost completely controlled combustion. A further series of experiments are also planned, with a view to improving the water separation in front of the waste gas discharge and the flarability of the latter.

Slurry deposited in two circular thickeners is substantially dehydrated by means of two vacuum filter drums and then pelletised in a rotary dryer. The pellets are mixed with the coarse slurry collected in a gravity separator up-stream of the settling tank and containing about 6% of moisture, and then taken by a sintering plant for a corresponding credit allowance.

3.5 **Exhaustion of dusts and fumes from arc furnaces** (Study PS 45)

To obtain data for designing installations for cleaning arc furnaces producing high-grade steels, financial aid was given to a study relating to an efficient method of *removing waste gases from a basic 15 ton arc furnace smelting high-chromium steels.*

This type of unalloyed steel requires large injections of oxygen to melt down the scrap so as to reach a high bath temperature in the minimum of time. The sooner it is reached, the more carbon is burned before the chromium, thereby reducing chromium losses. This process quickly gives rise to great volumes of fumes with a high

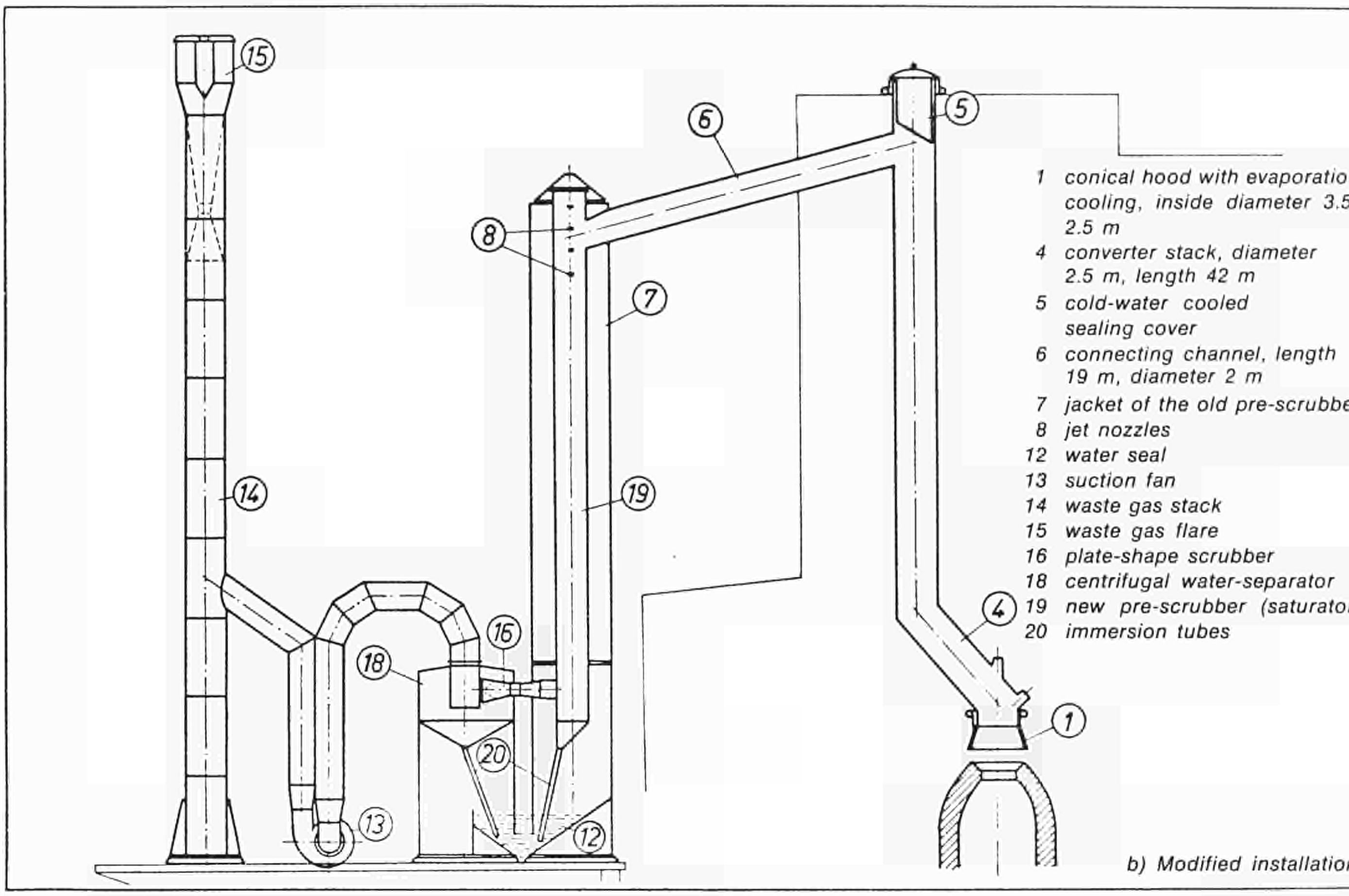


Fig. 20 b

Wet-scrubbing of unburned LDAC-converter gases (schematic diagram)
(Study PS 132)

CO content whose removal and combustion creates many different technical problems of furnace operation and choice of cleaning system.

For instance, the open suction hoods favoured in the U.S., which cover the entire furnace, electrode passages and the slag hole, causes serious furnace operating difficulties and called for large and expensive cleaning installations owing to the great volumes of fumes due to infiltrating air.

In the present study the dust- and CO-laden gas was exhausted at the top of the furnace, not cleaned, but vented to the air above the plant roof (Figs. 21, 22, 23).

Although this solves the dust problem as it affects the steelworker at his location, it is no solution for the surrounding population. But, as stated above, this research work was only concerned with establishing certain essential conditions for cleaning fumes of this type (these were applied by the plant some years later).

In the event, some very useful data were obtained both on the optimum dimensions of the flue for the cover used for capturing the fumes, the design of the adjoining suction line, and the flue gas composition, volume and temperature and dust evolution during smelting and refining with gaseous oxygen.

Thus experiments with varying amounts of oxygen showed that with large amounts (about 50 m^3/min N.T.P.) the selected cross-section on the flue capturing the gas was too small and that the suction pipe for cooling the flue gases should be water-cooled over a longer distance. A a result, the original movable suction pipe could no longer be used, and a water-cooled suction pipe pivotable at the front, was mounted over a length of 13 metres, leaving a small slit of about 10 mm on the furnace pipe of which the inside diameter had been enlarged from 400 to 470 mm.

One extremely interesting observation was that a linear relationship appeared to exist between the carbon monoxide evolved and dust yield. The experiments showed that the dust content of the furnace gas evolved had a constant of 119 g/m^3 N.T.P. of CO.

3.6 **Utilization of the brown fume deposits** (Study PS 102)

The *economic use of the dust and slurry produced from brown fumes* was the subject of a study aimed at finding for this new steelworks by-product possibilities of re-use as good as those afforded, for instance, by the blast-furnace slag from which cement is produced, or by the basic Bessemer converter slag which is the raw material of ground basic slag. In fact, such an application is naturally suggested by the large potential of crystalline formation stored in brown fume particles and the latter's fineness and chemical and thermal stability.

Ten possible applications were described in sufficient detail to enable local tests to be made after adjustment to actual plant conditions. It was found that the use of these dusts for land and highway consolidation work, (the first idea has also been tested in Japan) does not correspond to the value of the raw material.

Completely novel applications can hardly be expected from products not yet on the market, although one possible solution might be to manufacture sandwich panels for double-walled vessels.

The dust from brown fumes could also be used for manufacturing tiles, filler for concrete floors, plastering and coating walls, and for paint pigments.

Probably the simplest and cheapest solution is that recommended by the research worker, viz. briquetting the brown fumes with or without the addition of powdered lime and/or tannin. The resultant briquettes would simplify the re-use of the fumes in the converter or even the blast furnace (Fig. 24).

At the present date, it is still difficult to assess the profitability of the various uses of brown fume dust as this raw material is still without a market price and would no doubt be calculated differently for lack of plant.

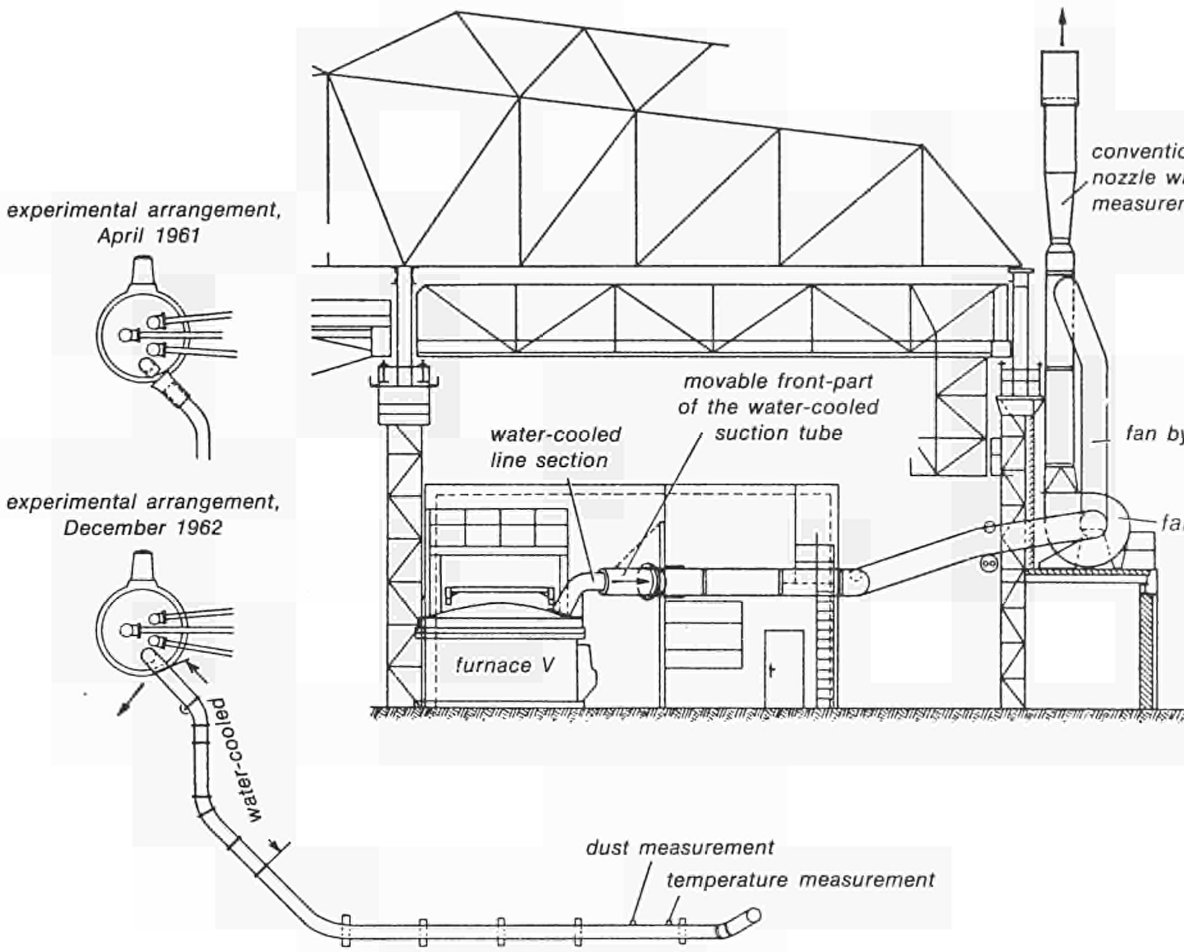


Fig. 21

Pilot arc furnace cleaning plant (schematic diagram)
(Study PS 45)

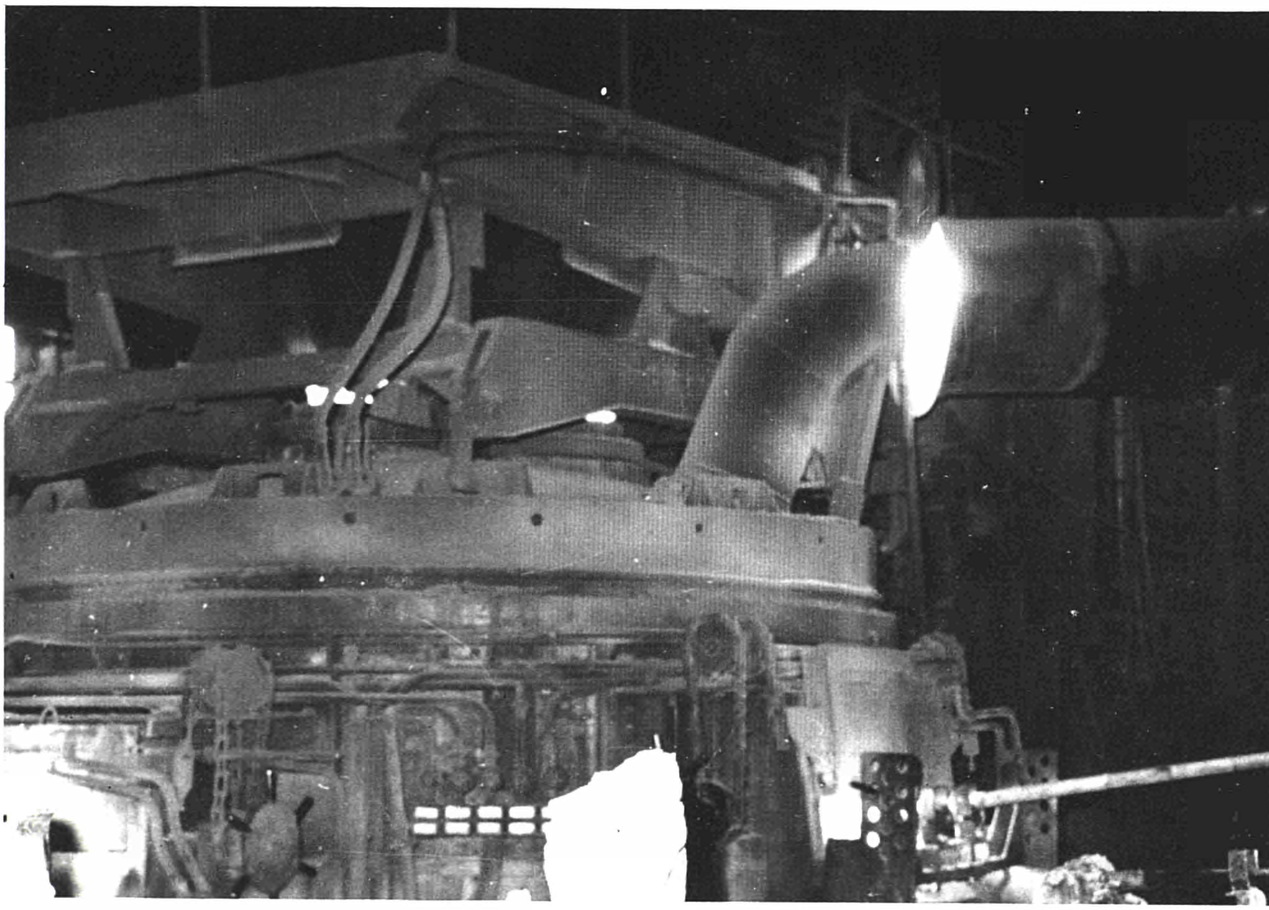


Fig. 22

Pilot arc furnace cleaning plant (assembly)
(Study PS 45)

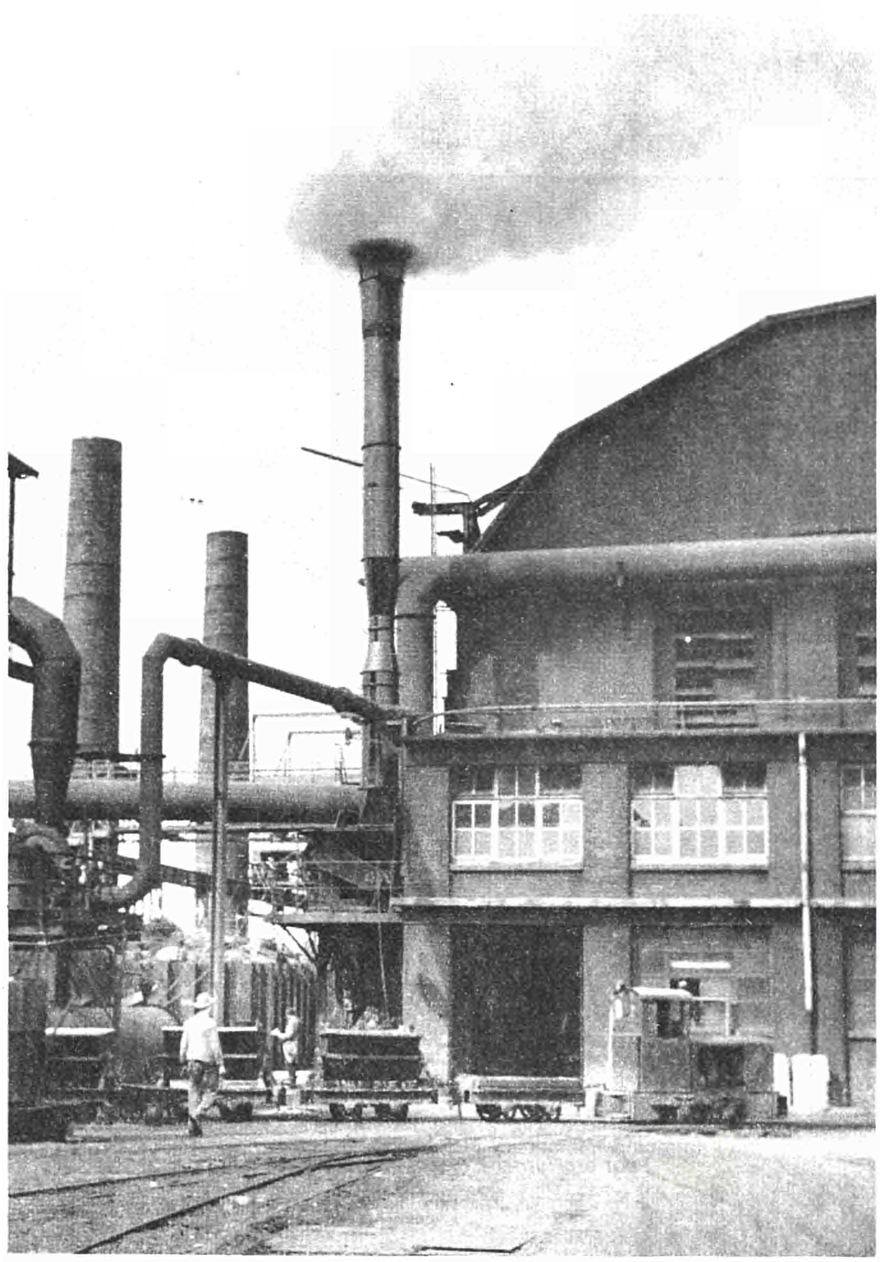


Fig. 23

Fumes discharged from an arc furnace
(Study PS 45)

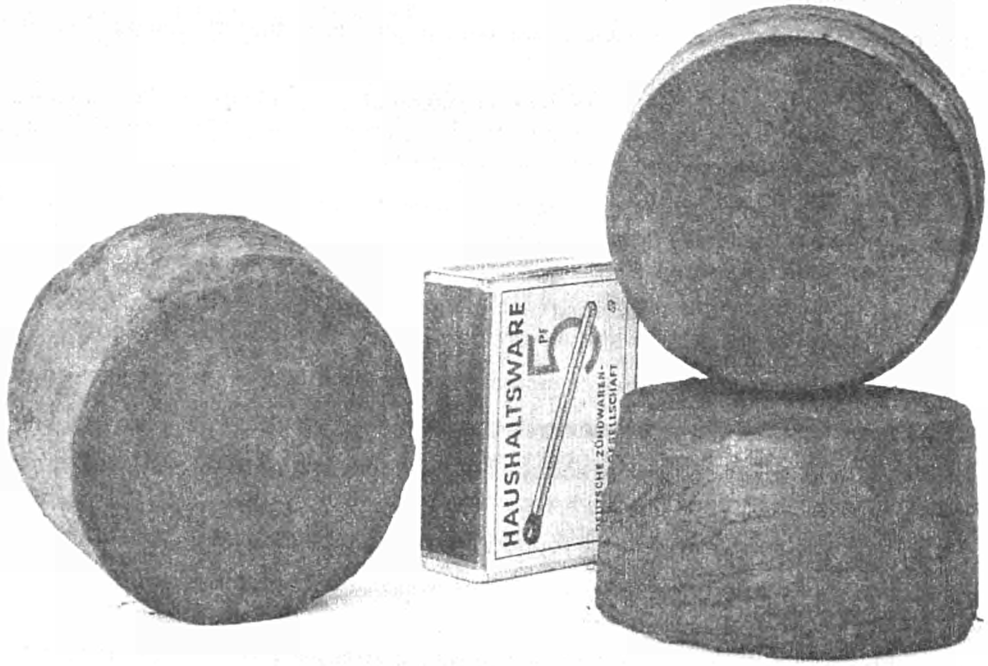


Fig. 24

Briquettes manufactured from brown dust
(Study PS 102)

4. THE CONTROL OF OTHER DUSTS AND WASTE GASES

4.0 Scope and problems

It is very obvious from a consideration of the point sources of dust and waste gas in the iron and steel industry (cf. Fig. 2a-d) that the brown fume discussed in the previous chapter is only a comparatively small, although important, part of the industry's air pollution control problem.

Among the numerous "other" dust and waste gas control problems, that of "silicogenous dusts" headed the draft research programme.

There is good reason for this, since although the precentage of iron and steel workers exposed to silicosis hazard may seem small compared to the mining industry, the distress suffered by every silicosis patient illustrates the prime importance of the control of silicogenous dusts.

All respirable dusts containing quartz or other forms of free crystalline silicon dioxide (SiO_2) are essentially a silicosis hazard. The present generally accepted definition of "respirable dusts" is dusts having a grain size of less than about 5 μm diameter.

Apart from differences in individual predisposition and habits, the causal factors of silicosis are the duration of the dust exposure and the concentration and mineralogical composition of the inhaled dusts.

The harmfulness of the various forms of silica increases in the order quartz—cristobalite—tridymite.

In the iron and steel industry silica-containing dusts are mainly produced in:

(a) repairing, renewing and removing the refractory lining of industrial furnaces, air heaters, casting ladles, ingots, casting plates, etc.,

(b) processing moulding and coring sand in the foundry, emptying moulding boxes and fettling castings,

(c) compressed air blasting with quartz sand (e.g. bridges, waste gas lines, etc. so as to dress the surface for painting).

Depending on the various thermal, chemical and physical stresses involved, the iron and steel industry employs refractory bricks and materials which not only differ in their technical properties but in their silicotic potency.

Whereas, for instance, the basic magnesite, dolomite and chromium-magnesite bricks are free from silicogenous matter, the various fireclay bricks contain varying amounts of quartz and cristobalite. Silica bricks even contain over 90% quartz, cristobalite and tridymite.

Depending on the temperatures reached in the brickwork and the residence time in the furnace, most of the quartz is converted into cristobalite and tridymite. The same happens in the quartz moulding and coring sand in the layers in the immediate vicinity of the casting. The dusts raised during emptying of the moulding boxes, fettling of castings and the demolition of furnaces lined with such materials are therefore a greater silicosis hazard than dusts resulting from the processing of fresh sand and new fireclay and silica bricks.

During sand-blasting with quartz sand very fine dusts are formed by the crushing of the particles, and their newly fractured surfaces seem to have a highly silicogenous effect. Thus cases are known in which despite strict safety precautions (work isolated in protected spaces with exhaust systems, the wearing of protective clothing and respirators), many persons engaged in this type of work contracted silicosis, and the malady even extended to staff not directly engaged in sand-blasting but often merely situated in the neighbourhood of sand-blasting units.

In many cases considerable improvement in health has been obtained by the introduction of wet fettling with pressurised water and steel-shot blasting. But in various other cases the wet method is technically unfeasible, and both technical and economic reasons preclude the use of steel shot. The latter is especially true of blasting performed in the open, when the blasting medium cannot usually be recovered and used again.

For this reason it has hitherto been continually necessary to issue special permits, even in countries where sand-blasting (quartz-blasting) is generally prohibited.

When seeking suitable technical methods of overcoming these dust hazards, particular attention should be paid to the following:

(a) discovering or developing suitable safe substitutes for the silicogenous materials for which hitherto no substitute has appeared possible.

(b) developing machinery and systems so that only the minimum number of persons need remain in dangerously dusty areas for the minimum time,

(c) the use of dust binders to prevent deposited dusts from being raised and to precipitate air-borne dusts,

(d) suitable installations for effectively exhausting and precipitating dust and ensuring a supply of fresh air to hot areas and narrow spaces (as in furnace lining),

(e) developing efficient dust respirators and air masks enabling the wearers to work with little or no hindrance.

Among the other air pollution control problems confronting the iron and steel industry, those connected with pig iron production deserve special mention.

When the steelworks have their own coking plants, the control of dusts and flue gases evolved in discharging and extinguishing the coke creates extremely difficult problems which have not hitherto been broached within the context of ECSC-aided research work.

Sinter production is also giving rise to increasingly difficult air pollution control problems, some of which have been dealt with by the ECSC.

As is known, for technical and economic reasons a great deal of sinter is at present used for pig-iron production, in addition to lump ore and scrap. Sinter consists of mineral fines with a high iron content, roasted pyrites from sulphuric acid plants, red mud from the aluminium industry, flue dusts, dusts from converter waste gases, etc., which are heated to reduce them to a lumpy but porous form suitable for the blast furnace.

Large dust clouds are often formed in ore crushing and grading plants, both in the transloading and storage of fine-grained raw materials for sintering, these clouds not only affect the workers concerned but under certain wind conditions may be a minor or major nuisance over a wide area inside and outside the plants.

The most important sources of dust in the actual sintering plants are the equipment used for conveying, mixing and discharging the raw materials, and the places where the agglomerate is discharged, crushed and screened. Attempts are being made to reduce to a tolerable level the dust nuisance caused to staff i.e. by precipitating the dusts by spraying water, or exhausting and then separating them in a central cleaning unit (e.g. multiklon, bag-filter or electrical precipitator).

The great amounts of dusty waste gases removed from underneath trucks and ladles loaded with an incandescent mixture of sinter, while not involving any particular staff protection problem, do constitute a general air pollution control problem.

The amount of waste gas in proportional to the size of the suction area, usually it may be assumed that some 70 m^3 of air is exhausted per m^2 of suction area. For a medium-sized conveyor sintering plant handling about 100 tons of sinter an hour, this would correspond to about 250,000 m^3 of waste gas an hour. These gases are cleaned to greater or lesser extent in one or more large cyclones or (in more up-to-date plants) in electrical precipitators, before being vented to the air via a high stack. But they contain varying amounts of such noxious materials as lead, arsenic, fluoride and SO_2, depending on the raw materials and fuels employed.

However, no satisfactory and economic method has yet been found for removing these pollutants under the given conditions.

4.1 Dust suppression with a view to protecting furnace relining workers against silica-bearing dusts (Study PS 101)

In a study relating to the *protection of furnace reliners against silica-bearing dusts* an older type of gas-heated open-hearth furnace was the subject of research. In these furnaces the lower part mainly consisted of fireclay and silica bricks, whereas the hearth was made of dolomite and chromium-magnesite bricks, the roof entirely of silica bricks, and the gas and air ports mainly of the same material.

Inspection of demolition work on these furnaces revealed three factors conducive to pneumoconiosis, viz.:

1. Owing to frequent fluctuations in temperature the mineral becomes very friable, so that during demolition an extremely fine dust is raised, the bricks being already highly fissured. Consequently there is a considerable concentration of fine dust during demolition.

2. During demolition, high temperatures prevail in the brickwork and its resultant dryness combined with the thermal ascent of the gases leads to very rapid dispersion of the fine dusts.

3. Owing to the high atmospheric temperature the work is particularly strenuous, which means that furnace reliners have a very high respiration rate. The filtering action of the upper respiratory tract is greatly impaired and is smaller than under normal working conditions.

A high-capacity fan giving a downward movement of air was installed to reduce the temperatures and dust concentration during the work of demolishing the walls and hearth and cleaning out the chambers, but this measure was not a complete success.

Work on the top of the furnace, and even more on the bottom, was carried out at very high temperatures. The hot firebricks caused an extremely hot air current which greatly hindered the fan ventilation. In this way a considerable amount of dust was concentrated at the head level of the workers. At lower air and firebrick temperatures conditions are far better, the downwardly directed air flow set up by the fan is more effective and more likely to give tolerable dust loadings.

Three initial measures appeared feasible for ensuring better conditions:

1. Cleaning out and demolition work should not begin until the brickwork has thoroughly cooled down.

2. The exhaust fan should have a high capacity to ensure rapid cooling of the chambers and adequate ventilation during work.

3. It is advisable to speed up cooling of the chambers of the bottom of the furnace by breaking the brick-work in good time at floor level and on the teeming box side.

However, in the last resort the dust control problem was not solved by further experiments of this kind, but by taking the radical step of converting the mixed gas furnaces, of which the roof and lining were acidic, to oil-fired furnaces with a basic lining and by cleaning out the chambers mechanically.

4.2 **Replacement of quartz sand by non-silicogenous minerals in compressed air blasting** (Study PS 119)

As mentioned earlier, it was practically impossible until recently, to *replace the quartz sand used in sand blasting by non-silicogenous minerals,* particularly when blasting was carried out in the open.

This was simply due to the fact that no substitute was known of which the dusts were not only harmless but also compared well with quartz sand as regards cleaning effect and cost.

In an ECSC-aided study a laboratory examination was therefore made of the basic technical suitability of a number of natural minerals and slags having a free silica content of not more than 1%. Large-scale tests with free jet sand blasting were then carried out with the most promising materials (certain copper and blast-furnace slags) (Fig. 25). These tests also gave good results.

If it can be prove that coats of paint applied to surfaces treated with these non-silicogenous materials are just as durable as with the use of quartz sand there would be no further objection to the general adoption of these substitutes.

4.3 **Dust control in sintering plants and during belt-conveyor charging of blast furnaces** (Study PS 1)

One study related to the *use of water jets in particular for the suppression of dust arising in the preparation of the furnace burden and in sintering plants* at the following points:

(a) the transport and discharge of coke in the bunkers,
(b) the transport and discharge of sinter in the bunkers,
(c) the belt-conveyor charging of blast furnaces with coke, ore and sinter.

The use of water jets (Fig. 26) produced some notable results.

In the transport of coke to the bunkers the number of dust particles of from 5 to 0.5 μm was reduced by 45%-50% and by 60% in the screening of coke during the belt-conveyor charging of blast furnaces.

At another point where very hot dusts are formed (transport of the sinter in the immediate vicinity of the pulsed air jet cooling system) water jets proved unsuccessful. The dust sources were therefore covered and the dusts precipitated in an Airmix scrubber, as a result of which the concentration of respirable dust particles was reduced by 80%.

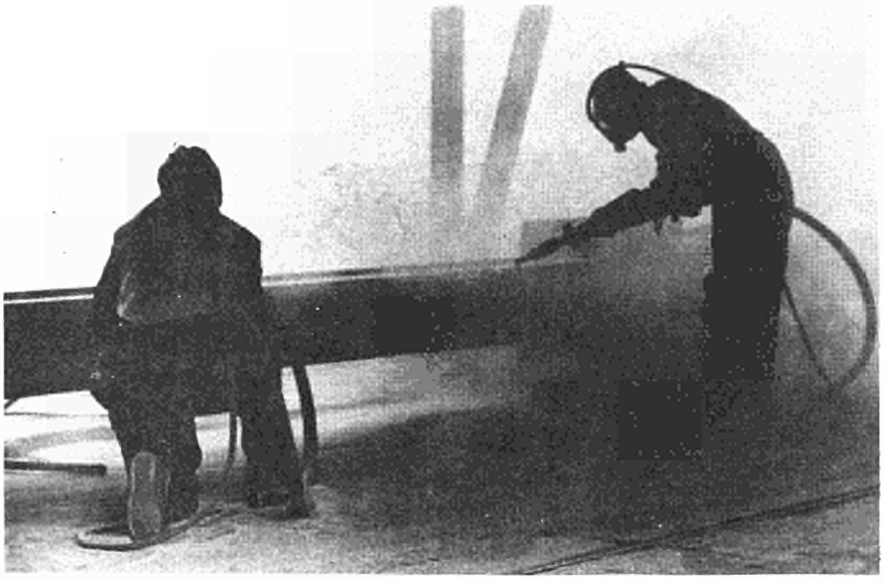


Fig. 25

Sandblasters (Study PS 119)

Among other things it was found that purified water is very important for the efficient operations of the water jets and that the choice of a suitable filter is apparently more important than the choice of water jet.

The dust concentration was measured by means of thermal precipitators.

4.4 Control of dust produced in discharging fine ores and during the preparation of the blast furnace burden (Study PS 121)

Another study was concerned with the *control of dust produced in discharging fine ores and charging furnaces.*

The dust produced in discharging fine ores (Folldal residues) from special skips into the sintering plant bunkers (Fig. 27) was reduced by 40%-90% by spraying with water to which were added minor amounts of surface-active wetters (c. 0.1% texapon).

The following dust deposits were measured per m² monthly at distances of 10 m and 50-60 m from the bunker with the use of Diem foils at a discharge height of, say, 2-3 m and a specific water consumption of 0.16 m³ per ton of very fine ore:

	10 m	*50-60 m*
Without water jet	7.0 kg	1.0 kg
With a jet of recycled water	4.5 kg	0.25 kg
With a jet of recycled water and a wetter additive	3.0 kg	0.1 kg

The discharge heigth and moisture content of the fines have a considerable effect on the amount of dust precipitated.

The tests were carried out with simple spray nozzles, first with fresh water and subsequently, for reasons of economy, with recycled water from the gas scrubbing plant. This recycled water has a suspended matter content of 25 mg/m³ and a temperature in the region of 60°C, which had a good effect on the surface tension.

The method was applied with equally good results to the car tipper during the discharge of extremely dusty raw materials and has now also been adopted for the transport of fine ore from the skip to the tipper by conveyor belt.

By exhausting dust from the bunker gates it was possible to reduce the dust concentration by about 80% at the work location of the driver of the burden-charging carriage and by about 50% at the burden preparation chute about 3 m from the bunker gate. Thus the average dust concentration during discharge of the sinter was:

	at the work location	in the chute
Without exhaustion	219.1 mg/m³	53.0 mg/m³
With exhaustion	38.0 mg/m³	25.5 mg/m³

Fig. 26

Water vaporization above a conveyor belt in a sintering plant (Study PS 1)

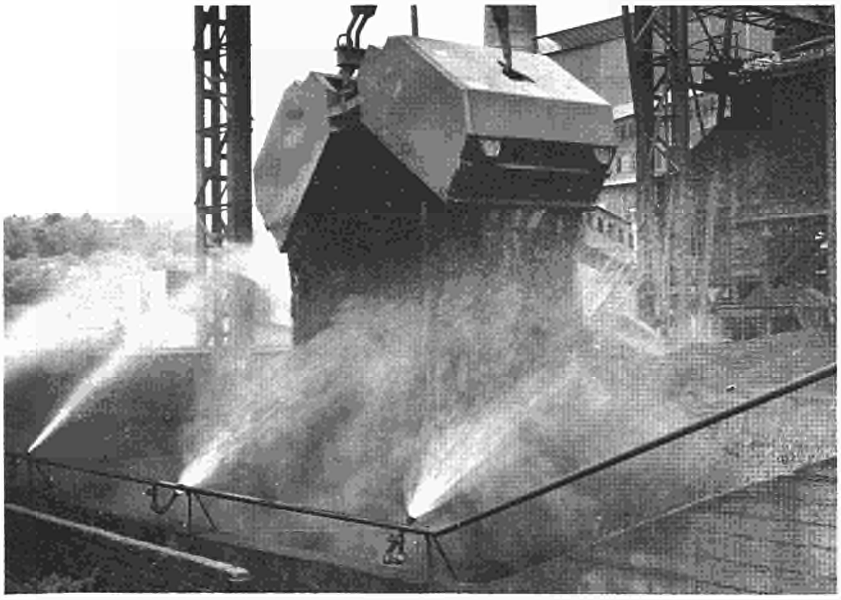


Fig. 27

Spraying surface-active water on fine-ore bunkers.
(Study PS 121)

4.5 **Control of dust produced in the dry granulation of blast-furnace slag** (Study PS 120)

Considerable difficulties have hitherto been experienced in the *control of dust produced in the dry granulation of blast-furnace slag.*

Whereas wet granulation provides a granulate with about 20%-40% moisture which has to be expelled at the cement works, the granulate obtained in dry granulation[12] can be processed by the cement works in the form as supplied by the blast-furnace works.

In the plant concerned the blast-furnace slag is passed in a molten state via slag troughs to the rotary granulating drums where it is broken up and cooled with a cold air blast. The drums, which slope in the direction of flow, discharge the resultant granulate to a rising conveyor platform with convex steel sheets, whence it is transferred to two loading bunkers.

To control the dust evolved, all discharge points and runways were encased and connected to a cyclone. After this installation had been started up, it was found that particles of slag wool and dust entrained by the outlet air clogged the suction lines and the blower and formed such a deposit of fibres in the dust collecting bunkers that they could not be emptied.

As a result the cleaning system had to be shut down and the uncleaned waste gases vented to the atmosphere. This situation led to intolerable fouling of the neighbouring plants and area (Fig. 28). The initial aim of the relevant ECSC-aided study was to prevent the formation of slag wool and dust during granulation by regulating the amount of slag, the air volume and the rate of air flow from the nozzle (Fig. 29). But it was found that even with an improved method of granulation it was still necessary to clean the waste gas. Finally a double hood of sheet steel was fitted over the granulation drum outlet (Fig. 30), each hood having two lines with a total of 50 nozzles with a flow rate of 2 m^3/h each at a pressure of 4 atms. gauge which reduce the dust volume of the waste gases from 4.5 to 0.5 g/m^3, thereby satisfying the clean air requirements of the industrial supervisory office.

After several weeks' operation it was found that the lower part of the hood in contact with the water had been severely eroded by the sulphurous waste gases and angular solids entrained in the dirty water.

These drawbacks were successfully overcome by the following measures:

(a) for the lower part of the hood, which for structural reasons had to be made of reinforced concrete, use was made of the Gunite process by which an acid resistant, water repellent cement was applied and smoothed under pressure on the reinforced concrete base,

(b) a ferritic-perlitic steel (Novonox F 13 AL with about 0.06% C, 13% Cr and an alloying addition of about 0.16% of AL to reduce air-hardening and susceptibility to weld cracks) was used for the part of the sheet metal in contact with water, and for the remainder sheet steel of quality TR 37, DIN 17100 killed basic Bessemer steel.

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(12) But not for the manufacture of high-grade cements of which the good hydraulic properties are due to an amorphous, vitreous solidification of the slag as obtained in the sudden cooling provided by wet granulation, but not by dry granulation.

After filtration of the solids, the cyanogen-containing waste water together with the waste water from the electrical precipitator used for cleaning the furnace top gas were cleaned in a settling basin provided with a cyclone unit and processed for re-use in a completely sealed, joint circuit.

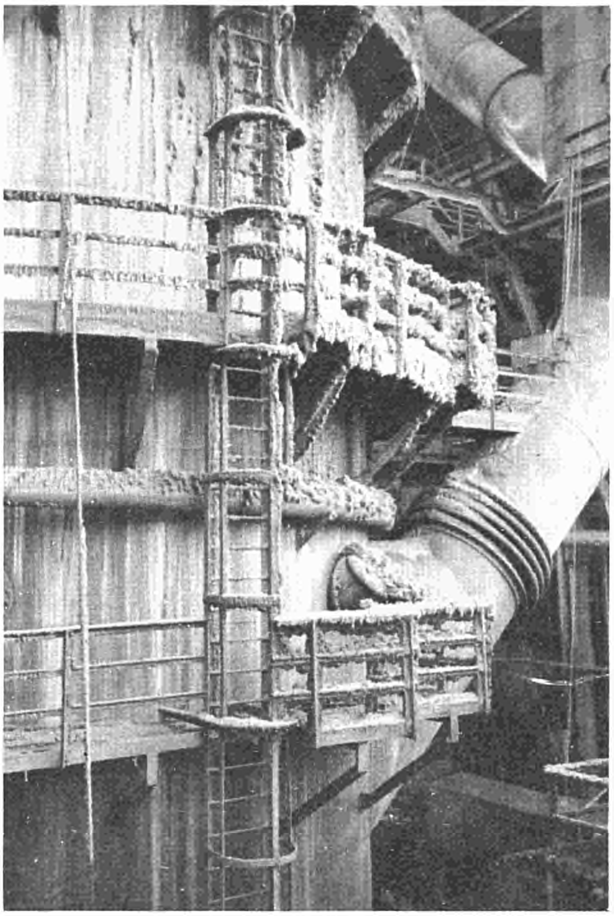


Fig. 28

Parts of a blast furnace fouled by unclean dry granulation of slag.

(Study PS 120)

1 cooled vibrating gutter
2 slag gutter
3 slag
4 water inlet
5 water outlet
6 air supply
7 granulating drum

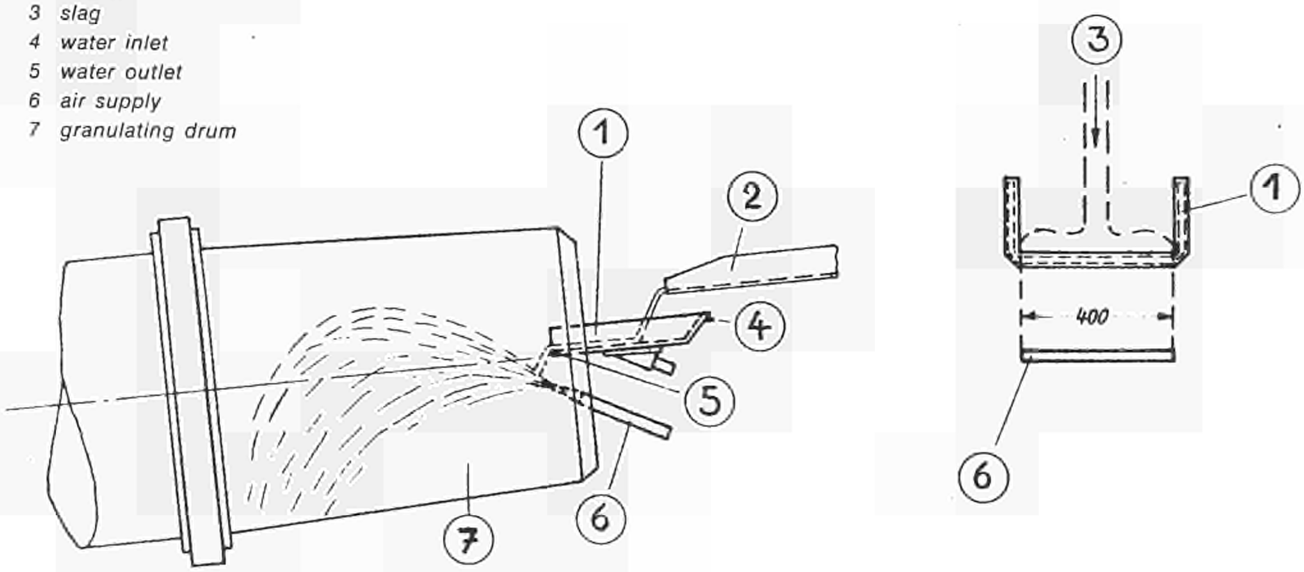
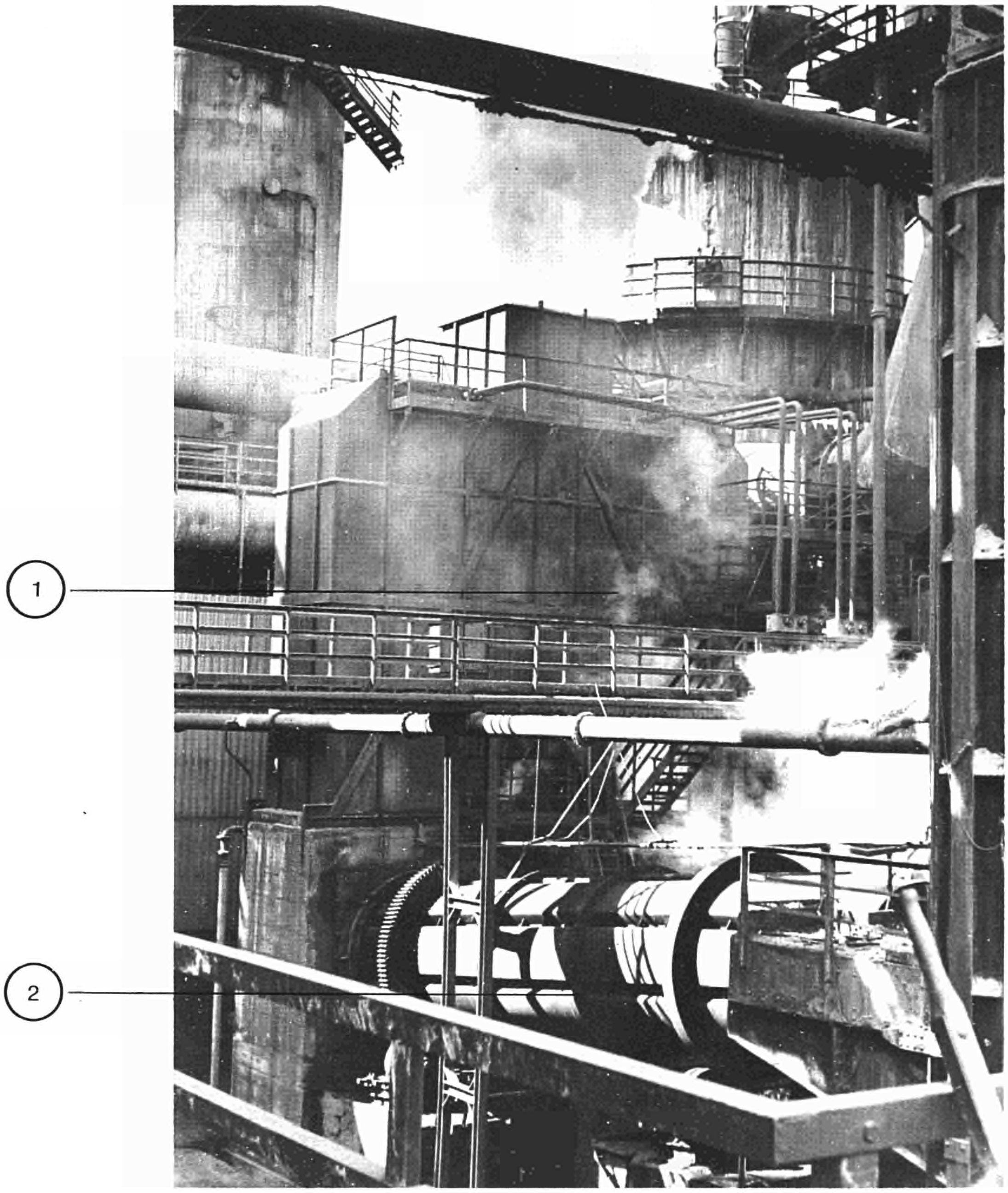


Fig. 29

Dry granulation of slag (schematic diagram)
(Study PS 120)



1 wet-scrubbing hood
2 granulation drum

Fig. 30

Dry granulation of slag (assembly)
(Study PS 120)

5. SUMMARY AND CONCLUSIONS

The introduction calls attention to the dual aspect of air pollution both outside and inside steelworks, the principal dust and flue gas sources found in the iron and steel industry, and the background of ECSC-aided research in this field.

The next three chapters deal with the general problems involved and then give a report on the results of 30 studies carried out with the ECSC's financial aid.

The last part of the report contains the photographs, drawing and tables referred to in the text, as well as a table (Fig. 31) giving a brief survey of the various research bodies, research subjects and results and the relevant publications and ECSC documents.

To sum up, the position is as follows:

1. 16 studies were carried out in the sphere of *dust and gas measurement,* of which

(a) 9 were concerned with the comparison and improvement of dust-measuring instruments and the development of new ones,

(b) 5 were concerned with measuring the dust concentration at work locations,

(c) 2 related to the emission and ground level concentration of dusts and gases.

As regards the *comparison of dust-measuring instruments,* a joint research programme carried out by 6 institutes from 4 Community countries and Austria produced important data for equating the methods of sampling and measurement of dust concentration. Although some questions call for closer investigation, it is now established that gravimetric methods constitute the soundest basis for the comparison of dust-concentration measurements.

For certain purposes, however, particle counts are still important.

As regards the improvement of dust-measuring instruments and the development of new ones, mention should first be made of the development of a small gravimetric dust-measuring instrument with a high sampling rate. This can easily be carried on the back even when the work involves constant movement from place to place, the dust concentration in the respiratory zone being measured by means of a suction nozzle.

Substantial progress was also made in particle counting, from the detection and elimination of many errors likely to occur when working with membrane filters and immersion oils, to the manufacture of a handy gauge for the microscopic visibility limit and counting of dust particles which gives a constant point of reference for counting and measuring.

Considerable success was obtained in determining the origin of dusts concentrated at all kinds of point sources. For instance, by improving microscopy methods it proved possible to distinguish between iron oxide particles from steelmaking processes and Lorraine and Swedish iron ores in the mixed dusts usually found in a steelworks, and even between coke particles originating in coke furnaces and pulverised coal furnaces. A microprobe method was also found extremely useful for identifying fine dusts often found at a great distance from their point sources.

In addition a number of electrical contact instruments for automatic continuous measurement and recording of the dust concentration were developed or improved. These could be extremely useful for monitoring certain work locations, filter systems, etc. The next step is to test the reliability of these instruments under practical conditions and to eliminate any faults in design or method.

Measurements of the dust concentration at different working areas, initially envisaged as pilot studies only, established that certain jobs in the iron and steel industry, e.g. the demolition of open hearth furnaces, the cutting, polishing and laying of refractory firebricks, or in stripping, fettling and polishing castings poured in sand moulds, may sometimes involve a very considerable silicosis hazard.

To obtain a clearer insight into air pollution in steelmaking plants and their immediate vicinity we still need well co-ordinated systematic research work using as far as possible the same sampling and analytical techniques. An attempt must also be made, in cooperation with other interested international organisations, to harmonize formulas for the appraisal of dust hazards and silicosis hazards in particular.

In *research on the emission and ground level concentration of dusts and gases* a clear relationship was established between high fluorine and sulphur levels in plants, and the main wind direction, charged materials and the uncleaned flue gases discharged from electric and open hearth furnaces. Moreover considerable improvements have been made to the analytical methods for the correct determination of fluorine. The conditions under which fluorine compounds are adsorbed to dust—free fluorine scarcely ever occurs in the waste gases of steelworks—and possible methods of precipitating them were also discovered.

2. Considerable progress has been made in the *control of brown fumes* to which 9 studies were devoted (a 10th has not yet given any definite results), although all objectives were not fully attained and several new problems arose which can only be solved by further research.

Among successful studies, mention should first be made of the cleaning of waste gases of a bottom-blown basic Bessemer converter by means of an electrical precipitator. But in this study, it was found that the cleaning installation occupies more space than is generally available in basic Bessemer steelworks (which are usually of an older type), and that the use of waste steam needed to make the method profitable calls for conditions which in many plants are not found.

Hence we are still faced with the problem of finding a suitable method of cleaning such basic Bessemer steel plants as are still in operation. As is known many have meanwhile been replaced by top-blown oxygen steelworks.

Hopes of considerably reducing the cost and space required by cleaning installations have unfortunately not been fulfilled by the development of a new type of electrostatic system for the precipitation of brown fumes. After very encouraging results had been obtained in the laboratory and subsequently in a semi-technical plant, the third project in this sphere failed as a result of structural defects in the large-scale pilot plant.

On the other hand, outstanding results were obtained in cleaning completely burned L-D converter waste gases with a bag-filter installation. Hitherto it was hazardous to use plastic, cotton or similar tissues for cleaning such gases at temperatures of over 100°C-150°C, and they also became clogged by the wettened dusts when the cooling water jet was under too high pressure. These risks have now been overcome by installing a large Cowper-type heat exchanger at the rear of the converter stack. This method has now been adopted in various steelworks both inside and outside the Community.

Should it be possible to develop filter tissues with sufficient resistance to temperatures of 600°C or over and to the mechanical stresses set up during cleaning, this would certainly lead to a far greater use of bag filters of which the cleaning efficiency is well known.

In order to reduce to a minimum the size of the cleaning installations and their cost, two studies were devoted to the improvement of a number of different methods. They consist in substantially preventing the combustion of the converter gases before cleaning by means of a suitable collection and exhaust system. For safety reasons, flue gases containing carbon monoxide, which form an explosive mixture when air is added in certain proportions, have to be cleaned in scrubbers.

In both cases good cleaning results were obtained. But the main drawback of these installations is the great amount of energy consumed by the scrubbers, and the expensive and troublesome problem of disposing of the water and slurry.

This being the case, it would obviously be a great advantage to the iron and steel industry if the recently proposed methods of electrostatic precipitation of unburned, captured converter gases could be applied in an explosion-proof embodiment.

As regards the exhaustion of the brown fumes produced in the electric furnace during oxygen refining, some useful information has been gained on the best dimensions of the flue and the design of the adjoining suction line.

Experiments aimed at discovering an economic use of the dust and slurry obtained from brown fumes revealed a number of interesting possibilities, the simplest and cheapest method being the briquetting of the dust, after which it can be readily used again in the converter or blast furnace.

3. Five studies were devoted to the *control of other types of air pollution.*

Although it was only possible to close some of the gaps in our knowledge of this subject, some very considerable specific progress was made.

For instance, means were discovered for protecting furnace relining workers against silica dusts, other discoveries relate to an efficient method of working and adequate ventilation during the demolition of basic Bessemer furnaces, mechanical cleaning of the chambers, and basic lining of the furnaces.

As a substitute for the silicogenous quartz sand, which hitherto it has proved impossible to replace in compressed-air sandblasting, non-silicogenous abrasives were found which as regards cleaning effect and cost compare well with the quartz sand.

Although nothing is yet known about the durability of coats of paint applied to surfaces previously freed from rust, old paint, etc. with these new abrasives, a further study could easily settle past doubts as to whether they would be a perfect substitute for quartz sand in compressed-air sandblasting of bridges, flue-gas lines, etc.

Dust control measures adapted to the prevailing conditions proved very effective in sintering plants, in the conveyor loading of blast furnaces, the discharging of fine ores from special skips and car tippers, and at the working area of the driver of the burden-charging carriage. The measures partly consisted in exhausting the dusts from the point source and partly in spraying them with water with or without the addition of a wetting agent.

Lastly, an extremely irritating dust problem arising in the dry granulation of blast-furnace slag was solved in spraying the dust with water in a special suction hood.

As stated above, despite al the successes achieved a great deal still remains to be done in the latter sector also.

For instance, no practical solution has yet been found to the problem of controlling the dust raised in discharging coke, and no method has been found for preventing SO_2 discharges in sintering plants. In this connection we must also mention certain problems arising out of the application of air pollution control measures, such as the purification and disposal of the dusts, slurries and waste waters.

There is also a vast field of research to be done on the satisfactory removal of dusts deposits and the improvement of individual protective equipment.

But in the future, as in the past, all efforts at ensuring cleaner air will be essentially directed towards finding practical solutions that fully meet the basic requirements of an efficient health service and whose expense can also be borne by the Community's iron and steel industry, despite the keen competition to which it is subjected.

Fig. 31 a) — Synoptic Table of ECSC Studies on Air Pollution

Dust and gas measurement

Designation (dealt with in section)	Study carried out by	Subject of study
PS 150 (2.11)	Clinica del Lavoro, Milan Institut National de Recherche Chimique Appliquée (IRCHA), Paris Silikose-Forschungsinstitut, Bochum Staubforschungsinstitut, Bonn Instituut voor Gezondheidstechniek T.N.O., Delft Verein Deutscher Eisenhuttenleute (V.D.E.), Düsseldorf Österreichische Staub-(silikose) Bekaempfungsstelle Leoben	Harmonization of dust-measuring methods. Comparison of dust-sampling devices and methods.
PS 139 (2.12)	Staubforschungsinstitut des Hauptverbandes der gewerblichen Berufsgenossenschaften Bonn — Langwartweg 103	Development of a portable dust-measuring device with a high air intake ratio. Use of micropore membranes.
PS 10 (2.13)	Clinica del Lavoro dell'Università di Milano Milan — Via S. Barnaba, 8	Research on the development of a simple method for determining free SiO_2 content.
PS 37 (2.14)	Association des Industriels de Belgique (A.I.B.) Brussel 16 — 27-29, avenue André Drouart	Research on the development of a simple method of determining free SiO_2 content.
PS 135 (2.15)	Institut National de Recherche Chimique Appliquée (IRCHA), Paris 4e — 12, quai Henry IV	Manufacture of a gauge for microscopic visibility limits and dust particle counting.
PS 141 (2.16)	IRCHA Paris 4e — 12, quai Henri IV	Development of an electro-acoustic device for determining the size of aerosol particles.
PS 35 (2.17)	Centre Belge d'Étude et de Documentation des Eaux (CEBEDEAU), Liège — 2, rue Armand Stévart	Establishing the source of dusts in sintering plants.
PS 15 (2.18)	Prof. Dr.-Ing. Eugen Feifel, Wien, and Dr.-Ing. Rudolf Prochazka, Munich, Pfarrstrasse 3 (Bayer. Landesinstitut für Arbeitsschutz)	Testing and further development of continuously recording contact-electric dust-measuring devices with high air intake (50 m^3/h).
PS 138 (2.18)	Staubforschungsinstitut Bonn — Langwartweg 103	Development of a contact-electric recording dust measuring instrument with lower air intake (6 m^3/h)

Control in the Iron and Steel Industry

Comparison and improvement of dust-measuring devices and methods and the development of new ones

Results	Publications and ECSC-documents
Good agreement between the gravimetric determinations of dust concentration. Poor agreement between the particle number determinations, but results successfully extrapolated to instruments already in use (standard deviation of 15%).	Avy, A.P., Benarie, M. and Hartogensis, F.: Staub-Reinhalt. Luft 27 (1967), pp. 469/80. Poll. Atm. 10 (1968) No. 37, pp. 1/16.
Portable dust-measuring instrument, 24 × 24 × 14 cm, 8 kg for carrying on the back air velocity 10 m^3/h; air measuring device and flexible suction nozzle permits accurate measurement of the dust concentration in the respiratory zone.	Winkel, A. and Coenen, W.: Staub-Reinhalt. Luft 26 (1966), pp. 9/11. French translation available (ECSC document No. 1546/67 f.).
Assessment of possible errors and their avoidance in counting dust particles precipitated on membrane filters.	ECSC document 5238/64, d, f and i.
Aim not achieved, but some interesting incidenta results on immersion oils used for filter membranes.	ECSC document 5239/64 d and f.
Successful production of a handy gauge with a constant point of reference for counting and measuring.	Benarie, M.: Poll. Atm. 6 (1964) No. 21, pp. 32/48. Staub 24 (1964) pp. 514/20. ECSC document 6874/65 f.
Aim not entirely achieved, but other possible applications of this principle established for dust-measuring problems.	Original report from IRCHA dated 28.12.64. German translation available (ECSC document No. 485/65d). Cf. also Avy, A.P. and Benarie, M. Staub 24 (1964), pp. 343/44.
By improving the analytical method, dust e.g. iron and coal particles of different origin could be identified and even emittents at a greater distance.	ECSC document 7217/65 d and f.
Sensitivity within further ranges can be regulated from 3 g to 1 millionth g/m^3. Possibility of measuring and continuously recording respirable fine dust concentration and total dust concentration.	Various publication, including: Prochazka, R.: Moderne Unfallverhütung Heft 6 (Vulkan-Verlag, Essen). French translation available (ECSC document No. 5300/62 f.) Prochazka, R.: Arch. Eisenhüttenwes, 39 (1968), pp. 439/47. French translation available (ECSC document No. 2100 /68 f.)
Concentrations of 0.1 mg/m^3 of dusts of less than 5 μ could still be identified. No risk of polarity reversal of the leakage current by certain mixed dust components leading to errors in measurements.	Schütz, A.: Staub 24 (1964) pp. 359/63. French translation available (ECSC document 6915/64 f) also Schütz, A.: Staub-Reinhalt. Luft 26 (1966), pp. 198/201. French translation available (ECSC document 1545/67 f.)

Fig. 31 b) — Synoptic Table of ECSC Studies on Air Pollution

Measurements of the dustiness of working areas

Designation (dealt with in section)	Study carried out by	Subject of study
PS 20 (2.21)	Staubforschungsinstitut, Bonn — Langwartweg 103	Measurement of dust concentration in various working areas of the iron and steel industry.
PS 11+12 (2.22)	Clinica del Lavoro, Milan — Via S. Barnaba, 8	Determination of the physical, chemical and mineralogical characteristics of dust and fumes in the iron and steel industry.
PS 49 (2.23)	Direction de la Santé Publique, Luxembourg — 1, rue Auguste-Lumière	Dust survey in the Luxembourg iron and steel industry.
PS 144 (2.23)	Laboratoire de Minéralogie du Musée d'Histoire Naturelle, Luxembourg, rue Sigefroi	Crystallographic characteristics of minerals in different dusts occurring in the Luxembourg iron and steel industry.
PS 17 (2.24)	Instituut voor Gezondheidstechniek T.N.O., Delft — Schoenmakerstraat 97	Determination of the dust concentration in various working areas in iron and steel foundries.
PS 129 (2.31)	Kloeckner-Werke AG: Georgsmarienwerke, Georgsmarienhütte (Kreis Osnabrück)	Research on the emission and ground level concentration of fluorine- and SO_2 -containing waste gases discharged by steelworks.
PS 149 (2.32)	August.Thyssen-Hütte AG: Werk Ruhrort, Duisburg — Ruhrort	Detection and removal of fluorine in waste gases.

Control in the Iron and Steel Industry

Research on dust and gas emissions and their ground level concentration

Results	Publications and ECSC-documents
Appraisal of silicosis hazard according to own formula in 8 German steelworks and foundries.	Winkel, A. and Schütz, A.: Staub 24 (1964) pp. 497/504. French translation available (ECSC document 8304/65.)
Appraisal of silicosis hazard according to own formula in 5 Italian steelworks.	ECSC document 5237/64 d, f and i.
Dust measurements in blast furnace plants, basic Bessemer steelworks, basic slag mills, rolling mills and foundries.	ECSC document 8114/64, d and f.
Different types of dust distinguished. Compilation of a card-index system as an aid to the identification of various dust sources.	Heyart, H.: Revue Technique Luxembourgeoise 59 (1967) No. 1, pp. 9/20. German translation available (ECSC document 609/67 d.)
Dust measurements in 9 Dutch foundries. Analysis not yet completed.	Various interim reports published, e.g. in Proceedings XVth Int. Congr. Occup. Health, Semt. 1966 Wien. Section A III-123, pp. 623/27. The latter interim report is included in ECSC document 4066/67 d and f.
One result of measuring and recording the F and SO_2 emissions and their ground level concentrations discharged by several different open-hearth furnaces and an electric furnace belonging to a steelworks located in a rural area was that far higher F and S concentrations were found in vegetation oriented along the direction of the prevailing wind.	ECSC document 4232/62 d and f (summary in Doc. 4516/64 d and f.)
Improvement of the analytical method. Measurements of the fluoride concentration in the town area showed no concentrations in the neighbourhood of the steelworks. In non-acidic waste gases almost complete adsorption of the fluorine compounds to the solid waste gas components.	Graue, G. and Nagel, H.: Staub-Reinhalt. Luft 28 (1968), pp. 7/13. French translation available (ECSC document 1157/68 f.)

Fig. 31 c) — Synoptic Table of ECSC Studies on Air Polluti

Control of brown fum

Designation (dealt with in section)	Study carried out by	Subject of study
Huckingen (3.1)	Mannesmann AG Hüttenwerke Werk Huckingen — Duisburg-Huckingen	Cleaning brown fumes from bottom-blown Bessemer convertors by means of electrical precipitators.
PS 18 (3.2)	Staubforschungsinstitut, Bonn — Langwartweg 103	Agglomeration of brown fumes at fairly high temperatures in electric fields.
PS 43 (3.2)	Phoenix-Rheinrohr AG (now August-Thyssen-Hütte), Werk Ruhrort, Duisburg-Ruhrort	Cleaning brown fumes from convertors by means of a new electrostatic method.
PS 131 (3.2)	as above	as above
PS 128 (3.3)	Société des Aciéries de Pompey, S.A. Werk Pompey — Pompey	Cleaning of L-D convertor fumes with bag filters.
PS 130 (3.41)	Usinor S.A., Werk Dünkirchen	Scrubbing of unburned L-D converter waste gases captured by the IRSID-CAFL method.
PS 132 (3.42)	D.H.H.U. AG (now Hoesch AG Hüttenwerke), Werk Phönix — Dortmund-Hörde	Scrubbing of the L-D AC converter waste gases captured by the Krupp-method.
PS 45 (3.5)	Gebrueder Boehler, AG, Düsseldorf — Oberkassel	Exhaustion of electric furnace fumes.
PS 102 (3.6)	Laboratorium für Staubtechnik (Prof. Meldau) Gütersloh, Wilhelmstrasse 4	Utilization of precipitated brown fumes from converters.
Sulzbach	Eisenwerk-Gesellschaft Maximilianshütte m.b.H., Sulzbach-Rosenberg-Hütte	Prevention of brown fumes from bottom-blown basic converters by the use of converter floors with minimum-size blowholes.

Results	Publication and ECSC documents
Average dust concentration of the cleaned waste gases from a 40 ton basic Bessemer converter at 100 g/m³ N.T.P. Reduction of cleaning costs through the use of steam produced by cooling of waste gases for electrical current generation.	Dehne, W. and Müller, H.G.: Stahl u. Eisen 82 (1962), pp. 762/71 Circ. Inform. techn. 19 (1962), No. 11, pp. 2345/65.
Good cleaning results with a laboratory plant for 5 m³/h N.T.P. at about 400°C in electrostatic fields, having no reversed polarity and in electric fields with ionisation.	Winkel, A. and Schütz, A. Staub 22 (1962), pp. 343/59. A summary is available (ECSC document 3079/63 d, f, i and n.)
Dust concentrations of less than 100 mg/m³ N.T.P. were obtained in pure electrostatic fields with a pilot cleaning plant for 2000 m³/h N.T.P.	Flossmann, R. and Schütz, A.: Staub 23 (1963), pp. 443/51. French translation available (ECSC document 8302/65 f.)
Owing to structural defects in the pilot plant for 25,000 m³/h N.T.P., no purified gas dust concentrations of less than 200 mg/m³ N.T.P. were obtained even with the use of ionisation paths.	Graue, G. and Flossmann, R.: Staub-Reinhalt. Luft 27 (1967) pp. 434/37. French translation available (ECSC document 1116/68 f.)
Cleaning of the waste gases of an 18 ton L-D converter with the use of a Cowpertype heat exchanger gave an average dust concentration of only 6 mg/m³ 6 mg/m³ N.T.P. in the purified gas.	Various publications e.g. Debruille, P.: Poll. ATM. Numéro spécial September 1962, pp. 123/49. Muhlrad, W.: Stahl u. Eisen 82 (1962), pp. 1579/84. Also: ECSC document 3684/63 d, f.
Cleaning of the waste gases of 130 ton L-D converters to an average dust concentration of from 85 to 160 mg/m³ N.T.P. Utilization of waste gases with a high CO content (at present flared) is not at present envisaged.	Dumont-Fillon, J. Namy, G. et Spreux, M. Livre du "Congrès Internat. sur les aciéries à l'oxygène" Sept. 1963, pp. 455/66 (G, F and E summary on p. 455) Huysman, M. et Maubon, AK: Rev. Métallurg. 65 (1968) No. 5, pp. 333/43. German translation available (ECSC document 1925/68 d.)
Cleaning of the waste gases of 160 ton L-D AC converters to an average dust concentration of less than 150 mg/m³ N.T.P.; experiments on improved flarability of the purified gas still in progress.	Simon, R. Stahl u. Eisen 85 (1965), pp. 385/91. In addition more recent interim reports are available (ECSC documents 466/67 d and f; 5493/67 d and f.)
Good results with 15 ton arc furnace by exhaustion in the flue and cooling of the waste gases by water-cooled suction line and water injection.	Kahnwald, H. and Etterich, O.: Stahl u. Eisen 83 (1963) pp. 1067/70. French translation available (ECSC document 3005/65 f.)
Various possible applications recommended, especially briquetting for simplifying re-use in converter or blast furnace.	Meldau, R.: Arch. Eisenhüttenwes. 35 (1964), pp. 203/08. French translation available (ECSC document 8303/65 f.)
Research too recent to enable publication of results.	

Fig. 31 d) — Synoptic Table of ECSC Studies on Air Pollutio

Control of other air pollutan

Designation (dealt with in section)	Study carried out by	Subject of study
PS 101 (4.1)	Niederrheinische Hütte AG, Duisburg-Hochfeld	Dust suppression with a view to protecting furnace reliners against silica bearing dusts.
PS 119 (4.2)	Dipl.-Ing. W. Gesell, Staatl. Ingenieurschule Bochum, Kohlenstrasse 70	Replacement of quartz sand by non-silicogenous minerals in compressed air blasting.
PS 1 (4.3)	Cockerill-Ougrée S.A., Seraing	Dust control in sintering plants and during belt-conveyor charging of blast furnaces.
PS 121 (4.4)	Kloeckner-Werke AG, Hüttenwerk Haspe, Hagen-Haspe	Control of dust produced in discharging fine ores and during the preparation of the blast furnace burden.
PS 120 (4.5)	Hessische Berg- und Hüttenwerke A.G. Wetzlar	Control of dust produced in the dry granulation of blast-furnace slag.

Results	Publications and ECSC documents
Possible reduction of dust hazards in demolition work on open hearth furnaces by special process and ventilation with forced draught. Silicosis hazard substantially overcome by mechanical cleaning of chambers and basic relining of furnaces.	ECSC document 3493/63 d and f.
Copper and blast-furnace slags were found of which the abrasive effect and cost are as favourable as quartz sand but without silicosis hazard.	Gesell, W.: Stahl u. Eisen 86 (1966) pp. 906/12. French translation available (ECSC document No. 6471/66 f.)
45%-60% reduction of the concentration of fine dusts in belt conveyor installations by water jet; 80% reduction of very hot dusts by exhaustion and precipitation in the scrubber.	ECSC document No. 5618/63 d and f.
40%-90% reduction of dust concentration by spraying recycled water with wetter additive in the discharging of fine ores from car tippers or special skips. Dust concentration reduced 80% by exhausting dust at the work location of the driver of the burden-charging carriage.	Räbel, G. Neuhaus, H. und Vetterbrodt, KH.: Staub 25 (1965), pp. 218/21. French translation available (ECSC document No. 4682/65 f.).
Dust concentration of waste gases reduced from 4.5-0.5 g/m^3 and less by the use of suction hood with spray.	ECSC document 2903/63 d and f.

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