EUROPEAN COAL AND STEEL COMMUNITY — THE HIGH AUTHORITY

Technical measures of dust prevention and suppression in mines

Report on the results of research in industrial medicine, hygiene and safety (as of January 1, 1967)

LUXEMBOURG, 1967

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NOTE TO THE READER

The development of research programmes involves an increase in the volume of information, and it is important that interested persons should be kept abreast of this information as the different programmes advance. In order to achieve this, it has been decided that each field of research shall in future be covered separately by an annual report.

This document is devoted to the present state of work undertaken within the framework of the second programme "Technical measures of dust prevention and suppression in mines", which is listed at C. a) in the table on page 56.

An examination of this table will enable the reader to see the programme here described in its relationship to the various promotion activities carried out by the High Authority in the fields of industrial medicine, hygiene and safety.

Moreover, the principles which have guided the action of the High Authority of the European Coal and Steel Community and the methods used are described in detail in the publication "The policy of the High Authority in promoting investigations and research concerning industrial medicine, hygiene and safety". (1)

For the benefit of the reader who does not have this publication before him, the principles and methods concerned can be summarized as follows:

(a) Promotion of the health and safety of the workers, by the collection and distribution of knowledge which can be applied:

(i) to the prevention of industrial diseases and accidents;

(ii) to the treatment of their symptoms and consequences;

(iii) to the rehabilitation of workers who have been affected by these industrial diseases or accidents.

Discussions and exchanges of view, research projects and original investigations are arranged and encouraged with this end in view.

(b) The use of the Community levies to finance research projects and other undertakings in the framework of the financing arrangements for programmes over several years, each programme having its specific field of investigation.

(1) Publications Departments of the European Communities, Luxembourg, 1966.

(c) Close co-operation between the High Authority on the one hand, and the appropriate professional organizations and government services on the other, both in the preparation of the programmes and during their execution, as well as in the distribution of the results.

M. CONVENEVOLE
Director

TABLE OF CONTENTS

Preface

The work reported on here comprises the projects developed in carrying out the second programme "Technical measures of dust prevention and suppression in mines", adopted on the December 21, 1964 by the High Authority which has at its disposal, for the discharge of its tasks, a total budget of 6,000,000 E. M. A. units of account.

On March 31, 1965, a first group of 67 research projects—undertaken by 12 institutes especially concerned with mining research—was approved by the High Authority and the research work was commenced immediately.

Let us recall that these research projects had previously been examined by scientific, professional and government committees, and that these committees had strongly recommended the projects in question. Of course, certain projects contained in this second programme were in fact the continuation of work already carried out during the preceding periods.

In 1965 a supplementary project of research into the use of salt pastes had been added to the first series of research projects. The purpose of this item was to complete the development of the technique of application of this process, and to investigate its effectiveness from two points of view: the binding of silico-genetic dusts deposited on the walls of mine roadways, and the prevention of coaldust explosions.

During the financial year 1966, a new item of research was recommended by the High Authority; this was a programme of epidemological investigations put forward by the Institute of Industrial Medicine at the University of Cagliari (Sardinia).

An appendix to this report contains the complete list of the research projects grouped under the names of the institutes which carried out the work.

To facilitate reference to this report, the research projects have been grouped under the four headings which have now become so well known in dealing with measures against dust in mines:

(a) Technical measures against dust during winning operations,

(b) Technical measures against dust in other operations,

(c) Measurement of the dust and determination of its characteristics,

(d) Pneumoconioses and environmental factors.

The research programme is still in its period of full development; consequently, we can do no more at this moment than to present provisional or partial results, in general. Nevertheless, in certain instances, it is possible to quote certain results which can already be used in practical winning operations or in the laboratory.

Technical measures of dust prevention and suppression during winning operations

Seam infusion

Research in this field has in all cases been carried out with the intention of adapting this technique to the conditions resulting from the modernization of working methods.

The increase in the daily rate of advance of workings and the mechanization of winning and transport operations call for infusion methods which are more independent than hitherto of the production cycles. In addition, the fact that infusion is now carried out at greater depths has brought up new requirements with regard to the equipment used, from two points of view: first, the drilling operation and second, suitability of the infusion equipment for the new conditions encountered. In particular, in addition to the traditional properties of robust construction and easy handling required underground, the equipment must be able to withstand the very high pressures now very commonly used (Figs. 1, 2, 3).

In addition, since the winning operations in mining are still an art when it comes to the application of techniques, it has been necessary to some extent to carry out a large number of developments of the processes as a function of a fairly large geographical and geological distribution. In doing this, allowance was made for the various conditions of deposition and the various methods of exploitation, which sometimes differ very widely even within a given coalfield.

Research into seam infusion has been carried out actively in all the Community coalfields. The reader will find below a description of the efforts made in this field.

Infusion by holes at right angles to the face

(a) These techniques have been applied in a series of operations in the Douai group of the Nord and Pas-de-Calais Coalfield.

Technically the methods are fully developed, at least for operations up to a certain depth. It is now necessary to encourage their use on a much wider scale, as allowed by local conditions and by the working plans, although certain details of the application will need to be improved in the process.

These operations have made it possible to establish the principles which we summarize as follows :

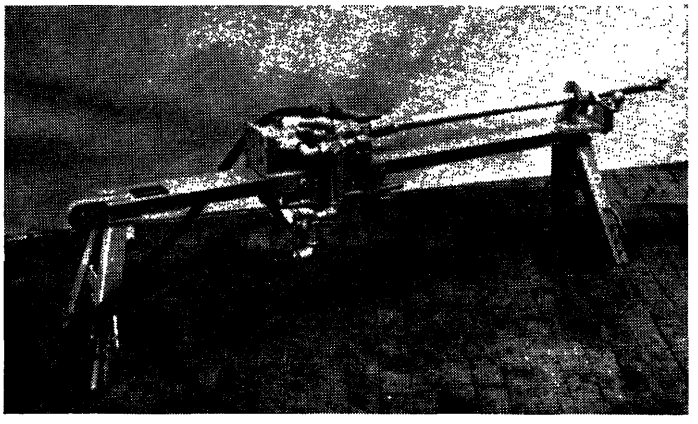


Fig. 1

General view of a carriage-mounted drilling machine (Hauhinco)

(i) the depth of infusion must be markedly greater than the daily linear advance of the face;

(ii) in seams which are only slightly porous and in unfissured rock, it has been proved that deep infusion did not allow the infusion of a sufficient quantity of water; on the other hand, infusion at very shallow depth, in a zone where the coal is crushed, also gives bad results. The optimum depth giving the maximum quantity of infused water clearly lies between these two extremes;

(iii) no clear evidence has yet been given to show that a wetting agent has any substantial effect on the penetration of water into the solid coal or rock.

(b) In one pit in the Campine, infusion is carried out using long holes drilled at right angles to the coalface, two holes being drilled each week. The depth of the holes was between 22 and 26 m during the trial period, the head of the

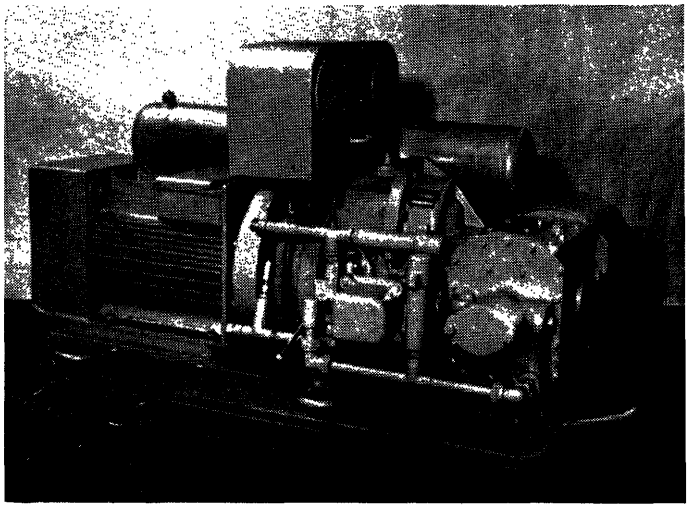


Fig. 2

Infusion pump (EHP 300) with electric motor (Hauhinco)

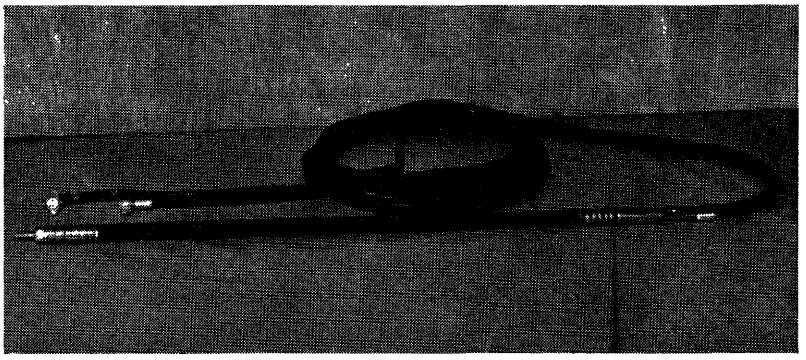


Fig. 3

Twin-circuit infusion probe (Neuffer)

infusion probe being between 18 and 23 m from the orifice. On an average, the quantity of water injected per hole was 12 cu.m at a pressure of 195 to 250 bars, with a low flow rate of the order of 10 to 15 litres per minute.

In the working where these experiments were going on, the rate of advance is 7 m a week over a face length of 250 m. It is thus possible to drill an average of 7 holes at regular intervals along the face before the working has advanced beyond the depth reached by the initial holes. This process therefore fully meets the requirement of making the operation of infusion independent of the production operations. The increase in the moisture content of the coal is from 0.7 to 0.8%.

The average nuisance index recorded in the air at the head of the face was 4.5 (i.e. below the threshold limit) for a daily output of 700 tons spread over two shifts.

(c) In Germany, in the Ruhr, it has also been proposed to infuse a sufficient area for several days work. The results obtained have not been satisfactory in all instances. Hitherto, the best results were achieved in those faces with a daily rate of advance not exceeding 3 m where the depth of infusion was kept within the zone of pressure ahead of the face. Following this research it seemed necessary to obtain a better knowledge of the mechanics of the penetration of water into the solid, and to perfect the method of determining the moisture of the coal for this purpose. It is expected that this will make it possible to determine more accurately the primary moisture in the coal, and subsequently the additional moisture resulting from infusion. The trials have shown that in general, in the Ruhr seams, a quantity of water of the order of 10 litres per cu.m "in situ" is adequate. The experiments also drew attention to the very deleterious effects on the surrounding rock of excessively high infusion pressures.

For an equal volume of water, the effects are less serious when the infusion is carried out more slowly and at a lower pressure. This suggests infusion methods where the quantity of water to be handled per unit of time is considerably smaller, with the idea of freeing this operation from the limitations imposed on it by normal operating requirements.

Infusion by long holes parallel to the face

(a) The infusion method using long holes drilled parallel to the coalface was tried out experimentally in the Lens group of the Nord and Pas-de-Calais Coalfield. In the first place the trials were directed towards developing the equipment; they made it possible to develop the technique of drilling holes from 30 to 60 m deep and to perfect a system of sealing by means of concrete joints 15 to 20 m long.

The infusion pressures applied varied from one case to another between 130 and 280 bars.

The efficiency of dust suppression achieved, on a weight basis, lay between 50 and 85% according to circumstances. The effectiveness in terms of numbers of particles (counting the particles below 5 microns) varied from 50 to 73%.

In the seams which absorbed the water relatively easily into the solid coal, excellent results were obtained with a method using infusion holes parallel to the coalface, particularly if the infusion was continued until just before the arrival of the face. Nevertheless, one infusion experiment at very high pressure caused the ground to move and had appreciable effects on the roadways, accompanied by falls of stone.

It therefore seems preferable, and even necessary, to infuse at moderate pressures, making up for the low flow rate by infusing for a longer period, over three shifts, and, if necessary, connecting several adjacent holes at the same time. If a panel is treated sufficiently early (e.g. from the moment it is opened up) the infusion can be carried out at low pressure, and the flow rate can be kept low; this will give:

(i) more thorough "ramification" and better distribution of the water;

(ii) a reduced risk of damaging the surrounding rock;

(iii) an acceptable degree of residual moisture when the coal is cut.

In addition, infusion by means of long holes parallel to the coalface offers the following very important advantages:

(i) the coalface is completely free;

(ii) one drilling team can deal with several workings simultaneously, since the operation is carried on throughout three shifts under intermittent supervision.

In those instances where this primary infusion is not sufficient, it is always possible to supplement it by a second infusion operation from the front of the face, to add the required quantity of water.

Compared with infusion from the roadways, infusion via the coalface involves from 3 to 17 times more drilling.

However, infusion parallel to the face requires that the gateroads should be driven sufficiently far ahead of the face.

(b) In Germany, trials have been made of infusion using holes 40 to 80 m long. By reason of the geological conditions and the nature of the coal, drilling lengths of this order are not current practice, however.

Most of the trials were carried out using 20-metre holes. In general, results were satisfactory; they depend very largely on the porosity of the coal, which is in turn governed by the tectonic structure of the seam.

Difficulties arose in gassy deposits, as a result of return flow of the water after infusion. Special protective measures must be taken in such cases.

Trials of deep infusion have been carried out at Friedrich Heinrich Colliery at the suggestion of the "Silikose-Forschungsinstitut."

Starting from the bottom road, 50-metre holes were drilled parallel to the coalface and infusion probes 20 m long inserted into them. These probes acted as sealing plugs over their whole length. The infusion cavity is thus kept to a depth of approximately 30 m. This very long cavity length was selected to ensure that the rates of flow—and consequently the infusion pressure—did not rise excessively; the pump delivery was maintained at 50 litres/min. During the first test, approximately 33 cu.m of water were infused at a pressure of between 160 and 280 bars.

Following this, holes were drilled from the face and from the bottom road, so as to obtain an idea of the distribution of water in the seam. At varying depths, increases in the moisture content were recorded in these boreholes. However, at the coalface, even when cutting through zones which were known from the exploratory drillings to be moist, it was not possible to demonstrate any significant increase in the moisture content. Moreover, no damage to the surrounding rock by the water was observed.

During another series of tests, the flow of infusion water was reduced to 3 litres per minute. The infusion hole parallel to the coalface was initially 100 m away from the face. A total of 73.4 cu.m were infused via this hole over a period of 408 hours. Following this operation, the coalface was kept under continual observation and drilled samples were taken to assess the moisture content of the solids. These measurements did not give enough information regarding the distribution of the water. The procedure is undoubtedly too inaccurate to assess slight variations in moisture content. It is intended to add indicators to the infusion water so as to obtain a clear idea of its distribution.

It should be recalled that research is being prepared at this moment in the Netherlands to follow the flow of water in the solid coal and in the surrounding rock by using radio-active tracers.

Advance remote infusion

The technique of advance remote infusion, which has now been in use for several years, was developed in several workings in the Campine, where the number of successful applications has considerably risen in conse-

quence of a better understanding of the process and of the secondary phenomena—which sometimes cause disturbances—accompanying these operations. This work has been described in a number of publications; the latest to be published: "Deep injection in the micro-fissured zone. Advance remote infusion or injection in a panel before cutting the coal" by G. Degueldre and H. Lavallée, was published in the "Revue de l'Institut d'Hygiène des Mines"—1965—vol. 20, no. 4.

Recently, further developments of the method have given rise to new variants of the arrangement of the different boreholes so as to cover the panel to be infused as thoroughly as possible.

To give a general idea, it can be stated that the quantity of water infused during the treatment of one panel was 917 cu.m.

Infusion assisted by camouflet shotfiring

This method involves preliminary infusion of water into the solid, followed by the placing of the explosive at the bottom of the hole; the infusion probe is then reinserted and serves as stemming. A water pressure is created and then the shot is fired.

This technique was investigated in association with infusion at medium depth and infusion from the gateroads in faces in steep seams, in level seams and also in rise headings.

The tests were carried out in the Valenciennes group, using two variants of the technique:

(i) infusion at medium depth (3 to 7 metres);

(ii) infusion at great depth (10 to 40 metres).

Trials of *infusion at medium depth* made it possible to establish that the difference between the degree of wetness after infusion and the natural moistness of the solid coal rose with the depth of the hole and the degree of penetration of the joint. The measurements showed a reduction in the degree of dustiness with the depth of infusion.

Nevertheless, the process still achieves only a variable degree of success and seems to depend to a large degree on the seam itself and on the method of stowing.

The investigations of *infusion at great depth* were carried out:

(i) in slant-method workings;

(ii) in steep seams won with pneumatic picks or rams;

(iii) in level seams won by pneumatic picks or ploughs;

(iv) in a rise heading.

In general, the effect of the camouflet shotfiring on the quantities and pressures of water employed were approximately as follows:

(i) the quantity of water increased by roughly 70 to 100%;

(ii) the pressures required were reduced by 30 to 60%.

The changes in pressure and in quantity seem to be connected with the method of working. Camouflet shotfiring doubles the quantity of water infused while generally reducing the water pressure.

Infusion carried out in rise headings and pillars had an appreciable effect on the hardness of the seam and on the degree of dustiness.

In the rise headings, the coniotic indexes varied from between 3.5 and 4 before infusion to 1.2 to 1.4 after infusion. In the pillars, the degree of dustiness gave indexes of 2.4 to 2.8 before infusion and between 1 and 1.2 after infusion.

Pulsed water infusion

This method involves sending out a flow of water at very high pressure during the normal infusion process. This flow of water, under a pressure of e. g. 300 to 400 bars, is transmitted by a high-pressure source which may be a hydro-pneumatic reservoir and is violently expelled into the infusion circuit.

The aim is to use the suddenness and force of this operation to produce the simultaneous opening-up of a large number of fissures, so improving infusion; an additional advantage is the mechanical dissociation of the solid coal which it causes.

The trials were carried out with the aid of a 300-bar overpressure device. This process can compete with winning by pneumatic pick or by shotfiring. It has been noted hitherto that the results are better in relatively hard seams than in soft seams, and that the dustiness of the working is very considerably reduced.

Measures to suppress dust produced by winning and loading

Introduction

One of the most serious dust problems at present is undoubtedly the production of dust caused by the winning machines.

The use of these machines has increased considerably in recent years, largely because they work so well in hard seams and because the arrangement of the cutter jibs allows of winning all the coal in the seam and of loading it away. But the dust suppression methods called for by the use of such machines is considerable and requires the application of techniques which are difficult to adapt for underground use in the mines.

Firstly, efforts have been devoted to research into designs of drum and pick arrangements which give minimum stirring-up of dust. These investigations seem to promise good results; moreover, they have been combined with studies of water sprayed from jets placed above the cutting drums.

Secondly, studies have begun on the positive removal of the dust, either by wet methods or by dry methods, the latter category being envisaged where e. g. the amount of dust produced is too high or where the use of water would cause difficulties in respect of the behaviour of the ground or of the climate of the workings.

One of the aims of these investigations is to provide the manufacturers with the information necessary for them to fit their machines with appropriate equipment before they are used underground.

Several research workers have also turned their attention to the problem—not yet completely solved—of dust suppression in plough faces.

Dust suppression on winning machines

(a) The research carried out by Cerchar in this field dealt with both machines for level seams and for inclined seams.

Studies were made of the pick lacing producing the smallest quantity of dust. The aim was to cut into the solid coal a series of channels separated by fairly large ridges, the latter being broken out by a series of truncated-cone breakers.

Experiments were made with the level-seam machines using 850×600 (mm) drums carrying 21 picks and 850×850 mm drums carrying 29 picks. All these picks have two lateral water orifices.

The trials were carried out successively in three workings:

(i) a face winning coal only;

(ii) a face cutting an included dirt band;

(iii) a face where floor and roof rock were being cut.

In all three cases this type of drum was found to be very effective in suppressing the dust, its effect being greater the greater proportion of rock cut.

For the inclined-seam machines, trials are under way with a new auger head having different pick lacings and different arrangements of the sprays between the picks.

(b) Experiments have been continued, both in the laboratory and underground, with the injection of water via the picks on coal-cutters. For this purpose Cerchar has made and tested a special type of drum on which the water is expelled from the pick near its point.

In general, it has been found that the quantities of water required to provide an adequate effect are fairly high—approximately 80 litres of water being needed per cu.m of solid coal to obtain 60% effectiveness. These quantities are considerably above the deliveries obtained underground hitherto.

It therefore seems advisable in future to provide water-supply installations with a considerable margin to allow of drawing such large quantities of water.

(c) A beginning has been made with applying the information obtained in the laboratory regarding the laws of dust suppression by water sprays(1) to dedusting a Marietta continuous miner. A special system is operating in the Bruay group, and its numerical efficiency is 65% for the minus 5 micron particles.

Trials of aspiration and capture of the dusts have been carried out in cutter-loader faces.

It should be recalled that the principle of precipitating dust by wet means which had previously been developed was applied to suppressing the dust produced at transfer points (50 devices of this type are at present in service in the various groups of the Nord and Pas-de-Calais coalfields), and at the discharge points from faces.

Up to the present, this latter type of dedusting equipment was best suited for pneumatic-pick faces. The existing design is unable to stand up for a sufficiently long period of time to the passage of large blocks of coal on the conveyor, such as are produced by the other coal-winning methods.

(d) Attempts to trap the dust produced during coal-cutting have been started at the "Kleiner Johannes" pit at Pegnitz. In this instance it was not possible to spray large quantities of water, as the product brought down tended to coagulate, which made its transport difficult. The investigation of the mechanics of the entry into suspension of the dust during the cutting operation made it clear that it was necessary to insulate a zone around the drums in order to have effective capture of the dust produced.

This led to the development of apparatus which, combined with aspiration at the rate of 100 cu.m/min., prevents propagation of the dust outside the "insulating" zone around the drum.

Although during these trials the dust aspirated was not retained by the filters, a considerable reduction in the amount of dust in suspension was nevertheless observed. This phenomenon was attributed to the fact that the concentrations of dust are so dense inside the "insulated" zone that a partial coagulation of the fine particles occurs, under the action of electrostatic forces of attraction.

The research work is now directed to designing compact dust filters which can be attached to the coal-cutters.

(1) Compare the results of the First Programme of Research. See the publication "Technical measures of dust prevention and suppression in coal-mines," Luxembourg 1966 (3890/5/66/1).

It is not possible to envisage the use of cloth filters for this purpose, because they are too large. It was therefore suggested that cyclones or centrifugal dedusters should be employed; the first trials have given satisfactory results. It is now necessary to reduce the dimensions of these devices, while increasing their filtering capacity at the same time.

(e) To reduce the dustiness caused by winning machines, the Steinkohlenbergbauverein has explored the following three possibilities:

1. Improvement of the cutting operation to reduce dust production.
2. Precipitation of the dust produced by means of sprays.
3. Positive capture of the dust on the machine itself.

With regard to the first point, it was found that the following factors have a considerable effect on the dust production:

(a) speed of rotation of the drum;

(b) depth of cut of the drum;

(c) speed of movement of the machine;

(d) nature of the coal cut;

(e) quantity of ventilation air (Figs. 4 and 5).

It has been noted that there is a critical speed of rotation of the drum; below this speed, dustiness increases because the coal brought down is thrown out and crushed by recycling, while above this speed dustiness tends to decrease because removal of the coal towards the conveyor is improved. Similar considerations apply to the width of the drums. Up to a certain limit value, it is beneficial to increase the speed of movement of the cutter-loader.

Finally, measurements have been made of increases in the entry into suspension of fine dust of up to 75% where the ventilation quantity was increased from 600 to 1,000 cu.m/min. All these provisional figures will need confirmation by subsequent experiments.

Investigation of water spraying was carried out using two types of wet drum with internal water supply, one built by Eickhoff, and the other with water issuing from the picks themselves, the system investigated by Cerchar (see para. b above) (Figs. 6 and 7).

These two processes—in respect of which no appreciable difference in efficiency was observed—have been found to be effective in precipitating course dust (a reduction of 90 to 95%). As against this, the precipitation of fine dust, measured by the Tyndalloscope and by the BAT apparatus, was very low.

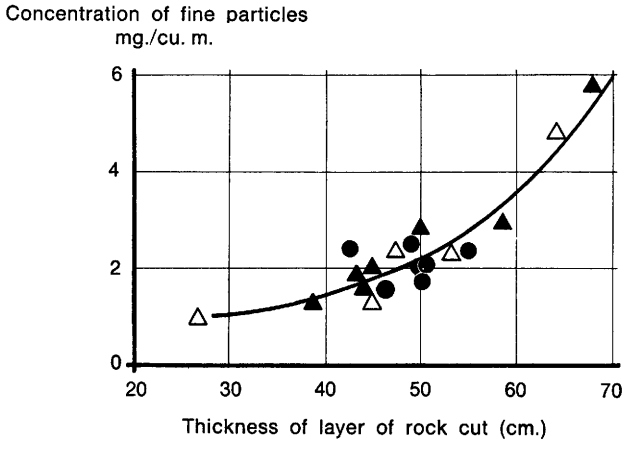


Fig. 4

Influence of the thickness of the layer of material cut on the concentration of fine particles of dust

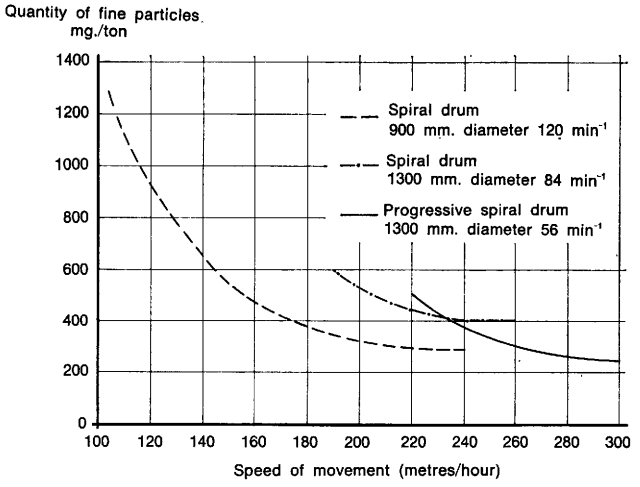


Fig. 5

Development of fine dust in shearer faces as a function of speed of movement and shape of drum

Neither increasing the quantity of water nor adding a wetting agent to the spraying water were very effective.

The action of the drums as they cut into the surrounding rock cause the entry into suspension of quantities of fine dust.

From the foregoing remarks it is clear that other methods of dedusting must be sought than spraying water directly on to the drums. Attention has therefore been given to developing, for attachment to the machines, dust-trapping devices which are fairly compact and can aspirate a quantity of air of between 100 and 150 cubic metres/minute. Several such devices are being investigated.

Research in this field has hitherto shown that the maximum increase in effectiveness was primarily obtained by improvements in the technique of cutting by drums and picks, rather than by the conventional method of spraying.

However, this research project was not without its utility in respect of the coal-cutting operation itself.

Dust suppression in plough workings

Several methods of water spraying in plough faces have been developed with the encouragement of the Silikose-Forschungsinstitut of Bochum. One system employed the increase in pressure occurring in the pushing rams when the plough passed that point, but this device cannot be adjusted to the different types of plough or of pushing rams. In particular, for the drag-hook plough, the supplementary pressure produced along the axis of the rams when the plough passes is only very low, and quite inadequate to trip the sprays.

A special spraying device—tripped by purely mechanical means—was therefore developed for the drag-hook plough. A spring-loaded roller is pressed against the chain and is pushed back, when the plough passes, into a slot in the plough attachment gear. This movement operates a delayed-action valve. After the plough has passed, the roller is returned to its original position and, after the delay has elapsed, the valve stops the supply of water to the sprays.

In the Netherlands, a device achieving the same end has just been developed, and several examples have been made. It can at present be used only with plough installations using compressed-air pushing rams. It operates in every case where the coal is hard enough to cause a recoil movement of the cylinder stem.

In France, a face has been fitted with continuously-operating sprays every 6 or 9 metres on the spill-plates of the afc.

The numerical effectiveness, in comparison with the effect of water infusion to a depth of 7 metres at right angles to the face, is 35% in respect of particles below 5 microns. This means that there is an additional increase of 35% in comparison with this type of infusion.

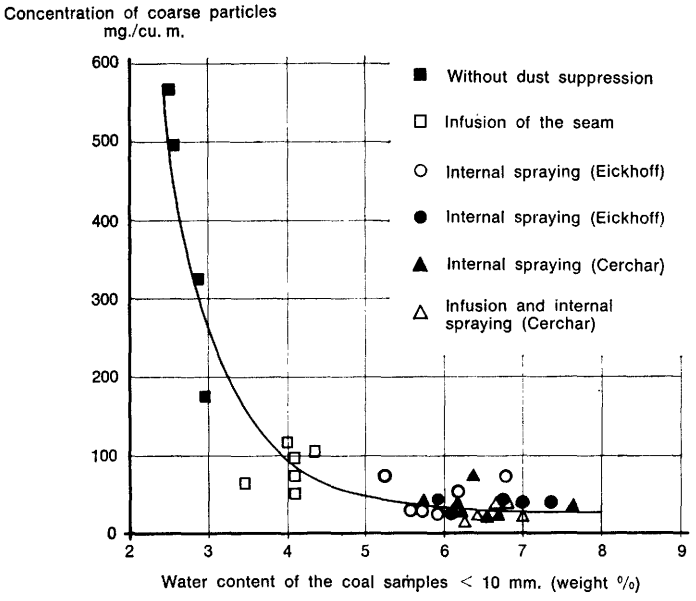


Fig. 6

Reduction of the concentration of coarse dust by infusion and spraying in a shearer face

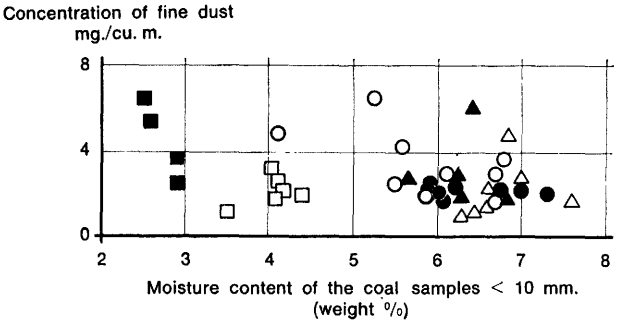


Fig. 7

Reduction of the concentration of fine dust by infusion and spraying in a shearer face

Measures to suppress dust produced by shotfiring to bring down the coal

Research into shotfiring in water has already been dealt with in the chapter on camouflet shotfiring, which is employed to make it easier for the infusion water to penetrate into the solid coal.

Other tests have been begun in Belgium, in deposits liable to instantaneous outbursts of gas, where advantage could be taken of the fact that inducer shotfiring is employed to apply shotfiring under water to moisten the solid coal. These trials have not yet progressed sufficiently far for final conclusions to be drawn. The fact that it is necessary to observe the special regulations laid down for safety reasons when explosives are used in such seams has precluded, up to the present, treating more than 60 metres of face in one shift.

Effectiveness trials have been carried out in Germany using a new technique in which the explosive is sheathed in water-containing ampoules. This makes sure that there is no loss of water into the solid before the explosive is detonated. The technique based on the use of an electric contact which prevents firing the explosive unless water is present has not been pursued further; the permission of the Inspectorate is awaited.

Studies have also been begun on the distribution of water in the solid following on shotfiring.

Technical measures of dust prevention and suppression during operations other than winning

Pneumatic stowing

(a) In the field of pneumatic stowing, a research project on "the addition to the stowing material of products which reduce the amount of dust released" has given interesting results, which were reported on in detail in the publication by M. Landwehr and H. D. Bauer: "Improving dust suppression measures during pneumatic stowing by the addition of paste to the stowing material" (Bergfreiheit, July 1966, pp. 181-192, 20 Figs.).

The product selected was a "Tratex" paste (manufactured by Lichtenberg & Co., Dortmund).

The practical results of this research project can be summarized as follows:

1. To obtain optimum results it is essential to take the normal precautions against the production of dust ([1]):

(a) to restrict the upper size of the particles in the stowing material to 80 mm and to reduce the proportion of fines as much as possible;

(b) to adjust the moisture content of the stowing material to the optimum value;

(c) to make a careful choice of the diameter and length of the stowing line;

(d) to use the lowest possible specific consumption of stowing air;

(e) to avoid interruptions in the stowing;

(f) to spray the slope of the stowing material, as well as the roof and floor in the stowing area;

(g) to avoid eddies caused by the blast of compressed air, by cutting off the face from the stowing zone by means of special brattice cloth.

(1) See "Merkblatt" (Bulletin) *Measures to suppress dust during pneumatic stowing*, published by the Hauptstelle für Staub- und Silikosebekämpfung of the Steinkohlenbergbauverein, Essen, 1965.

2. Approximately 9% by weight of Tratex powder is required in the water, and at least 20 kgs of paste per cubic metre of stowing material. The paste has to be well mixed into the stowing material and must not be diluted by an excessive amount of water (Fig. 8).

Efficiency trials have shown that there was an average reduction in dustiness of the order of 30%; the improvement is greatest when the stowing material

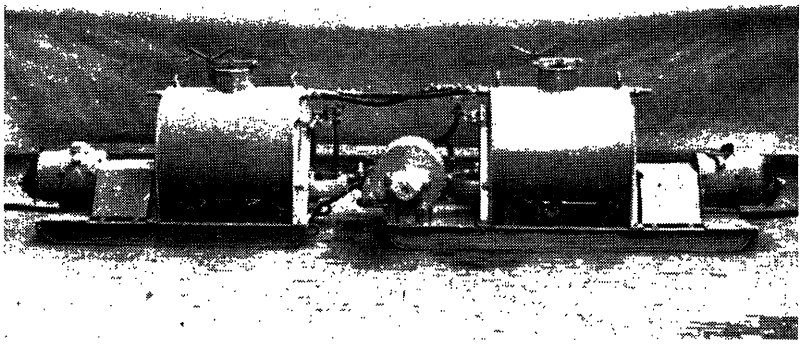


Fig. 8

Mixing vessels for preparing Tratex paste

consists of washery waste, and is less marked when crushed stone is used. In a good case, the use of the paste reduced the dustiness category by two steps on the scale.

This process therefore serves to clean up rapidly-advancing workings where production is carried on over several shifts per day.

(b) In Italy, research has been carried out to obtain minimum dustiness conditions resulting from the breakage during transport of materials used for pneumatic stowing in the Tuscan pyrite mines. The results obtained from a test installation are to be submitted to further trial in practice.

These studies have shown, by other means, how inconvenient it is to have the stowing material too wet—a fact which had already been revealed by research carried out by the Steinkohlenbergbauverein.

Measures to suppress dust produced during transport other than in faces

(a) Work carried on with a view to developing vacuum cleaners of a type suitable for use in mine roadways and capable of removing from them the dust deposited there has continued in Germany.

Firstly, the work of perfecting the vacuum cleaner intended, for some time now, to be used in roadways fitted with rail tracks, has been continued.

Secondly, a prototype cleaner is being investigated for use in belt roads, and the specification has been laid down as follows:

It must be capable of handling 1 to 1.5 cu.metres of dust per hour (dust dimensions 0 to 40 mm). The underpressure to be applied is of the order of 1,000 mm of water. Its overall dimensions should not exceed 1,600 mm in height during transport with a diameter of 700 mm. The removal of the dust aspirated must be by means of a 100 mm pipe of a length up to 500 metres.

Preparations towards an investigation of this kind have been begun in Belgium, but the principle used to trap the dust is different. Experience in this field based on research over several years has shown that the problem is difficult and progress is slow.

(b) Transport of products on belt conveyors presents serious problems with regard to the entry into suspension of dust. Heavy spraying does not generally deal with the problem, creates problems of its own in dirtying the roadways and moreover, in deep mines, has a deleterious effect on the mine climate.

The Institut d'hygiène des Mines at Hasselt had, during the previous research programme, studied evaporation-retarding agents. The use of such products mixed with the water used to spray the conveyors is set to reduce the quantity necessary for spraying since it evaporates more slowly.

The first measurements were made in a roadway leading to a working at a depth of 1,350 metres, on a plate conveyor more than 600 metres long.

It was found that the dust concentration varied very strongly with the level of filling in the bunker at the loading-point, and that a 2% increase in the moisture of the 0 to 10 raw coal reduced the emission of fine dust by a factor of about three times. The quantity of water which evaporates over the length of such a conveyor exceeds 300 kg. per hour, while the total heat emission is of the order of 200,000 kcal/hour, figures which are far from unimportant.

Measures to suppress dust in headings

Research into new methods of stemming for shots

The work concerned with this research project was reported on in detail by M. Landwehr and H. D. Bauer in "Bergbau" No. 7, 1966, under the title "Erprobung neuartiger Besatzmittel beim Schießen" (Trying out new stemming materials for shots).

The intention of these trials was to try to check on the substances used for stemming shots which were capable of giving equivalent dust-suppression results to those obtained by water-spraying systems which have been correctly installed and adjusted.

During this research, experiments were made with various types of hydraulic stemming, of different capacity and of different shapes, as well as high-humidity gelatinous pastes, either in cartridges or without. The results showed that paste stemmings of a least 258 cc or water stemmings of at least 250 cc, give the same dust-suppression effect as the water spray system.

Stemming using sand or limestone were not considered, because they are difficult to handle, although their effect on dust is generally satisfactory.

The wet stemming which behaved best was of the type using polyethylene ampoules. This material is sufficiently strong—which is not true of P. V. C. ampoules which are liable to swell and consequently to become torn during handling.

Rendering dust and shotfiring fumes harmless

This research programme carried out in France produced as its main result a development of a mist gun for bringing down the dust at the moment the shot is fired.

Various prototypes of water-air sprays of high capacity have been made, taking into account the information obtained from a fundamental research study carried out by Cerchar on the precipitation of dust by sprays.

The research programme has two purposes:

(i) to improve the efficiency of precipitation of the dust produced by shotfiring in cross-cuts, by means of a fairly large flow of water and compressed air, the flow being of acceptable dimensions because the apparatus is used only for short periods of time;

(ii) to direct the sprays of water on to the heap of debris, so that it is wetted at the same time, and thus to save a great deal of the time necessary for hand wetting of the debris before it is loaded.

An efficiency index of about 55% was measured during the trials.

Since the water flow reaches 60 litres per minute, the time for which the device functions must be restricted to a few minutes to ensure that the heap of debris is adequately but not excessively wetted.

The consumption of compressed air, which is of the order of 9 cu.metres per minute, is large but it is acceptable for an apparatus which is operative only for a few minutes per round of shot.

An item of research in hand at the Institut National des Mines at Pâturages is intended to determine the method of formation of the nitrogen oxides and hydrochloric acid found in shotfiring fumes. At a later stage in the research it is intended to examine the conditions giving the lowest figures for contents of NO_3 and Cl ions in the shotfiring fumes.

Measures of dustiness carried out at the moment of shotfiring in a seam road in Germany have showed that the quantity of dust produced depended very much on the shotfiring method used; thus, a two-stage round produced approximately twice as much dust as a single-stage round.

Work will be resumed once an experimental roadway is available again, the old roadway having had to be abandoned because of geological faults.

Trials of dust precipitation were carried out using sprays and filters set along the roadway where the shots were fired. It was shown that the degree of efficiency of the sprays was dependent on the speed of the air current (to which it is inversely proportional), on the water pressure and the amount of water flowing. Changing from a pressure of 10 bars to one of 19.5 bars occasions an increase in efficiency varying from 10 to 15%.

The combined use of filters and sprays in the experimental roadway showed the poor efficiency of the process in respect of fine dusts produced by shotfiring (100% less than 5 microns).

Dust suppression on roadway-heading machines

The Institut National de l'Industrie Charbonnière, of Liège, has begun work on the development of a device to suppress dust on a heading machine used in stonedrifts (Joy ripper). After carrying out an analytical study of the causes of dust production during the use of this machine, they proceeded to experiment with a certain number of improvements, most of which consisted in changing the arrangement of the original components.

This shows once again the advantages obtained from collaboration between the manufacturers and the users.

These tests, which are only in the initial stages, have nevertheless shown hitherto that dust suppression rates of up to 80% can be expected for the use of a total spray-water flow of 65 to 70 litres per minute. It will be noted that this quantity of water is very high and cannot be obtained in a very large number of workings, nor even maintained for the duration of operations. It will probably be advisable to provide, in certain instances, a dust-aspiration system mounted on the ripper jib.

The same general trend is indicated by the German research work on dedusting machines which produce large quantities of dust. Beginning from laboratory research, various types of deduster have been proposed and their construction encouraged. Figure 9 shows the present state of affairs with respect to dedusters designed for a throughput of 100 cu.metres per minute.

Bag-shaped cloth filters, occupying a volume of 6.8 cu.metres, have already been used successfully for dedusting the Wohlmeyer roadway-heading machine. The dust content of the aspirated air was of the order of 10 grams per cu.metre. In the wet filter, the dust is trapped by synthetic filtering substances sprayed

with water. Trials of this deduster are under way. Seeing that it causes only low pressure losses, it should be suitable to dedust a strong flow of air up to about 300 cu.metres per minute. In the Zyklonette system, the dust is sedimented by movement caused by the centrifugal force of the fluid in little cyclones 1 cm in diameter sprayed with water. The different cyclones are cast in the metal sheets. The Zyklonette device occupies 3.1 cu.metres. This deduster is intended to be fitted to roadway-heading machines which produce less dust than the

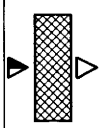
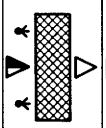
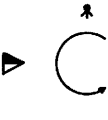
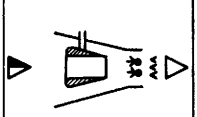
Method of separation	Dry	Wet	Wet/mechanical	Wet/mechanical
System				
Designation	Bag filter	Wet filter	Cyclonette	Aspirated-jet deduster
Length (metres)	4.7	3.5	3.2	2.7
Width (metres)	0.9	0.9	0.8	0.7
Height metres)	1.6	1.4	1.2	0.4
Total volume occupied (cu. m.)	6.8	4.4	3.1	0.8
Pressure loss (kg./sq. m)	80-100	40-80	350-500	Compressed air = 3.5 kg./cu. cm. 10 to 15 cubic metres aspirated air per minute at NTP
Power requirement (kW.)	7.5	5.5	12	

Fig. 9

Comparative values of various dedusters for an air throughout of 100 cu. m/minute

Wohlmeyer machine. The aspirated-jet deduster can be built to much smaller sizes than the types referred to above. It does not exceed 0.4 metre in height. It can therefore be mounted on coal-cutters used in seams above 1.8 metres in thickness. This device is operated by compressed air, and the dust aspirated is precipitated by being sprayed with water in the relaxation zone. The dust-charged drops of water are decanted in a mist separator.

Other dust-suppression measures

(a) The Steinkohlenbergbauverein has undertaken a series of measurements regarding the behaviour of dust in the ventilation airflow. The data thus obtained could be used, inter alia, as a basis for the use of coagulants to bind the dust (salt paste) or even for helping in the selection of sites for devices measuring dustiness in workings.

The measurements have been carried out hitherto:

(i) in headings, where the features of the clouds of dust produced by shot-firing were examined,

(ii) in return airways, in either inclined or level workings,

(iii) upstream of spraying installations, to determine the efficiency of the spray.

The statistical study is envisaged to assess the effect of the air current and of the air velocity on the deposition of dust in 300 to 400 faces or gateroads.

(b) At the Peißenberg colliery, research undertaken by the Silikose-Forschungsinstitut of Bochum is intended to achieve dedusting of transfer points between faces and small-section roadways.

One condition that is imposed is that the aspiration equipment should be easily moved and that it should be able to keep pace with the daily advance of the face. It has been noted that in descensionally-ventilated faces it was not necessary to enclose the transfer station completely, because of the existence of zones where strong eddies of dust were produced. It was therefore thought—and the first experiments confirmed this idea—that the dust-aspiration equipment should be placed in these eddy zones. The quantity of air to be aspirated at these points is approximately 150 cu.metres per minute. Cloth filters cannot be used to retain the aspirated dust because they are too big. It therefore became necessary to consider the use of compact wet dedusters, preceded by batteries of cyclones to take out the coarse dust.

The first model tests of the wet separator gave satisfactory dedusting performance so that a full-scale equipment has been ordered.

Special problems of iron mines

(a) A research project has developed at the Haverlahwiese mine, owned by the Salzgitter Erzbergbau AG, in connection with the suppression of dust during heading and winning in thick veins of iron ore.

The details of this research project were published by M. Landwehr and H. D. Bauer in "Bergbauwissenschaften" (Vol. 13, 1966, No. 7, pp. 281-286).

The deposits, which are very thick, are worked by the block caving method. In this method the section to be won is underworked by a network of roadways, and the ore broken up in this way is systematically withdrawn from below (Fig. 10).

Efforts to improve dedusting were applied to all the winning operations, beginning with drilling and shotfiring and extending to the transport and transfer of the ore.

In addition to active measures against dust at all production points, a reduction of the dustiness level was obtained by changing the method of ventilation by modifying various technical processes in connection with winning and transport. Before these research studies were carried out, 83% of the workings were classified as bad from the point of view of dustiness. After the work was finished, 98.4% of all workings were classified as satisfactory.

(b) A series of research projects is being carried out by the Clinica del Lavoro (of Milan) in the roadways in the pyrites mines of Gavorrano. Taking into account the special dustiness conditions which arise in roadways driven in granite, it was proposed inter alia to carry out certain modifications *on the drills and the drill steels* to obtain improved wetting of the drilling dust. Drilling a second wetting hole a few centimetres from the end of the drill steel contributed to reducing the dustiness by between 30 and 40%. The best results were obtained when this orifice is drilled 5 cm from the end of the steel, with a diameter 10% smaller than that of the normal orifice. The water pressure used during the tests was 2.5 bars and the air pressure 6 bars.

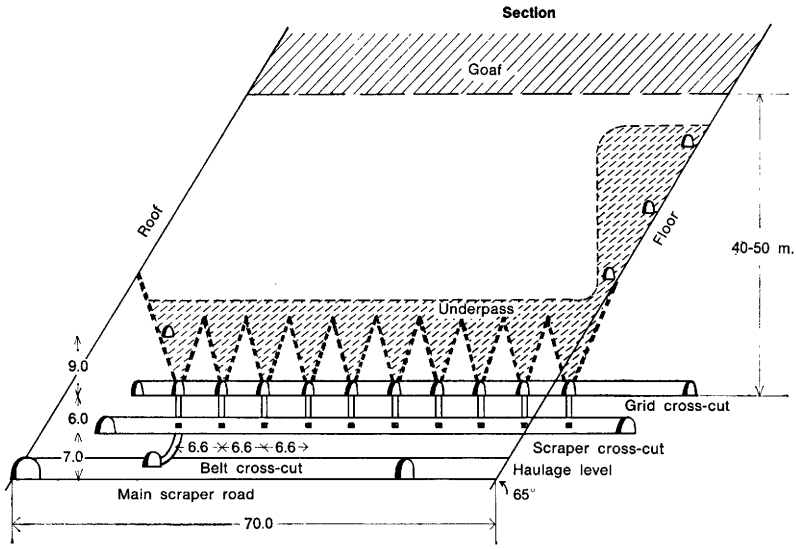


Fig. 10

Diagrammatic representation of block caving method with grid chambers

The Clinica del Lavoro has undertaken the examination of a long series of *wetting agents*, intended for industrial-scale use in the wetting of the loosened product and the products carried on the conveyors and also for the injection of water during percussive drilling. Two recent preliminary tests carried out in an experimental roadway in granite at Gavorrano made it possible to perfect the installation used to distribute the mixture of wetting agent and water to be injected during drilling. These first experiments have clearly shown the possi-

bility of reducing the total dustiness in drilling operations by some 25 to 30% (the efficiency being counted numerically on particles from 0.7 to 5 microns).

Studies have also been made in the same experimental roadways on the efficiency of *aspirating ventilation* applied at the moment of drilling or of firing shots. The work in this field has up to now been concerned with the distribution of the "threads" of fluid as a function of the speed of movement and shape of the aspiration zone. The investigation is being continued to determine the effect of turbulence on the transport of the dust, in particular in the area lying between the aspiration device and the working face.

Measurement and analysis of dust

Dust measurement

1. The *gravimetric method* of dust measurement is simple and rapid. It does not call for the training of qualified staff, and fits in well with sampling operations carried out over long periods in one or more shifts. None of the biological investigations made hitherto have made it possible to decide that the weight of dust breathed in does not express the risk of silicosis as well as the number of particles. On the contrary, the present state of medical research regarding pneumoconiotic diseases due to coal, and not concerned with pure silicosis, lends support to the idea that the mass of respirable particles is the most representative index of the risk. In the case of coalminers, the disease is said to be due to blockage of the respiratory passages by a large quantity of dust, coupled with the action of mineral particles which have a more or less fibrogenic action. This blockage by a large mass of dust is said to be better expressed by measurement by weight of the dustiness of the working.

As against this, the gravimetric method does not lend itself to short-term measurements because it requires fairly large samples to allow of a normal weighing operation, i.e. a minimum of 10 milligrams. For the same reason, the method is less satisfactory when the dustiness level is low. It would therefore seem that its field of application is that of routine measurements, in which integration of the dustiness figures over long periods offers the double advantage of providing a better representation of the quantity of the dust inhaled by the miner during the shift than would a few separate samples distributed over the whole duration of the working period, as is the practice with numerical assessment of dustiness.

This method based on weight also simplifies the interpretation of the results.

(a) During the duration of the research, Cerchar developed a self-contained apparatus capable of taking samples over one whole working shift—the number of dust samples being sufficiently high for them to be weighed and for a particle count to be taken. The dusty air is aspirated through a micropore filter 90 mm in diameter with a throughput adjustable from 0 to 2 cu.metres/hour.

The independance of the apparatus, which is fed by an integral battery, enables it to work for a period of six hours. An electronic device allows of simultaneous

measurement of the throughput and the recording of the total volume sampled, to the nearest litre.

The energy source consists of two 24-volt lead batteries and has a capacity of 5 ampères per hour. The entire apparatus is intrinsically safe and weighs 10 kg. Investigations were also made of a selector which could be fitted on the apparatus and which eliminates the coarser particles. The device selected for this purpose is of the cyclone type, making its cut at 2.5 microns, thus retaining 50% of the 2.5 micron particles.

This apparatus (without the selector) was adopted by the Working Group for Dust Measurement as reference apparatus for the comparative tests on criteria of industrial hygiene to be carried out in various coalfields. The first of these tests was carried out in May 1966 at the Fohnsdorf pit in Austria.

(b) During some preceding work (see in particular the report on the state of research in 1965), there had been developed a gravimetric sampling device fitted with a pre-separator to remove the coarse dust; for this purpose it used the cyclone principle and was driven by compressed air. This apparatus is known by the designation B. A. T. The fact that the number of measuring points where there was no supply of compressed air had risen, and that it is likely to grow even further, underlines the necessity for a self-contained apparatus. Nevertheless, the pressure loss caused by the filter would vary very considerably according to the load of dust on it (between 2,000 and 4,000 mm of water), and recourse was therefore had to a different separation principle for the fine dust. The use of a second cyclone intended to separate out the fine sizes is thus now envisaged. For a throughput of dusty air of 5 cu.metres per hour, the resistance of the system of this kind lies between 200 and 250 mm of water, i. e. no more than 10% of the resistance of the compressed-air device.

(c) To meet the wishes of the scientific workers concerned with dust nuisance, work has begun on a construction of a long-period sampling device which provides a distribution of the entire size consist into a large number of clearly-defined size classes from the dust as found in suspension. In this way, errors due to the separation of aggregates into their component particles are avoided. The design of this apparatus stems from the principle of sedimentation of dust in a channel traversed by a laminar current. The interpretation of the results is based on weighing. Prototypes of devices built to this design are already operating in the installations which are used to provide artificial dusty conditions for animal tests (one such device has been operating for more than 1,000 hours). These sampling devices are, however, not designed solely for this type of installation, but also for underground measurements.

2. Two series of investigations should be referred to in connection with the *tyndallometric* method of assessing dustiness, supplemented by measurements with a mine conimeter, as used in Germany.

Work has been continued to obtain better understanding of diffused light in its application to the technique of dust measurement. Experiments, which were

begun using spherical particles, are now being carried on on genuine dust particles of random shape. The investigations with spherical particles showed the satisfactory degree of correspondence existing between theory and experiment.

In this same field, the Institute of Medical Physics at Munster University has studied the indications given by the tyndalloscope (in connection with diffused light and the magnitudes which are governed by the surface area of the dust particles) and the comparison of these readings with those given by other measurement apparatus.

The surface area of dust particles is measured by two methods: the permeability method and the gas-absorption method; the results of the two series of measurements are compared with each other. Up to the present, the results of these studies have shown that it is possible to calibrate the tyndalloscope in terms of the values dependent on the surface area of the dust particles, for a homogeneous substance. This would therefore represent an advance over the use of the conventional conversion factor for the tyndalloscope, which is used to indicate the relation between the intensity of the diffused light and the weight of the dust. In this manner it would be possible to take better account of the action of dust on the organism.

3. With regard to dust particle *counting* a research project has been begun by the Clinica del Lavoro in Milan on the "power of resolution on the microscopes used for particle counts."

The first studies were devoted to examining the differences observed between particles of dust counted after deposition on microscope membranes, between the examination in light-field illumination and in dark-field illumination as a function of the index of refraction of the most strongly-wetted membrane (the wetting being due to the solvent added to the membrane).

To facilitate particle counts, studies are under way to determine the optimum conditions to obtain thin layers of solvents without changing the arrangement of the dust particles in the preparation. The optimum density of the dusts in the preparation to be used for counting has also been investigated. It was found that in light-field illumination and for an enlargement of 250 (sizes consist from 0.7 to 5 microns), a value of 40 particles per 1,600 square microns should not be exceeded, a figure corresponding to an error of 10%.

For magnifications of 500 × (0.5 to 5 microns) and 750 × (0.35 to 5 microns) the respective figures are 80 and 100 particles per 1,600 square microns.

4. In modern mine operations, it has now been generally recognized that there are great advantages in being able to transmit various items of technical information towards control centres, which may be even at the surface, by means of telemetry.

This advantage applies not only to information regarding production, but also to data on safety, e. g. methane measurements. The same technique has been envisaged for data on dust measurement.

The Steinkohlenbergbauverein have set out to solve this problem, and have approached it by considering several techniques.

In collaboration with Leitz, it has been envisaged to modify the tyndalloscope into a direct-reading apparatus (tyndallograph), by using the diffused light which it emits. As this diffused light is of very low intensity, the brightness of the light source must be increased first of all.

Working together with the Walsum pit, the electrical and mechanical components of the Gast balance have been improved; this device was already capable of use underground for recording dust concentrations (Fig. 11).

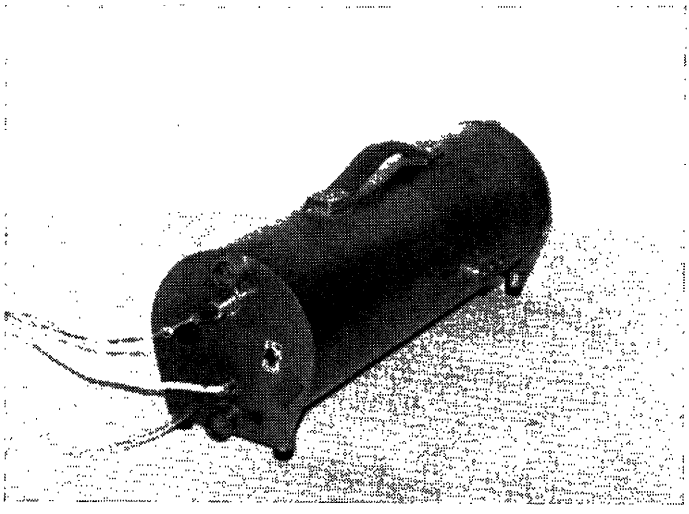


Fig. 11

Gast dust balance

In collaboration with Mollidor & Muller, the development of the apparatus has been pursued with a view to providing continuous recording of the dustiness levels over a long period, the apparatus being based on the photo-electric principle (see literature published earlier). It is now possible to add to this apparatus a device which allows of determining separately and without incineration the concentration of coal dust and rock dust (Figs. 12 and 13).

5. In the Netherlands, comparison has been undertaken of the measurements carried out underground by means of three categories of gravimetric sampling device:

(i) the C. P. apparatus, with a throughput of 1 cu.metre per hour, used for a number of years as a routine apparatus in that country;

(ii) the Siter apparatus, with a throughput of 4 cu.metres per hour;

(iii) the Gothe apparatus, with a throughput varying between 20 and 30 plus cu.metres per hour.

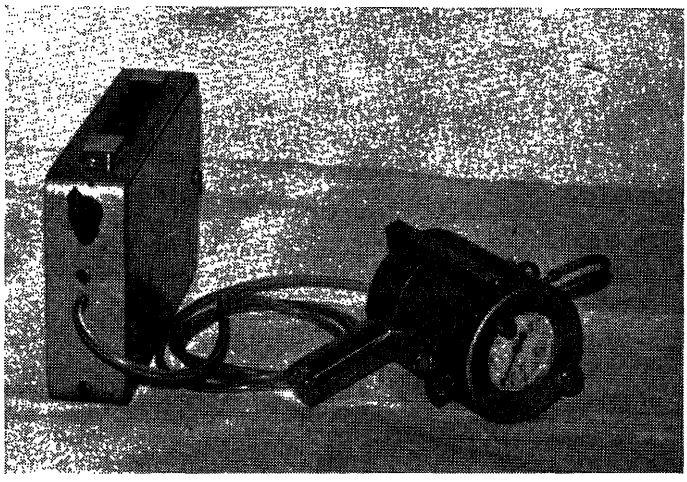


Fig. 12

Long-period dust sampler TM II

Each of the first two devices was compared with the Gothe apparatus: 117 measurements over a period of 3 to 4 hours for the first device, and 71 measurements over 3 to 4 hours for the second. The devices were then compared with one another.

These measurements showed that the Siter apparatus gave results which were less scattered than those given by the C. P. apparatus, and that, for low concentrations of dust, its throughput per hour—four times higher than the former—made it possible to achieve more accurate analyses. The explanation of these variations is to be found in factors which are frequently outside the apparatus itself, such as: the power source, the arrangement of the aspiration channel, fluctuations in pressure of the compressed air, dirtying of the apparatus, variations in throughput, unexpected fluctuations in the ash content of the dust samples.

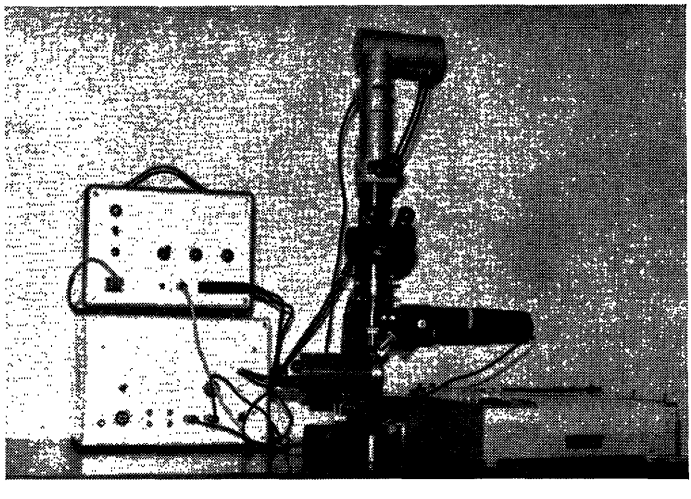


Fig. 13

Analysis apparatus for the long-period sampler TM II

6. In the Grand Duchy of Luxembourg, work has begun on preparatory studies of the dustiness conditions in iron mines. These studies fell into two parts: first, measurement of the underground dustiness levels and, second, petrographic studies of the seams worked in the southern part of the country. The object is to find the relationships between the different composition of the various rocks and the composition of the dust emitted.

Analysis of the dust

(The composition of the dust)

1. The Steinkohlenbergbauverein, of Essen, has begun research into the relationship between the quantity and the mineralogical composition of dust and the nature and structure of the substances in which they originate.

It has been shown that the mineral content of the various size classes of the dust which can penetrate into the lung does not correspond to the mineralogical composition of the rocks giving rise to them. The quartz content of the latter is much higher than that of the dust in suspensions. More than 95% of all the quartz particles present in the suspended dust are below 5 microns in size. The clay minerals such as ilite and sericite are particularly fine. Feldspar is found only exceptionally in the rock dust.

In addition, the rock dust is markedly finer than coal dust; this fact is important with regard to the estimate which can be made by deduction from the intensity of the diffused light emitted in the tyndalloscope. The particular consequence of this is that the concentration of rock dust is over-estimated by this method. The results of these studies are of important application in the investigation of the harmful nature of the dust and in the interpretation of the data obtained from dustiness measurement.

2. A special research project is devoted to studying the semi-conducting properties of minerals, in particular of quartz and its mineral varieties. It has been shown that the harmfulness of the mineral forms of SiO_2 is related to the activation energy of the electrons and their bonds. The intensity of the activating charge depends on the quantity of free ions in the sample. The activation energies can be measured by the luminescence method. This thus offers the possibility of determining in advance the harmfulness of the dust by a simple physical measurement.

3. The application of infra-red spectroscopy, which is now a routine technique for quartz determination in samples, has been examined with a view to applying it to the determination of mineral components other than quartz. Research into the determination of quartz had shown the relation between the size consist and the intensity of absorption. The research now under way deals with the formulations of these relationships for the other constituents of the dust. The application of the infra-red spectroscopic technique to the quantitative determination of the dust present in the lungs was also studied at the same time.

4. The same trend in research occurs in the determination by X-ray methods of the mineral substances present in the dust samples. It will be remembered that, with respect to quartz, the work carried out had already had satisfactory results, and that an automatic analysis apparatus had been constructed and taken into service. The same method is now being developed for the quantitative determination of the other minerals. The purpose of the research is to find a method of preparing the samples which can be adapted to a routine examination technique and which can provide sufficiently reproducible observations.

5. The Silikose-Forschungsinstitut, of Bochum, has begun research into a method intended to separate out the size classes of the suspended dust which can be breathed into the lungs, by means of sedimentation. The device developed for this purpose is powered by an electric battery, and sets up a laminar current of air which carries the dust. This laminar current is produced by means of a small membrane pump and a device which smooths out the flow of the aspirated air. Accurate sedimentation of the size classes of the dust depends in essence on the regularity of flow of the air, and on the absence of disturbing substances such as, e. g. alcohol fumes.

Pneumoconioses and environmental factors

The research projects examining the relationship between the pneumoconiotic diseases and environmental factors were begun in Germany in 1960, starting from documentary information provided, on the one hand, by the card index "Working activity and dustiness levels," and, on the other, by the results of medical examinations undergone by mineworkers.

In practice these research projects are intended to provide the basic material for the determination of proven dustiness limits.

The present data refer to a period of observation of seven years, during which a population of 10,000 miners working at eleven pits were examined. Reisner presented a report on this research project at the 2nd International Symposium on Respirable Dusts and Gases at Cambridge in September 1965.

This research programme provided an observation of the very highest interest in respect of the relationships between the appearance and development of the pneumoconiotic diseases and the dust concentrations.

The use of the data contained in the card index has made it possible to deduce a number related to the dustiness level, and this number can be used to indicate the risk of the first changes in the lung appearing.

These data have, moreover, begun to be employed in preparing the formulation of new mining regulations. It is also clear that this work provides a solid foundation for deploying to workings safe from the health point of view those workers who have already begun to suffer the preliminary stages of pneumoconiosis.

Nevertheless, the results at present available from seven years of research are inadequate and there are still special problems which must be dealt with in the same manner. Among others, we may refer to investigation of the consequences of short exposure to heavy levels of dustiness (peak effects). In addition, a start has also been made with the investigation of exceptional cases, i. e. pits where the frequency of pneumoconiotic symptoms varies very widely, while the dust concentrations are not particularly abnormal. Special attention is paid to the part which may be played by the mineral components of the dust in these pits.

The study of similar problems carried out in Belgium over a number of years in a Campine colliery was continued until the 31st December, 1965, with regard to actual measurements performed in underground workings. Recording of data

could not be continued beyond that date, because of redeployment of the men resulting from the reorganisation of the workings where the research had been carried out, all this following upon the merger between two companies.

Interpretation of the data for the years 1964 and 1965 has confirmed the preceding observations, in particular with regard to the proportion of workmen assigned to workings with danger indexes below 5 (provisional threshold value).

Nevertheless, a slight increase was noted in the average values observed, under the effect of winning by shearers.

Efforts are being made to discover the precise working conditions of workers who have been solely assigned for a period of ten years either to coal, or to stone, so as to obtain a precise indication of the most likely value of the threshold index.

Research into the use of salt pastes

This research programme was undertaken by the "Versuchsgrubengesellschaft", of Dortmund, in collaboration with two groups from the Steinkohlenbergbauverein, of Essen, with a view to improving the technology of the application of saline pastes and to investigate the efficiency of the process, from both the health point of view (binding dust below 5 microns) and the safety point of view (protection against dust explosion).

First of all, it became necessary to make a detailed study of the questions relating not only to the nature of the chemical used but also of its constitution and the method of manufacture. The tests have therefore hitherto been devoted to determining the binding power of the pastes, and the homogeneity and stability of their constitution, and, at the same time, information was sought regarding the corrosive damage which the paste might cause to the metal components of supports and other machines, and to the disturbance it might cause in electrical equipment.

The effectiveness and active life of the pastes vary in the different applications; they depend not only on the amount of dust deposited on the paste but also on the kind of coal, on the size consist and the dust content of the rock. It was noted that the salt pastes bind between 1 and 1.6 times their own weight in coal dust.

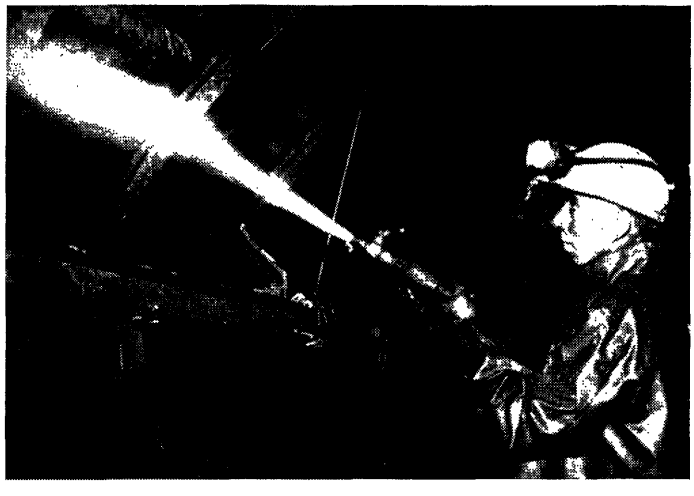


Fig. 14

Treating a road with salt paste

Fig. 15

Feeding the surface stock vessels by means of special paste-transporting containers

Additional tests were carried out in two Ruhr pits (Grimberg 1/2 and Friedrich der Große) with a view to increasing the binding capacity of the Montan powder, which is a mixture containing a high proportion of calcium chloride. This powder had been found to be effective for binding the dust; it combined from 4.5 to 6 kg of coal dust per kg of powder, but its action is of shorter duration than that of salt paste.

Other trials have been carried out at the Saarbergwerke AG and the Friedrich der Große pit with the object of studying the transport and handling of these pastes; pumps, reservoirs and piping systems were all subjected to scrutiny (Figs. 14 and 15).

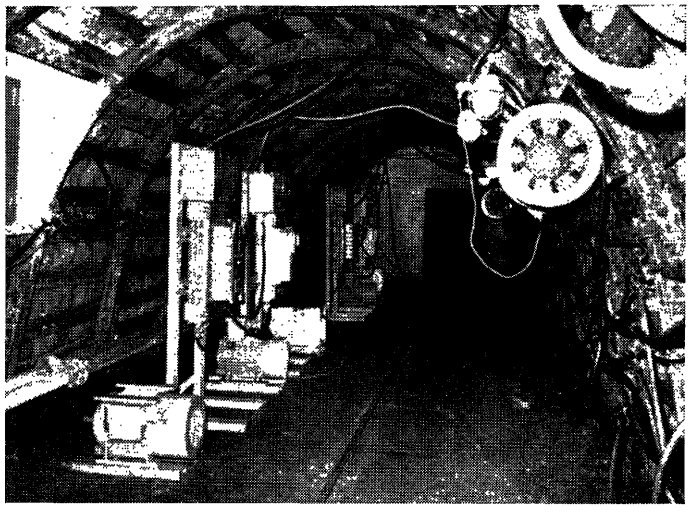


Fig. 16

Test installation at the Tremonia Experimental Pit for the investigation of the effect of hygroscopic salts on electrical equipment

In addition, a group of experts, including chemists, is investigating steps to improve the quality and stability of the structure of the paste.

To examine the disturbing influences on electrical equipment, the experimental mine has set up a research department which studies the behaviour of the insulation of electrical equipment under voltage and which also carries out experiments with protective devices. These durability tests are under way and will go on for several months (Fig. 16).

Nor has the medical aspect of the use of salt paste been left out of the count, nor trials of protective equipment intended for the use of workers assigned to handle these products. An industrial medicine report is being prepared.

SECOND PROGRAMME OF RESEARCH (1)
"TECHNICAL MEASURES OF DUST PREVENTION AND SUPPRESSION IN MINES"
DETAILED LIST OF RESEARCH PROJECTS (2)

Name of the requesting research institute (receiving financial support)	Purpose of the research project
Steinkohlenbergbauverein, Essen	Measures against dust produced during caving by developing an apparatus for spraying the debris to be used in powered-support faces.
Steinkohlenbergbauverein, Essen	Research into the different factors causing stirring-up of dust during shotfiring. Development of new processes intended to reduce the production of dust and to precipitate it.
Steinkohlenbergbauverein, Essen	Behaviour of the dust in the ventilation air. Research into: a) distribution of the dust in the ventilation air; b) the sedimentation of the dust; c) the influence of the air quantity, air velocity, turbulence and direction of ventilation on the dust concentration; d) the behaviour of the dust in a turbulent current of air (theoretical and experimental investigation).
Steinkohlenbergbauverein, Essen	Development and trial of new de-dusting processes using aspiration and precipitation: a) used with winning machines and roadway-heading machines; b) used in stowing operations; c) used at moving or fixed transfer points; d) used during shotfiring; e) used in roadways driven in the solid associated with faces of high dustiness.

(1) Decision of the High Authority of December 21, 1964.
(2) First group (decision of the High Authority of March 31, 1965).

Name of the requesting research institute (receiving financial support)	Purpose of the research project
Steinkohlenbergbauverein, Essen	Development of apparatus for measuring fine dusts, intended to operate over long periods and based on fractional separation of the dust.
Steinkohlenbergbauverein, Essen	Research into the relationships existing between the quantities and the mineralogical composition of suspended dust which enter into the workers' lungs, and the nature and structure of the substances giving rise to the dust and the way in which they break up.
Steinkohlenbergbauverein, Essen	Infusion of water into the seam, in particularly intensive mechanised faces with high rates of advance, paying particular attention to deep or remote infusion, coupled with the development of apparatus, high-pressure hoses and armatures required for these applications.
Steinkohlenbergbauverein, Essen	Measures against dust produced by winning and loading machines.
Steinkohlenbergbauverein, Essen	Shots fired in water.
Steinkohlenbergbauverein, Essen	Physical principles and development of apparatus intended to determine the concentration of dust in mines and to produce size analyses thereof.
Steinkohlenbergbauverein, Essen	Development of recording dust-measuring apparatus: (i) allowing of transmission of the measured values to a central control point; (ii) allowing of remote indication of the removal of dust beyond dedusting installation.
Steinkohlenbergbauverein, Essen	Development of the B. A. T. I. filtration sampling apparatus for fine particles of dust, in the form of a self-powered sampling device.
Steinkohlenbergbauverein, Essen	Research into the physical properties of coals and rocks and the behaviour of the dust formed therefrom.
Steinkohlenbergbauverein, Essen	Research into the spectroscopic determination of the inorganic components of mine dusts and of the dusts which penetrate into the lungs.

Name of the requesting research institute (receiving financial support)	Purpose of the research project
Steinkohlenbergbauverein, Essen	Development of a routine quantitative X-ray analysis method to determine the mineral content of dusts occurring in coal-mines.
Steinkohlenbergbauverein, Essen	Research into the relationship between pneumoconiotic diseases and dustiness.
Steinkohlenbergbauverein, Essen	Research into the influence of activity, geological conditions and occupation of the development of pneumoconiotic diseases.
Steinkohlenbergbauverein, Essen	Special research in certain mine workings with regard to anomalies in the frequency and seriousness of pneumoconiotic diseases.
Istituto di Arte Mineraria del Politecnico di Torino	Technical measures against dust during pneumatic stowing.
Musée d'histoire naturelle, Luxembourg	Measurement of dust in iron-mines and analysis of the dusts.
Clinica del Lavoro, Milano	The use of wetting agents to reduce the degree of dustiness.
Clinica del Lavoro, Milano	Resarch on the power of separation of microscopes used for the counting of dust particles.
Clinica del Lavoro, Milano	Research into ventilation of heading faces.
Clinica del Lavoro, Milano	Comparative study of degrees of dustiness produced by drilling machines.
Institut national de l'industrie charbonnière (Inichar), Liège	Development of an adequate apparatus for suppressing dust on a driving and loading machine in a rapid-advance face.
Faculté polytechnique de Mons	Protection of the surrounding rock of coal seams against the effects of water infusion.
Institut d'hygiène des mines, Hasselt	Investigation of the dustiness conditions during caving.
Institut d'hygiène des mines, Hasselt	Comparative measurements of the degree of dustiness in underground working. Comparison of the "assessment criteria" of the dust nuisance adopted in different Community countries.

Name of the requesting research institute (receiving financial support)	Purpose of the research project
Institut d'hygiène des mines, Hasselt	Investigation of degrees of dustiness in relation to the working activity and medical history of mine-workers.
Institut d'hygiène des mines, Hasselt	Infusion of water into the seam beyond the zone of macrofissuration: (i) by holes perpendicular to the coalface in mechanized faces; (ii) by holes parallel to the coalface in seams of irregular composition with friable surrounding rock.
Institut d'hygiène des mines, Hasselt	Water infusion combined with shotfiring in seams subject to instantaneous outbursts of methane.
Institut d'hygiène des mines, Hasselt	Infusion of water in a panel before working, to some depth, working from existing roadways or roadways which may have been driven for the purpose (advanced remote infusion).
Institut d'hygiène des mines, Hasselt	Contribution to the study of the degree of dustiness caused by mechanical stowing in faces. Scraper stowing. Means of preventing the dust.
Institut d'hygiène des mines, Hasselt	Investigation of water spraying under cowls with the use of evaporation-retarding additives. Effects on the cleaning of conveyor structures.
Institut d'hygiène des mines, Hasselt	Effect of the transport of products and the direction of ventilation on the dust produced in the face and in the gate-roads.
Institut national des mines, Pâturages	Reduction of nitrous vapours in shotfiring fumes.
Institut national des mines, Pâturages	Cleaning conveyor structures and eliminating dust deposited in district roads.
Silikose-Forschungsinstitut der Bergbauberufsgenossenschaft, Bochum	The addition to pneumatic stowing material of additives reducing the amount of dust freed.
Silikose-Forschungsinstitut der Bergbauberufsgenossenschaft, Bochum	Dust suppression measures during winning and transport in thick seams of iron ore.

Name of the requesting research institute (receiving financial support)	Purpose of the research project
Silikose-Forschungsinstitut der Bergbauberufsgenossenschaft, Bochum	Research into new methods of stemming for shot-firing.
Silikose-Forschungsinstitut der Bergbauberufsgenossenschaft, Bochum	Dedusting at loading points.
Silikose-Forschungsinstitut der Bergbauberufsgenossenschaft, Bochum	Development of a process for separating respirable dust according to size by sedimentation. Comparison of the diameter projected in the microscope and the Stokes diameter.
Silikose-Forschungsinstitut der Bergbauberufsgenossenschaft, Bochum	Development of automatic spraying system to bring down dust produced during ploughing.
Silikose-Forschungsinstitut der Bergbauberufsgenossenschaft, Bochum	Measures to suppress dust produced by shearers.
Silikose-Forschungsinstitut der Bergbauberufsgenossenschaft, Bochum	Development of water infusion in deep holes.
Silikose-Forschungsinstitut der Bergbauberufsgenossenschaft, Bochum	Use of evaporation-retarding substances in bad climatic conditions.
Silikose-Forschungsinstitut der Bergbauberufsgenossenschaft, Bochum	Research into the mineralogical composition of "respirable" dusts before and after inhalation, so as to determine their pathogenical action in pneumoconiotic diseases. Research into the possibility of selective separation of the dust in filters and in the air passages.
Silikose-Forschungsinstitut der Bergbauberufsgenossenschaft, Bochum	Elimination of dust deposited by coaldust-aspirating apparatus.
Silikose-Forschungsinstitut der Bergbauberufsgenossenschaft, Bochum	Relationships between diffused light and the magnitudes indicated by the tyndalloscope for the surface area of dust particles. Comparison of the tyndalloscope reading—making allowance for the magnitudes indicated for the surface areas of the particles—and the readings given by other measurement devices.

Name of the requesting research institute (receiving financial support)	Purpose of the research project
De Gezamenlijke Steenkolenmijnen in Limburg	Establishing a comparison between different methods of measuring dust with a view to establishing threshold dustiness values.
De Gezamenlijke Steenkolenmijnen in Limburg	Dust-suppression measures in mechanised faces during caving.
De Gezamenlijke Steenkolenmijnen in Limburg	Comparison of the criteria for assessing dustiness levels, by means of measures carried out in underground mine workings.
De Gezamenlijke Steenkolenmijnen in Limburg	Development of a recording dust-measuring device.
De Gezamenlijke Steenkolenmijnen in Limburg	Research into the emission of gas simultaneously with dust during shotfiring, in particular carbon monoxide and nitrous vapours.
De Gezamenlijke Steenkolenmijnen in Limburg	Investigation of the effect of the intensity and direction of the ventilation current on the degree of stirring-up of dust when the current of air strikes the dust source.
De Gezamenlijke Steenkolenmijnen in Limburg	The influence of water sprays installed in the stowing lines. The effect of the moisture of the stowing material on the quantity of dust produced during pneumatic stowing.
De Gezamenlijke Steenkolenmijnen in Limburg	Water infusion in an unworked panel.
De Gezamenlijke Steenkolenmijnen in Limburg	Investigation of water infusion where very high back-pressures occur.
De Gezamenlijke Steenkolenmijnen in Limburg	Study of the flow of liquids in the coal.
Cerchar, Paris	Measures to suppress dust during vertical transport.
Cerchar, Paris	Research into the development of an apparatus indicating the dustiness level for immediate reading, giving accurate values in moist conditions and capable of use underground.
Cerchar, Paris	Practical investigations into water infusion.

Name of the requesting research institute (receiving financial support)	Purpose of the research project
Cerchar, Paris	Investigation of water spraying during winning with pneumatic picks.
Cerchar, Paris	Study of winning and of dust aspiration in the face.
Cerchar, Paris	Cleaning up shotfiring fumes in the face and in rapid headings.
Cerchar, Paris	Study of the best conditions for water infusion in the solid coal.
Cerchar, Paris	Development of a simple, portable and independent continuous dust-sampling apparatus.
Versuchsgrubengesellschaft mbH, Dortmund	The use of hygroscopic salts as a means of protection against dust and against explosions in coal-mines. (1)
Istituto di Medicina del Lavoro dell'Università di Cagliari	Systematic control of dust concentrations and of the chemical nature of the dust in the Sulcis (Carbonia) coal-mines, together with the relationship of these factors with the development of pneumoconiotic diseases. (2)
1. Physikalisches Institut der Universität Wien (3)	Measurement of the distribution function of dust by means of cascade impactors.
Steinkohlenbergbauverein, Essen	Investigation of the different factors likely to affect the freeing of dust during shotfiring and the development of new processes for reducing the amount of dust freed or for precipitating the dust.
Steinkohlenbergbauverein, Essen	Complete development of apparatus for measuring fine dust, to carry out measurements over a long period with fractional separation of the dusts.
Steinkohlenbergbauverein, Essen	Development of a routine quantitative X-ray analysis method to determine the minerals present in the dust occurring in coal-mines
Steinkohlenbergbauverein, Essen	Special investigations in various mine workings where the frequency and seriousness of pneumoconiotic diseases are high.

(1) Decision of the High Authority of September 15, 1965.

(2) Decision of the High Authority of November 16, 1966.

(3) The following research projects belong to a second group of items financially supported by the High Authority (March 15, 1967).

Name of the requesting research institute (receiving financial support)	Purpose of the research project
Institut d'hygiène des mines, Hasselt	Investigation of the possibility of infusing water into banded anthracitic seams.
Institut d'hygiène des mines, Hasselt	Investigation of the penetration of water into the solid coal with the purpose of ensuring longer-lasting wetting of the coal brought down without bad effects on the climatic conditions.
Silikose-Forschungsinstitut der Bergbauberufsgenossenschaft, Bochum	Dust suppression measures during coal cutting by means of suitable apparatus.
Silikose-Forschungsinstitut der Bergbauberufsgenossenschaft, Bochum	Removal of sedimented dust by coaldust-aspirating equipment.
Cerchar, Paris	Practical investigations into water infusion.
Cerchar, Paris	Investigation of the optimum conditions for seam infusion.
Cerchar, Paris	Investigation of the bringing-down and aspiration of dust.
Cerchar, Paris	Investigation of a continuous dust-sampling device.

Programme of research in industrial medicine, hygiene and safety, up to December 31, 1966

Field covered and designation	Decision of:	Budget (round figures, in units of account)	
		Total budget	Money expended
A—*Industrial medicine and hygiene*			
a) Physiopathology and clinical medicine			
1st programme (Industrial medicine)	October 5, 1955	1,200,000	1,200,000
2nd programme (Industrial medicine)	April 7, 1960	2,800,000	2,700,000
3rd programme (Physiopathology and clinical medicine)	April 28, 1964	3,000,000	2,275,000
b) Traumatology and rehabilitation			
1st programme (Rehabilitation) (1)	December 5, 1957	500,000	500,000
2nd programme (Traumatology and rehabilitation)	June 19, 1964	1,800,000	990,000
3rd programme (Burns)	May 18, 1966	1,500,000	281
B—*Industrial physiology and psychology*			
a) Human factors and safety			
1st programme (Human factors and safety) (1)	December 5, 1957	1,000,000	1,000,000
2nd programme (Human factors and safety) (2)	November 4, 1964	1,200,000	321,348
b) Ergonomics			
1st programme (Physiology and organization of work) (2)	November 4, 1964	2,000,000	859,552
C—*Industrial hygiene*			
a) Measures against dust in mines			
1st programme (Technical measures against dust in mines) (1)	December 5, 1957	900,000	900,000
2nd programme (Technical measures against dust in mines)	December 21, 1964	6,000,000	3,613,300
b) Technical measures against dust in steelworks			
1st programme (Technical measures against dust in steelworks) (1)	December 5, 1957	600,000	428,000
2nd programme (Technical measures against dust in steelworks)			
c) Separate research projects			
Red fumes in convertors	July 18, 1961	1,000,000	800,000
Red fumes in convertors	June 19, 1964	1,825,000	1,050,000
Climatic factors in mines	March 16, 1966	116,000	116,000
		25,441,000	16,753,481

(1) This programme is part of a single budgeting plan, under the general title of "Safety," and comprising four programmes.

(2) This programme is part of a single budgeting plan, under the general title of "Human factors and ergonomics," and comprising two programmes.

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