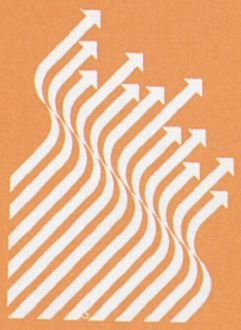
Commission of the European Communities

technical coal research

ECSC coal research
Annual report 1988



Report

EUR 12292 EN

Commission of the European Communities

technical coal research

ECSC coal research Annual report 1988

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Rue de la Loi 200
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Directorate-General
Energy

1989

Published by the
COMMISSION OF THE EUROPEAN COMMUNITIES
Directorate-General
Telecommunications, Information Industries and Innovation
L-2920 Luxembourg

Cataloguing data can be found at the end of this publication

Luxembourg: Office for Official Publications of the European Communities, 1989

ISBN 92-826-0677-5 Catalogue number: CD-NA-12292-EN-C

Printed in Belgium

Dear Reader,

This issue gives a brief overview of the scope of the ECSC coal research activities and complements a number of publications of the European Commission which aim to disseminate the research activities to all interested bodies. From this you will be able to decide which research projects are of most interest to you and you may request additional information either from the Commission, or from the contractors, if you prefer to have direct contact.

Today, more than ever, the Commission of the European Communities endeavours to promote technical and economic research relating to the economic production and increased use of coal, as well as occupational safety in the coal industry. In 1989, the new "medium-term guidelines for technical coal research (1990-1995)", were approved including a number of technical priority areas, as well as other activities which can be summed up as follows:

1. Contribution to the achievement of the objectives of the Single Act and the objectives of energy policy for 1995.

2. Reduction of production costs, particularly through increased productivity.

3. Improved safety and working conditions.

4. Improved benefits and utilisation of the coal industry's products.

5. Fulfillment of the requirements for environmental protection.

In order to achieve this, it is necessary to have close cooperation between technicians, producers and researchers in the Community and this is one of the reasons why we have produced this overview of ECSC research activities.

The Commission of the European Communities likes encourage cooperation and in order to achieve this, all the projects in this report were selected and periodically discussed at specialised Experts' Committees, at which most of the revelant specialists from the mining industry, research centres and universities were represented. We thank them for their cooperation and, especially, for their contribution to the production of this Annual Report. We would also like to thank the Coal Research Committee for the recommendations which they gave us when we presented this report at their meeting.

F. KINDERMANN
Coal Technology Division

CONTENTS

Note for the Reader

The projects are classified according to the areas set out in the 'medium-term guidelines for technical coal research 1986-1990' and the following information is provided:

- for projects completed in the course of the year, a summary of the aims and main results;

- for projects on which work is in hand, a brief progress report;

- for projects started in 1988, a brief description of the aims.

I. MINING TECHNIQUES

I.1 ACTIVITIES OF THE COMMITTEE OF EXPERTS ON ROADWAY DRIVAGE SYSTEMS

Although recent years have seen the development of new and very powerful machines and more efficient rock cutting technology, drivage rates continue to be restricted by the difficulty of carrying out ground-breaking and support operations simultaneously. This aim, together with others relating to the need for machine control and real-time health monitoring, was discussed by a specialised working party, which met for the first time on 25 July 1988 in Essen-Kray to lay down lines of action and coordinate the projects in this field.

The Committee of Experts met in Oviedo (Spain) on 7 and 8 July 1988 and in Brussels/Beringen (Belgium) on 20 and 21 October 1988. At both these meetings, the Committee studied two drivage systems with full-face machines, both for weak ground and both of fairly small diameter (about 4.7 m). In one case, a WVR 4,7 shield-type heading machine from GEW was used and in the other a Bouyges tunnelling machine with concrete segment supports.

Five final reports were approved and nine new projects started. Two main themes emerge from the final reports: firstly, the need for machines to work precisely in order to maintain direction and produce accurate roadway profiles and, secondly, the improvement of roadway support design methods.

Significant progress was made in the following areas:

- development of roadway alignment and profile control systems using a combination of laser beam technology and inertial navigation systems;
- the use of expert systems for roadway support design;
- the solution of strata control problems at face/gate junctions by means of long strata bolts.

7220-AB/810 Alignment and profile guidance of roadheaders - BCC

Duration from 01.04.1983 to 31.03.1987
(Approved at the meeting of 07.07.1988)

This project is concerned with controlling the cutting elements of roadheading machines in order to cut automatically a true, aligned and accurate profile.

Unless roadheader machine operators are very skilled and have a conscientious care for machinery, roadway profiles are often cut haphazardly and machines abused by being used incorrectly.

It is normal practice for a machine operator to cut a profile by manual operation of a joystick, or two lever control valves, which actuate the slew and lift hydraulic rams that operate the cutter boom.

On the heavy-duty series of machines in particular, operator visibility is limited, certainly for part of the 360° boom movement, especially the lower part of the profile. During the cutting of stone and dirt, visibility is further reduced because of the dust produced at the cutting head, making accurate profile cutting even more difficult.

In these circumstances, difficulties can be created for operators in producing a correctly aligned, profiled and sized extraction with a minimum overcut. It is normal for an additional man, acting as a spotter, to assist machine drivers during cutting operations, and he is exposed to considerable danger from both falling debris and the rotating cutter head.

The reported project is concerned with the control of movements of the cutting elements of roadheading machines, in order to produce a precise roadway profile and the linking of this with a roadway alignment device based on a laser beam datum. This datum is arranged continuously to adjust the alignment and profile control so that the finished roadway is excavated on the correct and designed line.

The objectives are to automate a roadheader and, in particular, to control the path of a cutting head to enable headings to be extracted and profiled automatically.

A suitable control system would give the facility for the operator automatically to cut out a heading in 0.5 m or 1 m sumps, and it is reasonable to suppose that a standard predictable cutting time could be achieved on a regular basis. In addition, because the operation is automatically controlled, machine abuse should be reduced and any lack of skilled operators (especially when three-shift working) need not significantly affect the drivage performance.

Summarising these objectives, the equipment is aimed at:

- increasing machine performance,
- reducing operator abuse of machines,
- eliminating additional men for spotting purposes with the benefit of increased safety,
- producing a correctly aligned and profiled extraction,
- reducing arch erection time by cutting a correctly sized and profiled extraction, while producing minimum overcutting,
- ensuring better arch contact with the excavation, and hence more uniform loading on arches, thus giving better roadway support.

A correctly produced tunnel profile can provide a number of benefits, for example:

An accurate roadway profile reduces the amount of overcutting, enables better contact between roof support arch and roadway, improves load distribution on the arched roadway supports giving reduced roadway deformation and could possibly lead to the use of lighter section supports with subsequent reductions in the cost of drivage.

A major safety hazard still exists at roadheads, not only from roof falls under unsupported areas but also from the spalling of rock from the face, roof and sides of the roadhead. Many facilities and injuries still occur in this area.

Canopies of various designs have been tested in conjunction with roadheaders and, if made to operate efficiently, these would undoubtedly provide cover in the danger area. However, a roadheader canopy cannot operate successfully unless a good profile is produced.

The general plan of work was to study a number of alternative systems already being marketed for alignment and profile control of tunnelling machinery used in civil engineering applications. Following this study, two systems were to be selected and modified where necessary for application to boom-type roadheading machines. Surface testing and underground trials would be carried out in order to evaluate the reliability and performance of the equipment and to make recommendations as to future use and/or development.

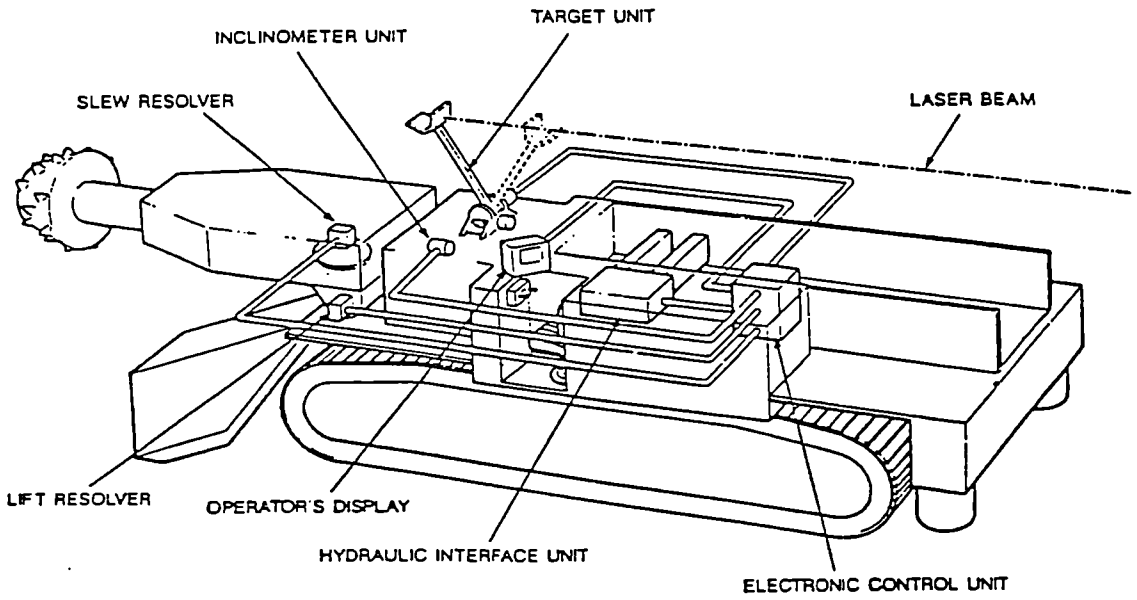
The roadheader chosen to carry out these trials was a Dosco Mk3 because of its potential for use in long-life roadways, where the benefits of good profile control would be most cost-effective.

Headquarters Technical Department (HQTD) produced a specification for an alignment and profile guidance device.

Systems were selected and purchased from ZED Instruments and Perard-Torque Tension (PTT). ZED were chosen because of their known expertise in laser-based guidance equipment for tunnelling machines in Civil Engineering and PTT for their experience in computer-controlled rock drilling equipment in association with Furuholmen of Norway.

The report sets out the objectives and expected benefits of an alignment and profile guidance device and includes a section for each manufacturer. These sections contain a brief description of each system and full descriptions of the surface and underground trials together with the general conclusions of each trial carried out. Full descriptions of the equipment supplied are to be found in the Appendices to the main report.

The report draws overall conclusions and recommendations and also suggests areas of future work.



Diagrammatic Layout of Pit System

7220-AC/825 Thermal effects during in-situ concrete lining of shafts - BCC

Duration from 01.04.1983 to 30.03.1987
(Approved at the meeting of 07.07.1988)

In the UK a major shaft sinking programme is being undertaken to bring a number of large new deep coal mines into production. For reasons of economy, non-reinforced mass concrete is being used to line the shaft walls. Many of the shafts are being sunk through heavily water bearing strata. Since it is very desirable that the completed shafts should be dry, it is important that the lining through the water bearing strata should not suffer even minor cracks and that joints should be effectively sealed. However, in water bearing rocks the design thickness of the shaft wall is increased locally and thus the danger of thermal cracking caused by the heat involved during hydration of the cement may be increased in these high water pressure zones.

This research was designed to provide information which would lead to improvements in the design and construction of concrete linings in shafts.

At some shafts measurements of temperature and strain were measured in the newly cast linings at depths corresponding to ground conditions which included weak dry and wet rocks, frozen water bearing strata, and potentially squeezing ground. Site data related to the cement, the concrete mix, and pour conditions were also collected.

A literature survey was carried out and using the range of values which might be expected the most influential concrete properties and site conditions were identified.

A Temperature Profile Simulation Rig was designed and constructed. Using concrete mixes the same as on site, temperature time profiles were obtained under adiabatic conditions. Tests to determine the early age

properties of the various mixes, notably the compressive and tensile strengths, coefficient of thermal expansion, and Young's modulus, were made on specimens cured under the appropriate temperature regimes previously obtained.

Theoretical expressions were derived from which it was possible to approximate the temperature time profiles at different points within the lining section by using an experimentally derived rate of heat of hydration profile as input. Loss of heat into the rock mass and into the air was taken into account. Another approximate method was derived which used the temperature distribution in an estimation of the stresses and strains in the lining at various stages in the thermal cycle by incorporating early age properties determined for the mix in the laboratory.

Thus the risk of thermal cracking in shaft linings can be minimised by means of laboratory tests and the utilisation of the theoretical approach evolved in the project. It is very important that cements used in the preliminary laboratory tests are identical to those which may be used on site. The sensitivity of a proposed mix to placing temperature and to small variations in cement content should be examined and appropriate control exercised in the field. Stresses predicted using the temperature profiles may be compared with the tensile strengths of the concrete mix at early age and the tendency to cracking may be assessed on a comparative basis between mixes. Constructional factors have an influence on thermal cracking.

A standardised procedure for collecting and collating data relevant to individual concrete pours is suggested. The data report should be compiled by the British Coal resident engineer from information provided by contractors, geologists, surveyors etc. These data should be recorded for each pour at every shaft. Variations in materials and conditions which occur would be established. If thermal cracking were to occur, investigation of the cause would be facilitated by possession of these data.

7220-AB/114 Development of new systems for the cutting of accurate roadway profiles - StBV

Duration from 01.04.1985 to 30.06.1987
(Approved at the meeting of 07.07.1988)

To improve the still low extent of mechanisation in roadheading, rather than straightforward technical evolution or, in other words, the continuing progress of presently available roadheading systems which have now attained a high technical level, the time is due for some kind of technical mutation or leap forward, i.e. for a completely new concept of roadheading systems using novel-type rock cutting techniques.

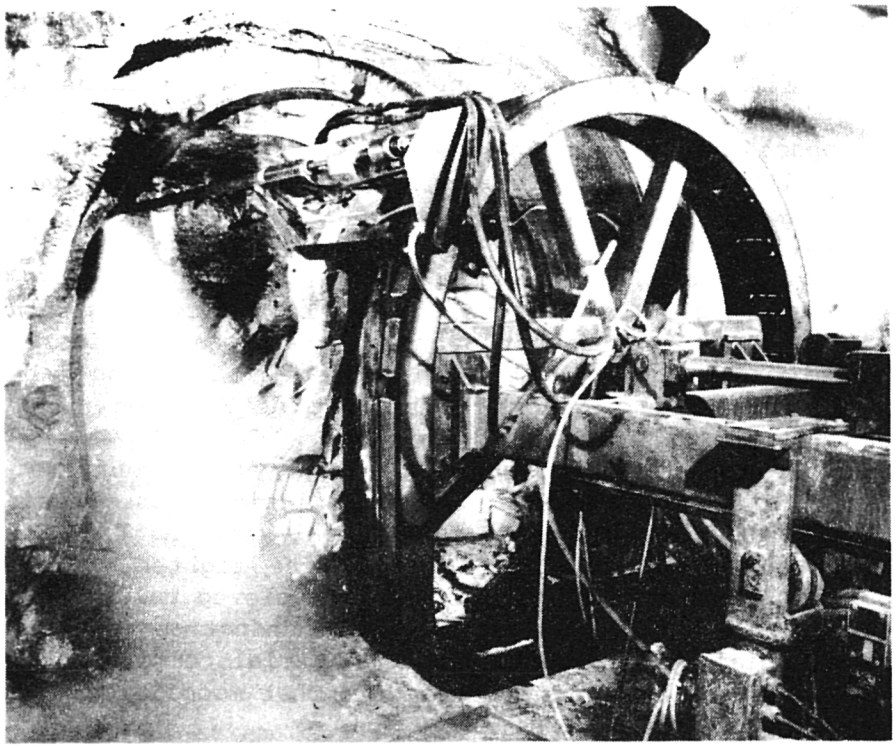
One of those promising cutting techniques is the production of grooves in the rock by using abrasive water jets, transformed from high pressure water into jets of high speed and narrow diameter under the addition of solid abrasives.

The fundamental experiments carried out at the test rig of Bergbau-Forschung GmbH now permit the technical and economic evaluation of 52 different abrasives of varying hardness, grain size, grain shape, and density, used for cutting into sandstone. Different types of corundum performed best, whereas quartz sands turned out to yield the most favourable cost-effectiveness.

The dependency of the performance of abrasive water jets on the main operational parameters was determined by extensive test series. Parameters tested were: dosage of abrasives, cutting speed, water pressure, nozzle

diameter, ejection pipe diameter, ejection pipe length, impact angle of the cutting jet on the rock. All this allows optimised application of the cutting technique under due consideration of its technical and economic restriction as well as of the specific purpose of use; it furthermore contributed greatly to enhancing scientific knowledge on the mechanisms during abrasive water jet cutting.

Starting from the results of such fundamental research, concepts of a roadheading system using abrasive water jets were established and a relevant rotating cutter head constructed. The cutter head is undergoing suitability tests in conjunction with an existing test set-up as an integrative part of the roadheading system relying on profile cutting and subsequent removal of the centre part of the front.



Experimental device for roadway profile cutting using a rotating cutter head with abrasive high-pressure water jets

7220-AC/123 Improvement of roof support techniques in gate and main roads - StBV

Duration from 01.08.1985 to 31.07.1987
(Approved at the meeting of 07.07.1988)

This research and development project was above all concentrated on further development of gateroad support in underground hardcoal mining. Even the simplest design of a roadway support constitutes a system composed of basic units or elements. The development was concentrated on the most important support elements:

- yielding arches,
- light weight support as temporary support and lagging,
- strata bolts,
- bolt plates and lagging,
- mortars for consolidation made from products of flue gas desulphurisation.

The elements of a support system need to be matched to each other so that they might add up their respective positive influence against roadway deformation. The development work largely consisted in matching these support elements.

When composing support systems, it is also important to know exactly the limits of deformability of the individual components as well as of the overall system. Neither the elements nor the system must be allowed to fail due to overload. The determination of the application limits of roadway support, accordingly, was another target to be arrived at by the work described.

The application limits for a support system with yielding arches is, as shown by reduced scale model tests, dependent e.g. on the kind of roadway where this support is set, on the quality of the floor strata, and on the bedding of the yielding arches. The results obtained with reduced scale model tests coincide quite well with the results from earlier observations underground.

Based on this work, dimensioning methods for support could be improved in that the required quantity of steel could be reduced, without affecting the support's capacity, by better overlapping instead of increased profile weight. Furthermore, the optimal initial yielding load could be determined for model arches as a function of the highest deformation energy which the yielding arch opposes to the deforming strata.

The reduced scale model tests could not yet be confirmed by results obtained with the newly built test rig for full-size arches because, during the first three yielding arch tests, the initial yielding loads to the joints could not yet be defined as a function of the tightening torques of the connector bolts. Possibly, this will not be achieved unless newly developed yielding connectors are used for which clear distinction can be made between tangential and radial force induction. The initial comparison of full-scale and reduced scale tests have shown, however, that model arches are suited in any case for trend investigations.

With increasing roadway convergence, destruction and disintegration of the surrounding strata also increase. The lagging of the yielding arches therefore is subjected to continuously increasing loads and furthermore, the lagging serves more and more frequently as shuttering for sometimes not very viscous mortar suspensions for backfilling.

Scale-model and underground tests have shown that both tasks can be fulfilled by a light weight support consisting of 1.3 mm (minimum value arrived at up to present) thin steel sheets which, due to beading and corrugation of the sheets, constitutes a stable-shape steel sheet tunnel. With such support, the operation sequence standard up to present, viz setting of yielding arches with subsequent lagging and backfilling, can be inverted. The light weight support which at the same time constitutes the lagging, and its backfilling, may then serve as provisional support, which, according to requirement, can be reinforced by yielding arches or may do without.

For widening the application range of strata bolt support, a new bolt was developed which in the early phase of strata deformation develops high tensile and shear strength, then however, still withstands high extension and shear deformation without being destroyed. A newly developed yielding plate system assures favourable load distributions onto the lagging mats. By

lagging reinforcements which can be brought in additionally, the strata bolt ends and the lagging can be matched to each other in such a way that both can cater for the theoretically required forces and deformations. Up to the present the lagging, in comparison to the bolt ends including the bolt plates, has exhibited an unfavourable shape and constituted the weakest link of the support compound. The new bolt support discussed now enters the phase of underground testing.

The most successful strata bolt application is the one as additional support in gates and base roads for securing yielding arches and for stabilising the roadsides during the passage of the face.

In level seams this method is applied meanwhile in more than 45% of all gates in which the legs of the yielding arches are removed for the passage of the face.

Today the drilling and setting work is done predominantly by means of this method's application range to brittle strata and formations exposed to high rock pressures could be arrived at, i.a. via introduction of the mortar backfill technology and by means of special drilling equipment for reduced roadway cross-sections.

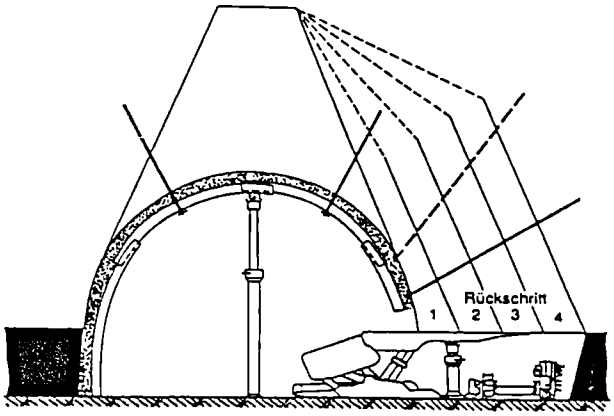
The start-up of coal faces from base roads was particularly successful in cases in which the roadway convergences could be kept low until the road site packs had been set up outbye the face line.

For determining the stability of the very complex support system in the face end areas in inclined seams, a calculation method was developed which allows to cater for the changes versus time of the face entry over the period of one working day in terms of its geometry and the number of support elements effective at any given moment.

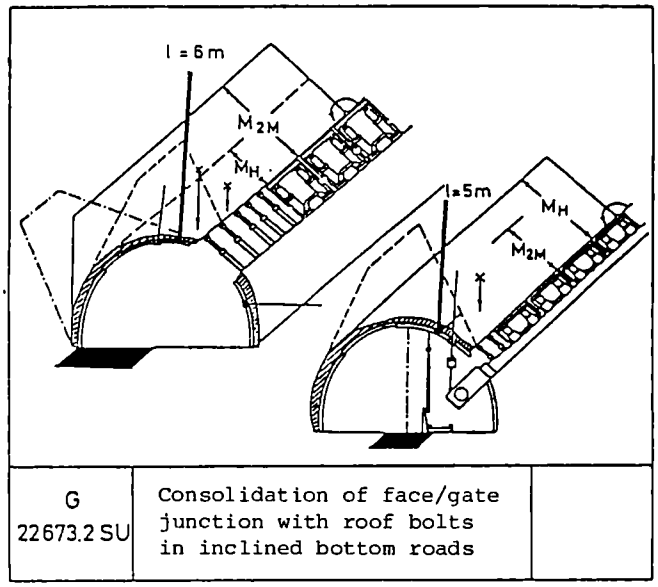
This calculation method was improved to cater also for the reliably available frictional forces on the rock surfaces. Furthermore, loads suspended on the support can be considered as well, e.g. the conveyor drives secured on the support. For the foreseeable future we may predict already the need to extend the method up to present development only for conveyor gates in inclined deposits, to cover also safety calculations for supply gates. The method then may cater for inclinations of up to 80 gon. Up to present the maximum was 60 gon. In addition, we may expect that the use of heavy hydraulic props will no longer be possible in thick seams because of the accident risks involved. Here not only the method for safety calculations needs to be extended, but also development of the appurtenant new support elements needs to be taken on.

The consolidation method developed for working through faults and through zones under high rock pressure in underground hardcoal mining was very expensive due to the high standards which the mortar qualities had to meet. Meanwhile, cheaper blends for making up what is called immediate bearing mortars can be produced from waste products of flue gas desulphurisation for successful use underground. These mortar qualities termed 'REA-Baustoffe' present only be spread in thin layers. The use of such mortar qualities, e.g. in road site packs, is impossible because of the temperature sensitivity of these mortars. In this field, too, development is still in full progress.

The reader of this report will find that the length and the penetration into details varies with the individual chapters. For subjects covered already by more detailed publications the scope of the text was confined to the absolutely necessary. For other subjects a more detailed description of the research results had to be given in order not to leave gaps in reporting.



Consolidation of the extended body of failed ground at the fourth pushover



G 22673.2 SU	Consolidation of face/gate junction with roof bolts in inclined bottom roads	

7220-AB/307 Improved rules on choice of roadway support - CERCHAR

Duration from 01.01.1986 to 31.03.1988
(Approved at the meeting of 20.10.1988)

In view of its effect on the total cost price of workings, optimum roadway management has in recent years become a subject of major concern to most mines.

Selection of supports must take account of a large volume of data as well as a whole series of constraints, making decision-aiding tools essential.

Charbonnages de France has developed such a tool. Its research in this area, which has intensified in recent years, has concentrated on two points:

- compiling existing support selection methods and adapting them to present conditions in mines;
- incorporating these methods into a decision-aiding tool, using expert system technology.

Unlike traditional computing algorithms, this method makes it possible to:

- formalise past experience with ease;
- gain access to numerous rules and ensure that procedures are consistent with them;
- update selection methods without difficulty, essential for a problem which changes with the coal deposit or technology.

This study, partially financed by the ECSC, gave birth to the expert system known as 'SOUT', the characteristics and performance of which are described in this report.

1. 'SOUT' - Knowledge Base

The decision to install a particular support system in a given working is based primarily on experience, backed in some cases by the results of numerical calculations which enable orders of magnitude to be established.

This experience is more or less formalised in the 'rules of the art' published and practised by experts. We have summarised it on the basis of:

- French and foreign literature,
- interviews with experts,
- analysis of actual cases, the information deriving from a survey on recently driven roadways.

a) The aim of the survey was to establish a database covering natural and operating conditions, supports, and general conditions in roadways at the various stages in their lifetime.

Each case was studied with a view to:

- testing methods or rules for choosing supports and where appropriate adapting them to our conditions before input into the expert system knowledge base;
- deducing support selection rules on the basis of prior statistical processing.

This operation covered 117 samples and 23 preselected arched roadways. The state of arches was found to be very much dependent on what part of its lifetime the roadway was in, the mine layout, the density of supports and the presence of faults in the zone. Discriminatory analysis was used to identify the optimum support density for correct arch conditions, i.e. deformed but not broken after the first face has passed.

Following this analysis, the arch support selection method was added to the expert system knowledge base in the form of a rule for the dimensioning of this type of support.

b) In 'SOUT' the dimensioning rules are formalised with the following syntax:

```
        IF condition THEN action
e.g.    IF rectangular roadway
        AND stratified ground
        THEN risk of strata shearing
        AND distributed resin anchorage recommended
```

On the basis of the three sources mentioned above, more then 300 rules of this type relating to roof-bolting and arching have been formulated, structured and incorporated into 'SOUT'.

The system as it stands is also capable of initiating a calculation and retrieving and utilising the results in its reasoning; it does this automatically, without intervention by the user.

2. 'SOUT' - Design and Performance

The architecture of an expert system is founded on the knowledge base, the main components of which are the dimensioning rules and an inference engine with reasoning strategies.

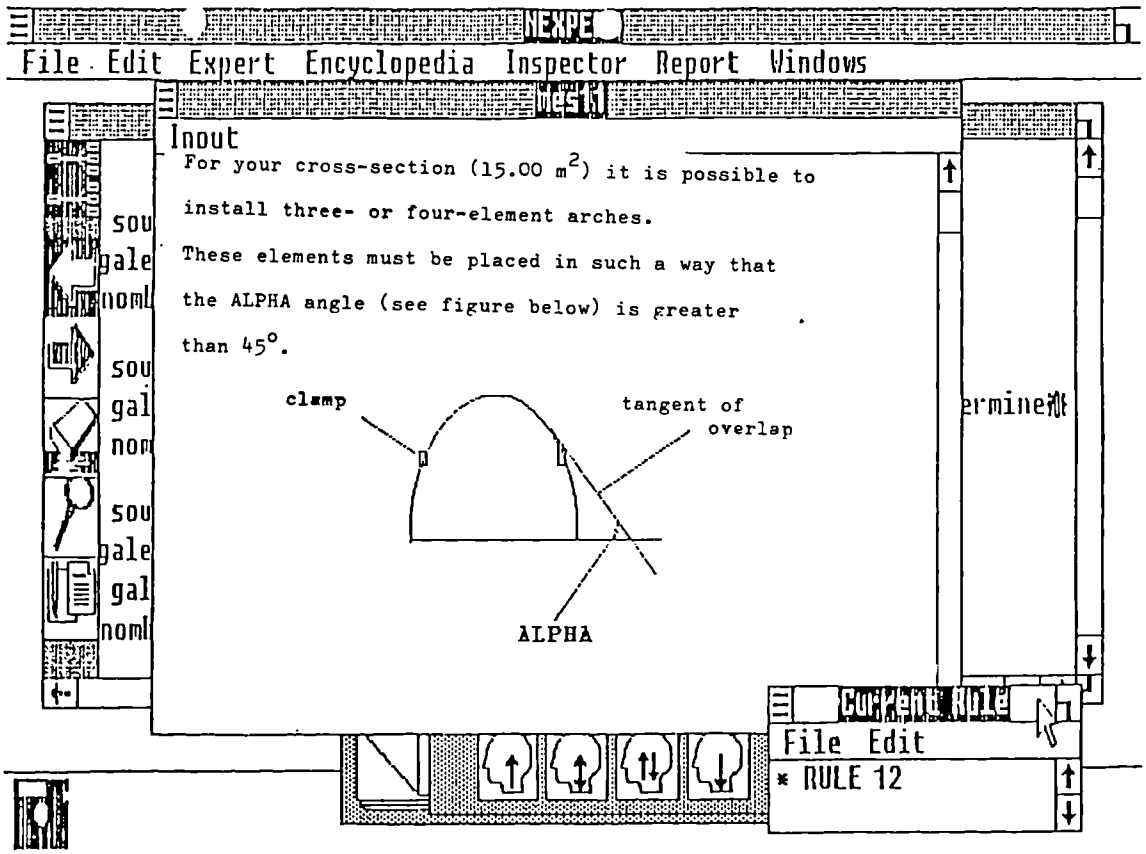
The final version of 'SOUT' was developed under the inference engine 'NEXPERT OBJECT' (NEURON DATA). This product, which we selected after a preliminary feasibility study, provided the following facilities:

- a studied representation of knowledge, object-based and taking into account the problem of variables - an absolute necessity here, as conditions may vary from one case to another;
- consideration of certainty factors to compensate for our '(lack of) knowledge' of certain phenomena;
- reasoning strategies permitting backchaining, even in respect of variables;
- interfacing of inference engine with a high-level programming language in such a way as to involve mathematical models during consultation;
- an implementing facility at both the development and utilisation stage.

Dialogue during consultation is user-friendly and uninterrupted:

- questions put in high-level language,
- conclusions provided in the form of messages and reports,
- use of graphics to illustrate important points,
- explanation of reasoning.

'SOUT' is currently being installed at the Houillères du Bassin de Lorraine to aid decision making in roadway support selection. Its 'day to day' use on this site, combined with the possibility of updating knowledge, should ensure that a highly-developed and well-adapted product is available to us on a permanent basis.



Example of Installation Recommendations

7220-AB/306 New drilling techniques for blast and roof-bolting holes - CERCHAR

Duration from 01.04.1986 to 31.03.1988

The project was carried out in two French coal fields and consisted mainly in the development of drilling techniques for strata bolting. The operational conditions necessarily depended on the workings and ground in which this drilling was carried out.

Each of the areas devised solutions to its specific problems.

The Provence Group, which uses strata bolting to support 11 km per year of gateroads accompanying faces, initially designed and tested a light bolting machine but encountered difficulties in using it because of a change in the dip of the strata.

At the same time it proved possible, by adapting hand-held rotary drilling equipment, to make the work less arduous and improve performance (by 35%) in the drilling of holes for strata bolts.

The Lorraine Area concentrated on two aspects.

- In a stone drivage supported entirely by strata bolts, it commissioned the first two-boom electrohydraulic rock bolting machine, produced by MONTABERT.

A comparative study of the performance of this machine and that of conventional electropneumatic jumbos shows a 40% reduction in the time required for bolt installation. In addition, trials of special drill rods and bolts were carried out on both types of machine.

For production districts, more specifically in steep seams, the special hand-held rotary drilling equipment was subjected to a series of laboratory tests and pit trials. As a result, a number of drill rods and bits were eliminated for strata bolting purposes and the most efficient equipment was adopted as standard.

CONVENTIONAL HEADINGS

7220-AB/812 Automatic control of drilling jumbos - BCC

Duration from 01.09.1984 to 30.08.1988

This project has now been completed and a final report has been prepared. The feasibility of the automation of drilling holes to a predetermined pattern has been proven, although this feature has not been fully demonstrated in an underground coal mine. Basic work on the alignment and steering of drivage machines has been incorporated into other current projects (7220-AD/821).

7220-AB/115 Improved technique and organisation of shotfiring - StBV

Duration from 01.04.1986 to 31.03.1989

Comparative drilling trials with chisel, cross and button bits for hand-held jackhammers established that cross bits and button bits with aggressive insert geometry are the most suitable for coal measures strata. If the hole diameter is increased from 43 to 50 mm so that large-diameter cartridges can be used, the penetration rate with hand-held jackhammers falls by 25 to 50%.

Special means of sealing are required when backfill materials are placed hydraulically behind the roadway supports. Novel fabric and foil matting was therefore tested in backfill trials to determine whether they were impervious towards the paste and could withstand the hydrostatic pressure of the column of material. The new matting was much more convenient to handle than the steel mesh hitherto used.

A disadvantage of hydraulic backfill is loss of strength due to the use of water-glass as an accelerator. Initial backfilling trials with newly developed accelerators which do not contain water-glass yielded good results.

In order to contribute to better planning of drivages, the two planning aids 'Working platforms' and 'Backfilling practice' were brought up to date and a second edition was published.

7220-AB/308 Optimised technique for the drivage of large roadways - influence of dip - CERCHAR

Duration from 01.07.1987 to 30.06.1990

In level in-seam drivages in the Provence Group, experiments have begun with the use of long (6 m) bolts in faulted zones and work has started on developing an endoprobe allowing in-hole observations at depths of up to 6 m.

In the square-work roadways in the Lorraine Area, which are more than 6 m in width, roof deformation has been measured and a ground-breaking and support system (the MT 65 frontal strike machine) has been prepared for use, with the necessary modifications to ensure better performance and greater safety.

A system for remote monitoring of deformation and threshold alarm indication was designed and should be operational in a drivage. The first trials of data transmission from the working to the surface are to be carried out in the first half of 1989.

MECHANISED HEADINGS

7220-AB/811 Alternative methods of coal production from remnant or urban districts - BCC

Duration from 01.07.1983 to 30.06.1989

Work has continued to derive efficient systems of mining small areas of coal. Particular success has been gained with the introduction of short, single entry faces at Wistow Mine in the Selby Coalfield. Equipment manufactured in a modular form has been utilised to allow rapid transfer of complete face systems. Faces with a total length of 15 m are now being worked with expected advance rates of 30 m and outputs of over 10 000 tonnes per week. At Sherwood Colliery, difficulties have been experienced with the steering of the ISM 3000 heading machine. Integral roof bolting operations also proved to be difficult to engineer into the system. It is now planned to extract the remnant pillar at this colliery by use of conventional heading machines.

7220-AB/207 Mechanised drivage of circular or elliptical roadways with heading machines - INIEX

Duration from 01.09.1985 to 31.08.1989

Circular or elliptic heading drifting by means of a point attack machine.

To develop and to prove a new heading machine able to drive circular sections.

The assembly of the heading machine prototype in the workshop was completed during the first semester, so that in the beginning of October it could be dismantled and transported underground to drive a circular heating (workplace No.1016, Zolder Colliery, NV Kempense Steenkolenmijnen).

The transport and assembly of the equipment have been achieved within 40 shifts.

The drivage operations started on 22nd December.

The rates of advance have rapidly increased from 0.6 to 2.4 m shift, which represents a performance of 48 cm/m.s. The length of the driven heading amounts now to 32 m.

7220-AB/814 Development of a general purpose monitoring system for tunnelling machines - BCC

Duration from 01.04.1985 to 31.03.1989

A decision was made at the end of 1987 to build the monitoring system around British Coal's Multi-purpose Automation and Control Equipment (MACE) System. Work has concentrated on developing a suitable system specification incorporating essential parameters as the nucleus of the system and adding desirable features as optional extras. To obtain this information, use was made of a discussion document distributed to operating collieries. In parallel, development work to devise suitable transducers to measure essential parameters, such as oil levels, condition of filters, oil contamination, etc., has been carried out.

7220-AB/117 Increasing the range of application of mechanised drivage II - StBV

Duration from 01.04.1987 to 31.03.1990

1. Further development of mechanised drivage for difficult operating conditions

In mechanised in-seam drivages, more severe demands will be made on support arrangements as depths increase. Studies were carried out to investigate the suitability of formwork systems. In particular, methods of support which are known in tunnelling technology were investigated to determine whether they were suitable for use in in-seam roadways. An even distribution of stresses around the drivage system can be achieved by placing material behind a shuttering close to the head end. Structural action can be taken to deal with early convergence. Methods studies have shown that the use of formwork can increase the rate of advance of a mechanised drivage by 50%.

2. Development of monitoring systems

Stationary and mobile measuring systems were installed in two mines so that drivages could be assessed on the basis of objective data and cutting aids could be provided for the machine operators. The development of suitable processing software makes it possible to link the measured cutting paths with the electrical power consumption of the cutting motors and to display the relationship so that the heading face can be cut systematically to improve performance.

3. Further development of new activated cutting tools

The development of an electro-mechanically activated head is intended to substitute oscillation for the high static thrust forces required to break rock. Performance was substantially improved by increasing the drive power from 25 to 75 kW and the centrifugal forces from 200 to 600 kN. The horizontal amplitudes, which adversely affect the operation and life of the activated head, were considerably reduced.

7220-AB/118 Mechanised heading systems for special roadways - StBV

Duration from 01.04.1987 to 31.03.1989

With a view to mechanising work on in-seam roadway junctions, model studies were carried out at the mining department of the Clausthal Technical University on a system consisting of a modified Webster 3000 CL cutter loader with integral manipulator for support withdrawal and setting and a dinting machine. These studies showed that the equipment satisfied the requirement for the 'making of a roadway junction and setting of the first supports complying with the normal support rules in the branch roadway', subject to only minor reservations. The method was calculated to be 15 to 17% cheaper than conventional practice when transport, assembly and dismantling costs were taken into account. The investigations were continued with the aim of assessing the suitability of the system for the following applications:

- drivage of the branch roadway beyond the first normal supports,
- drivage of short roadways,
- preparation of launch chambers for conventional mechanised drivage systems.

Model studies were also carried out at the mining department of the TU Clausthal on a system comprising a scrolled sumping head in combination with an impact ripper and support setting device for drivage of gateroads accompanying production faces. The system was shown to be technically feasible. However, a calculation of costs revealed that with a possible advance rate of 4.8 m/d the specific drivage costs were 25% higher than in drill-and-fire drivage. The possibility of using the Webster 3000 CL cutter loader mentioned above is now being investigated.

7220-AB/121 Development of a new system for the cutting of accurate roadway profiles (II) - StBV

Duration from 01.07.1987 to 30.06.1990

Work was completed on investigating the applicability of abrasive high-pressure water jets to drivage in coal mines, with particular reference to the cutting of sandstone.

The basic research yielded optimised parameters which improve the performance and cost-effectiveness of high-pressure water jets with abrasive feed. Because of the high specific energy requirements, however, this technique is to be preferred to proven cutting technology only for special applications. It should therefore be used only for duties which cannot be performed by conventional cutting.

In the current state of the art in abrasive ultra-high pressure jet cutting technology, problems arise with regard to power requirements for the necessary exposure and slot width, cost-effectiveness and applicability in terms of system engineering. The only possible designs based on roadway profiling using abrasive ultra high-pressure water jets are therefore those in combination, e.g. with roller cutters. This cutting technology cannot be used in the designs so far investigated.

In an attempt to identify new means of slotting in rock for a drivage method based on the roadway profiling principle, a miniature cutting head with PCD tools was developed. Initial trials on a test rig were carried out

in a strong artificial stone and in a high-strength sandstone. Since the results of these trials were positive, further work was carried out on design and construction.

7220-AB/210 Improved efficiency of gateroad dinting techniques - INIEX

Duration from 01.09.1987 to 31.08.1991

Increase of the efficiency of the dinting operations in the gates.

To develop new techniques and equipments to increase the efficiency of the dinting operations.

1. Specification book

A specification book has been completed. Two major conclusions have been highlighted:

- the most difficult problem to solve is the loading of the products over the conveyor belt,
- there is a place in the Kempense coal fields for different dinting equipments owing the varying operation conditions:
  - dinting behind the coal face
  - dinting of the whole gate length
  - dinting of gate parts which are submitted to specially high strata pressure

2. Inquiry by constructors

Several mining equipment constructors have been contacted and it seems that several equipments could be used to develop a new prototype.

A joint venture is possible within the limits of the project.

3. Development of new equipments

3.1 Dinting machines

3.1.1 Machine HZ IB

A face-end machine has been adapted to perform dinting operations.

The machine has been tested underground, the results showed that the cut principle is good but it would be necessary to increase the cutting power.

3.1.2 Machine ESA 60

On the basis of the experience gained by the trial of the machine HZ IB, it has been decided to develop a new prototype from the parts of the ESA 60 machine.

3.2 Mobile conveyor

The problem of the loading over the conveyor belt is now being studied separately from the dinting operations.

A mobile conveyor prototype is being developed.

7220-AB/815 Phased high-pressure water for heading machines - BCC

Duration from 01.04.1985 to 31.03.1990

With regard to roadheaders, trials were carried out with a prototype phasing device at an underground site. A fail-safe feature has now been added and a production version, partly incorporated into a boom trunk section, has now been produced. This has successfully undergone trials. An operational site is now being sought. Trials have also been carried out with a cam-operated system for shearers. As a result of problems encountered, the use of mechanical systems have now been discounted. Effort has subsequently been concentrated on the development of hydraulic phasing devices. It is expected that the first underground trials of this system will take place in spring, 1989.

7220-AB/209 Driving of rise headings with pilot borehole - KS and INIEX

Duration from 01.10.1986 to 30.09.1990

The purpose of the project is to transfer to the Belgian collieries the technology of guided longhole drilling developed by British Coal; a pilot hole has to be bored with a 'down-hole' motor on a length of about 240 m in a coal seam; the position of the bit is controlled by a probe measuring the natural gamma radiation of the rock strata above and below the bit. The pilot hole will be further reamed to a diameter of 600 mm so as to improve the ventilation of the heading and to ease the cutting of the coal during the driving.

Measurements of natural gamma radiation in Belgian coal seams have taken place and showed that the technique is applicable in Belgium. The gamma sonde was of course approved by the Belgian Mine Inspectorate.

A mission to the British Coal Technical Headquarters to train a Belgian engineer in the technology of guided hole with gamma probe foreseen in 1988 has to be postponed in 1989. Despite several problems with the probe, still under development by British Coal and the manufacturer SEI, the project is going on smoothly and an in-seam trial is being organised for September 1989.

The following technical reports are to be issued in 1989:

- inventory of techniques for in-seam drilling and horizontal steering;
- draining of the cuttings during reaming;
- support of the hole after reaming.

7220-AB/813 Development of an instrumentation package for guided longhole drilling - BCC

Duration from 01.08.1984 to 30.07.1988

This project has been completed during 1988 and a final report has been prepared. Work during the year has centred around the evaluation of various types of instrumentation such as the SEI Mk.2 survey probe, azimuth sensing,

longer range strata interface sensing and measurement-while-drilling (MWD) instrumentation. Survey probes have been used in underground trials with no reported problems. Developments with extended strata interface sensing has continued with systems based on radar and acoustic approaches. Down-hole testing has been carried out on the MWD systems.

SUPPORTS

7220-AB/816 The use of exploration techniques in the design of mine entries - BCC

Duration from 01.10.1986 to 30.09.1989
Subcontractor: Newcastle University

The comprehensive suite of geophysical wireline logging data for the Poplars borehole at Lea Hall Colliery, near Rugeley in the West Midlands (supplied by British Coal) has been transferred to the Newcastle University mainframe computer for analysis and can be successfully handled there.

Approximately half of the 68 waxed core samples from Poplars borehole have undergone comprehensive rock testing as itemised in the previous six monthly report. Some initial correlations between some of the more important rock and geophysical properties have been conducted. Empirical relationships have been developed which should provide reasonable predictions of unconfined compressive strength and static Young's modulus from compressional wave velocity and neutron response: these are adequate for practical purposes.

Arrangements have been made to instrument B48's cross-measures drivage at Lea Hall Colliery, the start of which, unfortunately, has been delayed until the end of May 1989. Most of the underground instrumentation has been purchased in order to compare excavation behaviour with the geophysical log data in the nearby Poplars borehole.

An interim literature review has been produced, providing a useful background to the project. A more comprehensive review is expected within the next six months.

7220-AB/208 Adaptation of reinforced concrete panel support to roadway diameters over 4.20 m - INIEX

Duration from 01.04.1986 to 31.03.1990

Adaptation of the concrete panels support to circular gallery with a greater diameter than 4.20 m.

- Adaptation of the drivage techniques based on the use of the tunnelling machine Bouygues.
- Development of new concrete segments.
- Development of new panel handling techniques.

1. Adaptation of the drivage techniques based on the use of the tunnelling machine Bouygues

The tunnelling machine has been put again into service to drive a connection between the collieries Zolder and Beringen. The circular section of the driven roadway has a 4.20 m diameter and is lined by 30 cm thick concrete panels.

The machine had to drive a curve with a radius of ± 120 m. The conveying system must be adapted for these special requirements.

The average performance achieved during the curve drivage was 13 cm/m.s.

2. Development of new concrete panels

Several compound panel types have been manufactured.

They are composed of concrete panels into which 40 mm thick compressible joints are equally distributed. The diameter of the reinforced bars vary following the panel type between 8 mm and 16 mm.

The panels must be soon tested underground at Zolder Colliery.

3. Development of new panels handling techniques

The development works have led to the manufacture by Klöckner Becorit GmbH of a new handling machine which hangs on the monorail.

The prototype is able to hand 1.5 ton concrete panels and to set them in a 5.1 m diameter circular section.

7220-AB/817 Testing roadway support systems - BCC

Duration from 01.09.1986 to 30.08.1990

To date 57 'bench-mark' support assemblies have been tested. These have been with a fixed width but with variations in section size, support profile and loading configuration. The major loading configurations used have varied from single point loads to triple point loads with side restraint. The profiles used so far include arches and rectangular supports. The section sizes have included 152 x 127 mm, 127 x 114 mm and 114 x 114 mm. Tests on supports with a section size of 102 x 102 mm are currently being tested to complete the first phase. Future tests will centre on variations in support width and joint strength.

7220-AB/119 Improved support techniques for gate and main roadways - StBV

Duration from 01.08.1987 to 30.07.1990

The development of composite strata bolts and investigation of mesh for use in conjunction with bolts progressed to the point where it was possible to carry out a large-scale trial. These bolts were successfully used at the Rheinland Colliery on an 86 m length of face and demonstrated their ability to absorb considerable deformation. Progress was also made in the use of tubular bolts for grout injection.

Model and test rig studies with yielding arches revealed considerable scope for improving the elastic and plastic deformation of the arches. The investigations clearly showed that it was not desirable for coal mines to adopt the arch form normally used in tunnelling (section sides open towards the roadway) since this shape absorbed less deformation than that customarily used in the coal mining industry.

Laboratory tests with pulverulent materials showed that although they were naturally late-bearing they could be made early-bearing when processed as a paste by adding a liquid accelerator.

7220-AB/120 Improved dimensioning of roof bolting support in main and gateroads - RWTH

Duration from 01.10.1987 to 30.09.1989

Investigations were carried out in 1988 into the way in which subsequent strata behaviour around a roadway can be influenced during tunnelling. This led to a recommendation to go back to the idea of roadways of small cross-section, and to choose a profile in the form of a horizontal ellipse.

The interaction between rock properties and support characteristics can be described diagramatically, showing that there is an interrelationship between the stress in the surroundings of bolted roadways, the support strength and the break-up of the strata, and that this exists over the whole lifetime of the roadway. A comparative study has been undertaken of the interaction of various types of bolt with the strata.

Evaluation of the influence of bolts on strata movement at slip planes was also carried out. By considering the bolt strength and tension it is possible to calculate the most favourable angle for the placing of bolts in relation to slip planes.

Towards the end of the year an investigation was begun to relate occurrences of damage in bolted roadways more closely to their causes, using data provided by the mines.

7220-AB/751 Geomechanics and roadway support in a deposit having complex geological structures - douro

Duration from 01.11.1987 to 31.10.1989

- Geological characterisation: continuation of the detailed geological mapping with particular incidence in lithologic types and tectonics. Total metres 1 700.
- Mechanical characterisation: continuation of the sampling in representative geological units. Total metres of sampling 60.
- Geomechanical characterisation: continuation of the convergence systematic measuring. Installed already 165 stations in metallic support and 165 stations in rock.

Continuation of the development, in a personal computer, of the database for the convergences. Obtention of graphics about, the evolution of the behaviour of the rocks and respective support and the lines of the equal behaviour.

- Superficial geomechanical characterisation: subsidence systematic measuring. Installed already five transversal line and one longitudinal of reading. Continuation of the database for the subsidences and the obtention of graphics about evolution of the subsidences.
- Beginning of the Pullout resistance tests of the roof-bolt.
- Interpretation of the results in due course.

7220-AB/818 Development of geotechnical software for roadways and support systems - BCC

Duration from 01.04.1987 to 31.03.1990

This project, essentially, has concentrated on producing a suite of software programs intended to assist specialists involved in all aspects of support system design. A desk-top computer program has been completed to allow the design of rectangular pillars (RPILLARS). Storage and retrieval programs to assist with data presentation and database management have been produced. A program to analyse data from strain-gauged rock-bolts is close to being fully developed. Also under development is a program designed to analyse and compare various theoretical and empirical methods of designing rock-bolted roadway support systems.

7220-AC/831 Further work on design and stability of roadway support systems - BCC

Duration from 01.04.1985 to 31.03.1988

Work on this project was completed in 1988 and a final report has been produced. The main areas of investigation were: gateroad stability associated with thick seams; concrete circular supports; major spine roadways at Selby; physical scale models; the mechanical characteristics of steel support system components; numerical prediction techniques.

SHAFTS

7220-AB/116 Shaft lining in water-bearing strata at great depth - StBV

Duration from 01.03.1986 to 28.02.1989

A program system was developed and installed for numerical frame analysis of stress and strain phenomena affecting shaft curbs and arch supports, and development of the associated software was completed.

Investigation of the bearing characteristics of various designs for the outer linings of shafts sunk by the freezing technique was completed. Measurements of the tangential expansion at the lower end of the outer shaft lining above the free face show that when the face is displaced the stresses on the relatively rigid outer shaft lining are rearranged. This leads to additional stress.

The computer program developed to optimise composite shaft linings was tested.

7220-AB/819 Alternative mechanised systems for mine shaft formation - BCC

A state-of-the-art report has been compiled describing all known methods of shaft sinking through water-bearing strata. Appraisals of blind shaft boring and shaft drilling techniques, together with recommendations as to the most suitable systems for specific shaft-sinking sites, will be complete by spring 1989. Sub-contract work at Newcastle University is concentrating on investigations into microsilica concrete as a suitable material for lining mine shafts.

7220-AB/309 Higher rates of advance in conventional stone drivages - CERCHAR

Duration from 01.07.1988 to 30.06.1990

Better working conditions, higher rates of advance, better organisation and lower costs through the application of most modern technical means in conventional stone drivages in order to optimise each phase of the cycle.

Drilling:

- twin drilling jumbo with hydraulic drilling machines (drilling speed 3.5 to 4.5 m/min);
- improvement in profile cutting by the storing in memory of several standard drilling schemes as well as programming the drilling tools by microprocessor.

Loading:

- electro-hydraulic loading machines with great capacity (2 m^3), improving the system of mine-car exchange, advancing and belt prolongation.

Support:

- improving the drilling techniques for roof-bolting (jumbos with hydraulic jacks, new drilling bits);
- mechanisation of support setting in roadways with arch-type support.

The project began in the second half of 1988. Noteworthy results have already been obtained in one drivage as soon as it started up in respect of shot-hole drilling, loading times and time required for strata bolting. For example, a drivage rate of 8.7 m/day was achieved in a roadway of 28 m^2 cross-section in the month in which the drivage began.

7220-AB/211 Optimisation of tunnelling driving techniques with a Bouygues TBM with the aim to improve rate of advance in various working conditions - KS and INIEX

Duration from 01.08.1988 to 31.07.1991

To improve reliability and maintenance of machine components so as to diminish breakdown.

Adaptation of the machine so as to drive a curve.

Settlement of new panels ('voussoirs') to increase compressibility of tunnel support.

The driving of the curve has been carried out successfully, as foreseen by the feasibility study.

A review of the hydraulic components and other spare parts is being made.

Drawings of new 'voussoirs' have been made taking into account results of other research works. The fabrication will start early 1989 and in-situ measurements will begin three months later, in relation with TBM driving technique.

7220-AB/752 Construction and underground testing of a boom header for the mechanised drivage of roadways in coal at small cross-sections - MSP

Duration from 01.09.1988 to 31.08.1990

Increased performance and speed in small roadways in coal (9 m^2 maximum) by the development and testing of a boom-type roadheading machine (type WAV 250) of smaller physical dimensions and lower weight than other machines. The new roadheader will have total power of 390 kW and will be equipped with ancillary devices for the setting of supports.

- Planning and design of the machines.
- Construction of a prototype (Westfalia Lünen).
- Underground trials on the La Camocha Colliery (six months).

7220-AB/820 Visual indicator for position and alignment - BCC

Duration from 01.04.1988 to 30.09.1990

More safety (no personnel near the boom) and better profile cutting by the development of a visual aid to the operators, while still retaining normal manual control of the machine.

- Development of a microprocessor-based system to indicate the position of the boom relative to a stored drilling pattern or profile (sensor module).
- Mathematical calculation to convert the various signals into meaningful values.
- Development of an operator's display representing a mimic of the boom and its position related to the front.

Work on this project started in 1988. A boom, PTT type DB 1220, has been chosen for all trial purposes. Initial work assessing various transducers, instrumentation systems and display methods have been undertaken.

7220-AB/821 New cementitious matrices materials for multi-purpose uses underground - BCC

Duration from 01.05.1988 to 31.10.1991

Reduction in material types and costs as well as safer handling by the development of a new family of cementitious materials as an alternative to ettringite and using raw materials that are readily and cheaply available.

- State-of-the-art study investigating current theory and practice.
- Study of chemical and structural/physical variations.
- Improvement of existing ettringite systems by use of alternative materials.
- Chemical investigations into a new cementitious matrix (or matrices) including gypsum-based and calcium sulphate systems.
- Investigation into the development of dual or single mix systems including appropriate additives for different applications.

Work on this project commenced in 1988. A literature survey has been carried out on the use of ettringite systems. Some evaluation work on calcium carbonate bases has been carried out, together with investigations into aluminates. Various ground granulated blast furnace slags have been incorporated into existing packing systems to assess the effects on pack performance, especially with regard to strength development.

7220-AB/822 Mechanised setting of roadway supports - BCC

Duration from 01.04.1988 to 31.03.1991

Better working and safety conditions, increased machine running time and advance rates as well as cost reduction by the development of support setting devices to be used in conjunction with roadheading machines and allowing support assembly and erection to be carried out simultaneously with cutting and loading operations.

- Study of conventional support setting operations in order to assess the techniques employed and to identify problem areas.
- Investigation into previous research and development to assess what elements could usefully be adopted within the new development.
- Survey and assessment of equipment already available.
- Final specification and scheme for a prototype device, and design and construction of such a device.
- Demonstration of the prototype and assessment of its performance and potential.
- Design and manufacture of a production version for full-scale underground trials prior to exploitation.

Work on this project started in 1988. An appraisal has been made on the scale model used as a first design. The arch erection system has been redesigned to accommodate three piece arch profiles. A specification for manufacturing purposes is currently being drawn up.

7220-AB/823 Roof bolter and mobile roof support - BCC

Duration from 01.06.1988 to 31.05.1990

More safety, higher drivage rates, less roadway repair and reduction of costs through the use of roof-bolting, either to reinforce existing arch girder support or as supplementary support allowing the setting of arches at wider intervals.

- Completion of an existing mobile roadway support device by drilling and roof-bolting equipment.
- Design and manufacture of a prototype.
- Underground trial (three months) and redesign if necessary.

Work on this project started in 1988. An initial design of mobile roof support has been agreed with the sub-contractor. This design is in modular form to cater for a range of roadway support profiles. The prototype will be constructed in spring 1989. Underground trials will then commence using at least one commercially available roof-bolting machine attached to the mobile support.

7220-AB/122 Controllable, directional, drilling system for drilling pilot holes in all directions - StBV

Duration from 01.04.1988 to 31.03.1991

The autonomously controlled directional drilling system developed by Bergbau-Forschung GmbH and Schwing Hydraulik Elektronik GmbH and Co. has so far been used successfully, both in Germany and abroad, to drill a total of 45 holes up to 600 m in length, mainly upwards but also downwards in many recent cases.

Further upward trial holes, each 100 m in length, have been drilled accurately with the Bergbau-Forschung experimental drilling rig at the Tremonia experimental mine. A simulation borehole was prepared to test the new sensors and drilling system components required to enable the directional drilling system to be used in drilling deep downward holes. This facility allows drilling conditions in deep holes, such as high pressures and temperatures, to be realistically simulated.

At the same time, a drilling site with a mobile deep-drilling rig was set up at the Herdecke testing facility to allow the operational reliability of the directional drilling system to be further improved in downward drilling to great depths. Since the stresses imposed on the system when used on a rotary table rig differ from those in previous applications, particular interest attaches to the effects of the drilling process on the performance of the guidance system. The lessons learned from the trial and the consequent technical improvements represent a major step towards the planned use of the system in the Continental Deep Drilling Programme.

With a view to further development of the system for guided drilling in all directions, laboratory work for the development of a suitable navigation system was completed. The further stages of development concern the adaptation and integration of the navigation system so that it can be accommodated within the limited space available in the directional drilling system.

7220-AB/824 Effect of in-situ stress on mining conditions - BCC

Duration from 01.07.1988 to 30.06.1991

Improvement of mine safety and of the economic results of several new mines by investigating the phenomena of high in-situ deviatoric stresses in virgin coal fields with single-seam working and by overcoming the related serious strata control problems.

- Measurement of the in-situ stress field at a number of sites where anomalous stress fields are suspected of causing unusual strata control problems.
- Relation of the observed modes of rock failure to the measured magnitudes and directions of in-situ stress as modified by stress concentration effects around the excavations.
- Development of methods whereby mines may be planned to alleviate strata control problems associated with anisotropic virgin stress.

Work started on this project in 1988. Preliminary work has been carried out to assess the feasibility of using the overcoring method to measure stress in a coal mine, especially with regard to the equipment necessary. Observational techniques are also being compared with breakout logs as a qualitative tool.

I.2 ACTIVITIES OF THE COMMITTEE OF EXPERTS ON MINE GASES, VENTILATION, CLIMATE

One of the most important problems arising in this Committee's area of activity is dilution of the high firedamp concentrations originating at the top ends of retreating faces. While longwall retreating is recognised as the method with the greatest potential for productivity, failure to solve these problems might be a major constraint. Some of the new projects starting in 1989 will address this problem.

The Committee of Experts met on 12 and 13 April 1989 in Essen and was thus able to acquaint itself directly with some of the projects being conducted at the Bergbau-Forschung and to visit a mine to see the ventilation systems (including air cooling and dust extraction equipment) in a highly mechanised drivage.

The Committee of Experts approved three final reports concerned with the problems of main ventilation with partial air recirculation and of air cooling in drivages using heavy-duty machines. Four new projects were started.

The most notable results were as follows:

- use of partial air recirculation systems in an undersea mine, making it possible to reduce the air quantities entering and leaving the mine and hence the required roadway sections;
- a new computer program for climate prediction in drivages, allowing greater accuracy than existing programs in areas containing several auxiliary ventilation ducts and heavy-duty machines;
- adaptation of existing climate prediction programs to other European coal fields.

7220-AC/826 Further studies of the controlled recirculation of air in mine workings with particular attention to transients - BCC

Duration from 01.08.1984 to 30.07.1987
(Approved at the meeting of 13.04.1989)

The primary purpose of a mine ventilation system is to provide a safe and suitable working environment. As faces become more remote, mechanised and productive, this objective becomes increasingly difficult and costly to achieve.

In many UK coal mines air is transported over great distances, in some cases over 10 km, which sometimes results in insufficient air being available at the faces to achieve the desired velocities, although this air is often returned in a relatively uncontaminated condition. In 1984 British Coal's total power costs were £182.5 M of which 35% was directly attributable to ventilation operating costs (Pearce, 1984).

Recirculation studies were conducted within the Department of Mining Engineering at the University of Nottingham in three main areas:

- the characterisation of recirculation circuits and the optimisation of circuit design;
- the study of multi-district recirculation transients and the application of monitoring and control;
- the study of the effect on the climate of the application of recirculation for highly mechanised mines possessing a VST in excess of 30°C.

This report also attempts to provide an overview of the topic and to identify the differing effects which may be produced within a recirculation circuit if various design parameters are altered or external constraints are applied to the operation of the recirculation system.

Recirculation involves the re-use of air within an area of a mine. In the case of district recirculation this would be achieved by passing a controlled proportion of the return air, known as the recirculation fraction, through a suitably constructed crosscut outbye of the face and back into the intake airway. The recirculation of mine air has in the past been avoided principally because of the fear of a build-up of pollutants, particularly methane concentration in the general body of the air. This is reflected in the UK 1954 Mines and Quarries Act which forbids the installation of an auxiliary fan unless the supply of fresh air is sufficient to ensure that recirculation does not take place.

The preliminary theoretical steady state studies (Anon, 1984, Hardcastle et al, 1984) confirmed that there is no build-up of contaminants such as gas or dust around the recirculation circuit. Further verification of the theory was provided by Robinson who conducted short trials of a district recirculation system at Wearmouth Colliery (Pickering and Robinson, 1984). Passing contaminated air into the intake airstream will cause the intake air contaminant concentration to rise. However, provided that the recirculation does not cause a reduction in the fresh air supplied to the district, the maximum return air concentration will not rise. The increase in intake concentration will, however, be small. Thus recirculation by increasing the face air velocity ensures a more rapid dilution of methane at source and hence reduces the risk that flammable gas will ignite.

It has also been predicted (Stokes, 1982) that in mines possessing a VRT of up to 30°C district recirculation will provide a higher value of air cooling power or lower effective temperature which reflects an improvement in the climatic conditions.

Fires represent a more difficult problem as products of combustion cannot be allowed to enter the fresh airstream. In the case of a fire within the recirculation zone, the recirculation fan would have to be stopped and the crosscut doors closed. This would revert the ventilation to that of a conventional system, leaving the intake free of recirculated contamination. For the above reasons, a recirculation district would have to be extensively and reliably monitored. This is becoming more feasible with the evolution of the current generation of online environmental transducers.

However, it is prudent that in order to site correctly and subsequently interpret the transmitted data from these transducers, the steady state flow and pressure patterns both within and outbye of the recirculation zone are well known, that is the behaviour characteristics of the particular circuit are understood. Secondly, so that the appropriate remedial measures may be implemented on the detection of an abnormal occurrence, such as an outburst of methane from the strata, there exists a great need to be able to simulate the causes and determine the subsequent transient behaviour within a recirculation circuit.

In addition, the exploitation of deeper coal reserves in the British coal field has meant the introduction of highly mechanised longwall coal faces in strata zones with VST temperatures in excess of 38°C. Therefore an extension of the earlier work of Stokes has been conducted to evaluate the effects this will have on the mine climate of such districts on the application of controlled district recirculation.

The majority of the initial research at Nottingham considered the application of controlled recirculation to a single district. However, it is now envisaged that recirculation will often be effected around a zone containing two or more working districts. There is therefore a demand for the prediction of any general characteristics which such systems might possess so that the recirculation system may be designed to operate safely and efficiently. Coupled to the design of such a system is the ability to predict the effect of any transient processes so that the relevant manual or automatic control mechanisms may be instigated. An investigation into the possible contribution of controlled recirculation in the strategy of producing a satisfactory mine climate around highly mechanised faces operating in VRTs in excess of 30°C has also been conducted. The following three chapters of this report summarise the recent work which has been carried out into these three subject areas.

7220-AC/315 Improvement of mine climate in workings with new, very powerful machines - CERCHAR

Duration from 01.03.1985 to 29.02.1988
(Approved at the meeting of 13.04.1989)

This report describes a method developed with a view to predicting climatic conditions in drivages equipped with full-face or selective heading machines and quantifying the impact of possible lines of action.

First of all it was necessary to:

- carry out a series of in-situ measurements covering various phenomena,
- develop physical models for interpreting those phenomena regarded as important,
- integrate these models into a computing program.

The aim of this report is to describe these stages and to explain the procedures used to validate the program from measurements and perfect the prediction method.

It also takes stock of various possible lines of action and shows how using the program allows their impact to be quantified and the best method to be selected.

The main report is followed by two annexes describing the following physical models:

1. Consideration of temporary phenomena in the surrounding strata.
2. Steady state resulting from the uniform advance in rock of a fixed-temperature face.

Eight series of measurements were carried out, three in a heading driven by a tunnelling machine and five in workings driven by selective heading machines, and led to the formulation of a criterion to assess whether the air flow rate at the face is sufficient or not from the point of view of climatic conditions. It was shown that where the ratio between maximum power dissipation in the zone with exhaust ventilation (in kW) and the air flow rates in this zone (in kg/s) were below 150 kJ/kg, the amplitudes of climatic variations in time remained moderate, which was not so above this value.

The measurements enabled energy consumption ratios to be calculated in kWh per m^3 of ground excavated.

With regard to the influence of power dissipation on climatic conditions, it was found that there was:

- a clear link in drivages equipped with a tunnelling machine,
- a much less clear link in workings driven by selective heading machines with non-continuous ventilation for dedusting.

Finally, the measurements were used to prepare energy balances quantifying the roles of the various factors in the evacuation of heat. It proved essential to take account of water use and spraying.

For the development and validation of a prediction method, a model was designed to take into consideration, in simplified fashion, the energy exchanges which take place. This entailed assessing the significance of the 'wave' of heat in the rock, preceding the arrival of the face.

Two other models were also used. Developed by the Ecole des Mines in Paris, they take account of the temporary phenomena of heat accumulation and consumption in the strata surrounding the roadway.

These models were incorporated into a computing program called POLYFAN, which can, among other things, take account of any number and layout of auxiliary ventilation ducts. This program, written in FORTRAN, is IBM-PC-compatible.

Observations during in-situ measurements enabled it to be validated. The use of the POLYFAN program allowed the energy balances deduced from the measurements to be completed.

It was also possible to deduce rules relating to the influence of coal clearance method, water use, and intake air flow rate. Indications are provided with a view to:

- increasing the beneficial effects of this influence,
- limiting its adverse effects.

To summarise, a new method has been developed to predict climatic conditions in mechanised drivages, using a computing program by the name of POLYFAN. Further validation should be undertaken in cooled workings driven in hot ground (45°C or more), for other types of machine and other ventilation systems.

It proved very satisfactory when used in moderately warm ground. This is presumably due to the care taken to describe actual phenomena by specific models. This procedure did away with the need to carry out calculations using data which are artificially different from real data. Consequently, this is a genuine prediction method.

7220-AC/817 Investigation of factors contributing to mine climate - BCC

Duration from 01.10.1981 to 30.09.1986
(Approved at the meeting of 13.04.1989)

The aims of the work now reported were as follows:

1. To obtain more data for use in climate prediction, in particular with respect to the electrical power consumption of heading machines.
2. To construct testing facilities whereby the performance of typical cooling equipment used in British Coal mines could be assessed and to consider new ways of cooling coal faces.
3. To develop more refined methods of computer modelling of the heat flows occurring on coal faces and headings. Since air temperatures can fluctuate by as much as 5°C in these regions it was thought that modelling the transient heat flows would provide more accurate predictions, as well as giving a greater understanding of the mechanisms involved.

The work on this project can be conveniently divided into the following four parts:

1. heading machine energy consumption;
2. climate test facilities;
3. modelling transient heat flows in faces;
4. computer modelling of heading air temperatures.

The investigation of the power consumption of heading machines encompassed 13 sites, seven of which were driven through rock and the remainder through coal.

The climate test facilities were constructed at the Swadlincote Test Site in one of the Test Halls and consisted of a ducted air circuit which could either be coupled to an insulated room or a length of test ducting.

The modelling of the transient heat flow in faces has been achieved using a finite element method in order to simulate the variable geometry of a coal face caused by the machine cutting along it.

The computer modelling of heading air temperatures was developed using data from the full face tunnelling machine.

The general conclusions are as follows:

- The measurement of the power consumption of heading machines has resulted in the following empirical relationship for drivages in rock:

$$E_D = 3.35\ N + 10.8\ V_D + 3.23\ C - 6.14\ H - 770 \quad (1)$$

where

E_D is the daily energy consumption of the heading machine (kWh)

N is the nominal power (kW)

V_D is the daily volume of extraction (m^3)

C is the rock uniaxial compressive strength (MPa)

H is the rock shore scleroscope hardness index

and in coal

$$E_D = -2.72\ N + 0.78\ V_D + 0.095 + 473 \quad (2)$$

where S is the coal laboratory drilling specific energy (J/cm^3).

Equation 1 gave mean errors of ± 2.9% between the measured and predicted energy consumption over the range of 290 kWh to 1250 kWh. Equation 2 gave mean errors of ± 6.2% over the range of 190 kWh to 350 kWh. The results from the full face tunnelling machine driving through rock gave a mean daily energy consumption of some 5000 kWh, well outside the range of Equation 1.

- The construction of the climate test facilities has enabled testing of underground cooling equipment to be carried out under controlled conditions. These conditions simulate those met underground and, providing the cooling levels are not too high, operate between ambient and 35°C dry-bulb temperature and 95% RH. Although the maximum cooling levels measured were some 150 kW, equipment having a greater capacity can be tested at a reduced level and the results extrapolated to indicate their performance under operational conditions.

Two types of passive panels were examined, having capacities of between 0.5 kW and 1 kW, which could be used in banks to provide cooling in coal faces. Similarly, two gate coolers have been tested having nominal capacities of 100 kW and 200 kW. The relationship between cooling capacity, dry-bulb temperature, relative humidity, water temperature, water and air flow have been examined for each cooler. These have shown that the cooling system has its maximum efficiency when air and water flows are balanced.

- Solutions have been found for the transient cooling of strata surrounding both a face and a heading using a finite element method. In the case of the face model, the finite element method simplifies the treatment of the variations in face geometry caused by mining operations. For the heading, the method enables a greater precision to solve the heat transfer at the face of the heading, where by dint of the machine concentration and effect of advance the temperature field is more complex. Both models simulate the mass transfer from wet surfaces using the modified Lewis's Law for partially wetted surfaces.

- Computer programs have been developed which include the effect of steelwork, heat from machines and conveyed coal. In the case of the face program, a simple model is used to calculate the heat from the waste. Both models are written in Fortran but whereas the face model runs on an IBM 370/145 computer, that for the heading runs on an IBM PC. Both models have had limited testing and shown good agreement with underground data. Although the heading model was developed for use at Gascoigne Wood, when a full-face tunnelling machine is used, it is applicable to other sites.

7220-AC/121 Further development of methods of methane control - StBV

Duration from 15.03.1985 to 14.03.1988

The project will be discussed in the next Experts' Committee and we advance this summary.

This project consists of four parts. In order to investigate migration phenomena in ground affected by mine workings, the permeability measuring technique was extended to cover radial flow geometry in boreholes perpendicular to the strata. Several series of measurements were carried out in four mines at depths of between 820 and 1 220 m. The findings were as follows.

- The gas pressure increases about 35 m ahead of the faceline in the seam worked and about 70 m ahead of the faceline 90 m below that seam. The pressure peak shortly before the face passes through attains 1.6 to 5.4 times the original gas pressure. Thereafter, when the strata has been deconsolidated, the pressure declines at varying rates to the ambient pressure.
- The gas permeability coefficient is an inverse function of the gas pressure.
- The gas flow rates calculated from the pressure and permeability values increase about 15 m ahead of the faceline in the seam worked and about 30 m ahead of the faceline 90 m below that seam.
- The gas pressure, permeability and volumetric gas flow curves in the superincumbent strata are virtually mirror images of those for the underlying strata. Among the factors influencing them are the coal properties, adjacent strata strengths and the presence of water as a second flow phase. The very low gas permeabilities of about 10^{-4} md in seams not affected by mining explain why pre-drainage by means of in-seam holes is ineffective under such conditions. Only when the ground has been deconsolidated by overlying or underlying workings covering a large area does the permeability increase, thus making successful pre-drainage possible.

Investigations of the relationship between the pressure mechanisms and dynamic gas emission processes in the coal were conducted on a high-pressure press in the laboratory using cubic coal samples of side 150 mm and at loadings of up to 178 MPa since this is the only apparatus which allows systematic manipulation of various factors.

After preliminary tests with virtually gas-free samples, the sample cubes were saturated with methane at 20 to 25 bar and subjected to pressures of up to several times the cover load while being drilled. At loads in excess of 130 MPa relaxation phenomena regularly occurred, sometimes of a gas outburst type. In such cases, the drill cuttings exhibited the properties of an outburst coal. Mylonitization began during the drilling process and increased with drilling duration.

The experiments showed that laboratory investigations of this type provide a wider knowledge of the effects of gas pressure, strata pressure and coal characteristics on the onset and course of gas outbursts and rock bursts and thus create a better basis for more reliable prediction and effective precautions. A new test rig is being built for further experiments.

In the investigations aimed at determining maximum coal production as a function of gas conditions it became possible to measure the gas drainage parameters continuously following development of the vortex-shedding anemometer and the Mytron methanometer for concentrations from 0 to 100%.

In two districts, all data on ventilation and gas emission were collected throughout the entire face life.

In the first district, the effect of increasing face length from 150 to 220 m was mainly apparent in the firedamp drainage. Gas emission into the ventilating air depended primarily on output. Although the scope for floor drainage was limited because of hard sandstone beds, the percentage capture of the methane drainage system was above average at 70%. The fact that power had to be cut off from electrical apparatus as a result of excessive firedamp concentrations in the ventilating air on days when the level of methane drainage was reduced show that maximum output in a district with a high gas make is possible only with optimum firedamp drainage.

This was confirmed in the second district studied. The gas content in the seam worked had been reduced by pre-drainage from 14 to 2 m^3/t over about half the area to be mined. However, since the average gas content was still 6 to 8 m^3/t, the face output came up against the limits of the methane removal capacity of the ventilating airflow and drainage system and downtime as a result of firedamp emission increased from 11 to over 20% as the face advanced. The only answer was to cut production from three to two coaling shifts. It also proved beneficial to adapt the ventilating air quantities to the variations in methane emission with time and location. This was made possible by computer-aided monitoring of the airflow and firedamp drainage.

Because of technical difficulties in constructing the necessary test apparatus it was not possible to proceed as planned with the water infusion experiments in cubes of coal saturated with gas and subjected to mechanical pressure which had been intended to contribute to improving methods of outburst prevention. A review of the literature was carried out, particular emphasis being placed on Eastern European publications in recent years.

The work is being continued under project 7220-AC/126.

FIREDAMP

7220-AC/832 Short-term forecasting of methane emission levels using continuously monitored data - BCC

Duration from 01.04.1986 to 31.03.1988

The project has shown that continuously monitored underground environmental data can be used to generate algorithms to forecast expect' methane emission given an estimate of the intended coal face advance on a shift by shift basis. Such algorithms, on colliery computer systems, would have the potential to highlight unusual emission trends and thus permit palliative measures to be taken in time to reduce the risk to life and production.

Two main approaches were used to produce suitable algorithms. The first involved generating a simple, constrained, empirical model and using measured data to fix its parameters. The second was to produce a program, not yet completed, based on a shift by shift theory of gas emission and to compensate for any consistent difference between predicted and measured data with a simple scaling factor.

A final report has been written.

7220-AC/829 Machine ventilation and face gas emission - BCC

Duration from 01.07.1985 to 30.06.1989

Theoretical and experimental work in connection with design and performance aspects of a coal face machine ventilation device, known as the Extraction Drum, has been virtually completed.

A new approach to the problem of forecasting coal face machine ventilation requirements, acknowledges that in making a prediction of gas emission in the vicinity of the coal cutting machine, consideration needs to be given to a range of sources including the coal face, uncut coal in the roof or floor, cut coal in the shearer drum, cut coal on the conveyors, coal seams in the immediate floor and developments that may pollute intake air. Temporal elements of the new model mean that effects of changing coal face advance rate and machine speed can be investigated. The algorithm has yet to be proved for machines without cowls.

7220-AC/834 Prediction of gas emissions on short faces and drivages - BCC

Duration from 01.10.1987 to 30.09.1989

Detailed gas emission data have been obtained from coal faces of lengths varying from 35 m to 200 m in the Selby coal field. Strong roof strata appear to be playing a major role in the development of gas emission across the coal field. The effects of strata strength, face length and face depth upon the degree of gas emission are currently being evaluated.

7220-AC/318 Irregular gas emissions in headings - CERCHAR

Duration from 01.07.1987 to 30.06.1990

One of the ways of attaining the project's aims is to characterise gas emissions in mechanised headings. The more drivages we study, the more accurate the results of this exercise will be. For this reason, work in the second half of 1988 concentrated on new mechanised drivages where heading started in 1988.

To characterise gas emissions in a drivage, we have to:

- record the level of CH_4 in the heading,
- have details of airflow, stratigraphy and the concentration of gas in the coal,
- know the working conditions.

Throughout the project, work has been conducted in conjunction with the UST (Unité des Service Techniques) and the HBL (Houillères du bassin de Lorraine).

7220-AC/751 Automatic control of systems of prediction and prevention of gas outbursts in order to allow the mechanisation of coal winning in hazardous seams - HUNOSA

Duration from 01.09.1987 to 28.02.1990

The purpose of the project will be to use microseismic techniques in the low-frequency range to find 'symptoms' identifying outburst-prone areas, the research being geared to locating the place where the phenomenon may occur. The project will also encompass environmental monitoring of the zone concerned.

Two parallel lines of action have thus been laid down:

- an environmental monitoring system (SISCOM II);
- a seismo-acoustic monitoring system.

The type of response to be transmitted by the environmental monitoring sensors has been specified, as has their location.

The signals received from the sensors and the operating commands will be generated from intelligent remote stations.

The Empresa Ingenieria Honorio Flórez (IHF) will collaborate in producing the environmental monitoring system.

The technical specifications and system logic have been completed and six remote stations are currently being produced with their supply sources, relays and communications interfaces.

Contact has been maintained with CERCHAR, British Coal (Swansea and Cardiff Universities) and the Instituto Geográfico Nacional (IGN) with regard to seismo-acoustic monitoring.

A surface seismic survey has been carried out in collaboration with the IGN.

A system for monitoring below ground has been devised in collaboration with CERCHAR and the necessary equipment is now being acquired and developed. British Coal has been asked for its assistance in the analysis of the surface records.

7220-AC/124 Monitoring and control of secondary ventilation equipment in mechanised headings - StBV

Duration from 01.07.1986 to 30.06.1989

In accordance with the research objectives, the following work was carried out and results obtained in the period covered by this report.

- Program development for the COMPEX stored program control unit (from the Tiefenbach company) for control and operation of a self-monitored auxiliary ventilation system.
- Final adjustment of the 70 kW fan motor to the BbM 160/500 constant-current converter (AEG).
- Determination of the performance characteristics and efficiency of the converter/fan combination in a test duct at the HGK fluid mechanics laboratory.
- Acquisition of a data transmission system and testing in conjunction with the transducers.
- Calibration and adaptation of the instruments for use with the plant configuration for service underground.
- Determination of correction coefficients for transducers for volumetric flow measurement in auxiliary ventilation systems.
- Testing the microprocessor-controlled plant combination and integrated component test for all necessary instruments in the HGK fluid mechanics laboratory.
- Checking of the program section for self-monitoring of the main air duct in respect of the resistance factor and leakage losses.
- Running-in of the fan motor with a view to approval of the plant combination for service below ground.
- Commissioning of the auxiliary ventilation system with microprocessor control and volumetric flow regulation for underground service at the Prosper Haniel Colliery.

After intensive trials of the whole system, including the audiofrequency transmission, pit trials began on 16 December 1988 at the Prosper Haniel Colliery, shaft 10. The auxiliary ventilation system with automatic control and volumetric flow regulation is being used for a new in-seam roadheader drivage of 18 m^2 cross-section at a depth of 1 000 m in seam 'R'. The main duct is 1.2 m in diameter and the duct length at the end of the year was 270 m.

As far as can be seen from the fairly short period of service, the system is working satisfactorily.

7220-AC/833 Feasibility of controlled ventilation - BCC

Duration from 01.03.1986 to 29.02.1988

The now completed study indicated that by exploiting currently available ventilation planning tools, more cost-effective ventilation systems could be designed and substantial savings in power costs achieved. The principle of selecting a main fan to run at a minimum duty in conjunction

with suitably sited underground booster fans can lead to a substantial lowering of power costs, compared with conventional whole mine ventilation from a surface fan. Air supply and demand could be more closely matched if greater use was made of variable speed fans, especially during non-production periods, when considerable power saving would accrue.

The opportunities for closely controlling ventilation in the UK are likely to decrease as greater continuity of production is being sought, e.g. six day working.

Limited automation of fan control has been successful but it is considered that expenditure on the technological developments required to approach total automatic control of mine ventilation cannot be justified either in terms of increased safety or reduced costs. However, computer assistance with information management and decision making, in connection with mine environmental control, could offer benefits leading to a reduction in stoppages and hence, a reduction in production costs.

A final report has been written.

7220-AC/125 Optimisation of mine air conditioning systems - StBV

Duration from 01.01.1987 to 31.12.1989

The purpose of the research is to bring about a substantial improvement in air cooling systems with central refrigeration plants and to obtain generally valid findings on the technical capacity of the various possible or existing machines and apparatus and to devise particularly cost-effective and reliable combinations and locations for the four components of an air cooling (air conditioning) system.

This presupposes a precise knowledge of the many important data on an air cooling system and in particular the cooling effect, chilled water temperatures and flow rates, cooler capacities, heat exchange on the pipe ranges, energy consumption of compressor, fan and pump motors and climatic improvement achieved in the working areas.

In the year under review, two complex air cooling systems were again investigated and various data were obtained, including all the above. One of the systems studied had a central refrigeration plant above ground and a Pelton turbine below ground, while the other had a central refrigeration plant below ground but central recooling above ground.

Both systems were characterised by very low chilled water supply temperatures of 4°C and 3°C in the pipe ranges below ground, by the relatively high actual cooling effect of the roadway coolers of 130 and 161 kW and the low specific energy consumption of 0.23 kW/kW for the underground plant. 1 kW of drive power (including fans and pumps) thus effected 4.4 kW or 3.0 kW of heat removal.

A further aspect of the research was investigation on the Bergbau-Forschung rigs of individual components of air cooling systems such as air coolers of various designs (surface and spray coolers) and size (large coolers, roadway and face spot coolers) and of water and air cooling apparatus but also of heat exchangers and insulated piping.

Investigation in the climate and air cooling laboratory of an air cooling unit with two evaporators of different designs but identical external measurements confirmed the previous results of measurements on air coolers, which indicated that the evaporator with novel flat tubes had a measurably greater cooling capacity than that with conventional tubes.

An interesting study was made of a roadway spot cooler which for two years was used in conjunction with spray coolers, i.e. in an 'open' chilled water circuit. The resulting increased dirt on the inside of the tubes led only to a very slight decline in performance of 2%. This proves that surface and spray coolers can be used in the same chilled water circuit provided most of the dirt accumulating in the spray coolers is filtered out of the circuit.

The research is proceeding as planned. In order to permit sufficiently detailed investigation of new designs of face cooler, the face cooler test rig, which was already about 20 years old, was extended and brought up to date. Using a new chilled water unit, it is now possible to select cooling capacities of between 100 kW and only 5 kW, the chilled water temperatures being extremely low - possibly as little as 0.5°C.

The work begun in the previous year on developing a computer program to calculate chilled water quantity and pressure distributions in extensive piping networks was continued.

Since this project, 7220-AC/125, will end on 31.12.1989, we have planned a follow-up project on 'Improved performance and control of air cooling equipment'.

7220-AC/210 Study of climatic conditions underground - prediction for new mines - IREA

Duration from 01.10.1983 to 31.12.1987

This project is finished and the final report will be presented in the next Experts' Committee.

7220-AC/835 Improving the prediction of mine climate - BCC

Duration from 01.09.1987 to 31.08.1989

An existing transient heat flow model has been examined in detail and several minor defects amended. Work is in hand to create a truly interactive and user-friendly package, providing interim reports to the computer screen of the progress of the simulation and with the facility to utilise simulation results as input to other models, such as ventilation network analysis program. Considerable improvements have already been made on both the computational speed of the model and to the format and presentation of input and output data. Future developments will concentrate upon refining the simplicity and accuracy of the various sub-routines, drawing, where appropriate, from other heat flow models and further improving the presentation of results.

7220-AC/126 Control of methane release at high rock pressure and of sudden gas outbursts - StBV

Duration from 01.04.1988 to 31.03.1991

Work on the project began on 1 July 1988. Interesting findings were obtained by initial studies on the pressure testing rig of the effect of high mechanical pressures on the methane sorption capacity of coal. In particular, the creation of new sorption equilibrium when the gas pressure in the free pore space in the coal has increased is not as expected. Further study will be necessary to elucidate this question.

Studies of changes in gas composition as a function of depth have so far revealed clear differences only for the zone below the overburden. In this area greater percentages of the higher hydrocarbons were measured in the eastern Ruhr coal field. In the western part of the Ruhr coal field a greater percentage of higher hydrocarbons was found only at one mine at depths of 1 200 m.

A water separator was developed for in-situ permeability measurements in down holes where measurement is impeded by the presence of water. This device removed the water from the measurement zone in the borehole continuously without allowing any gas to escape. It has worked in a generally satisfactory manner in the laboratory and pit trials will begin shortly, after minor modifications.

Methane drainage holes in production districts at great depths have occasionally proved more effective when their lives were extended by inserting a long standpipe in the form of slotted tubes. Investigations are continuing.

Research into the cause and course of occurrences involving the sudden release of large quantities of firedamp without simultaneous coal projection began with a review of the documentation on past occurrences.

7220-AC/836 An investigation into possible means of improving methane capture on high performance coal faces - BCC

Duration from 01.09.1988 to 31.08.1991

Increased safety and higher output from high productivity coal faces by more effective and efficient control of firedamp emission, using firedamp drainage or pre-drainage techniques as well as enhanced firedamp recovery from the seam to be worked or from adjacent seams.

- Selection of two suitable sites.
- Detailed investigation into face layout, method of ventilation, methane flow rates and methane drainage performance at each mine.
- Review of drainage and pre-drainage applications with different face designs and identification of the most influencing factors.
- Examination of ways to improve the capture rate of existing methane drainage systems.

A database has been initiated for the compilation and analysis of information relating to current methane drainage practices. Work has started

on adapting a finite element model to determine change in coal and rock permeability due to the effects of stress and thus permit the calculation of gas flow.

7220-AC/212 Adaptation of digital data transmission for safety monitoring and mine climate studies - IREA

Duration from 01.12.1988 to 30.11.1991

Extension of previous work on the prediction and improvement of mine climate by adapting the technique of digital data transmission, including the development of particular measuring devices and of the appropriate software for data handling.

- Studies on mine climate: extension of the catalogue of parameters for the mine climate by the use of digital data transmission; data handling and analysis of anomalies; carrying out mine climate prediction.
- Safety monitoring: definition of ventilation and climate-related data to be included in the computerised safety monitoring system; development of the appropriate software.

7220-AC/837 Development of infra-red technology for detection of gases in mines - BCC

Duration from 01.11.1988 to 31.10.1991

Enhanced performance and reliability of safety monitoring equipment as well as operational savings in labour and servicing by the development of compact, intrinsically safe methane measurement instruments without moving parts, utilising microprocessor control and based on the absorption of infra-red molecules of the gas.

- Investigation into pulsed LED sources in view of the realisation of a compact methanometer, with no moving parts.
- Study of other absorption lines close to the infra-red at wavelengths where glass can be used for optical components in order to achieve lower cost designs (use of commercial optical fibres).
- Investigation into the measurement of the spectral detail over a broad absorption band in order to provide better identification of a gas. The use of specific chips for computerised use of Fourrier transform techniques should allow the construction of a compact, rugged gas detector.
- Study of the remote detection of gases by fibre optics by inserting interferometric means into optical processing.
- Development of instruments for detecting methane, carbon monoxide and carbon dioxide for specific application (area monitoring, methane drainage, detecting outbursts).
- Laboratory tests and field trials.

The intention of this recently started project is to develop compact, high performance safety monitoring equipment, utilising microprocessor control technology.

I.3 ACTIVITIES OF THE COMMITTEE OF EXPERTS ON METHODS OF WORKING AND TECHNIQUES OF COAL-WINNING

The projects in progress in this field reflect the wide variety of geological conditions and situations encountered in the European coal fields and the enormous wealth of technology which is consequently available in the Community.

The main purpose of the projects relating to the most difficult geology (very thick, thin or steep seams) is to develop new working methods particularly suited to these conditions. On the other hand, those projects which relate to areas with better geological conditions are directed towards a constant improvement in the systems used in the 'longwall' method, which accounts for most of European output.

The Committee met twice, on 14 and 15 April 1988 in Merlebach (France) and on 14 December 1988 in Brussels. On the first occasion, a district in the Albert seam was visited at the La Houve Colliery, where the latest technology has been used to achieve remarkable levels of production and productivity. The Committee acquainted itself on the spot with the ECSC project 'Remote control and robotization of shearers', whose practical value is illustrated by the fact that a single shearer has to ensure an output of up to 13 500 t per day.

In the course of 1988, 11 final reports were approved and six new projects started. Some of the most significant results are as follows:

- development of new sensors and control systems for continuous condition monitoring of power loaders;
- development of the technology and methods required to allow very fine residues from coal utilisation, such as flotation tailings, fly ash, desulphurisation products, etc. to be returned to the mine;
- development and testing of a new, fully mechanised method of working seams dipping at between 35 and 90°;
- remote control by surface computer and robotisation of shearers.

7220-AD/310 Remote control and robotisation of shearer loaders - CERCHAR

Duration from 01.04.1986 to 31.03.1988
(Approved at the meeting of 13.12.1988)

This report deals with studies worked out in the Lorraine collieries for the development of novel techniques allowing for the long range remote control of shearers and for their full automation based on supervision and control tools using real-time computers.

The great difficulty of this research program, driven in a quite short schedule, arises because all trials had to be done on machines working underground in normal operation; therefore it was necessary to disturb or slow down operations as little as possible.

The adopted strategy consisted of developing an on-board equipment accepting various remote control modes, such as normal radio remote control along the face, but also partial or total remote control from the surface with cuttermen still being priority holder supervisors. Safety during trials was achieved by this priority procedure allowing cuttermen to take back control of any function even when the machine was under surface control.

During first investigations, a computer system was developed and linked directly to a shearer operated in a very steep seam of the VOUTERS pit in the Lorraine collieries. Then the TELSAFE-CA system, allowing for data transmission (measurements, control commands) through the power trailing cable, was extended to the surface by coupling to telephone wires.

This first stage system allowed to store a lot of interesting data and parameters about the behaviour of the machine and its modes of control.

The method of automatic horizon control developed in this research program is based on a learning strategy with a first calibration pass used for further control of drums in following passes. A feasibility study of the method was carried out using computer simulations based on a geometrical model of the vertical face. It permitted to estimate the sensitivity of the method versus sensors accuracies and measurements quantifications introduced by the TELSAFE-CA transmission system itself.

Further developments were carried out on a different machine (shearer DTF-HBL) used in regular semi-steep seams. The experimental system installed there was based on the new TELSAFE DV-CA which allows mixed remote control modes without disturbing working operations. In addition, a multi-task real-time architecture was developed and installed in the surface computer.

This afforded further possibilities of supervision of the machine and therefore special software was developed for automatic real-time breakdown diagnosis and for automatic printing of operational statistics. This has been very much appreciated by mine operators.

Problems concerning the control of a mobile machine by numerical sampling methods were progressively solved by developing autoadaptative type algorithms for compensations of biases induced by the propagation of sampling errors through iterative procedures. The real-time automatic control of actuators has also been analysed.

During the program, ANDERSON AM 500 drum heads used initially on DTF-HBL shearers were progressively changed to SAGEM THV-300 heads because of standardisation needs in the colliery. As these heads were not accepting the previously used angular sensors, first operational trials of automatic horizon control using the surface computer were delayed to the end of 1988,

as a new angular sensor had to be tested. First, the machine will be controlled through a manual command panel by an operator executing the results of calculations represented on a graphical display.

Later, it will be possible to download control routines from the surface computer into an onboard computer based on the 68000 microprocessor.

At the end of the research program period, in early 1988, the TELSAFE DV-CA system with radio remote control underground and one-line surface monitoring was being standardised in all pits of the Lorraine colleries. Nine equipments for DTF-HBL shearers and one equipment for the PANDA shearer will be in operation by the end of 1988.

Studies have also been carried out on new sensing techniques for the mining environment, particularly aiming at automatic detection of the coal/shale interface. This work included a collaboration between CERCHAR and the Ecole des Mines in Paris on the analysis of sonic and vibration spectra of a shearer in operation. Two field trials have been done; one of them at La Houve pit in Lorraine made use of the experimental system installed there and resulted in comprehensive records of machine operations and vibration spectrum. The results presented here clearly show that the analysis of machine mechanical vibrations spectra is a promising technique.

Studies were also carried out with the LAAS in Toulouse (a laboratory of CNRS) on application of artificial vision and image processing to the robotisation of mine workings. Preliminary results are presented and show that, among other techniques, infra-red vision is of great interest for both coal interface detection and machine guidance problems in very dusty environmental conditions.

7220-AF/809 Machine health monitoring - BCC

Duration from 01.04.1981 to 30.11.1986
(Approved at the meeting of 14.04.1988)

The broad aim of the machine health monitoring project was to establish practical methods for monitoring the condition of mining machines and in doing so, help reduce unscheduled production downtime. To this end the project has been successful, for example, unpredicted breakdown of oil washed mining gearboxes is now a rare event since the introduction of the wear debris measuring package.

At the start of the project the main causes of delays to production in deep mining, apart from geological and operational, were overwhelmingly related to mechanical failures. In one study, over 80% of plant failures were of a mechanical nature, e.g. hosepipes, bearings, gears, etc. As a consequence, investigation work was first directed towards selecting the appropriate plant that would benefit the industry by having a health monitoring facility, the parameter change that would precede failure, and the selection of appropriate techniques for application to the mining industry.

In parallel with a study of failures within the industry, a comprehensive bibliography search into health monitoring techniques was made and is fully referenced in the text.

As a result, a laboratory evaluation of selected techniques was undertaken, using a standard Armoured Face Conveyor (AFC) gearbox, in as near a realistic situation as was possible. This feasibility study was concerned with the response, prior to component failure, of the following techniques:

- wide band vibration analysis;
- hand-held (narrow band) vibration analysis instrument, such as shock pulse, kurtosis, etc;
- temperature monitoring; and
- oil analysis, using techniques to monitor ferrous debris contamination, and water-in-oil.

The conclusions from this evaluation gave a clear indication that ferrous debris and vibration analysis held the greatest potential for gearbox health monitoring. It also highlighted the benefit of being able to measure oil level and contamination of oil by water.

The initial measurements of ferrous debris were carried out using the ferrographic technique, but as it required expensive equipment and technician status to operate it, it was impractical for pit use. It was, therefore, decided at the evaluation stage to find a practical method of measuring ferrous debris in oil samples. The solution was a simple package which deposited the ferrous debris on a membrane filter and then by inductive means (a commercial instrument called the Debris Tester) obtained a measure of the quantity of ferrous debris on the filter paper.

Its introduction had a profound effect on the momentum of machine health monitoring acceptance in British Coal. In less than six months of its development, collieries were employing wear debris monitoring on a regular basis. As an example of its worth, one colliery had 17 unexpected failures prior to the introduction of debris testing and no unpredictable failures in the six months after.

Following the success of the off-line wear debris package, an on-line wear debris transducer was developed for critical machines such as shearers. Initial trials again indicated the value of measuring the amount of ferrous debris.

To complement the on-line debris transducer, a water-in-oil transducer was developed to monitor the second most damaging contaminant. Based on a capacitive principle, the device measures the quantity of water within the body of oil up to 10%.

To complete the oil analysis/measurement package a number of passive/active oil level transducers have been developed and are now ready for field evaluation.

Vibration analysis for machine health monitoring, as a technique, has been shown to have a potentially wider application than wear debris monitoring; for example, vibration is not limited to the oil washed part of the machine. However, the early implementation of vibration monitoring within British Coal was hindered by Intrinsic Safety requirements. Nevertheless, the evaluation work, carried out using test rigs and a series of underground trials (using non-IS equipment with special permission), has partly demonstrated the basis of exploiting vibration analysis within British Coal. Two levels of vibration analysis are suggested (a) 'Front Line' broad band trend monitoring of machine vibration for colliery use and (b) 'Secondary', a deeper analysis facility for confirming suspect failing machines, resolving design problems, and checking the condition of repaired gearboxes, to be based at national centres.

The findings from the controlled tests and underground trials helped formulate the following criterion for applying broad band monitoring:

i trending of vibration monitoring should be used where possible;
ii the range of vibration monitoring should extend in frequency from 0.5 Hz to at least 10 kHz;
iii experience has shown that the minimum sampling rate for face machines is one week;

iv monitoring location is important, and for face machines it is necessary to have fixed, internally located transducers for good signal to noise ratios; and

v different component failures within a gearbox produce different vibration spectra changes, hence a need to monitor a range of vibration features in most applications.

For the purpose of providing a vibration monitoring facility underground, a rugged tape recorder and miniature accelerometer, designed to be fitted inside a machine, were developed and certified IS. In this way the specifically developed vibration transducer makes it possible to use commercial portable instruments (such as the partly modified Trolex Limited TX4488) for the 'front line' simple feature trending, and to enable the full vibration spectra to be extracted and recorded for deeper analysis when required.

Deeper or 'secondary' analysis relates to the ability to generate information for pit engineers on the type of suspected fault and, in so doing, pinpoint the defective component(s). Although the main requirement of secondary analysis is to give support to the 'front line' trend monitoring routine, it can also indicate design and build quality faults that would eventually lead to machine breakdown. It is in this latter respect that the major exploitation has been made on vibration monitoring to date. For example, in the vibration recording and analysis exercise on face machines most of the faults were either introduced at the last overhaul or as a result of assembly difficulties, i.e. alignment problems caused by bent AFC headframes etc. It was a result of such a post-failure examination, and with the supporting evidence from 'early' (in the first 25 000 m of operation) gearbox failure frequency statistics, that the idea of 'pre-delivery' testing of gearboxes was investigated. Using a form of vibration analysis known as 'time domain averaging', more common in helicopter gearbox monitoring than general industry, preliminary studies indicated that it was possible to assess the build quality of refurbished gearboxes. Workshops Facility for Quality Inspection of Gearboxes is now the subject of another ECSC supported project.

7220-AD/816 The investigation and development of a mechanised strata control and roadhead support system for face line ripping techniques - BCC

Duration from 01.07.1983 to 30.06.1987
(Approved at the meeting of 14.04.1988)

The requirements of face ends were considered from first principles and it soon became clear that the use of heading machines for face end work could only result in systems with severe inherent limitations, both with regard to operation and reliability. As the cutting element is the only part of the roadheader essential to face end work the remaining design was discarded and a new structure designed to accommodate the wider requirements of face ends. Having made this change in the basic concept it became possible to develop equipment providing the following features.

1. The potential consistently to support advance rates in excess of 2 m per shift for the majority of face ends over a wide range of systems by eliminating and reducing problems inherent in present mechanisation methods.

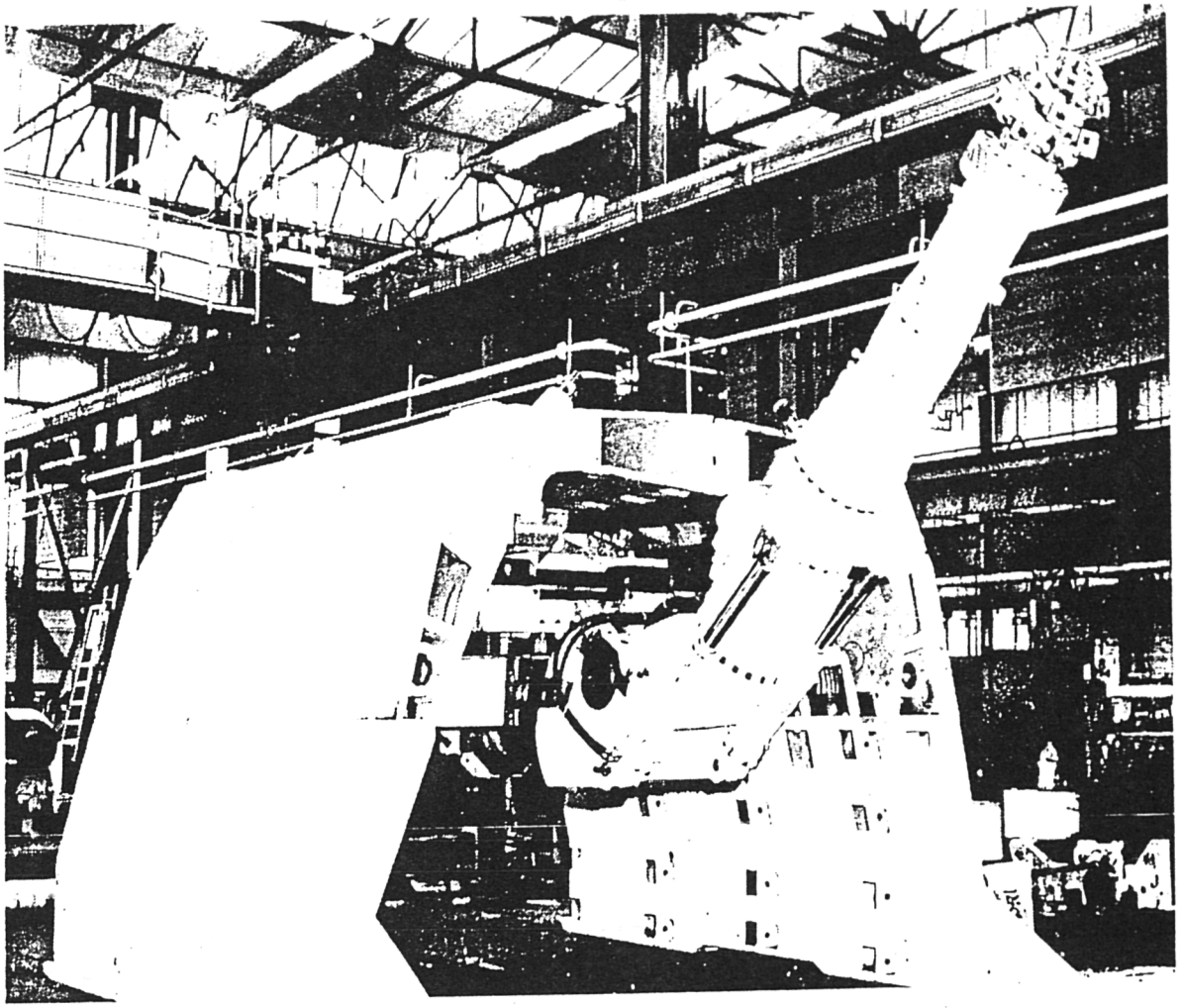
2. Good access to the face for both men and materials.
3. Accurate, simple automatic roadway profiling, combined with mechanised setting and preloading of arches to encourage the use of smaller section arches, increased arch centres, and reduced back-ripping costs.
4. New system design to improve reliability, including condition monitoring and easier maintenance.
5. Greatly improved machine stability and structural and hydraulic stiffness leading to more effective cutting of a greater range of rock hardness.
6. The optional supply of integral medium pressure 138 - 207 bar (2000 - 3000 lbf/in^2) water to the cutter head for improved dust suppression, increased pick life and better cutting efficiency.
7. Low ground pressure with no machine manoeuvring during cutting and loading.
8. An independent debris handling system to give improved versatility of application.
9. Suitable for both drivages and face ends.
10. Full automatic control and monitoring of all cutting functions by an onboard microcomputer with hand control via a 'wander-lead' for optimum operator positioning. (Manual emergency control is also provided.)

The machine which formed the nucleus of the new development was complete at 90% by the MRDE and operational tests on the cutting functions had started.

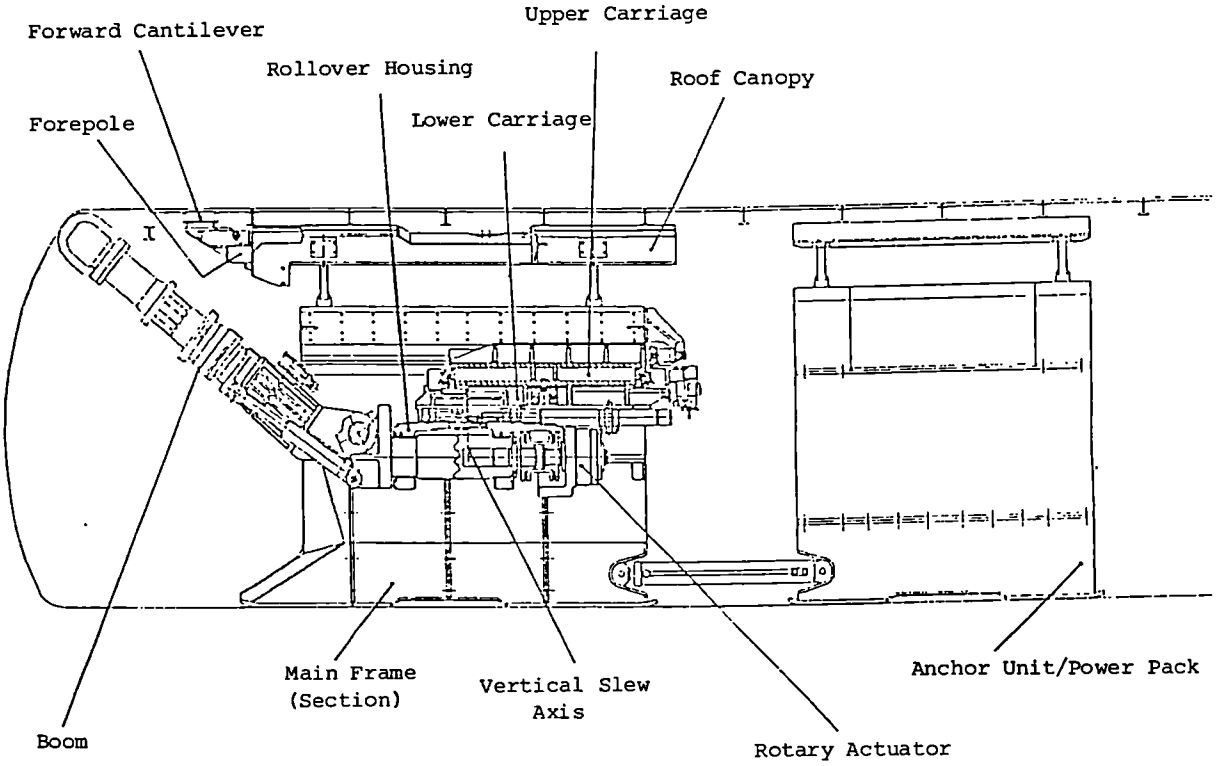
In order to ensure that the potential of the concept was exploited, appropriate UK machine manufacturers were invited to consider taking over the machine to complete its development and trials with a view to eventual marketing.

Dosco Engineering were chosen and the partly completed machine was transferred to their factory. Since the transfer the majority of the outstanding components have been manufactured and surface testing under manual control was carried out.

The final phase of the automatic control work will be reappraised in the near future.



Assembly of Main Components



Cross-section of Machine

7220-AD/127 Filling of the caved area or of abandoned workings with ESP ash and other small sized waste products by hydraulic transport from the surface - StBV

Duration from 01.04.1985 to 30.09.1987
(Approved at the meeting of 14.04.1988)

A process designed at Bergbau-Forschung, Essen, intends to transport fine refuse from preparations plants and power stations in the form of highly concentrated slurry through pipelines into the mine and to stow it in the goaf. In this way waste management problems in densely populated industrial areas may be solved. At the same time the stowing material can be used to avoid mining damage.

To develop the process to the operational state extensive tests were started at the Bergbau-Forschung test installation. First of all it was tested in model trials under which conditions EFA, tailings and crushed waste can be injected into loose debris without producing excess water. Moreover, the behaviour of stowed refuse samples under pressure was examined.

Prior to hydraulic conveying the solids have to be mixed intensively to reduce the viscosity as far as possible, thus minimising the pressure loss in the pipeline.

In various test installations the solid slurries were transported hydraulically, the pressure loss related to solid concentration, type and composition of the solids, flow rate, pipe diameter and the mixing intensity were measured. Fundamental examinations were carried out in a small 40 mm test installation whilst tests at production scale could be run in a large installation with pipe diameters of up to 150 mm and a capacity of 90 m^3/h.

It was the main finding of the tests that tailings account for significantly higher pressure losses compared to EFA, i.e. that the solid concentration has to be reduced with increasing flotation content of the slurry.

Whilst the solid concentration in an EFA slurry may amount to up to 60% by volume the solid concentration for tailings has to be less than 48% by volume to keep the pressure loss within acceptable limits, i.e. not more than 5 bar/100 m.

In another test installation piston pumps with pressures of up to 70 bar and various auxiliary installations to reduce pressure peaks were tested.

The tests showed that slurry pumping in the pipeline may be started again even after several days of standstill if an optimal solid concentration is chosen. To avoid adherence of the solid at the pipewall, go-devils in the medium are periodically pumped through the pipeline. The go-devils may introduced through a newly developed gate without interrupting the pumping process.

The development and testing of trailing pipes to introduce the slurry into the goaf was particularly important. The trailing pipes, which are sliding on the floor and are dragged along by the AFC, were used in the mine and have been well-proven.

To establish the measuring values existing instruments were tested and new devices were developed. Particularly for pressure measurements, under the complicated conditions in the mine, new transducers had to be developed. All measuring values will be registered. For their evaluation, programmes were set up which are to be used in the next underground tests.

The process and equipment was tested in a first underground test at Walsum Colliery. It turned out that the process concept was right and the goaf is in a position to take up large amounts of solid slurries. The tests also showed, however, that extensive examinations, both in the test installations and the mine, are required before the process will be operational.

7220-AC/827 The incorporation of strata control parameters in mine data and analysis systems - BCC

Duration from 01.07.1984 to 30.06.1987
(Approved at the meeting of 14.04.1988)

At the inception of the project, Colliery Management had routine access only to manually recorded hydraulic circuit pressures and visual impressions of on-face strata control when assessing the effectiveness of their powered support installations.

It was proposed that more meaningful data could be generated by automatically monitoring the powered support leg circuit pressures and convergence between competent roof and floor. This would enable not only setting pressure and pressure development to be confirmed cycle-by-cycle, but also permit conclusions to be made re strata control and the detrimental effect of debris accumulation below the base and above the canopy. Measurement of convergence would also facilitate monitoring of extracted section, enabling a check to be made to confirm that the supports were operating within their height range.

It was envisaged that this approach would require the installation of pressure transducers on all support leg circuits and supply circuits, and self-advancing convergence transducers located at five sites along the coal face. The output from all transducers would be retrieved automatically for processing and analysis either at the face end or on the surface.

The success of this approach would not only depend on the durability of the instrumentation, but also on a capability to reduce the large volume of data recorded to a format which could be readily interpreted by management.

Accordingly, the objectives of the project were:

i To produce and utilise on a short-term basis on a number of facelines a portable instrumentation system which, while being manually attended, would monitor the same data as the proposed automatic system.

ii To use the data produced in (i) to examine the validity of the proposed approach to the assessment of powered support effectiveness, and to develop interpretive software which would produce a condensed analysis for use by management.

iii To develop a self-advancing convergence transducer which, when combined with existing pressure transducers and data retrieval systems, would permit the unattended, automatic application of a system.

The main content of this report is presented under three headings, each of which is listed below.

Heading 1 - Development of Theory

This includes the following items.

- The case for the use of pressure and convergence measurements in the evaluation of powered support system efficiency.
- Support boosting as a method of determining floor and roof penetration properties.
- Evaluation of rigid canopy attitude relative to the base from three convergence measurements.
- A method for checking support hydraulic health.

Heading 2 - Development of Research Facilities

- Mechanical Pressure/Convergence Recorder.
- Electronic Data Logging System.
- Simulation of a soft floor for proving of the self-advancing convergence transducer.
- Laboratory rig for testing the self-advancing convergence transducer.

Heading 3 - Field Investigations

- Application of the Mechanical Pressure/Convergence Recorder at Killoch and Solsgirth Collieries (Ayr Hard and Upper Hirst Seams).
- Application of the manually advanced convergence transducer and data logging system at Welbeck Colliery (Top Hard Seam).
- Application of the self-advancing convergence transducer and data logging system at Bilston Glen Colliery (Peacock Seam) Phase 1 - Broken Roof.
- Application of the self-advancing convergence transducer and data logging system at Bilston Glen Colliery (Peacock Seam) Phase 2 - Good Roof.

- Application of the self-advancing convergence transducer with Minlog Data Transmission to Surface, Wistow Colliery (Barnsley Seam).

General Conclusions

The objectives specified for this project have been substantially achieved. The concept of measuring support efficiency has been established, the hardware required on the face to apply the concept has been developed and shown to be capable of surviving in a production environment. Data can be transmitted to the surface for store (HQTD's Minlog System) where it can be processed and interpreted sufficiently quickly to be relevant to current face conditions.

Interpretation of the data has detected correctable faults which detract from support system performance, e.g. the accumulation of debris below the support base, insufficient volumetric supply on a positive-set hydraulic main and a tendency for operators not to set the back legs of the supports, especially under broken roof. This last fault is due to the support canopy being pushed up into broken roof by the back legs of the four-leg chock shield, a problem which could be corrected with appropriate allocation of setting pressures to front and back legs.

Most encouragingly, Colliery Management has proved receptive to the provision of concise numerical data which provides a measure of the effectiveness of their longwall powered supports and specific directions re the correction of any deficiencies.

Major Recommendations

Having established that the approach developed for measuring support efficiency is a useful management tool, consideration should be given to application of the tool on selected coal faces. The proposed criteria for the selection of these coal faces are:

i Coal faces where strata control is marginal and roof falls delay production.
ii Coal faces where periodic weightings are liable to occur.
iii In the more general case, at collieries where the management wish assistance in maintaining consistently high standards of support utilisation on the coal face.

The field investigations highlighted a fault in the operating characteristics of the three/four-leg chock shield, i.e. when the roof is broken it is frequently impossible to set the back legs. Thus support density and support effectiveness falls at a time when they should be maximised. The occurrence of this fault can be reduced, certainly on high to medium strength floors by applying a higher setting pressure to the front legs, and/or having front legs of a larger diameter than the back legs. Given the ubiquitous nature of the fault, the proposed solution deserves serious consideration.

7220-AD/751 Investigation, development and demonstration of a fully mechanised coal-winning method for inclined seams (40°-60°) - HUNOSA

Duration from 01.03.1986 to 29.02.1988
(Approved at the meeting of 13.12.1988)

Complete mechanisation in semi-steep and steep seams (40°-90°) was a problem to which no satisfactory and generally applicable solution had been found in the coal mining industry. The aim of this project was to devise equipment which would help to overcome this difficulty.

Fourteen supports were designed and constructed in collaboration with Westfalia-Lünen GmbH and Mackina Westfalia and were installed on an experimental face in HUNOSA's Mª Luisa Mine, with a dip of 57° and an average seam section of 1.58 m.

The movement of stowing material at various angles of seam dip was also studied by means of a model, various measurements carried out below ground and a computer simulation program.

The working method adopted during the experiment is described and conclusions are drawn with regard to conditions for future use of the system and equipment and the general characteristics of the faces to which they may be applied.

The research has yielded the following conclusions with regard to the geology and layout.

- The system is viable in seams between 0.90 and 2.20 m thick, with medium or indeed poor roof conditions, strong floor strata and minimum face runs of 500-600 m.
- Whether or not the goaf is stowed, a large part of the roof caves after the face has passed through and faces should therefore be retreated, at least with respect to the upper level.

The following are the findings with regard to the supports.

- The design represents a major advance on previous models and has demonstrated that it may offer a solution to complete mechanisation of faces inclined at between 40° and 70°.
- The roof coverage must be increased.
- The support unit must be made lighter and shorter.
- Means must be developed to ensure that coal and stone pass down the face at an appropriate speed.
- Where the dip of the seam exceeds 70° further modifications will probably be necessary. These should be investigated in a pit trial.

7220-AD/820 Monitoring and prediction of the life of mining chain assemblies - BCC

Duration from 01.04.1985 to 31.03.1988
(Approved at the meeting of 13.12.1988)

Production delays associated with chain problems on armoured flexible conveyors (AFCs) currently account for approximately 3½ minutes per shift in British Coal. In an attempt to reduce this figure a study has been made of techniques for monitoring the condition of chain assemblies and for predicting residual life.

An examination was made of the principal reasons for chain failure and a comprehensive programme of work was undertaken to assess the manner and extent of chain assembly deterioration in service using a combination of non-destructive, metallurgical and mechanical tests.

The main conclusions are as follows.

1. A combination of on-site measurements and mechanical testing of samples taken periodically from AFC chain assemblies can provide a satisfactory means of monitoring the condition of chain assemblies. The use of data trend analysis obtained from the monitoring scheme plotted against a measure of work done by the assembly, e.g. tonnes conveyed, running time loaded and unloaded, is an essential part of the monitoring process.
2. Experience must be built up regarding the rates of deterioration of chain assembly performance for individual installations.
   This experience can be used to refine the monitoring process.
3. Useful on-site measurements are chain 'stretch', i.e. inter-link wear, numbers of links removed, and connector pad wear.
   Useful tests on chain samples taken periodically are hardness to check material properties against specifications, visual examination for gross damage and sprocket marking, and tensile testing to provide the Energy Absorption Factor (EAF). Chain should be removed from service when the EAF falls to 50% of the minimum value for new chain.
4. The following measurements and tests were found to be relatively insensitive to chain condition and residual life for chain within Specification initially:

   fatigue tests
   visual assessment of wear and corrosion
   metallurgical properties
   link dimensions and one-off weight determinations.

5. Little meaningful information was obtained from testing connectors because of the small numbers that could conveniently be made available for testing.
6. Where condition monitoring methods are being used, chains are currently being removed from service while they are still capable of further work because of the need to minimise the risk of breakdowns. This policy has impaired progress in refining the condition monitoring process and made prediction of residual useful life difficult.
7. Sprocket damage is a substantial contributor to the reduction of chain life. It is important that work is done to minimise the incidence of sprocket damage by examining the design, manufacture and heat treatment of sprockets.

Other conclusions which could be drawn from the work done were:

8. Of all the chain samples from service that were tensile tested, even the most heavily worn and corroded exhibited a breaking strength greater than 80% of the minimum requirement for new chain. The effect of service on elongation to failure was more significant than for the breaking strength. Elongation values of 4% were measured.
9. Incrementally straining new chain samples to fracture showed that almost the entire elongation arose from deformation of the link crowns, with very little contribution from extension of the link legs. Consequently, the most significant influence on the elongation appeared to be the presence and severity of sprocket contact damage on the link crowns.
10. Fatigue lives of chain samples tested under a stress amplitude of 140 MPa and R-value of 0.15 declined at an initially rapid rate from a value between 30 000 to 40 000 cycles to between 10 000 to 20 000 cycles and, thereafter, did not decline further with service life.
11. Over 90% of the fatigue test samples failed from the crown extrados surface of links that exhibited leg wear flats and, therefore, links that had been orientated vertically in service. Tests on artificially worn links showed that a redistribution of manufacturing residual stresses arising from leg wear would partly account for this percentage.
12. The changes in residual stress from leg wear would also account for the rapid decline in fatigue life since the increase in wear flat depth would initially be rapid on a circular cross-section, and a linear relation between stress change and wear flat-depth was found.

Recommendations

1. Instead of considering the suitability of a chain for further service on the tensile breaking force and elongation figures obtained from a sample of the chain, the single criterion of the Energy Absorption Factor, derived from the tensile test graph, should be used. This criterion combines the tensile strength and elongation figures for the chain and represents the energy absorbed in the fracture of the sample. An energy value of 7 kNm is recommended for 19 mm chain and 13 kNm for 22 mm chain as the limit when chain should be removed from service. These values represent 50% of the energy absorbed in chain meeting the minimum requirements for new chain.
2. The evidence from the tensile testing carried out during this project, and tensile testing carried out elsewhere within British Coal, indicates that chain with low elongation to fracture values almost invariably exhibits above average severity of sprocket contact damage. Since such damage may render otherwise satisfactory chain unfit for further service, every effort should be made to ensure that damage is kept to a minimum. This involves not only ensuring that sprockets meet their specification and that damaged or worn sprockets are replaced as soon as possible, but also seeking improvement in design, manufacture, and heat treatment to reduce the contact stresses between chain link and sprocket to minimise wear and damage to both components.

7220-AD/309 Application of pneumatic stowing in thick and steeply lined seams - CERCHAR

Duration from 01.04.1986 to 31.03.1988
(Approved at the meeting of 13.12.1988)

Pneumatic stowing is generally used in concentrated deposits, in production areas which are subject to subsidence or to limit the dumping of spoil.

The development of shield supports has been going on for some years, also in association with pneumatic stowing, which takes place in the goaf, over the hermetic shield supports. Shield supports for caving faces are the only ones which are suitable for inclined faces, and it was natural for solutions to the problem of pneumatic stowing to be developed on the basis of this method.

Lines of research

Three lines of research were explored:

- design of new support system with pneumatic stowing,
- packing materials and their placement,
- roof behaviour in faces with pneumatic stowing.

New support system with pneumatic stowing

This new design was intended to fulfil three objectives:

- face performance and safety of workforce,
- packing coefficients in excess of 70-75%,
- solution to problems of equipping and salvaging inclined faces.

The three main activities on the face:

- coal-winning and clearing,
- support operations,
- stowing,

were organised so that they were as independent as possible.

Coal-winning was handled in the same way as on a conventional caving face, thus benefiting from all the progress made in this area (high load-bearing capacity, Dynatrac, Panda Shearer).

Pneumatic stowing in independent of support advance within a two-shear limit and the main aim was to achieve performance and reliability at minimum cost, for example by using non-automatic ejectors, though at the same time special attention was paid to working conditions.

Packing materials

A. A first series of tests was carried out on the surface, covering the conveyance of stowing material:

- by gravity (material runs down the floor),
- by pumping.
- Conclusions:

Negative conclusions

Shale or deslimed sand will not run down a 30% dip unless excessively large volumes of water are used (500-800 l/min for 300 m^3/h of material).

Positive conclusions

Material will run over steel sheets or steel-lined roadways with only 5-7% water.

It is possible to pump a mixture of 40% sand, 50% shale, 5% cement and 5% water; Putzmeister pumps - quick-setting mixture, but high cost.

Possibilities of replacing pneumatic stowing for goaf filling do exist. However, special equipment will have to be designed, notably supports with shuttering.

The advantage of both these solutions is that they eliminate dust generation, though costs are increased by using cement in the pumped mixture.

B. Research covering dry sand stowing in steep workings.

This was undertaken as part of the trial working of a face along the line of full dip in a steep seam using the AKH method, an existing support system which is relatively hermetic on the goaf side.

Stowing using dry deslimed sand

The sand is obtained from a plant which eliminates fine particles less than 50µ in diameter which contain clay (LAMEX process). It is then transported hydraulically into filter-walled bays where the wet mixture is dried very rapidly. A bucket excavator is used for loading.

The sand is transported by belt conveyor to the face end and then into the goaf by a small loading conveyor equipped with mobile lateral ejectors.

The research included improving the performance of the bucket excavator, the operating rate and reliability of which were less than ideal.

To do this, and for the trial in the second Georgette seam panel, we built a second bucket excavator to take account of the problems encountered previously. The theoretical performance expected with this new machine is 300 m^3/h, with an average of 150 m^3/h.

We are also developing a high-speed sand stower for use in top roads.

Roof behaviour in faces with pneumatic stowing

A series of measurements recorded face convergence and pressure in the packing material in a face where pneumatic stowing was used at the Wendel Colliery of the Houillères du Bassin de Lorraine. Parallel to this, the typology of roof fractures was investigated. The results, together with those of previous work, enabled the boundary conditions to be defined for a model of a roof considered to be a continuous slab (finite element calculation).

Whilst remaining within the application limits of the 'elastic range' model, we were able to simulate the fracturing of a roof consisting of a succession of strata. Breaking of the first bed resulted in loose bulk material in the goaf, thus reducing the convergence of the second bed, and so

on. The stress calculation takes account of all the intact strata, i.e. a variable roof beam thickness. The maximum stress falls, and the point of equilibrium, at which no failure occurs, is soon reached.

This method, which allows the influence of the packing coefficient in a given stratographical situation to be assessed, was used to establish the position and bearing capacity of the legs for the support design described above.

Conclusion

The research showed that pneumatic stowing required a support system which was suited to the conditions in the relevant type of working. It would be possible to replace pneumatic stowing by other types but a specific type of equipment, which is more expensive, is then required.

The calculation model designed for this application is flexible and general enough for it to be used for research into roof behaviour in other types of working, in particular those using caving.

7220-AF/823 Condition monitoring of face support systems - BCC

Duration from 01.04.1985 to 31.03.1988
(Approved at the meeting of 13.12.1988)

Powered roof support systems are large complex hydraulic machines and are essential to the operation of modern coal faces. The main aim of the project was to develop methods of monitoring the condition of hydraulic powered support systems. The programme of work included development of techniques, evaluation and field trials. The main areas of work were:

- pressure deficiency profile;
- optical liquid level detector;
- mine water pump monitoring;
- suction filter blockage;
- 60/40 emulsion monitoring;
- 5/95 emulsion monitoring; and
- pump monitoring.

Pressure deficiency profile

A programme of work was carried out using data logging instrumentation and pressure transducers to monitor line pressure at the end of the face furthest from the power pack which, after processing, can be used to assess the condition of the distribution system.

Underground trials were carried out, which showed the system to be effective in distinguishing between poor and good hydraulic distribution systems.

Optical liquid level detector

This optical-based gauge uses the principle of total internal reflection from a series of conical refracting prisms located in the probe and has the advantages that it is simple, passive and has no moving parts. A gauge, which would normally be sited in some convenient position for viewing, is linked by a flexible armoured fibre-optic bundle to the probe mounted in the centre of an oil sump.

The optical liquid level detector principle has been patented and licensed to Eurotec and Hayden Nilos Conflow. The method is being used for difficult oil level monitoring applications.

Minewater pump monitoring

A pump was monitored comprehensively and trials were started with the objectives of assessing monitoring techniques and hardware and in the long term obtaining experience in the measurement of deterioration.

It has been concluded that the module monitoring systems with preconditioned transducers are well suited to this application and, being modular, they are also suitable for other applications such as powered support power pack monitoring.

Suction filter blockage

The ram-type pumps used by British Coal for roof support systems are sensitive to inlet pressure.

A solution was devised, which involved damping out the high frequency pulsations by introducing lengths of hydraulic hose between the measuring point and the pressure transducer. Testing was done to establish the optimum amount of damping required. This was followed by underground testing which proved the method to be satisfactory.

60/40 emulsion monitoring

It was decided to try to develop a technique using a chemical agent to split the emulsion back into its constituent parts, that is oil and water, and then to measure the ratio of the two volumes. National Chemsearch provided a suitable chemical and a practical technique suitable for use at collieries was developed.

The method is suitable for Century Oils Aquacent fluids and Croda Thelmul fluids.

5/95 emulsion monitoring

A number of different methods were looked at, these were:

- hand-held refractometers;
- built-in manual refractometers;
- 5/95 splitting technique; and
- automatic on-line refractometer.

Automatic on-line refractometers offer significant advantages since they have the potential to remove the manual content from the operation. An Index Instruments RIC-1 refractometer was evaluated in the laboratory. This was a critical angle refractometer working by back reflection of a collimated beam from a prism face.

The technique was found to be effective for surface mixing plants. However, for future application an improved instrument is desirable. This should have better zero stability with time and the flow path over the sensing head should be improved to avoid the build-up of scum.

Pump monitoring

The results of this work indicated that the two major indicators of pump operating condition were suction pressure and outlet flow under load, with both these parameters being necessary to indicate the source of any actual or potential fault.

Conclusion

A number of the areas which cause problems on powered support systems have been investigated. Techniques have been developed and evaluated, and are described in detail in the main report. The method can be used to monitor the condition of powered support systems and the results can be used by engineering management at collieries so that maintenance and corrective action can be taken to remedy problems before failures and delays are caused.

7220-AD/125 Further development of coal-winning machinery for improvement of ROM-II - StBV

Duration from 01.10.1985 to 31.03.1988
(Approved at the meeting of 13.12.1988)

Efficient and safe mining of hardcoal is possible by means of using percussion- and vibration-activated hydraulic cutting tools. Their sturdy design largely precludes any externally induced malfunctions.

Cutting forces are considerably reduced in comparison with static tools. The extracted material is of lump size and low moisture content and, as such, promises good sales profits as high-grade coal. Extremely little dust is produced during extraction.

It is still premature finally to assess the application potentials of different activated cutting tools either of the hydraulic/translatory or of the mechanical/rotary type.

The above fundamental studies have to be followed by other long-term tests also at the underground.

As for activated loading machines, any final assessment cannot be given as yet although the surface and underground trial runs on rotative disk loaders have been encouraging. Remarkable loading efficiencies were attained with the same time low defect-proneness. It remains to be demonstrated by continued tests though whether the high technical expenditure for reducing the tensile forces of chains is justifiable.

7220-AD/126 Development of new components for AFCS - StBV

Duration from 01.10.1985 to 31.03.1988
(Approved at the meeting of 13.12.1988)

Adjustment of chain pretensioning to optimise the running characteristics of AFCs was successfully tested for the first time on a single-drive face conveyor in the Borken lignite mine. Based on the experience gained, the surface plant was extended to include a double-drive test conveyor whose adjustment response in terms of identification of the chain geometry at the auxiliary drive and of chain sagging at the main drive unit was examined. Covering material to permit integration of the transducer

in the bottom plate proved to be successful. The entire concept was revised for allowing indication and processing of line errors and malfunctions of indicators.

In order to examine the impact of different drive components, as flexible and fluid couplings, on the action of unblocking jammed conveyors, a special test rig was installed. Dependency of the starting behaviour on both supply network, motor rotation, and various types of fluid couplings was investigated. A diagram was drawn up to illustrate the limitations of flexible and fluid couplings.

For optimal utilisation of the torque available from a motor, a new filling method for fluid couplings was developed and successfully tested at the underground.

Furthermore, a measuring method for monitoring the filling level of fluid couplings was tested. The drawbacks of present day fluid couplings will be overcome thanks to a new adjustable fluid coupling, a prototype of which was installed and tested for functionality.

A specific power requirement of 5 kW/m of conveying length was determined during our investigations on the conveyor with intermediate drives. By applying some directed constructional modifications this specific requirement was reduced by 40% whilst the conveying performance improved.

Further improvements of the running characteristics were achieved after expensive examinations of and appropriate constructional changes to different components such as guide, chain belt and sprocket. Other problems still wait for a solution, e.g. agglutination of smalls in the chain guides and smalls accumulation on the lower strand.

Experiments for the identification and improvement of resistance coefficients were started on a newly installed test rig. First trials were run on plastic-coated scrapers and scrapers subjected to rolling friction. It was found that scrapers with rolling friction, when idling, exhibited the lowest resistance coefficients.

WINNING METHODS

7220-AD/752 Design and development of an activated plough for narrow coal seams - TAIM-TFG

Duration from 01.05.1986 to 30.04.1989

The purpose of this project is to design, construct and commission a mechanised system for the mining of coal seams which are thin (under 70 cm) and very hard (35/50 Mpa indentation hardness).

The mechanised winning system is based on a plough with hydraulically activated picks operating at high frequency and low impact energy. This plough may be regarded as half way between a conventional plough and a shearer.

The first stage in the project was to construct a test rig to study the performance of the HAUSHERR hydraulic hammer (activated pick) when used on rocks of different hardness and strength, and the effect of the different variables (e.g. angle of attack, haulage speed and pull).

In the various non-instrumented trials haulage speeds of 1.2 to 1.9 metres/minute were measured manually with a depth of cut of 30 to 34 mm in concrete with a compressive strength of 100-120 kg/cm^2. This is much lower than the desired haulage speeds. A depth of cut of about 10 cm causes the pick to become completely fast.

All these findings should be confirmed when the instrumented trials are carried out.

7220-AD/753 Research, development and demonstration of novel coal-winning equipment working with shield supports in a descending face in steep seams - HUNOSA

Duration from 01.09.1987 to 28.02.1990

The purpose of the project is to construct and test a coal-getting machine capable of cutting dirt partings and rock of medium hardness in the associated strata and compatible with the shield support systems for horizontal faces worked to the dip in steep thin seams.

The first idea developed was that of a system for winning and transporting coal comprising a rotating bucket arrangement and a small armoured conveyor. This approach was abandoned because of insoluble problems of space and connection with the shield support system.

It was decided to proceed by designing a shearing drum with incorporated hydraulic motor, moving horizontally along the face.

A system of transport along the face is also being designed. It employs scraper bars hauled by an endless chain.

7220-AD/819 Development of a pickforce steering system - BCC

Duration from 01.10.1984 to 30.09.1989

Testing has continued on the pickforce transducers. This indicates an accuracy of 1% over one million cycles. A contract has been placed to manufacture the pickforce data transmission and pick position system. Work to produce a data transfer system and trials on a quarter scale cutting rig are now complete. The final report is in preparation and the project should be completed by spring 1989.

FACE TECHNOLOGY

7220-AD/129 Diagnosis of operations to improve the level of utilisation of ploughs II - StBV

Duration from 01.10.1986 to 30.09.1989

Development work on the instrumented blade was completed. The telemetry system was successfully tested below ground on a Gleithobel but further improvements are required before it can be generally used. Certification has meanwhile been obtained for the intrinsically safe power measuring unit. Programs for the diagnosis system were written and tested.

7220-AD/130 Development of controllable external drives for propulsion of winning machines II - StBV

Duration from 01.10.1986 to 31.03.1989

The surface trials with the controllable haulage drives for coal ploughs were successfully completed and an application was submitted for certification for use in methane atmosphere. Work on external haulage drives for shearers was delayed by alterations to the building housing the test facilities. It proved possible to make use of experience acquired with ploughs.

7220-AD/128 Development of methods and equipment for traversing faults II - StBV

Duration from 01.10.1986 to 30.09.1989

Hydromechanical and fully electrical plough push-over systems which operate automatically in conjunction with the plough or powered support system were studied on a test rig and in pit trials. For activated ploughing, mechanical impact tools have proved to possess certain advantages over hydraulic tools. For shearing, a new type of pick was investigated for wear and dust make and a hydraulic arm support was tested.

7220-AD/822 Longwall face alignment and advance control - BCC

Duration from 01.04.1986 to 31.12.1990

The current area of development involves the integration of a monitoring system to monitor the horizontal profile of a face and an electro-hydraulic control system. This will enable differential advance to be implemented hence allowing control of face alignment to be achieved automatically. Contract details have now been completed and development work is currently underway. The surface data transmission system is now complete.

FACE ENDS

7220-AD/132 Face ends - interactions between face and gateroads - StBV

Duration from 01.07.1986 to 30.06.1989

Application of the recommendations developed in the preceding project was improved by means of computer programs and they were thus made more acceptable. Work continued on integration of the face end equipment. Significant findings emerged from a comparison of various components of face and face end surveying systems.

7220-AD/821 Improvement of roadway stability by producing accurate roadway profiles - BCC

Duration from 15.03.1985 to 14.09.1989

Efforts have been concentrated on the alignment systems. The trolley pole system has successfully undergone field trials. This was closely followed by trials with the scanning laser (laser-fix) system. Plans are currently in hand to install both these systems in an operational coal mining environment for further trials.

7220-AD/823 Research into the influence of the design of permanent support systems on gateroad stability under differing geological conditions and mining methods - BCC

Duration from 01.04.1986 to 31.03.1989

Work has continued on investigating various mathematical and physical modelling techniques for predicting the behaviour of permanent gateroad support systems. Field work has centred on the prediction of steel support behaviour by use of computer modelling techniques. The project will be completed in March 1989.

7220-AC/317 Choice of the properties of mechanised support for steep and thick seams - CERCHAR

Duration from 01.07.1985 to 30.06.1988

Mechanised supports have developed as a function of seam thickness and dip. Load-bearing capacity has been increased to cope with the problems of the stability of ground.

The project has adopted two different approaches:

- as thorough an analytical approach as possible, the limiting factors being the available resources and conditions underground;
- a general approach using statistical methods.

The latter approach served to confirm earlier findings, but came up with nothing new.

The former approach, however, was applied to high-output faces and enabled face behaviour to be characterised by reference to the mechanics of the stratified media.

In the light of the results thus obtained, we can take a fresh look at earlier results and postulate rules for the choice of support systems depending on the nature of the roof.

There are two possibilities here:

(a) Where it is technically feasible to envisage a load-bearing capacity which would avoid roof flaking and allow it to occur behind the face supports, we can work out exactly what supports are needed.

(b) Where it is impossible to avoid spalling of the face and the supports have to bear the weight of the resultant blocks, we have to resort to conventional prediction methods.

7220-AC/830 Further work on control of deformation processes at longwall coal faces - BCC

Duration from 01.04.1985 to 31.03.1988

This project is finished and the final report will be discussed at the next Experts' Committee.

7220-AD/131 Better strata control by mining in distressed zones and by the design of appropriate support - StBV

Duration from 01.09.1986 to 30.08.1989

In order to determine strata pressures in the goaf, robust, damage-resistant pressure cells were developed and installed in two districts where the waste was pneumatically stowed. The first measurements indicate that strata pressures in the goaf are higher and those at the rib edge lower than anticipated.

Further improvement of the use of the digital model to calculate strata pressure.

The relationship between drivage-related convergence and strata stress was investigated by analysing measurements in 24 gateroads. As a result, it will be possible in future to predict the drivage-related convergence for gateroads serving production faces as well as for other roads. In the investigations aimed at predicting convergence in face development headings and relieving stress on these headings it has not yet been possible to reconcile the results of model tests and underground measurements.

7220-AD/133 Shield support for face ends at great depth - StBV

Duration from 01.05.1987 to 30.04.1989

The investigation and further development of powered support systems for face ends has yielded two usable designs. The prototypes tested are now being used successfully below ground.

The testing and further development of displacement measuring cylinders led to two pitworthy systems - a helical rod with a potentiometer and the use of reed contacts.

In order to reduce dust make as shield supports are advanced, an automatic thrust control system was developed and successfully tested.

7220-AD/754 Trials with the 'COTO CORTES' type powered support in 35-39° inclined face of 180 m in length having mechanised winning by a TEMP-1 shearer - BCC

Duration from 01.07.1987 to 31.12.1988

The first trials for this project were carried out in a short face, 25 m in length, during which the behaviour of the support system, combined with the shearer, was very successful.

Financial support was obtained in order to extend the trials to a face, 200 m in length, in which the complete system must work under production conditions.

7220-AD/755 Self advancing roof support, thin seams - FABREMIN

Duration from 01.11.1987 to 31.10.1989

Until now the project development has satisfactorily fulfilled the previously fitted steps, which can be summed up as follows.

Essays of the prototypes with satisfactory results, homologation in Spain and Germany, manufacturing of 16 Soporta units (including the changes suggested by the mine), and making those units available to the mine, just to test with them. This test will begin at the end of March in order to do a full cut of 100 units, afterwards.

7220-AD/824 Full extraction of the Barnsley seam, South Yorkshire - BCC

Duration from 01.04.1988 to 31.03.1991

Better use of the remaining reserves in the Barnsley seam and improvement of productivity in the faces by the development of a support system allowing the extraction of the full thickness of 3 m despite very weak roof and floor measures.

- Development of the software for the geotechnical appraisal programme to build in complete artificial intelligence and simultaneously a numerical model for the determination of support requirements (strata modelling).
- Design of the most suitable powered support which can successfully be applied to obtain full section extraction.
- Design of a face and system which can free the coal face from operational constraints associated with support setting and packing in a thick extraction.
- Adaptation of methods of roadway support to allow roadway re-use, including the use of roof-bolting.

This project started in 1988. A complete geotechnical assessment of the Barnsley seam at one colliery has been completed. Initial trials have been carried out to assess the suitability of the seam for retreat working, utilising rock-bolting as an additional roadway support. It is now considered that the major key to increased productivity will be the wide-scale application of retreating systems and future work will concentrate on the roadway support aspects.

7220-AD/756 Application of new winning and support techniques in very hard, thin, coal seams, 50-70 cm thick, extensible up to 1 m thick for slopes between 0 and 40° - Antracitas de Gaiztarro SA

Duration from 01.07.1988 to 30.06.1990

Fully automatic exploitation of coal seams with limited characteristics in order to improve working conditions and output. The machine will cut the coal by means of a specially adapted plough with rotating bits. Design of shields with dimensions and characteristics adapted to all the particular parameters of the Bierzo (Léón) seam. Remote control from the gates of the winning system and the support.

The following equipment will be provided by various companies, of which the main one is Westfalia Lünen:

- plough with rotating and static bits as well as ancillaries;
- face conveyor;
- shield supports;
- control equipment;
- electronic remote control.

Tests.

7220-AD/825 Adoption of multi-entry system working in the UK - BCC

Duration from 01.08.1988 to 31.07.1991

Studies into the advantages of winning methods with several roadways, as known in the United States: faster development, reduced dirt production, separate roadways for various tasks, greater flexibility, better roof control, etc. This requires geotechnical as well as operational studies in order to answer the technical and economic questions.

- literature survey and overseas enquiries;
- laboratory testing of rock samples;
- strata modelling of multiple entries and pillars;
- in-situ strata measurements;
- development of pillar design techniques;
- use of numerical techniques for designing entries;
- adaptation or development of methods of assessing support requirements;
- analysis of operational aspects.

Work on this project started in 1988. The work has begun with an assessment of the requirements for a suitable site. An initial proposal for a multi-entry drivage, incorporating both support and operational aspects, has been made and is being considered. Preliminary investigations on pillar stability have been carried out at a site utilising two entries to serve a planned retreat face.

7220-AD/826 Cutting drum design database system - BCC

Duration from 01.04.1988 to 30.06.1990

Lower costs, longer life of drums, reduced dust and ignition potential, etc. by improving the design and specification of shearer drums on the basis of a new database.

- Development of the computer program to construct the database, including information from collieries and manufacturers, as well as the results of laboratory and underground measurements.
- Laboratory and underground test work to gather information on machine performance, product size, etc.
- Examination of data in order to establish the principal factors determining machine performance, product size and pick and drum life.
- Establishment of the database for incorporation into an existing computer-aided drum design system.

Work on this project started in 1988. A pilot study has been completed to collect data on the best performing faces in categories of extracted height. Initial findings are that good management and motivated workforces are as least as significant as equipment design on productivity. Work is in hand to test efficiency of drum design by implementing designs from the 'best faces' on faces with less favourable conditions.

7220-AD/134 Development and testing of new components for AFCs - phase II - StBV

Duration from 01.04.1988 to 30.09.1990

Extension of current work on the improved operating results in the face area by further development of the face conveyor (avoidance of chain breakage and starting difficulties, reduced cost, higher face production rates or longer faces).

- Use of new materials for scraper bars and pans.
- Development and testing of scraper bars having optimal profiles and forms.
- Trials with vibrating pans.
- Development and testing of fully welded pans.
- Development and testing of telescopic tensioning systems.
- Utilisation of an automatic pretensioning device.
- Reduction of chain load by the use of booster drives.

In order to reduce the resistance factor, various flight bars were investigated at different speeds and with different depths of conveyed product.

The automatic chain pre-tensioning device was further developed and the certification procedure for the electronics completed. The measuring principle for fluid level in hydraulic couplings can be regarded as satisfactory. A soft start facility can be provided by controllable filling fluid couplings. The design of the intermediate drives must be revised in the light of the tests of the prototype.

7220-AD/135 Use of fly ash and other firm debris, pumped hydraulically from the surface, to stow goaf or other abandoned workings - StBV

Duration from 01.04.1988 to 31.03.1990

Continuation of current work in order to avoid subsidence and environmentally harmful tips, improve mine safety and reduce the costs of stowing by the use of waste material from coal preparation and power generation plants as stowing materials in seams below 1.8 m thickness.

- Examination of various finely grained waste products with a view to their applicability for the stowing or depositing process.
- Development of basic knowledge on the flow properties of highly concentrated solid/water mixtures with various compositions.
- Execution of mixing and pumping trials as well as pressure loss measurements.
- Development of suitable measuring processes and establishment of characteristic measuring values for the control of the proportioning and mixing process.
- Pressure loading of packed test cubes.
- Model scale goaf packing.
- Support of collieries during the execution of large-scale trials aiming at the construction of a pilot plant.

Work began on 1 April 1988. Various pumps were tested and several series of trials carried out with different mixes of PFA, flotation tailings and fine washery discard.

I.4 ACTIVITIES OF THE COMMITTEE OF EXPERTS ON MINE INFRASTRUCTURE

This Committee is concerned with an important and varied field comprising outbye services underground and in particular power transmission and supply.

Some projects are intended to develop new machinery or better systems, while others are concerned with rationalising manpower-intensive services.

The Committee of Experts met twice, on 7 and 8 July 1988 in León (Spain) and on 21 November 1988 in Brussels. In connection with the León meeting, a visit was made to the hydraulic coal transport system at Hulleras de Sabero SA, which is a major innovation in the Spanish coal mining industry.

In all, eight final reports were approved and six new projects launched. The main results relate to:

- automation of strata bunker systems to regulate coal clearance;
- new designs of winding rope for deep shafts employing preforming and prestretching techniques with a consequent reduction in rope elongation and hence in the number of times the rope must be recapped in the initial stages of its life;
- improvement of systems for transport by free-steered vehicles without load breaking (uninterrupted trackless haulage);
- development of new systems for checking shaft guide distances and profiles;
- new means of discriminating earth fault detection in electrical systems.

7220-AE/117 Uninterrupted trackless transport in roadways and shafts - StBV

Duration from 01.10.1983 to 30.06.1987
(Approved at the meeting of 05.07.1988)

Originally the subject of the project 'Uninterrupted trackless haulage in roadways and shafts' was the development of a highly performant trackless haulage system including development and design of planning and control systems and their components. After one year, the range of tasks was adapted to the changing situation in agreement with the Commission of the European Communities, including reduction of the budget. The heading of the project remained unchanged, but the range of tasks was newly defined and matched to general transport technology. Now the project included design and development of planning and monitoring systems for material transport, and the design of the required transport system components along the route from the pit yard to the inbye places of transshipment underground. Testing of new free steered vehicles was kept to for the sake of completeness.

The work involved was done by Bergbau-Forschung GmbH, other qualified institutes, and collieries, all monitored by small working parties.

The main concentration point of the project, eventually, was the development of a computer-based transport planning system. A preliminary study had shown that, due to lacking managerial tools, the deployment of means of transport exhibits less an acting than a reacting characteristic, i.e. it merely responds to changing operation conditions. A planning program was run which, by VDU dialogue with a large Siemens computer, determines the transport capacity demand of the individual sectors of operation at any time, sums up the resulting traffic density of each route and eventually calculates the transport capacities with consideration of particular transport/ technological data. The program also gives consideration to statutory and geological restrictions and, for purposes of comparison, issues, besides the technical data, also the required number of shifts and the planning costs. The handling of the program is described in detail in the report. At present the program is tested on a comprehensive planning example and, later on, is scheduled to be able to be run on PCs.

In another chapter, present day material transport is described, and the development of means of transport and of loading/unloading aids as well as the choice of means of transport which, in the future, will always gain more importance, is material flow monitoring and tracing. In this context some examples of present day improved monitoring systems, the beginning intensified use of EDP in this field, and the new way of thinking about material management are described.

The difficulties encountered when developing special loading units for use on free-steered vehicles with respect to varying requirements arising throughout the transport route, are described in another chapter.

Since uninterrupted transport is simply not feasible in German hardcoal mining, a variety of transshipment points is to be catered for, and these points need to be equipped in the best possible way. The role of transshipment points within the transport network is discussed, all transshipment points from the surface to the point of use underground are listed, and concepts for alternative solutions are proposed. Relative to the proposed components for transshipment points, five different solutions matched to the technologies used for transport in both directions were developed for two new transshipment points of a colliery.

Even though at present no clear development trend in the field of vehicle technology, in particular of free-steered vehicle technology, can be recognised, and since in mainroad haulage over distances of more than 3 km trackless haulage can hardly compete with the locomotive haulage today, a comprehensive performance specification based on the results of vehicle tests and of talks with operators and manufacturers, was set up for such a vehicle.

Furthermore, tests of a crawler vehicle with elastomer 'caterpillars', of a mainroad transport vehicle with two transshipment cranes, and of compact vehicles with hydraulic high-torque wheel hub motors run on inflammable fluids for manriding, are described.

On the basis of the last mentioned vehicles, a heavy equipment transport vehicle with tandem wheel sets on the load module is under construction at present. The last item of the report is the description of the modifications on the mainroad transport vehicle under test in terms of the transshipment technology involved.

7220-AE/120 Optimisation of underground belt conveyor and rail-guided transport - StBV

Duration from 01.10.1984 to 30.06.1987
(Approved at the meeting of 05.07.1988)

The extensive investigations in the Bergbau-Forschung GmbH test field for belt conveyors were continued and resulted in a number of improvements to belt conveyor components.

Studies on hydrodynamic flow couplings of 422 size were successfully completed after some other long-term and comparative tests. It turned out that the couplings improved during the preceding project:

- 422 TvlaW (Schumacher) and
- 422 TWV-R (Voith)

can be considered identical as far as their suitability for operation of belt conveyors (using water as a medium) is concerned.

Their compatibility was confirmed by comparative tests on four other existing couplings modified to fit the 422 TWV-R (Voith) system.

Tests on a double-drum drive revealed that an integrated drive system always performs better than individual drives.

Tests on couplings were extended to size 487 (after modification of the test facilities) and completed as well. The types made available by Voith and Schumacher (487 TWV-R and 487 TvlaW) are suitable, with certain reserves (see page 12), in their respective categories (90 to 130 kW) and in their respective load classes for use with belt conveyors.

Among the three transfer point alternatives improved in the test field for conveyor belts, segmental sliding and rotating chutes have been widely introduced in underground operations. Unlike this the raw coal guide-plate had to be remodified.

Subsequently to tests on counterweight-supported rubber wipers other cleaning systems (Hosch, Joto, Roskopf) were included in the investigations. According to the present state of research the finned wiper by Hosch turned out to be most suitable particularly if used in conjunction with a novel type front wiping system.

After successful test runs on rubber-coated belt idlers, other coating alternatives (ceramic, nylon, epoxy, polyurethane and nickel-plating) some of which are cheaper, were included in the tests. Besides rubber coatings,

ceramic lining may be considered a technically mature method as well which is supported by many years of underground use. On the other hand nickel-plated idlers do not comply with underground requirements.

Tests on conveyor belts of low tensile properties were carried out at the test workshop of Bergbau-Forschung GmbH. Executions of belt joints (non-detachable) were laid down under DIN 22 121, section 2.

Although progress has been achieved on the telemetric systems for monitoring the tensile forces in belts during operation, a number of problems still waits for solution, e.g. power supply to the electronics (suitable battery).

The prototype of an external auxiliary drive to support operation of electric crabs in inclined roadways was put to work at Heinrich Robert Colliery. The unit lagged far behind its design capacity. It will have to be decided by the bodies in charge whether and in what form the project can be carried on.

The rope testing agency continued its work on the sub-project 'running behaviour of relevant parts of suspended monorail trains'. The running resistance coefficients of eight characteristic running systems were determined and their respective constructional features compared. The results are referred to level roadways. Behaviour in inclined roadways and curves has not been considered. As for traction the aforesaid coefficient was as much as 100% better than with pushing operation. Values found varied between 0.005 and 0.012.

7220-AE/121 Diagnosis of hydraulic and pneumatic controls - WBK

Duration from 01.10.1984 to 30.09.1987
(Approved at the meeting of 05.07.1988)

Thanks to the premature identification of flaws or imminent damages the presently high proportion of avoidable successive damage will go down dramatically. Moreover, if damages occur within a very short time and without being identified, they can be located and repaired rapidly.

To be able to locate flaws at all one needs reference data of the sound or undisturbed operation. Further to this reference, vectors associated to each of the defect categories to be located, as well as knowledge on the tolerances of operation-induced data scatter, have to be on hand.

The basic concept of diagnosing hydraulic machinery relies on the analysis of a comparison between rated and effective physical parameters of that machine. Any and all typical machine parameters are logged and fed to a microprocessor. In that processor the typical rated values for any given operational motor status are compared with the temporary effective values.

Moreover, it is possible to explain unusual phenomena by way of comparing several operational parameters to each other.

Practical application of machine diagnosing is shown by way of the hydromotor example. The results from examinations on the hydromotor were subjected to regression analyses which allow to determine the rated status for any given operational phase.

Any deviation of the effective status from the rated value beyond a defined range gives rise to the allocation of error points. Error reportings are triggered depending on the number of error points allocated.

7220-AE/119 **Study of the improvement of measurements, costs and reliability in the monitoring of shaft control equipment, and of the avoidance of breakdown and damage to transport equipment - WBK**

Duration from 01.07.1983 to 30.06.1987
(Approved at the meeting of 05.07.1988)

When checking the guide rails in mine shafts the following measurements have been taken so far, by some mechanical and continuously operating instrument during slow travelling through the shaft:

- the relative distance of guide rails and
- the width of guide rails.

Moreover, random measurements are done for:

- the depth of guide rails.

By monitoring the guide rail distance one tries to find out those points of the travelway where there is a risk that the mine cage will either be squeezed or derailed.

The instrument for guide rail measurement presently used and functioning on lateral viz face-side scanning rollers, transfers the measuring data, as a function of the travelway and via Bowden wires, to a graphic recorder. Evaluation of the graph is done according to authority regulations and by hand. As the device is merely a mechanical one there are no problems in shafts where explosive gases might be present.

Under the present research project the mechanical device was modified in such a way that virtual (mechanical) progress through the shaft is no longer registered by Bowden wires - via inductive travelway sensors - but in the form of electric signals on a magnetic tape recorder. For checking purposes the recorded values are displayed in the analog and digital modes. The relevant values, i.e. deviation of guide rail distance (Spw) from the rated value viz deviation of guide rail width (h_x) of both the tracks from rated values, are displayed as a function of the travelway and in the form of analog diagrams on paper.

Comparison of the diagrams yielded by mechanical versus electrical recording, shows a sufficient correlation of measuring data.

The electric guide rail measuring device needs the approval of the Chief Mines Inspectorate of North-Rhine Westphalia as a flameproof viz intrinsically safe unit. Subsequently, a program will have to be established for computer-aided evaluation of the measuring data stored on tape. It will only be this computer-aided evaluation, replacing the manual one, which will comply with the specifications of improved guide rail measurements.

Furthermore, under the present project, a completely new method in terms of guide rail measurement was tried out. To measure guide rail tracks for their deviation from straightness and verticality, we adapted the inertial ISSM shaft measuring system, originally designed for surveying activities in the shaft, to the specific requirements of guide rail measurement.

The complete ISSM measuring set consists of an inertia measuring unit, two guide rail scanning units, one data memory and a mobile computer.

During measuring operations the data yielded are stored in the data memory by 50 Hz cycles and, once measurement is completed, transmitted to the mobile surface computer. Data from the inertia measuring unit serve to

compute track and turning movements of the mine cage and, via polar inclusion of the measured guide rail distances, the tracks of the guide rails in terms of straightness and verticality.

Speeds and travelways of the mine cage are determined, via integration, from the acceleration signals of three accelerometers arranged in a relative vertical position. By its measuring principle alone, the method offers simultaneously logging of kinetics and geometry and as such allows to find out about the correlations between guide rail geometry and cage kinetics.

Thanks to specific calibration, filtering and backing provisions in conjunction with off-line evaluation, it was possible to improve the measuring accuracy by several orders of magnitude against usual applications in aeronautics and space travel.

The following errors were found, on a sample of 52 measurements, by comparative measurements using a vertical laser:

Verticality errors $\leqslant$ 5 cm/1000 m
Travelway errors $\leqslant$ 0.5 m /1000 m.

7220-AE/122 Earth fault discrimination - WBK

Duration from 01.10.1984 to 30.09.1987
(Approved at the meeting of 05.07.1988)

The Bergbau-Versuchsstrecke (BVS), an institute of the Westfälische Berggewerkschaftskasse (WBK), Bochum, Germany, has been the first to be successful in developing a cable protection system which prevents gas ignition in the case of damaged electric power cables. The components of this cable protection system are quick-acting earth fault detection units combined with electronic and mechanical switching elements actuated by electrodynamic linear motors. The total response time of the system is shorter than one millisecond. Within this time interval the system cuts off any power from the point of fault and prevents the ignition of even hydrogen-air mixtures with a minimum ignition energy of only 7% in comparison with methane-air mixtures. The working face will be the field of application for this cable protection system.

It is the first time in history that coal mines have had a cable protection system at their disposal which certainly prevents the explosion of gas-air or coal dust-air mixtures in case of internal faults or mechanical damages of electric power cables. There exists no limitation in power transmission capacity imposed by the cable protection system.

Meanwhile, the series production of this protection system has been started. The WBK-Bergbau-Versuchsstrecke accompanies the underground trials of this system in cooperation with two coal mines situated in the Ruhr and Saar areas.

7220-AE/123 Operational behaviour of pre-stretched strand type ropes in shafts II - WBK

Duration from 01.02.1985 to 31.01.1988
(Approved at the meeting of 21.11.1988)

Part 1. Pre-stretching of Ropes and Practical Trials in the Shaft

The present research project is a continuation of a previous one of the same title. This report is thus a continuation of the first final report of July 1985. Further practical trials were run to reduce undesirable elongations of newly installed ropes, by pre-stretching. Further tests are carried out on the influence of homogenised elongation behaviour of pre-stretched ropes of multi-rope sets on shaft-winding operations and on the service life of pre-stretched ropes.

Representation of trial results. Pre-stretching of the ropes anticipates much of the permanent elongation occurring during the initial phase of operation. This procedure helps to reduce interruptions and expenditure for shortening the ropes at attachments as well as to mitigate previous problems during the start-up period.

The frequently occurring difficulties of equilibrating rope loads on multi-rope installations are eliminated when using pre-stretched ropes. This, again, reduces winding interruptions on operational troubles; winding becomes safer. The expected extension of operational life of pre-stretched ropes was reconfirmed by the present project.

Part 2. Rope Elongation Measurement

Continuation of the development started under the previous project to provide magnetic rope markers for no-contact measurement of local rope elongations. The new system no longer relies on coils, but on Hall effect sensors.

The measuring technology, most of which has been combined from novel-type components, was tested at the test winding installation of Versuchsgrube Tremonia for its suitability, reliability and accuracy. The tests are indicative of the suitability of the new system in shaft-winding.

For newly installed winding ropes one has to expect elongations between 0.4% and 0.8% during the first operational phase; the required measuring accuracy was attained.

7220-AE/307 Material transport - CERCHAR

Duration from 01.04.1986 to 31.03.1988
(Approved at the meeting of 21.11.1988)

The purpose of this project was to devise and implement new methods of materials transport and handling with a view to:

- increasing productivity,
- improving safety standards.

The topics dealt with in the project were as follows:

- production and distribution of a technical document for the users of the 800 duorail;
- computerisation of transport systems (monorail - duorail);
- design and development of a main haulage/monorail transshipment station;
- design and development of a method of installing and salvaging an AKH winning/support system;
- design and development of a method of transport on faces worked by box-scraper loading;
- feasibility study with a view to replacing the JOY-SCOUT-CAR by a multi-purpose vehicle for which specifications were to be drawn up.

7220-AE/814 Monitoring, control and automation of strata bunkers - BCC

Duration from 01.04.1985 to 31.03.1988
(Approved at the meeting of 21.11.1988)

The objective of this research was to develop a package for the automation of the more common types of HSB, leading to their integration with the colliery coal clearance system, a reduction in manpower, and an increase in efficiency. Originally there were many different designs for HSBs, but the most universally adopted layout now comprises a belt conveyor and moving plough infeed arrangement operating in conjunction with a loading machine (shearer and scroll) outfeed mounted on an armoured flexible conveyor (AFC). It was therefore for this type of HSB that the automation package was developed.

To achieve these objectives the first step was to find a means of controlling the flow of coal in and out of the bunker. This was achieved by having the inbye trunk conveyor delivering onto a metering conveyor having a hopper capacity in the order of 10 tonnes and an overspill arrangement at the rear.

To monitor and control the bunker a programmable control unit was developed in conjunction with Transmitton Ltd. The unit was based on their HA range of equipment which permits a high degree of flexibility to suit varying requirements. The operating system provides 36 digital and eight analogue programmable functions which may be configured to perform a required task.

Changes can be implemented rapidly by entering the outstation parameters into a configuration program run on a DEC PDP-11 computer; this produces an EEPROM which is then plugged into the HA1 unit along with a PROM containing the standard operating system. The unit was constructed with an upper intrinsically safe compartment (IS) housing the main processor, controls, liquid crystal display (LCD) mimic diagram and cable terminations, whilst the lower flameproof (FLP) compartment housed the pilot circuit and section trip relays.

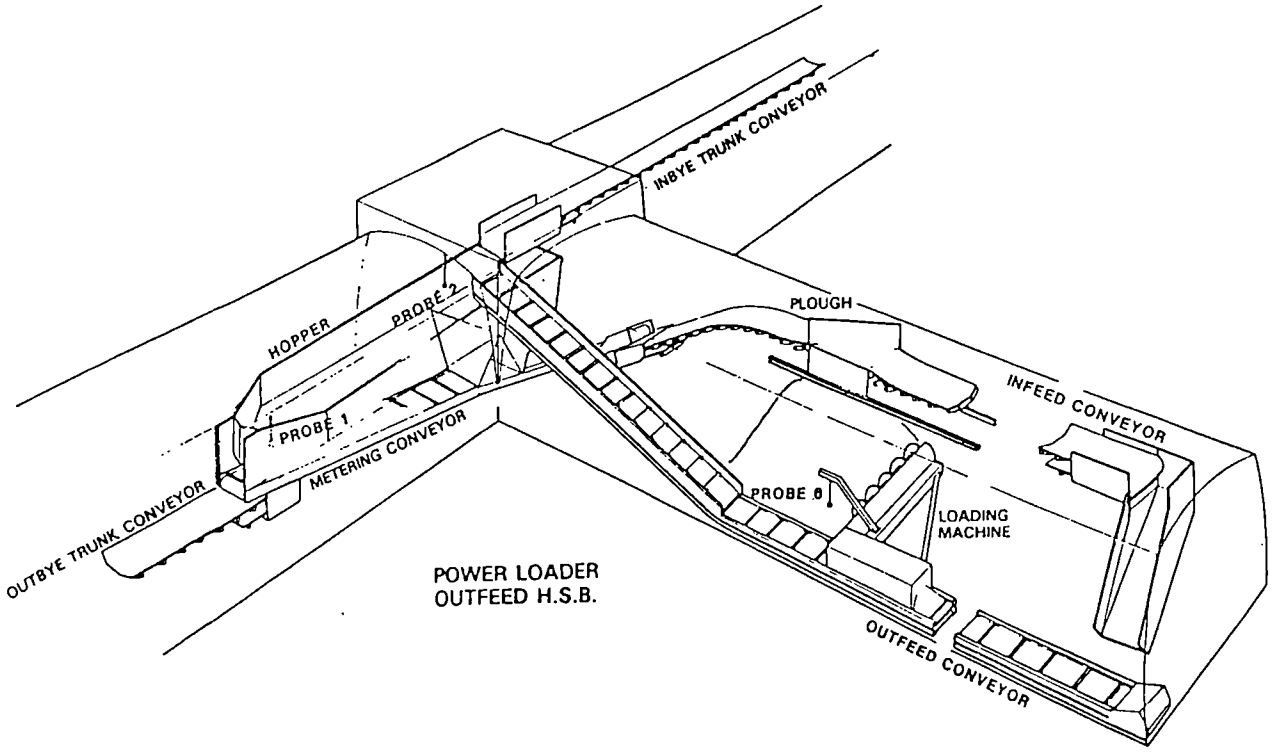
Dependent upon the compatibility of the Mine Operating System (MINOS) control system used at a particular colliery, the monitoring and status information is available to the surface control room. Three command signals are available to the control unit from the surface: bunker stop, to completely disable the bunker; infeed stop, to prevent further coal entering the bunker; and outfeed stop, to prevent the bunker discharging. Three modes of operation can be set on the control unit: automatic, for normal operation

under surface command; manual, to give control of the outloading machine to a driver; and maintenance, to permit the operation of individual items of machinery for testing purposes.

In operation the bunker will automatically start if either the inbye or outbye trunk conveyors are running. When the inbye flow rate is less than the outbye flow rate, the hopper will empty.

The underground trials were carried out at Bersham Colliery, Western Area and Annesley Colliery, Nottinghamshire area. During the automation system trials at Annesley Colliery a number of minor alterations were made to the bunker computer operating program to achieve satisfactory operation. The only major change was the replacement of the IS solenoid operated hydraulic valves controlling the AB16 shearer. Following a number of valve failures due to contaminated oil, it was decided to replace these valves with FLP (240 v) operated poppet valves which were proved to be reliable throughout the rest of the trials.

Delays on conveyors inbye of the bunker have been reduced from 9.6% prior to the installation of the horizontal strata bunker to 5.9% when the bunker was in full automatic operation.



Horizontal Strata Bunker (HSB) Arranged for Full Automation

TRANSPORT

7220-AE/751 Hydraulic transport of coal from the face to the surface - SABERO

Duration from 01.04.1986 to 01.10.1989

The Committee of Experts visited the Hulleras de Sabero installations. The gravity hydrotransport system in the production area and the pumped horizontal and vertical system in the roadways and the Herrera shaft were working very satisfactorily.

In the coming months, coal production will begin in a part of the mine in which it is hoped to achieve higher unit output.

7220-AE/401 Design and development of a trackless electric trolley transport system for main roadways - CARBOSULCIS

Duration from 01.03.1986 to 31.03.1990

The materials transport vehicle has been ordered to colliery specifications. Preparatory work is being carried out for trials of the equipment.

7220-AE/813 Movement of heavy equipment underground - BCC

Duration from 01.09.1984 to 31.08.1988

Equipment in use in North Yorkshire, Western and Notts areas, comprising three FSVs, a powered support trailer and a rail-mounted transporter, have been monitored. Their respective operating characteristics, problems and advantages will form the basis of the final report now being compiled.

7220-AE/125 Optimisation of belt conveyor system in coal winning districts - StBV

Duration from 01.04.1987 to 30.09.1989

The aim is to improve the reliability of major conveyor components in safety and operational terms and to develop a telemetry system to measure belt tensions in service.

In the year covered by this report, work was carried out on belt cleaning and spillage recovery devices, idler coverings, non-destructive testing of idlers, snub pulleys, separable and permanent belt joints and an instrumented belt.

7220-AE/126 Adaptation and further development of conventional manriding and transportation techniques in view of medium term requirements - StBV

Duration from 01.07.1987 to 31.12.1989

Existing conventional systems for manriding and materials transport will be further developed, optimised and better coordinated in respect of operational reliability, availability, performance and hence cost-effectiveness.

In the year covered by this report, work was carried out on further development and new developments such as leading axle gear, a rapid chairlift/cabinlift, a materials planning program, dinting and floor clean- systems and auxiliary and replacement drives for overhead monorails.

7220-AE/753 Automation of the main Carrasconte and Lumajo transportation system through the Villablino Transversal: radio-controlled locomotives and dispatching by microprocessor - MSP

Duration from 01.09.1987 to 31.08.1989

Conditioning works on main transport roadway (railway, rail switches, overhead power cable, catch drain) have been started. Final structure of transport and control system has been defined. Sensors and effectors have been defined and ordered. Railway control microcomputers and several sensors have been developed at prototype level. Locomotive assembling and wagon conditioning have been started.

7220-AE/816 Underground disposal and utilisation of colliery wastes - BCC

Duration from 01.04.1987 to 31.03.1990

Pumping and stabilisation trials have been undertaken and a workable system devised. Investigations to find a rapid hardening for earlier stabilisation are continuing. Surface trials are planned, the specification for a plant capable of handling 500 000 tonnes p.a. of dirt/tailings is agreed.

SHAFTS

7220-AE/127 Development and testing of new equipment and information techniques in order to improve measurement costs and reliability in the monitoring of shaft guiding equipment - WBK

Duration from 01.07.1987 to 30.06.1990

Extensive work is in progress at the WBK laboratories. The first interim findings will be described in the next report.

7220-AE/124 Improvement of electrical supply techniques II - StBV

Duration from 01.03.1986 to 31.08.1988

The purpose of the project was to improve aspects of electrical circuits. The following work was carried out.

- A rapid-action reactive current compensator safe for use in methane atmospheres was tested below ground.
- A double change-over switch for pole-changing induction motors up to 1 000 V was developed.
- A system analysis was carried out and led to the construction of a low-line 10 kV compact switching unit safe for use in methane atmospheres and employing SF6 arc suppression.

7220-AE/752 Automatic inspection of trolley wire in locomotive transport systems by means of artificial vision - AITEMIN

Duration from 01.03.1986 to 28.02.1989

A prototype of an inspection system has been built up on an adapted manriding car. It includes the sensor, which is composed of a CCD camera mounted on a mobile framework, to follow the trolley wire, and the image analysis and computing machines. A special power supply unit allows the use of DC power from the wire line or from batteries. Laboratory tests have been carried out to check the whole system before starting mine site tests.

7220-AE/308 Expert systems for the diagnosis of breakdowns and the preventive maintenance of mining machinery - CERCHAR

Duration from 01.07.1987 to 30.06.1990

The objective is to obtain a means of rapid and accurate diagnosis of faults or deterioration during the operation of power loaders in order to reduce downtime. Continuous computer monitoring of the functional parameters will also make it possible to address the problem of preventive maintenance.

After a review of the literature on the industrial applications of expert systems as aids to fault diagnosis, a model expert system was developed in an MS DOS environment.

7220-AE/815 Electric trolley system - BCC

Duration from 01.04.1987 to 31.03.1991

Testing of the prototype current collector trolley has been extensive and is continuing. Results have been good and developments to reduce maintenance and increase life have been undertaken. Evaluation of new aluminium-free compact brushgear has also been possible. The end-entry retrieval mechanism is now being treated.

7220-AE/817 Development of a workshops facility for quality inspection of gearboxes - BCC

Duration from 01.04.1987 to 30.09.1988, extended to 30.09.1989

The load test rig is commissioned at Bestwood Workshops and has been used for gearbox testing; full commissioning of the analytical system is now planned for February 1989. The programme has been extended to September 1989 for the full system results to be produced.

7220-AE/818 Investigations and production of AC-driven electric locomotive - BCC

Duration from 01.04.1988 to 30.09.1990

More safety and efficiency in locomotive haulage and reduction of costs by the development of a rugged, reliable AC-driven battery powered locomotive offering speed/tractive effort characteristics similar to that of existing DC-driven units.

- Design of a suitable AC-driven locomotive for operation from the standard DC battery, using an AC-induction motor without commutator brushes and a wound rotor.
- Development of a power control system using a microcomputer and advanced power transistors in order to give high reliability and virtually maintenance-free operation.
- Development of appropriate flameproof housing.
- Construction and trial of a fully operational locomotive including AC motor and control equipment.

Typical locomotive duty and specification have been established. The AC motor specification and design for its incorporation into the loco design has been approved. A power stack, designed after selection from four alternatives, will be evaluated during laboratory testing. Control system design is in hand.

7220-AE/128 Investigation into the possibilities of improving protection against corrosion of winding ropes by a novel zinc-aluminium coating - WBK

Duration from 01.04.1988 to 31.03.1991

Prolongation of the lifetime of winding ropes and, thus, cost reduction, by applying a zinc-aluminium coating in order to prevent corrosion.

- Static and dynamic studies of the effects of Zn/Al coating on the mechanical properties of the rope.
- Laboratory tests and trials on the protective mechanism to optimise the coating of the wire/string/rope under combined tribologic and corrosive stress.
- Monitoring the use of a coated rope in a shaft with a corrosive environment.
- Comparison of the results obtained using coated ropes with those using conventionally protected ones.

7220-AE/819 Continuous vertical conveying of mineral - BCC

Duration from 01.06.1988 to 30.11.1990

Lower costs, increased extractable reserves and extended lifetime of collieries (particularly if output is limited by the winding system) through the replacement or supplementing of the winder by a vertical continuous conveyor or by operating the latter between mining levels.

- Development of cross-rigid steelcord belting, in particular adhesive gum and cover for steelcord belt as well as adhesive gum and compound for cleats and sidewall.
- Investigations into the availability of potential sites.
- Cost comparison studies between vertical continuous conveying and other forms of transport.
- Selection of one site and full design of the whole conveying system.

Three main areas of application have been identified; extension of existing shaft capacity from shallow working to the surface, reduction of winding cycles by conveying from pit bottom to winding inset, and as an alternative to cross measure drifts by staple shaft conveying. A number of sites are being analysed on both technical and economic grounds.

7220-AE/129 Optimisation of electric drive technique - StBV

Duration from 01.09.1988 to 31.08.1991

Reduction of energy cost and heat release, as well as improvement of the degree of equipment utilisation, by the development of a static frequency changer to control three-phase asynchronous motors for hydraulic power transmission and of the inductive feed of an intrinsically safe electric drive for manriding purposes.

Static frequency change:

- system study,
- study of the required explosion protection,
- study of new types of frequency changes.

Inductive feed:

- system study,
- preliminary investigations,
- development of the inductive-fed drive heads,
- integration of the drive into the manriding systems.

7220-AE/820 An on-line fluid condition monitor - BCC

Duration from 01.06.1988 to 30.11.1990

Reduced machinery downtime as well as increased productivity and profitability by the introduction of a system of planned, predictive maintenance based on the on-line measuring of the conditions of hydraulic liquids. This system should not only warn the operator, but also provide warnings and supported actions to management. Finally, the ability to collect real-time should allow feedback from the user to manufacturers and designers.

- Development of an on-line contamination measuring device which can be retrofitted to existing machinery.
- Development of a temperature measuring device which could be used for both temperature and viscosity monitoring.
- Development of an oil level measuring device.
- Establishment of the communication link to the surface computer.
- Elaboration of the software to analyse data from the device and to provide appropriate warnings such as filter blocking, contamination ingress and machine wear.

Full assessment of the importance of the various characteristics of fluids used in coal mining is being conducted. Close liaison with mining machinery manufacturers is being undertaken to explore the options for retrofitting of transducers within the known constraints of physical size and shape.

7220-AE/130 Monitoring of the safety of pressurised hydraulic systems - WBK

Duration from 01.07.1988 to 30.06.1990

Reduced power requirements, longer life of hydraulic drives, less heat transfer to the air, reduced risk of accidents by the development and adaptation of load sensing systems (LS systems) for the simultaneous control of the pressure and the yield of hydraulic pumps.

- Laboratory test to define the characteristics of LS systems and to compare them with conventional solutions (control of pressure or yield).
- Surface and underground trials to test the function and reliability of LS systems.
- Long-term measurements to define the reduction of power consumption.

I.5 ACTIVITIES OF THE COMMITTEE OF EXPERTS ON MODERN MANAGEMENT

A conference on 'Improving productivity through technology - Modern management in the coal mines of the European Communities' was held on 4-6 May in Luxembourg. It was attended by about 250 representatives of various sectors of the coal industry, who showed great interest in the work described.

Mr M.S. Shelton (Head of Information Technology Dept. British Coal Corporation) and Mr H.E.F. Rauhut (Bergwerksdirektor, Bergbau AG Niederrhein) presented a brilliant technical introduction on the subject of the symposium. In the final session Mr E. Horton (Director of the South Yorkshire Area, British Coal Corporation) drew the conclusions from the conference and from the three round tables.

The main conclusion was that the European coal industry already has the equipment and technology, but that it is now necessary to use them more efficiently in order to reduce the production costs. This may be obtained by:

- Increasing the reliability of the selected panels to be worked, exploring in advance by means of the in-seam seismic methods.
- Extensive application of remote control and automation in order to reduce the gap between present production and potential production of the faces.
- Provide colliery management with integrated and selected information, to be utilised in problem solving and decision making.
- Improvement of machine reliability and manpower information.
- Working in the direction of the new International standards in search of interconnection of the systems and, to achieve this, increased Member State cooperation. These items will also form the subject of future research activities, the importance of which was underlined by several speakers.

The Committee of Experts met on 3 and 4 May 1988 in Luxembourg and on 12 December 1988 in Brussels. It was agreed that a study should be carried out on 'Harmonisation of data communications'. The working party was set up and work began on 20 January 1989.

Seven final reports were approved and 14 new projects started. The main results include the following:

- experiments with systems for fault detection ahead of the face by means of elastic-wave radar;
- development of a full range of portable devices for automatic data acquisition below ground;
- computer-based automation and control systems for the trunk conveyors in the Selby complex;
- development of sensors incorporating the necessary electronics for digital data transmission;
- development of new computer programs to predict deposit characteristics.

7220-AF/111 Prediction of the characteristics of deposits - StBV

Duration from 01.04.1985 to 31.03.1987
(Approved at the meeting of 02/03.05.1988)

The application of geostatistic methods is another means to explore the area ahead of the face in the coal mining industry. Corresponding to the different tasks resulting from the precalculation of a deposit characteristic in the various planning phases the efficiency of these modern prediction methods was tested. Due to its economic significance the precalculations were mainly concentrated on the characteristic 'seam thickness'.

The examinations showed that suitable results may be arrived at using the kriging developed for the area directly ahead of the face in an early planning phase at various states of the exploration work. Comparisons between the desired and actual data, however, also showed that in the case of an insufficient density and distribution of the exploration data the under- and over-estimated seam sections had approximately the same dimensions. Larger local deviations between the values for neighbouring deposits could i.a. not be registered due to the so-called smoothing effect so that the estimated values calculated by means of kriging for only a lower exploration density frequently behave in a more balanced way than the real deposit values.

For mining-related decision making in these early exploration phases a prediction which is more realistic in relation to the deposit behaviour is produced compared to kriging by applying the advanced geostatistic methods, in particular the conditioned simulation and the co-kriging. To apply these two methods to the problems existing in connection with the exploration of the area ahead of the face in the coal mining industry, extensive programming work had to be carried out in advance. Subsequent examinations show that the simulation method is particularly suitable for efficiency- and safety-related questions. Comparative calculations between simulation and kriging when evaluating panels in relation to their area portions above a present limit revealed that the values calculated by simulation are reflected in a more realistic way than the results of kriging.

Co-kriging has to be applied preferably if high estimation errors are to be expected due to a low exploration density. Calculations using this method showed that the estimation errors could be reduced by up to 20% compared to kriging for example.

By means of a post-mortem study it could be shown that an economic mine planning based on geostatistic methods is possible. Using a face which is being mined as an example it could be illustrated that the end of its life, which could not be predicted from the mining point of view, could have been established already at an earlier point in time if modern prediction methods had been applied to calculate the seam thickness of the face.

Finally work commenced to set up a geostatistic programme system for mines which can also be applied to those users not knowing the theoretic background of the methods.

7220-AF/112 Operational testing of new sensors for the measurement of physical quantities - StBV

Duration from 01.04.1985 to 31.03.1987
(Approved at themeeting of 02/03.05.1988)

The work within the research project 'Transducers with integrated data processing' (7220-AF/108) was continued without interruption. Besides the inspectorate's approval of modified or newly developed transducers and measuring equipment, work on new developments was also carried out, such as development of a cheaper pressure transducer and a line measuring system for three-phase AC networks.

During underground trials, mechanical and electrical defects were found with some sensors. These deficiencies could either be eliminated or they led to other design configurations for future developments.

In parallel to this work a complementary research project 'Measuring station for transducers with integrated processing' (7220-AF/113) was carried out.

The work is carried on - as far as necessary and logical - within the R&D project 'Transducers with integrated processing, Part 2' (7220-AF/119).

During field testing of the transducers it was also found that inspectorate-approved testing systems for the analog outlet interfaces of transducers and input interfaces of data gathering systems are urgently required. These testing units are to be developed within the framework of the current research project 'Testing and service equipment for analog and digital interfaces' (7220-AF/120).

The final reports for the four projects coded AF/108, AF/109, AF/113 and AF/119 will be submitted jointly.

7220-AF/203 Elastic wave radar for seam reconnaissance - INIEX

Duration from 01.04.1984 to 31.03.1988
(Approved at the meeting of 12.12.1988)

The theoretical studies on the construction of an acoustical radar for the detection of disturbances ahead of the coal face in a mine were carried out as far as it was possible. All the theoretical aspects have been perfectly mastered.

No further progress is possible here because the available experimental data are insufficient to be able to give quantitative conclusions to all the questions studied. Unfortunately, because of the problems encountered in the approval of the prototype generator developed by INIEX, these data are insufficient.

The experimental investigations were limited to one single site, the experimental TREMONIA Colliery, because of the lateness of the approval. This site presents a seam 50 cm thick, which is very small, and a coal face reduced to the height of the gallery, about 2.5 m, which does not permit all the desired tests.

In fact, it is useful, in an initial study, to examine the seam at several points (10 to 20 points). In the specific case of TREMONIA we were only able to place four separate points in the coal seam, that is a source point and three measurement points. Nevertheless, the experimental study conducted enabled us to demonstrate various phenomena that confirm the results of the theoretical studies.

By thus studying the behaviour of seismic waves at high frequencies, above 1 kHz, we have shown that the attenuation of these waves was not an increasing monotone function of the frequency, but on the contrary, beyond a critical frequency, this attenuation diminished.

The study of the distribution of energy between the coal seam and the surrounding strata has also proved that the coal seam could be a preferential support for the propagation of certain guide modes. Similarly, the different values obtained in the measurement of the velocity of propagation indicate that this propagation can be accomplished otherwise than by spherical dispersion.

Even though we were not able to conduct measurements in a larger seam, we are of the opinion that such a seam will turn out to be a more favourable propagation environment both for attenuation and for guided propagation in the coal layer. We note, in fact, that when the thickness of the seam increases, the phenomena observed shift toward lower frequencies. The result is that the diminution of the attenuation appears sooner, which strongly reduces this attenuation for all the frequencies above the critical frequency.

Finally, these studies have demonstrated the value of using acoustical radar and of using the cross correlation between the signals transmitted and received for the analysis of propagation phenomena. Therefore, we remain optimistic about the potential offered by the method developed to detect disturbance in exploitable coal seams.

Nevertheless, even though the limited results are very encouraging, we do not recommend that this project be continued unless additional data are obtained in advance. One cannot, at the present stage, recommend anything other than intensive measurements in an active coal mine.

7220-AF/815 Data gathering techniques - BCC

Duration from 01.04.1983 to 31.09.1987
(Approved at the meeting of 12.12.1988)

Recent increased competition in the energy market has accelerated the need for the British Coal Corporation to increase production efficiency by increasing machine utilisation. This aim necessitates a comprehensive knowledge of plant operation and machine performance over the full operating spectrum, and a thorough understanding of strata behaviour during the coal extraction process. In achieving this objective, portable underground instrumentation will have an important part to play. Firstly, it will complement existing on-board surveillance devices, providing additional on-site or more detailed information, and secondly, it will enable parameters to be recorded in areas where permanent instrumentation is not available.

A portable solid-state modular instrumentation package has been developed, specifically for use in operational and investigational applications. The interchangeable modular flexibility of the system permits a variety of configurations to suit specification applications. The system is compatible with existing data transmissions systems for on-line monitoring or long-term data gathering. In-situ verification that data have been successfully recorded and the ability to display data underground were essential features. Additionally recorded data can be retrieved underground and manually brought to the surface for computer analysis.

Since the commencement of this work, five recording elements, two data retrieval units and a 4-channel signal conditioning unit have been developed. All the instrumentation developed comply with recognised standards concerning analogue signals in coal mines, and are certified intrinsically safe to BS1259:1958 or are in the process of being certified.

7220-AF/816 Selby spine conveyor belt management and control system - BCC

Duration from 01.04.1983 to 31.12.1987
(Approved at the meeting of 12.12.1988)

The purpose of the project was to design and implement a computer-based control system for the spine conveyors at Selby. The Selby coal field covers an area of 280 km^2 with total deposits of over 2 000 million tonnes. Planning consent was granted in the late 1970s to mine 600 million tonnes from the Barnsley seam.

A key element of the mining plan is the coal clearance strategy, designed to gather coal from the satellite mines to central distribution points and transport it to the surface at a rate of up to 3 000 tonnes per hour through drifts (called spines) on one of two central conveyor belts. Because of the length of these belts and the variable gradients in the drifts, adjustable belt speeds and independently variable coal discharge rates from the bunkers along the spines, the problem of maximising coal throughput without exceeding the traction limits of the conveyor drives and without spillage at the transfer points is a complex one.

The Selby Spine Conveyor Belt Management and Control System was developed to maximise coal throughput without exceeding the tractive effort limits of the conveyor drive motors and without spillage at the bunker outfeed loading points. The software developed forms an extension of the currently available MINOS system (MINe Operation System), which is British Coal's standard for the monitoring and control of mining equipment by computer. The fundamental requirements of the system were to:

(a) maximise coal throughput,
(b) avoid power overload of the spine conveyor drive motors,
(c) avoid spillage at the loading points,
(d) prevent the filling of bunkers which could cause production stoppages at the satellite mines,
(e) optimise power consumed by the drive motors.

The requirements to maximise coal throughput and prevent the filling of bunkers have been satisfied by the use of the strategy element of the system. Strategy will compute bunker outfeed demand rates by applying a set of rules and conditions which reflect the contents of specific bunkers. A weakness in this philosophy was discussed in Section 6.

Strategy will compute bunker outfeed demand rates based on their respective bunker contents; this does not necessarily utilise the available spine belt capacity. A possible improvement on this situation would be the use of a new rule called SHAREUP, which would share out the available belt capacity proportionally amongst the bunker outfeeds dependent on their respective contents.

To avoid power overload and spillage at the loading points, the system potentially restricts the bunker outfeed demand rates computed by Strategy. Strategy computes a set of demand rates, but before implementation they are passed to the Overload Predictor as 'requested demands'. If a power overload

is predicted, the Optimiser is invoked to optimise (reduce) the 'requested demands' so that the overload is avoided. If spillage is also predicted, the demands will be further reduced. This combination of strategy and overload protection works extremely well, allowing the operators at Selby's Gascoigne Wood mine to run the spine conveyors at higher utilisation levels. The benefits of this higher utilisation becomes more meaningful when we consider, for example, that the normal maintenance costs for the spine conveyors are of the order of £30 000 per week.

The requirement to optimise power consumption of the drive motors has not, at the time of writing, been satisfied. A considerable cost saving will be achieved if the spine conveyors are run at the slowest possible speed. This condition is possible when production is low and, consequently, the bunker outfeed rates are low or stopped.

Currently, the spine conveyor belt management and control system operates in tandem with the standard MINOS coal transport software on one DEC PDP 11/73 computer. As the Selby complex matures, and more items of plant are monitored and controlled, it is possible that the capacity of the computer may be exhausted. In this event the solution would be to move to the PDP 11/83 machine which provides an approximate 15% improvement in performance over the PDP 11/73. A more likely solution would be to use two DEC PDP 11/73 or two PDP 11/83 computers.

If two machines were used they would communicate using DEC's networking product DECnet, which would allow the standard MINOS system to operate in one machine while the spine belt management system would operate in the second machine. There would be some cost involved in having DECnet installed on both machines, but this would be more than compensated for by the separation of MINOS from the Spine Conveyor Belt Management System.

The graphics terminal is currently only displaying information for the Anderson Strathclyde South spine belt. The operator will need to switch from a display of one spine conveyor to the other with a minimum of effort. It is proposed that a 'mouse' will be used in conjunction with the graphics terminal to page selectively from one display to another. Also, additional displays will be made available to the operator, offering an expanded range and depth of information concerning the spine conveyors.

7220-AF/812 Multiprocessor system development - BCC

Duration from 01.04.1982 to 31.03.1987
(Approved at the meeting of 12.12.1988)

The purpose of this project was to design and develop a new system architecture suited to the future needs of mining and to take advantage of new developments in computer technology and software procedures.

To achieve these aims, a high degree of flexibility was required in the system's design. To ensure that single failures did not affect an entire colliery and to enable the control equipment to be physically close to the plant under control, the system was designed as a distributed network of control elements which could be remotely monitored.

The study considered the operational requirements from an application view. It included the standard operating system facilities, the need to link together systems for large complexes, the need to have a much greater integration of secondary facilities as seen by the colliery and the possibility that information systems would be of a different form to those required for real-time control and monitoring facilities.

Consideration had also to be given to the needs of system design, catering for production and operation more rationally so that enhancement, repair and other software support could be provided more rapidly and with less effort than was currently the case.

As a result of this study, a design specification was produced.

The system design would attempt to meet the requirements of the design specification. System architectures should take account of the advantages and disadvantages found in the previous MINOS, and also of the communications and system designs being carried out under West Side (Selby) project. It attempted to make use of the existing application software base as much as was practical, although it was recognised that fundamental architecture changes would mean some restructuring of the application software.

Broadly, the design would attempt to provide single application hardware modules linked to common, but if necessary, multiple intelligent terminals with interprocess communication facilities. Data transmission would be handled outside the application processors, a method which would lend itself to the introduction of new standard communication protocols.

Once the initial designs had been established, a laboratory demonstration, test and evaluation system was to be constructed. Following successful completion of the design an experimental practical system was to be installed at a colliery before releasing the system to the industry.

In conclusion, this project has enabled a more versatile monitoring and control package to be developed. It has investigated hardware-independent, configurable control and monitoring systems and demonstrated some of the techniques on a remote monitoring package for complex automated mining equipment like shearers.

7220-AF/829 Electronic time study - BCC

Duration from 01.10.1986 to 31.03.1988
(Approved at the meeting of 12.12.1988)

In 1984 British Coal therefore began a project to develop, in collaboration with Anderson Strathclyde plc, an intrinsically safe hand-held data capture unit, the CS21 (DCU), for use underground, together with the driver software and the applications software for the four types of study carried out in mines.

The application software, contracted to Anderson Strathclyde plc, was produced in three stages.

- The performance of coal cutting/loading machines on longwall faces.
- The development of software for assessing the performance of machine controlled and manual activities on and around the coal face, using the technique of Rated Activity Sampling at fixed intervals (Snap Study).
- The provision of software for the remaining two techniques of Work Measurement used in the measurement of other machine controlled and manual activities on and around the coal face, namely Time Study and Operational Timing.

The completion of the applications software for Time Study, Operational Timing and the ability to change study types within the shift now means that British Coal have available a hand-held data capture unit with in-built applications software. This unit now gives method study engineers the facility to record data employing any of the four study techniques.

Whether using a stopwatch or DCU, a similar amount of time is needed to collect the study data. The benefit, however, is that with the completion of the complementary analysis software for the four study types there is up to a 50% saving in the time required to produce the final report.

RECONNAISSANCE

7220-AF/824 Initial investigations of improvements in in-seam seismic techniques - BCC

Duration from 01.04.1986 to 31.03.1989

Underground trials using the hydraulic impact seismic source have shown that impact direction can determine the polarity of the shear horizont channel wave. Despite the similarity in character of the shear horizontal channel waves produced by both the impact source and a normal shot suggesting a possible 'piston' effect associated with shots, the angle of the shot hole did not affect the polarity of these channel waves. The shot mechanism is therefore more complicated than a simple piston effect.

Recent investigations have shown that it would be difficult to up-rate the asymmetric seismic source bars to withstand the forces resulting from practical charge sizes. Work on this source has subsequently been abandoned in favour of an investigation into shaped charges. A contract has been placed with the Royal Military College of Science to design and test shaped charges made from a mine approved explosive.

A contract has been placed with the British Geological Survey to investigate the effects of anisotropy on the generation and propagation of SH channel waves.

An array of three triaxial geophones were inserted into a borehole at Littleton Colliery. The signals from the geophones placed at 160 m, 130 m and 100 m increased the confidence of a conventional in-seam seismic survey result.

7220-AF/115 Development of methods of precalculation rock and soil movements under consideration of today's mining conditions - StBV

Duration from 01.03.1986 to 30.09.1988

Methods for forecasting strata and ground movements are being studied for suitability and are being further developed in order to make it possible to take protective measures when long-term workings are created. Furthermore, the methods should provide the basis for avoiding damage to existing workings.

The project is concentrating on:

- the selection of comparative methods for forecasting the parameters of strata movements;
- underground measurements of characteristic measurable variables;
- evaluation of existing prediction methods using available data;
- comparison of the results with those obtained by forecasting surface ground movements;
- presentation and interpretation of the results.

Work carried out during the year:

Data processing routines for eliminating detected measurements errors or taking into account repair measures have been extended and applied as necessary.

Considerable progress has been made on the implementation and the testing phase for the desired conversion of the EDP programs developed for calculating and displaying the above-mentioned values so that they can run on IBM PCs, which are installed in the vast majority of mine surveying offices.

Decentralised data acquisition and processing, validity checking, right up to the interpretation of the measured and/or calculated values, are used to handle the considerable volume of data in a largely rational way.

7220-AF/116 Improvement of underground planning by predicting the expected geological conditions of the deposit from adjacent explorations - StBV

Duration from 01.04.1986 to 30.09.1988

Current work is being continued on finding a way of allocating accurately the seam and strata successions of unworked geological strata to each other. It is planned to develop appropriate methods for this and to test them using examples from the mines. Forecasting makes it possible to plan winning areas with few operating problems, thereby reducing costs.

The work is being concentrated on:

- the development of basic software;
- creating the possibility of graphic interactive dialogue;
- the execution of validity tests;
- interpolation using improved geostatistics and/or indicator-kriging;
- the execution of structural analyses of stratigraphics profiles and the application of similarity functions;
- the prediction of stratigraphic profiles using the models developed;
- the drawing of conclusions for further work.

Work carried out during the year:

The following program extensions to MATCH and MATCH PLOT were completed:

- evaluation of seam deviations and manually preset allocation lines as the limiting secondary conditions controlling program execution;
- inclusion of missing information at the end of log profiles and in the case of pick sections;
- transfer of the graphic display to IBM-AT-compatible computers. The need to dispense with the DISSPLA graphics system used in the original version made extensive reprogramming necessary;
- extension of the MATCH allocation program and the MATCH PLOT graphics program to a maximum of 20 log profiles.

In addition, a nomenclature of rock types of the Ruhr Carboniferous was introduced together with the adoption of valid symbols.

7220-AF/205 Optimal planning and conducting of underground operations by the interpretation of geological data and their automatic treatment during exploitation - INIEX

Duration from 01.11.1986 to 31.10.1989

Optimum mine production planning based on the interpretation of computer-processed geological data during the production.

To predict the composition of several coal seams to be mined in different working panels in an area covering two neighbouring collieries.

Large amounts of geological data had to be collected and selected from the colliery archives and different lithological parameters had to be defined first before their transfer into the geological database. The latter input necessitated to adapt several procedures within the available software.

The analysis of the resulting isopachyte maps (for the different coal seams, the individual coal leaves, and dirt bands) combined with their geological interpretation, proved to be most valuable. They enabled us to forecast wash-out zones, potential coal seam splits and abrupt changes in thickness for the studied coal seams.

The combination of isopachyte and isolith maps revealed positive or negative correlations between thicknesses of individual coal leaves and the lithological nature of the associated 'sterile' rocks.

7220-AF/825 Development of methods of projection of geological structure data in coal fields: a preliminary study - BCC University of Liverpool

Duration from 01.07.1985 to 02.03.1987

The purpose and objectives of the project are as follows:

- To develop a method of predicting the variable throw of geological faults in unworked ground on the basis of data from existing workings etc.
- To develop methods of predicting seam contour disturbances in the volume surrounding a fault.
- To describe the behaviour and spatial variability of faulting in the coal measures.
- To develop procedures and software for the automatic interpretation extrapolation and presentation of fault data in areas of good and relatively poor data density.

The progress of the project has been excellent with the systematics of throw, dip and associated ductile strain established for normal faults. These results have been published in a variety of geological journals. Work in the present year has concentrated on software development and studies on fault populations, while practical interpretative work has been undertaken in various collieries.

7220-AF/826 Prediction of water inflows into coal mines from aquifers - BCC

Duration from 01.04.1986 to 31.03.1990

The purpose of this project is to establish the parameters governing the migration of water through strata around mine workings and to develop design methods and predictive techniques to reduce the risk of water inflows from aquifers. A database containing details of geological and mining data for mine workings within the vicinity of aquifers is being compiled by Ian Farmer Associates. A total of 452 records have now been entered from data supplied by three British Coal areas.

Numerical modelling work (Golder Associates) has included a literature review and selection of finite elements as the primary technique, together with preliminary analyses. Physical scale modelling is being carried out by Nottingham University. Models this year have concentrated on assessing the effect of varying strata strengths. British Coal fieldwork has included the completion of four boreholes at the Asfordby new mine, in which a full range of geophysical and hydrological tests have been conducted to gather data for assessment of the risk of water inflow.

7220-AF/120 Testing and servicing instruments for analog and digital interfaces - StBV

Duration from 01.04.1987 to 31.03.1990

The purpose of the project is to develop intrinsically safe instruments to test sensors with analog output or recording equipment with analog input and to monitor equipment with digital interfaces.

Further interface modules built under sensor research and development projects were tested to see whether they could be used under the European regulations on 'intrinsically safe' protection. Discussions with the testing institute have been pursued with a view to free connection to all signal output points produced by the various manufacturers.

A working paper set out a number of fundamentals such as housing designs, handlability of the testing instruments and facilities for connection to the equipment to be tested.

Work began on development of the actual circuitry for the various testing and service instruments. A laboratory instrument was produced specifically for testing and calibrating a humidity and temperature sensor.

After extensive work and discussion of the housing material with the manufacturer and the testing institute, certification has been obtained for a mobile data collection unit for service below ground. This unit is the basis for devices for inspection or testing at serial interfaces. Development of plug-in modules has begun.

7220-AF/206 Clay minerals to be used for the stratigraphic correlation of coal-bearing strata - INIEX

Duration from 01.06.1987 to 31.05.1990

Clay minerals as a lithostratigraphical tool for correlating Carboniferous coal-bearing strata.

To carry out more reliable lithostratigraphical correlations between cored boreholes, when classic correlation techniques proved to be insufficient.

A detailed sedimentological study has been carried out on cores from two neighbouring exploration boreholes, from which several sequences have been selected, sampled and analysed by XR-diffraction.

Thanks to this clay-mineralogical investigation it is possible now to produce a series of curves with crystallinity values or percentages for the different identified clay minerals.

As a first result the curve characteristics allow a rather positive correlation between time-equivalent coal seams from both studied boreholes.

A third exploration borehole has now been selected for further sedimentological and clay-mineralogical study on the base of tectonic and sedimentological criteria.

7220-AF/307 Improved prediction of the behaviour of underground workings by modelling the discontinuities - CERCHAR

Duration from 01.07.1987 to 30.06.1990

Following the tests carried out on the first version of the block generation software (RESOBLOK), improvements were made to the data structure and the user interface. Data acquisition for RESOBLOK is by way of an appropriate language.

The methodology set up for the collection of the data needed upstream of this kind of model led to the development of software for the statistical processing of structural analyses of fracturing behaviour.

Two approaches have been considered for the mechanical study of block agglomeration:

(1) The statics approach: we have tested and studied the limits to Berkeley University's KEY-BLOC software, which analyses the stability of a single block under its own weight and frictional forces.

(2) The dynamic approach: this takes into account the interaction between blocks and the natural constraints of the rock mass. A foreign team has been contacted with a view to developing a calculating code for this purpose.

7220-AF/751 Autonomous system of stability control in mine workings - GEOCONTROL

Duration from 01.12.1987 to 30.11.1990

A two-channel digital sampling instrument from RAPID SYSTEMS INC. (USA) was used, with a sampling frequency of 2 MHz. Laboratory tests were carried out with this device, which employs a Bruel-Kjaer accelerometer, to record the acoustic emission (AE) produced when coal samples were broken.

It was established that emission occurred in the range 60-600 KHz when the samples were broken but data storage in the AT-compatible microcomputer was found to be too slow, since the hard disk access time was in the region of 30 milliseconds. As a result, information was lost when recording the acoustic emission and a number of routines in machine language were therefore

written to permit management of the digital sampling unit, handling of the data acquired and their storage, in about 20 microseconds, in the memory of the microcomputer.

This system makes it possible to store all the information produced during acoustic emission, sampling at 1 MHz over 20 seconds. This time may be increased up to three minutes if the memory is expanded to 16 Mbytes.

COMMUNICATIONS

7220-AF/811 Underground data communication - BCC

Duration from 01.04.1982 to 30.09.1988

The field trial of the High Speed Data Communication system at Frickley Colliery is now complete. During the final stages the system was expanded into a fully operational MINOS system incorporating high voltage switchgear monitoring and control, general purpose monitoring and control, and production monitoring. With the successful conclusion of the field trial the High Speed Data Transmission system has been submitted for acceptance as a British Coal standard.

The report of the work undertaken is nearing completion and will be presented to the next meeting of the Experts' Committee.

7220-AF/814 Development of underground switchgear - BCC

Duration from 01.04.1983 to 30.09.1988

The purpose of this project has been to develop remote control and monitoring for underground switchgear. Equipment modifications to facilitate control and monitoring have been undertaken by manufacturers. Frickley Colliery, the trial site for remote operation of high tension switchgear, opens and closes MIVAC units from the colliery control room, having demonstrated the integrity of the system to the satisfaction of HM Electrical Inspectorate. The switchgear, data transmission equipment and the surface computer software (part of the MINOS system) are now proven and available for other collieries to take up. The Baldwin and Francis modification to their gate end box is still on field trial.

The report of the work undertaken is nearing completion and it is hoped to present it to the next meeting of the Experts' Committee.

7220-AF/817 Pit-wide communication system - BCC

Duration from 01.12.1984 to 30.11.1989

Historically this project was originally put forward in 1984 for research into communications between underground mobiles. In response to the changing research and development requirements of the industry the project objectives were modified in 1985 to cover work on an integrated voice, data, and video transmission system using broadband techniques such as fibre optics. During 1987 the project was restructured on the basis of a number of

sub-contracts in four areas, the most promising of which would be pursued at least to a prototype stage. By November 1988 no sub-contracts had been placed and, in view of the delays and lack of progress, British Coal requested the cancellation of the agreement.

7220-AF/306 New leaky feeder radio control for mobile equipment driven by stationary motors - CERCHAR

Duration from 01.10.1985 to 30.09.1987

Work was completed on the various elements making up the Telsafe CP long distance remote control system for monorail haulage gear. The receiver equipment had to incorporate interfaces so that it could be connected directly with the monorail haulage drum control circuits (e.g. intrinsically safe circuits).

The equipment successfully completed a wide range of laboratory tests, e.g. environment tests (for variations in the ambient temperature) and functional testing. For the latter, an installation was set up in an underground channel with a 150 m long CERLIL wave-carrier cable. The certification papers have been finalised but no certificates of conformity have so far been issued.

The first Telsafe CP installation will be set up in the Simon Colliery in Lorraine in a road heading which was 1 100 m long in June 1988 and will have a final length of 1 500 m. The installation will take the form of a CERLIL carrier cable with a length of 1 100 m (incorporating an amplifier-repeater and a line-end generator), which will be extended by a monofil cable as the heading advances. Training material for the Telsafe CP equipment has been prepared for the use of workers involved in underground installation, utilisation and maintenance.

Underground operation will commence as soon as the certificate of conformity has been issued.

7220-AF/117 Mobile information system, Part B - StBV

Duration from 01.10.1986 to 30.09.1988

The aim of this R&D project is the further development of components of the mobile information system with terminal, control panels and a communications processor, followed by type-approval and practical operation.

The development work carried out in Part A of the project was continued.

The electronics circuitry in the mobile data terminal was modified for further testing at the Bergbau-Versuchsstrecke but the changes did not produce the desired result. Since it did not seem worthwhile to make further changes in the circuitry in view of the very high costs, the main thrust of development was switched to the hand-held terminal. All additional circuits and changes required for certification were made and tested step by step in collaboration with the test officer at the Bergbau-Versuchsstrecke. This development work took about three months, the aim being to retain the mass-produced mobile data collection unit with as few changes as possible and to find an economically viable solution for service in mines.

The problem of the outer plastic housing was solved by using a conductive plastic. It proved possible to use the material chosen in the existing injection moulds. The additional electronic circuitry required for certification is now being adapted to the specific mechanical configuration. Certification was successfully completed for the type of protection EExiaI.

So that the certified apparatus could be manufactured, the power supply module was completely redesigned. The two serial interfaces retained their full functional capability so that the unit could be used below ground for inspection, testing, programming and diagnosis.

The RS 485 modem has not yet been certified since testing is still in progress.

7220-AF/119 Measuring units for transducers with integrated data processing II - StBV

Duration from 01.12.1986 to 30.11.1988

The main aim of the research is to develop devices for coupling transducers with analog output to higher-ranking control and remote control systems, using a minimum of lines.

The 'measuring station for 16 analog input channels' developed in Part 1 of the project, which had been successfully employed below ground by several users for various measurement applications, was modified in accordance with users' wishes with regard to the software. Signal preprocessing below ground, for example, was adapted to take account of recent experience and further radical improvements were made in the software for analysis and display in personal computers.

The lessons learned from the 16-channel station led in the course of the period covered by this report to the development of a measuring station for four analog input channels in order e.g. to carry out local measurement tasks in a more flexible manner.

The certification procedure for a universal strain gauge amplifier, an isolating amplifier for connecting individual measuring systems with frequency output and a coupling amplifier for connecting simple resistive sensors has now been completed. All these transmitters have internationally standardised analog output interfaces, as do various sensors, and have been used in conjunction with the measuring station below ground. Their pit-worthiness was tested and improved in some cases. The same applies to the face advance instruments, which were further used below ground with good results.

The coupling device with integrated microcomputer system developed for connection to higher-ranking remote control or transmission systems was completed in the laboratory. It has a 20 mA line current interface as an output interface and means of isolation and the communication protocol is in accordance with German mining standards.

7220-AF/118 Computer-aided sub-station, Part C - StBV

Duration from 01.06.1986 to 31.05.1988

Development of the expert system for escape route guidelines has been completed. Its knowledge base includes the assessment principles for testing escape routes, taking into account the current guidelines of the

Landesoberbergamt (mining inspectorate). Once the system had been tested, a version which can run on an IBM-compatible personal computer with the MS-DOS operating system was produced. A user area with computerised dialogue was developed for this. To test user-friendliness for untrained staff, the system is to be used initially at one mine only.

This completes the pilot project for the introduction of knowledge-based data processing. The experience thus acquired will form the basis for the creation of expert systems for complex mine areas. At the same time the system developed can be used in the planning of new workings.

7220-AF/819 General purpose monitoring and control 3 - BCC

Duration from 01.04.1984 to 31.03.1990

The purpose of the project is the development of a single system for remote monitoring and control of mining operations which embraces all of the existing applications, provides a flexible base to which colliery staff can add transducer and equipment characteristics as necessary and expands existing control capability.

There are two principal components in this development. The first is the development of software to support the British Coal low-speed transmission standard BS6556, otherwise known as SAP (Simple Asynchronous Protocol). BS6556 provides specifications for a wide range of monitoring and control equipment and has been widely taken up by manufacturers. The second component is the development of a standard software package for monitoring and control applications (GPMC). This package is written in such a way as to provide features which are applicable to the solution of a variety of problems. The tailoring of the package to specific problems is known as configuring and is undertaken by area/colliery personnel.

Significant developments for BS6556 support have seen a large increase in the total number of plant items which can be supported, sufficient now even for a large site. End to end security has been enhanced, and the provision of diagnostic and statistical information on the performance of the transmission system has been improved. The major developments in the GPMC package are the provision of a more flexible operator interface, automatic output of set points, optional password protection on controls and improved visibility of the configured control logic.

All proven developments were pulled together with a single system. Following extensive site testing this package was released to the industry in November 1988 as MINOS VO5.2. It has already been taken up by a considerable number of sites.

7220-AF/822 Integrated mine control and monitoring systems - BCC

Duration from 01.10.1985 to 30.09.1990

The work for this period falls into two main areas. The development of a communications master station and a power loader slave station for the extension of the mine wide data communications system (developed under 7220-AF/811) into the face area.

CONIC V2 is being developed for use at the master station end to enable use to be made of the more powerful processors being incorporated into the waystation protocol converters and surface data communication interfaces. This work is being carried out using the UNIX operating system.

The applications protocol for power loading machines has been issued for experimental use. Hardware work has concentrated on adapting the current unidirectional power loader communications to bidirectional operation at 9.6 Kb/s. Various prototypes of the trailing cable modem have been built. PCB 80C186 prototypes of the trailing cable communications controller have been built for use on the power loader and used for development and testing of the HDLC protocol software.

Proposals for a face control centre were invited from potential suppliers. A tentative design based on a proprietary workstation plus waystation technology has been formulated. Methods of interfacing the proposed flameproof and intrinsically safe sections via a short section of local area network are being investigated as are alternatives to keyboard input.

7220-AF/827 Supervisory monitoring and control systems - BCC

Duration from 01.03.1986 to 28.02.1990

The SUMMIT surface supervisory system to support a number of applications, including vertical guidance and face alignment, has been developed to meet the aims of this project.

Progress has been made on the further development of the SUMMIT system and the transfer of the new technology to the industry. Its principal application is in the supervising and monitoring of vertical guidance systems for shearers (e.g. MIDAS); these systems currently represent the major thrust in the application of automation within the industry. Requirements have been defined for supporting power support chock control, and extensions to the vertical guidance and face alignment applications.

During the period three British Coal areas have had their first installation of SUMMIT systems. This should lead to wider exploitation in the future.

7220-AF/828 Run-of-mine coal/stone monitoring - BCC

Duration from 01.03.1986 to 31.08.1990

The results of the trials to determine the best combinations of sensors to form the basis of an on-line ash monitor have shown that the signals from a natural gamma detector suitably combined with those from a weigher or profiler give the best results, typically giving an error of around 2 to 4% ash.

The design of a control unit to combine these signals and provide display facilities for instantaneous and batch ash information has been undertaken. British Coal-developed, surface-only systems have recently been installed at two collieries. An intrinsically safe version is being developed under contract by SEI. This system should be completed and ready for underground use by the end of 1989.

A database is being set up on the specific activity of mine coals and stones. This is to enable the applicability of the technique to individual mines and seams. The technique will not work accurately in the presence of sandstone.

A study into the benefits on ROM monitoring has recently shown there is a potential application for 145 systems throughout British Coal. More detailed studies are being undertaken to determine the benefits at three specific collieries.

7220-AF/818 Underground equipment monitoring - BCC

Duration from 01.04.1984 to 31.03.1989

The purpose of this project has been to develop and prove the application of MINOS for monitoring and control of ancillary services such as pumps and fans.

Three demonstration sites were selected, each using equipment purchased from a different manufacturer; Seafield/Frances in Scotland using HSDE equipment, Westoe in the North East using Transmitton equipment and Clipstone (following the closure of Mansfield) in Nottinghamshire with Westinghouse.

The project is close to successful completion, with the Frances pumping scheme and the Westoe fan application well proven, using commercially available equipment.

7220-AF/830 Demonstration of ICON with integrated applications at a single site - BCC

Duration from 01.07.1987 to 31.06.1991

The site selected for the demonstration of ICON with integrated applications was Maltby Colliery where a major new development into a new seam is taking place.

The control room at Maltby has been modified and the monitoring control and information computers installed. Mineral clearance using ICON transmission is now in operation and surface switchgear control and monitoring equipment specified. Tenders have been invited to interface to the winder monitoring sub-system and the skip plant sub-system.

The mining developments are progressing more slowly than anticipated with the result that the monitoring control and information system development is correspondingly delayed.

7220-AF/831 Expert systems technology - BCC

Duration from 01.04.1987 to 31.03.1990

The main objectives of the application of expert systems techniques are to utilise the skills and expertise of management, engineers, craftsmen, operators and other specialists to obtain the best possible results from mining operations and mining equipment. The project is aimed at translating research ideas into practical application within the industry and identifying further areas where the techniques will be of benefit.

A prototype system for diagnosing faults on winding control systems has been implemented. From this work, a methodology has been defined and techniques developed for implementing knowledge-based diagnostic systems. The techniques are being used to develop a comprehensive fault diagnosis system for a cyclo haulage.

Work has continued on knowledge-based systems for environmental problems and the first of a number of small systems is being developed to tackle this complex area.

Expert systems techniques are also being explored for commercial applications and a system for advising on superannuation benefits is under development.

7220-AF/832 Advanced automation for mining - BCC

Duration from 01.04.1987 to 31.03.1992

Work continued during the year on investigations into the new technology required for an automated and fully integrated drivage system. Later in the year consideration was given to the type of heading machine best suited to the application of this new technology. This revealed that the future needs of the industry would be for rapid drivage of square-section roadways using uncomplicated technology. The original concept of producing a highly-automated system for driving circular roadways was, therefore, considered to be obsolete and an application to close this project has been submitted.

7220-AF/833 Scheme for monitoring and control of underground electrical distribution networks - BCC

Duration from 01.08.1987 to 31.07.1991

The purpose of this project is to support two demonstration installations of underground electrical distribution network monitoring and control and to develop facilities further in the light of experience gained.

The sites chosen are Castlebridge in Scotland and Carway Fawr in South Wales. Equipment has been ordered and installation begun.

A development contract has been placed with GEC to enhance their MIVAC monitoring and control unit to enable remote insulation testing. This is required before remote closing of a switch after certain fault conditions can be carried out.

7220-AF/813 Management information system (secondary computers) - BCC

Duration from 01.04.1983 to 31.03.1988

This project had two main themes, namely the provision of enabling facilities in terms of systems software and the development of applications.

The enabling facilities, including start-up, back-up, shutdown, data access methods and networking protocols, were chosen and implemented early in the project.

The development of applications then followed with the most comprehensive being a system called 'CIS Production Monitoring' which seeks to isolate the root cause of delays to the coal face. This system was developed with significant assistance from potential colliery users and has proved very successful. British Coal have now installed a further 12-15 similar systems and plan to install 30 during 1989.

The other applications covered are Coal Clearance and General Plant Monitoring. Further applications will also be developed, including a Fire Detection System.

The success of this project is largely due to the flexibility inherent in the system design which has enabled a rapid response to users' demands. CIS is now seen as the main reporting system for colliery operations producing routine reports as well as ad hoc enquiries and graphs.

The report of the work undertaken is nearing completion and it is hoped to present it to the next meeting of the Experts' Committee.

7220-AF/308 Improvement of planning and exploitation by the analysis of the state of constraint of the ground, induced seismic movements and dynamic phenomena - CERCHAR

Duration from 01.07.1988 to 30.06.1990

Study of rupture phenomena whose consequences may be felt in other workings and at the surface at considerable distances. Determination of their relationship to planning and exploitation, and establishment of rules for minimising their effects both underground and at the surface.

Study of seismic activity:

- development of a system suitable for mines;
- analysis of seismic activity;
- correlation between natural and mining parameters and the effects observed underground and at the surface.

Characterisation of sites:

- natural constraints, additional constraints of exploitation;
- mechanical characterisation of seams and surrounding rocks;
- role of water and absorbed gas;
- development of models;
- comparison of observed phenomena and model predictions.

7220-AF/752 Installation of an experimental block to monitor and optimise the technique of sub-level caving - HVL

Duration from 01.10.1988 to 30.09.1991

Installation of an experimental block, 15 to 20 m long, in order to study and modernise the winning of very steep and thick seams by sub-level caving of horizontal blocks. The face will be equipped with measuring instruments allowing the study of the most important parameters governing the winning method. The theoretical model will predict the technical and geomechanical behaviour of panels extracted by this method and will therefore allow the optimisation of coal winning.

- Analysis of HVL information by statistical computer treatment.
- Definition of operational and geomechanical parameters.
- Preparation of an experimental block equipped with a face conveyor, hydraulic props, a crusher to obtain representative samples of raw coal, a belt conveyor offering continuous belt weighing and a real-time ash analyser.
- Establishment of a theoretical model, adaptation after comparison of theoretical and practical results.
- Conclusions.

7220-AF/309 Consideration of layout and methane control in optimisation of the daily output of retreating, caving faces equipped with the most technologically advanced mining equipment - CERCHAR

Duration from 01.07.1988 to 30.06.1990

Control of methane concentration, especially at face ends, and determination of the most rational selection criteria for the positioning, cross-section and support of roadways, and for the orientation of faces in order to optimise the daily output of retreating, caving faces.

- Definition and tests of means of achieving marked improvements in methane drainage and capture.
- Rationalisation of the use of equipment for locating zones of high methane concentration and for continuously controlling and following the movement of methane.
- Survey of the state of the art in the field of methods of layout.
- Tests of modified layout schemes, tunnel cross-sections, support and treatment, particularly for dense deposits.
- Economic balance and selection criteria.

7220-AF/121 Requirements for a modern information system for the improvement of mine planning work - StBV

Duration from 01.04.1988 to 31.03.1989

The aim of this project is to use a modern information system to increase the reliability of mining planning, with reference also to pit safety. This desired improvement is to be achieved by simplifying and objectifying the recognition processes and is to take into account existing EDP systems installed in mining companies and user-specific requirements. The research work is intended to provide the basis for creating a user-friendly information system for modern works management.

The following work has already been carried out: the requirements to be imposed on an information system, as regards the extent to which it can be integrated into existing systems, have been investigated. Analyses have been made of the degree to which existing systems and files could be used/integrated, and an estimate has been made of the time and financial commitment required to produce the desired information system.

7220-AF/834 Embedded transducers for dynamic monitoring of armoured face conveyors - BCC

Duration from 01.04.1988 to 30.09.1990

The development of a range of embedded transducers to provide a vehicle for continuous monitoring of key parameters around pieces of plant, such as armoured face conveyors. The designed transducers will be installed into motors, gearboxes, etc. during manufacture.

Whilst existing routine monitoring of underground machines is achieving much success, it still remains limited to weekly measurement of oil debris and static measurement of pressures, tensions etc. In an AFC system

continuous measurement of debris, oil level in both the gearbox and the sprocket assembly and measurement of the dynamic loading on the chain itself are seen as the next step in upgrading AFC system monitoring; this forms the basis of this project. Work in developing and evaluating methods for achieving continuous monitoring of AFCs is well advanced and falls into three identifiable areas, namely: dynamic chain tension; gearbox condition; and sprocket bearing condition.

A method, using a strain gauge bearing 'collar' for measuring AFC chain tension is proving to be a practical option. The Ranco Control Ltd Continuous Debris Monitor (CDM), after comparative evaluation, represents the most promising method to date for the main AFC gearbox monitoring. Sprocket bearing debris monitoring, however, requires, physically, a much smaller device. Dowty Ltd have experimented with a method of measuring the obscurity of the oil by optical techniques. The results appear encouraging. An oil level detector, housed in the same probe as the sprocket debris level transducer, is being developed based on an optical retro-reflection method.

7220-AF/122 Reliability testing of electronic equipment for use underground Part II - StBV

Duration from 01.04.1988 to 31.03.1990

Continuation of a current project aiming to improve the reliability of electronic equipment through the development of methods of testing before underground installation.

- Study of stresses by vibrations provoked by different types of mining machine.
- Study and evaluation of the data obtained by Fourrier analysis.
- Establishment of testing guidelines and methods.
- Adaptation of existing test rig to the progress of the technique.

7220-AF/310 Application of artificial vision to the remote control of mining machinery and the improvement of safety - CERCHAR

Duration from 01.07.1988 to 30.06.1990

Remote control of coal winning machines through the use of CCD cameras with the aim of improving surveillance in very difficult conditions, signal transmission being not by cable but by ultra high frequency radio.

- Selection of miniaturised CCD cameras capable of being brought into conformity with regulations for gassy mines.
- Adaptation of the UHF system to the increased information density required for image transmission.
- Transmission tests in coal faces to optimise carrier frequencies and antennae.
- Study of installation on a machine of the camera/transmitter system:
  - resistance to shock and vibration;
  - protection.
- Full-scale tests on a machine in a face and processing of the image.
- Simulation of the approach of personnel to dangerous areas and tests of automatic detection of such an approach.

7220-AF/835 Data communication systems at collieries - BCC

Duration from 01.07.1988 to 30.06.1992

To establish data communication systems at collieries based on emerging ISO/OSI international standards, in order to permit advanced mine-wide control with the most cost-effective equipment from a wide range of suppliers complying with these standards.

- Investigation into the requirements of the various installed and planned underground applications, and definition of standard application data protocols.
- Integration of local control centres into the mine communicati' infrastructure based on ISO/OSI and MAP specifications.
- Demonstration in the laboratory and finally at a trial site; both surface and underground equipment will be integrated.

Discussions have been held with Sydney Communications on the suitability of their ISO/OSI communications product ISONET. A baseline system has been procured for evaluation.

7220-AF/123 Field bus system and test instruments for standardised data communication systems based on the OSI/ISO layer model, Part A - StBV

Duration from 01.04.1988 to 31.03.1990

More general use and enhanced compatibility of underground data treatment systems by the development of efficient field bus systems suitable for underground use to close the gap between sensors/actors and the superposed communication network.

- Examination and selection of suitable data transmission systems and monitoring methods.
- Development of a field bus controller station and an appropriate power supply unit, both intrinsically safe.
- Development of interface modules or units (gateways) for the connection of the field bus system to any outstation or to the communication network.

7220-AF/836 Computer-aided manpower deployment - BCC

Duration from 01.09.1988 to 31.08.1991

The development of a manpower deployment system incorporating the monitoring of men underground and which is fully integrated with associated industry information systems. The system will optimise the deployment, improve safety, locate men in the event of an emergency and will be integrated with time recording and wage payment systems.

A working group within British Coal produced a report and requirement specification for computer-assisted manpower deployment at collieries. This specification is accepted as a British Coal standard and it clearly defines the interfaces and communications with other British Coal systems. A modular system is proposed comprising:

- Attendance recording.
- Computer assisted deployment.
- Safety checking/overtime control.
- Manpower tracking.

Detailed requirements for the first three modules were produced and Module 4 only outlined as further R&D is required in the technology of fail-safe identification of men's presence at, or passing, underground locations.

A project team was formed and it was decided to have two pilot sites from alternative suppliers in order to ensure commercial competitiveness of supply. The selected pilot site collieries and suppliers are:

Maltby Colliery, South Yorkshire	-	Logica Energy Systems
Lea Hall Colliery, Central Area	-	ICL/Hoskyns

7220-AF/124 Experts' system for the monitoring of underground operations - StBV

Duration from 01.12.1988 to 30.11.1991

Enhanced efficiency of planning, monitoring and maintenance by the utilisation of experts' systems allowing quick access to a large amount of information and its rapid computation.

- Analysis of useful applications and definition of priorities.
- Elaboration of a development system for the realisation of experts' systems.
- Assembly of the database for a specific application.
- Practical tests of this system.
- Assembly of databases for other applications.

7220-AF/311 Modelling of 'wave guide' phenomena in coal seams - CERCHAR

Duration from 01.10.1988 to 30.09.1991

Improved understanding of the propagation and transmission of guided waves in different coal seams in order to improve the interpretation of the results of seismic measurements in seams in complex deposits.

- Laboratory measurements of the physical constants needed for the numerical application of the equations of propagation of guided waves.
- Adaptation of an existing numerical model.
- Use of the model with the results of seismic surveys.
- Adjustment of the model.
- Application of the model to a range of coal seams.

7220-AF/837 Automation of railborne weigh offices - BCC

Duration from 01.04.1988 to 31.03.1991

Development of an Automatic Vehicle Identification (AVI) system to improve the efficiency of the movement of coal by rail from despatch points to power stations and other customers' premises. Application of modern management techniques and microelectronic technologies to all parts of the system should improve the speed, accuracy and efficiency of the overall system.

Appropriate colliery 'operational surveys' have been carried out with the results being reviewed with the relevant British Coal areas. Associated 'engineering surveys' are virtually complete except for the final phase.

A 'tri-partite' test laboratory has been set up and fully equipped which will simulate train movements via trackside equipment and personal computers.

The first two phases of software, i.e. 'train load traffic' (single quality/single customer) and 'simple train-bill' (electronic network transfer of the train-bill) has been tested to British Coal's satisfaction.

The mainframe system for train orders and timetables has been installed in Yorkshire. The installation of automatic vehicle identification equipment at the Kellingley and Prince of Wales 'lead-in' sites is complete and 'field trials' of the software have commenced at these sites.

Communications have been established to enable direct input into the British Rail mainframe computer, i.e. a permanent circuit has been established between British Coal and British Rail mainframe computers from a personal computer at a colliery.

7220-AF/125 Development of an experts' system for computer-based three dimensional litho-stratigraphic correlation - StBV

Duration from 01.10.1988 to 30.03.1991

The aim of the project is to work on the use of computer-aided methods of strata parallelisation, as the manual procedure is often very time consuming. Expert systems in which specialist knowledge is applied seem the most appropriate. Existing connections between facts are described and recorded in a changeable form. Requests to the system are met by repeated application of the stored rules to input data and interim results. Appropriate strategies for problem-solving need to be drawn up.

The following work has been carried out. Selected data for the development of a pilot system have been made available. It is necessary to separate the knowledge basis from the problem-solving components, while at the same time taking into account the capacity for dialogue with the user and the ability to change the knowledge basis.

II. COAL UPGRADING

ECSC EXPERTS' COMMITTEE 'COKING OF COAL'

OBJECTIVES

The main objectives of research in the field of carbonisation, as laid down in the Medium-Term Guidelines for Technical Coal Research (1986-1990) are:

- to increase the throughput and profitability of coke ovens;
- to widen the range of coals that can be carbonised successfully;
- to maintain or improve the quality of metallurgical coke;
- to solve the problems of air and water pollution associated with coking plant.

As a result of the favourable coal supply situation there is currently less emphasis than in the past on the second of these objectives, although there is a continuing need to adapt to changes in the quality of coal available. Avoidance of pollution is, of course, a major consideration in any development in coke oven technology, but this aspect forms part of another ECSC research programme, and the Coal Research Programme does not include any work on carbonisation whose primary aim is pollution control.

Most of the research supported at present is aimed at improving the general economy of coke production in one way or another, and there is a strong interest in adapting coke quality to the users' requirements.

CURRENT RESEARCH

(See list of research contracts)

The programme includes a number of projects on rather fundamental aspects of coking technology (projects 7220-EB/133, 7220-EB/137, 7220-EB/328). These cover such topics as the behaviour of the plastic zone, thermal phenomena and mathematical modelling of the coking process. Project 7220-EB/414 employs a tracer technique to follow the progress of carbonisation in a full-scale oven, while project 7220-EB/134 deals with the extrapolation of the results of pilot-scale coking tests to the industrial scale. This is a problem of some importance, since opportunities for carrying out large-scale tests in the Community are very limited for the time being. Project 7220-EB/833 is aimed at developing a smaller-scale laboratory test for assessing coking blends.

Much of the programme concerns general technical development for the improvement of coke oven performance and economics. The topics covered include improved instrumentation and control (projects 7220-EB/326, 7220-EB/606), the study of transient phenomena (project 7220-EB/201), oven repair (project 7220-EB/829), improved charge distribution in the oven (project 7220-EB/131), the use of wide ovens (project 7220-EB/412), the use of preheating to widen the coal range (project 7220-EB/752), and measures aimed at improving the thermal economy of coking plant (project 7220-EB/330).

Three projects (7220-EB/130, 7220-EB/136, 7220-EB/834) are concerned with problems caused by sticking charges which are difficult to push and which may give rise to serious damage to coke oven batteries, while project 7220-EB/132 investigates the related and equally serious problem of carbonising swelling coal blends.

A central problem in coking technology is that of knowing what properties coke should possess in order to give satisfactory performance in use, particularly under the severe conditions encountered in the blast furnace, and how coke of the desired characteristics can be produced by controlling coal blend properties and carbonising conditions. Work on these questions has been included for many years and is covered at present by a series of related studies. In projects 7220-EB/825 and 7220-EB/830, special emphasis is placed on the influence on coke structure of the alkali metals present in the blast furnace. Coke microstructure is also investigated in projects 7220-EB/331 and 7220-EB/413. Projects 7220-EB/827, 7220-EB/831 and 7220-EB/832 are concerned with the effect of blast furnace conditions on coke and project 7220-EB/135 involves examination of coke samples as part of a comprehensive experiment in which the contents of a working blast furnace were 'frozen' under carefully controlled conditions. Projects 7220-EB/329 and 7220-EB/410 deal with the influence of carbonising conditions on coke quality, while attempts are being made to find means of producing coke that is resistant to alkali attack and coke of low sulphur content in projects 7220-EB/828 and 7220-EB/826 respectively. Project 7220-EB/411 considers the properties of coke for use in foundry cupolas.

Finally, two projects, 7220-EB/138 and 7220-EB/753, are concerned with improving the quality of by-product tar (it should be noted that some work on by-products falls under the aegis of the Experts' Committee 'Chemical and Physical Upgrading').

7220-EB/124 Umsatz von Koks mit wasserdampfhaltigen Gasen - StBV

Duration from 01.06.1985 to 31.12.1986

Coke dry quenching (CDQ) offers potential advantages in terms of energy recovery but the loss of coke by reaction with the cooling gases is not well understood. This project was aimed at obtaining the data necessary to calculate the burn-off in CDQ and conventional wet quenching, and at studying the possibility of reusing the energy recovered in CDQ, particularly for coal preheating.

Reaction kinetics were examined in the laboratory, and CDQ was studied on the pilot scale employing a combination of co- and countercurrent flow that was found to give significantly lower coke losses than wet quenching. Coal preheating, which itself investigated separately, was simulated in the pilot plant by means of a heat exchanger.

Expectations with regard to energy saving, economics and reduced emissions were fulfilled, but a few technical problems remain to be solved before the combination of CDQ with coal preheating can be applied in practice.

7220-EB/125 Kokereitechnische Grundlagen - StBV

Duration from 15.03.1984 to 30.08.1987

Developments in coking technology (higher throughput, larger ovens) have led to changes in coking conditions and to technical problems, particularly in relation to oven discharge.

The purpose of the project was to study the permeability of the plastic zone during carbonisation and its influence on internal gas pressure, and the influence of inhomogeneities in the coal charge on the coking process.

The results indicated a number of ways in which damage to the oven can be avoided: fine grinding of the coal, reduced charge bulk density and the use of appropriate additives, can significantly reduce the gas pressure in the plastic zone. It was noted that the greater the swelling propensities of the coal, the greater is the scatter in the experimental results, so that repeat tests are necessary in order to obtain reliable results for dangerously-swelling coals.

7220-EB/126 Bestimmung der Schüttdichterverteilung in einem 7m-Ofen - StBV

Duration from 01.04.1984 to 30.09.1987

A technique, capable of giving reliable results under the extreme conditions of coke oven operation, was developed for measuring the bulk density distribution in a 7 m coke oven. The measurements were made with a radiometric probe on the basis of back-scattering using y-radiation and neutrons. Calibration studies were carried out at the University of Clausthal.

Exact positioning of the probe in the oven was achieved by means of a specially constructed charge hole lid. The probe's source container was constructed in heat-resistant steel so that the probe could be left in place until the end of carbonisation without release of radioactive material. As a further precaution, radiation detectors were placed over and below the ramp. These automatically stopped the belt if high radiation levels occurred.

Initial measurements revealed large variations in bulk density with height. Moreover, the density was particularly high in the region under the charge holes, partly as a consequence of the concentration of water at the centre of the charge.

Detailed analysis of the results had not been completed at the time when the final report was presented.

7220-EB/129 Erprobung eines Koksofens für zweischichtigen Betrieb - StBV

Duration from 15.03.1985 to 14.09.1987

The use of wide (750 mm) coke ovens offers advantages in terms of output per manshift, reduction in the number of shifts worked and reduction in emissions.

Using ovens of this width in conjunction with charge preheating (which enables a wider range of coals to be carbonised), the coking time is 24 hours and it is possible to dispense with the night shift. The aim of this project was to study the operating cycle of such an oven.

Successful operation was achieved. Coke quality was unaffected and the above-mentioned advantages were found to outweigh completely the reduction in throughput (in terms of tonnes per unit time and unit area of heating surface) caused by the increase in oven width and the slight decrease in the calorific value of the gas produced.

7220-EB/325 Caractérisation des cokes par microscopie électronique par transmission - CERCHAR

Duration from 01.06.1985 to 30.11.1987

Transmission electron microscopy, used in metallography for the study of fine structure, has been applied to carbonaceous materials. This study showed that the technique could be used on pilot and industrial cokes as a complement to optical microscopy.

The results were as follows:

- transmission electron microscopy enables an improved distinction to be made between cokes, particularly those made from low-rank coals;
- the microtexture of cokes made from binary blends can be calculated on an additive basis from the microtexture of the cokes produced from the individual coals;
- transmission electron microscopy enables relationships to be determined between microtexture and industrially important coke properties such as reactivity and resistivity.

The technique could be used for the detailed study of industrial cokes and for the development of a method of predicting the properties of such cokes.

720-EB/605 De ontwikkeling en implementatie van een dynamisch model om het stoken van kooksofen automatisch te regelen - Hoogovens

Duration from 01.06.1985 to 31.05.1988

To adjust the heat input to a coke oven battery, Hoogovens Groep BV has developed and applied the Coke End Temperature Control system (CETCO) heating system, based on measurement of the coke end temperature and the regenerator temperature. The objective of the system is to produce coke at a target end temperature which is chosen with regard to coke quality, heat consumption and pushing problems.

Before the project began, the state of development of CETCO was such that after editing of the collected data, the results were presented to the coke oven operator, who then decided whether or not the heat input had to be adjusted. The aim of the research was to improve such off-line battery operation by the use of a dynamic model to control the heat input automatically.

The work was divided into four phases:

- developing a mathematical model of a battery;
- statistical evaluation of process data;
- development of a heating control model;
- practical implementation of the model.

The model was successfully developed and implemented. The change in the standard deviation of coke end temperature was improved as follows:

Conventional control	25.0°C
CETCO manual control	14.0°C
CETCO automatic control	8.5°C

The total heat input now seems to be more stable than before.

7220-EB/823 The influence of blend and carbonisation variables on coke discharge - BCC

Duration from 01.09.1984 to 01.03.1988

The aim of the project was to investigate the problems associated with coking pressure and coke discharge. Test work was carried out on a 300 kg movable-wall oven to determine the influence of coal blend and carbonisation variables on the pressure on the oven wall during carbonisation and in the early stages of coke pushing. With the aid of a mathematical model, the results of the pushing measurements can be used to calculate the force required to discharge a full-scale oven. Pushing difficulties may arise in the later stages of coke discharge as a result of the fracturing of weak coke, and this aspect of the problem was also studied.

The principal conclusions were as follows:

- that high coking pressure may result from the nature of the coal or from high charge bulk density;
- the extent of vertical expansion and contraction of the charge is related to the maximum wall pressure developed;

- pushing difficulties may often be ascribed to the poor condition of the wall;
- the force transferred to the wall in the initial stages of pushing is influenced by coal volatile matter content and the extent of thermal finishing of the coke: coke strength is not a significant factor;
- coke fragmentation produced by compression depends on the parent coal blend, the charge bulk density, the carbonisation rate and the applied force.

COKING OF COAL
CURRENT RESEARCH CONTRACTS

Number	Title	Contractor	Duration
7220-EB/201	Etude de régimes transitoires en cokéfaction: quantification de la réponse temporelle du processus de cokéfaction suite à des variations spontanées ou imposés de para mètres d'action du processus	CRM	01.10.85 31.03.88
7220-EB/410	Condizioni operative delle batterie, qualità del coke e prestazioni dell'altoforno	CSM	01.07.85 30.06.88
7220-EB/825	Coke quality and its prediction	LCL	01.10.85 30.09.89
7220-EB/826	Reducing sulphur in coke	BCC	01.04.85 30.09.88
7220-EB/130	Optimierung des Koksofenaus-drückvorganges zur Vermeidung von Wandschäden	StBV	01.10.86 30.09.88
7220-EB/131	Verbesserung der Einfülltechnik zur Vergleichmässigung des Koksofenbesatzes in Grossraumöfen	StBV	01.03.86 31.08.88
7220-EB/132	Die Verkokung treibgefahrlicher Kohlen in halb- und rosstechnischen Koksöfen	StBV	01.03.86 31.08.88
7220-EB/326	Instrumentation des cokeries	CERCHAR	01.06.86 30.11.88
7220-EB/411	Valutazione e condizionamente della proprietà carburante intrinseca del coke per fonderia	Italiana Coke	01.04.86 31.12.88
7220-EB/412	Influenza della densità di carica sui processo di cokefazione in forni a camera larga	CSM	01.07.86 30.06.88
7220-EB/606	Continuous measurement of sulphur, ammonia and naphthalene	Hoogovens	01.06.86 30.11.89
7220-EB/827	Investigation of the effect of blast furnace raceway temperature on coke properties	BS	01.07.86 31.12.89

7220-EB/828	Development of an alkali-resistant coke	BCC	01.04.86 31.03.89
7220-EB/829	A study of ceramic welding in relation to coke oven chamber repair, with an evaluation of its use in practice	BCC	01.12.86 31.08.89
7220-EB/133	Mathematische Beschreibung der Wärmetechnik des Koksofensystems	StBV	01.04.87 31.03.89
7220-EB/134	Verfahrenstechnische Grundlagen zum Scale-up halbtechnischer Verkokungsversuche	StBV	01.04.87 31.03.90
7220-EB/328	Etude de la couche plastique	CERCHAR	01.07.87 30.06.90
7220-EB/329	Recherche des conditions thermiques optimales pour la production d'un coke de qualité donnée	CERCHAR	01.07.87 30.06.90
7220-EB/330	Recuperation de la chaleur du gaz brut par trempe à l'huile	CERCHAR	01.07.87 30.06.90
7220-EB/413	Influenza delle caratteristiche dei carboni sulla microstruttura del coke	CSM	01.07.87 31.12.89
7220-EB/752	Ampliación de la gama de carbones por precalentado	CSIC	01.09.87 31.08.89
7220-EB/830	Fundamental study of the action of potassium on blast furnace coke	Newcastle University	01.04.87 30.09.89
7220-EB/831	Effect of tuyère injectants on the properties of coke in the blast furnace raceway region	BS	01.12.87 30.11.90
7220-EB/135	Koksdegradation im eingefroren Hochofen von Mannesmann als Ausgangspunkt zur Entwicklung resistenterer Koks	StBV	01.04.88 31.03.91
7220-EB/136	Optimierung des Koksofenausdrückvorganges - II	StBV	01.10.88 31.09.90
7220-EB/137	Kalorimetrische Bestimmung der exothermen Reaktion bei der Verkokung von Steinkohle	StBV	01.04.88 31.03.90

7220-EB/138	Separation von Teersedimenten	StBV	01.04.88 31.03.90
7220-EB/331	Structure et réactivité des cokes	CERCHAR	01.07.88 30.06.91
7220-EB/414	Tecniche traccianti in coke-fazione	CSM	01.07.88 31.12.90
7220-EB/753	Valoración de alquitranes producidos en la coquización	CSIC	01.09.88 31.08.90
7220-EB/832	Metallurgical coke behaviour under bosh and deadman conditions	BS	01.06.88 30.06.91
7220-EB/833	Small-scale assessment of coking charges	BCC	01.10.88 30.09.90
7220-EB/834	Coke fragmentation during pushing	BCC	01.10.88 30.09.90

ECSC EXPERTS' COMMITTEE 'UPGRADING PROCESSES'

OBJECTIVES

The research for which the Experts' Committee 'Upgrading Processes' is responsible is mainly of an applied nature and is aimed at process development for the convenient and environmentally acceptable utilisation of coal and the safe disposal of the associated residues.

Research on the combustion of solid fuels (i.e. coal, lignite and peat) was included in the third EEC Non-Nuclear Energy R&D Programme (1985-1988), where emphasis was placed on applications in the industrial sector. Coal combustion was therefore excluded from the Medium-Term Guidelines for Technical Coal Research (1986-1990) to avoid duplication of effort. In the follow-on EEC programme, 'JOULE', research on coal will be concentrated in the field of large-scale electricity generation. Since it is still important to encourage coal use in the industrial and commercial heat market, this topic has been reinstated in the new ECSC Guidelines, which cover the period from 1990 to 1995.

CURRENT RESEARCH

(See list of research contracts)

Despite the above exclusion, a certain number of combustion-related projects have appeared in the ECSC programme during the intervening period. These cover erosion of boiler components (project 7220-ED/808), reduction of particulate emissions (project 7220-ED/809), development of operating strategies to avoid the occurrence of slagging in large boilers (project 7220-EC/751), and a study of the use of fuel additives (project 7220-EC/846).

Several projects are concerned with improvements in transport, crushing, handling and storage on industrial sites, with a view to making coal a more convenient and attractive fuel for potential users (projects 7220-EA/813, 7220-EA/816, 7220-EA/821, 7220-EA/822, 7220-EA/304, 7220-EC/316, 7220-EC/844, 7220-EC/847). Project 7220-EA/823 deals with the development of improved additives for the preparation of coal-water mixtures, and project 7220-EA/824 with coal feed systems for pressurised fluidised bed combustors. Two projects, 7220-EA/817 and 7220-EA/818, cover the disposal of solid residues (PFBC ash and flue gas desulphurisation waste respectively).

Fluidised bed gasification of coal for various applications forms the subject of projects 7220-EC/832, 7220-EC/837, 7220-EC/838, 7220-EC/752, 7220-EC/841 and 7220-EC/842, while project 7220-EC/121 is concerned with full-scale cold model studies in connection with an EEC demonstration project on lignite gasification in a high-temperature Winkler gasifier, and project 7220-EC/702 with the catalytic gasification of lignite with a view to the subsequent production of liquid fuels. Work on hot gas clean-up for combined cycle power generation is being carried out in projects 7220-EC/833 and 7220-EC/835.

7220-EC/826 Fluidised bed gasification for low and medium calorific value gases - BCC

Duration from 01.07.1983 to 31.12.1986

Initial developments of the British Coal gasifier were directed towards its application for combined cycle operation for power generation. Subsequent work has extended the application of fluidised bed gasification of coal to the manufacture of industrial fuel gas. It was considered that, in order to make the process more attractive to industry, higher fuel conversions would be needed to avoid the need for a char combustor and that the system would be more competitive if the capital cost of the gasifier could be reduced in other ways.

Work during the period of the present contract concentrated on three main areas: improving coal conversion efficiency, reducing capital cost and providing design data for a larger plant.

Work on improving coal conversion efficiency concentrated initially on reducing carbon loss due to elutriation by recycling the fines to the gasifier. This was less successful than expected but work with oxygen-enriched fluidising gases demonstrated the ability of the process to utilise the fines more successfully, and gasification efficiency was increased even further by using sand rather than char, as the bed material.

A method was developed for direct feeding of industrial grades of coal into the gasifier. The direct use of such fuels will reduce the capital cost of the process.

Work continued on gas cleaning. Glass fibre filters for industrial use were tested at 200°C and were shown to be capable of reducing dust emissions to 0.1 g/mm^3. Much lower dust loadings are required for power generation purposes and work on the development of ceramic candle filters was therefore continued.

Because of their potential for causing damage in gas turbines, the removal of alkali metal compounds was investigated, but no significant degree of removal was achieved. Ninety five per cent removal of hydrogen chloride was obtained using barium sulphate at 900°C but attempts to encourage the deposition of chlorides by adding ammonia to the gas or limestone to the fluidised bed proved unsuccessful.

The project included cold modelling and mathematical modelling studies.

7220-ED/103 Verwertung von Aufbereitungsabgängen in anderen Industriezweigen - StBV

Duration from 01.07.1984 to 30.06.1987

This project formed a continuation of previous work on the use of treated and untreated washery tailings in a wide variety of applications, notably as a basis for the production of a range of materials for the building industry (bricks, lightweight aggregates, etc). Various material conforming to the appropriate DIN standards were developed.

The work included a study of the possibility of manufacturing aluminium from mine waste. It was concluded, however, that the production of aluminium oxide from spoil would cost about 30% more than production from bauxite at current prices, and would therefore be uneconomic.

7220-ED/304 Etude des risques liés au stockage du charbon pulvérisé - CERCHAR

Duration from 01.05.1985 to 30.04.1987

A study was carried out on laboratory- and full-scale to assess the risk of auto-ignition associated with the use of pulverised coal and to determine the best conditions for storing that material.

Various laboratory techniques were used to assess the susceptibility to self-heating of three coals and one lignite available on the European market. The methods applied were coupled thermogravimetric and differential thermal analyses, adiabatic calorimetry, and determination of the critical ignition temperature of a series of geometrically similar volumes. The behaviour of the fuels made it possible to classify them in order of risk. To aid the transposition of the results to the large scale, and also to evaluate preventive and protective measures, tests were carried out in parallel on volumes of several cubic metres of coal.

The occurrence and kinetics of self-heating were considered for two principal cases:

- a sealed hopper with air in the upper part;
- an unsealed hopper with a simulated influx of air.

As the result of auto-inertisation, no self-ignition occurred in the first of these cases. However, it occurred systematically when the second scenario was considered.

The results showed, among other things, that temperature measurement gives earlier detection of heating than does analysis of the gases evolved, although the correct placing of transducers poses a problem. Moreover, carbon dioxide gives a better early indication than carbon monoxide of both heating and the influx of air into the base of the hopper.

The results obtained make it possible to establish safety measures for the storage of pulverised coal, and should thus help to facilitate the return of coal to the industrial market.

7220-ED/403 Preparazione e caratterizzazione di sospensioni carbone-catrame con o senza aggiunte di acqua - CSM

Duration from 01.07.1985 to 07.06.1988

About 7 tonnes of coal-tar mixtures (CTM) were prepared in the CSM ball-mill pilot plant with good results up to 50% solid content. The preparation of coal-tar mixtures with water addition was also investigated on the laboratory and pilot scales, but major difficulties were encountered.

CTMs with solid contents ranging from 20% to 53% were characterised from the chemical/physical and rheological viewpoints, and pumping, storage and combustion trials were carried out on the mixtures, using special equipment. It was demonstrated that satisfactory mixtures (apparent viscosity 1000 cP) can be prepared with up to 50% solid content.

From the point of view of use, the mixtures did not give rise to storage problems at room temperature, and gave a combustion efficiency higher than that achieved with pulverised coal.

The CSM mathematical model of the blast furnace indicated that CTM could be injected at the tuyères at a specific rate of 30 kg to 100 kg per tonne of hot metal, the highest rate involving a 100°C decrease in the adiabatic flame temperature and a 3% oxygen enrichment of the blast.

7220-ED/802 Improvements to coal transport methods and associated site reception and handling facilities for the industrial user - BCC

Duration from 01.06.1982 to 30.11.1986

The project was aimed at encouraging the industrial use of coal by making its transport, reception, storage and handling more automated, cost-effective and environmentally acceptable.

A comprehensive coal handling system for receiving, storing and supplying coal to a test boilerhouse showed iteself to be generally reliable and environmentally attractive. The system comprised coal reception by means of a tipping hopper and storage in two silos, one of flat-bottomed concrete stave construction and the other of glassed steel with a hopper bottom. Transfer of coal between these components and boiler feed hoppers was by a dense-phase pneumatic conveying system. Minor improvements were made to prevent coal 'hang up' in the tipping hopper and enhance water drainage from the stave silo, and the tipping hopper was fitted with an all-weather cover to prevent ingress of rainwater.

Two further reception systems were also investigated:

- a facility for receiving and handling 20-tonne ISO containers was installed at a customer site, and was found to operate reliably;
- a novel system based on a wide belt lorry unloader and a lean phase pneumatic conveyor was successfully demonstrated.

Tests with a 200 mm diameter suction nozzle demonstrated that coal conveying rates of up to 61 tonnes/hr could be achieved. Studies confirmed the importance of using the correct conveying velocity for lean phase transport in order to minimise coal degradation.

The long-term storage of smalls coal in the concrete stave silo was studied over a period of 12 months. After a temperature rise caused by self-heating during the first six months, the temperature fell and then followed seasonal fluctuations. Although CO concentration in the headspace was found to vary with weather conditions, this parameter is nevertheless of use in detecting combustion in storage. Mathematical models were developed to improve understanding of gas evolution and dissipation in silos.

Pressure variations caused by the action of the rotating extraction auger at the base of the stave silo were investigated. The maximum pressures measured exceeded those predicted from the literature, and this may be a contributory cause of the cracking sometimes found in the walls of such containers.

The feasibility of using an hydraulic system for removing oversize ash extracted from a fluidised bed by means of an air classifier was tested. An ash sluicing system was subsequently installed on a 9 MWth furnace at an industrial site, but opportunities for commissioning were limited.

A low-cost, submerged rubber belt wet ash extraction system was installed on a modular boilerhouse. This unit underwent long-term evaluation trials and was operated successfully over a nine month period.

7220-ED/804 A measure of coal handlability applicable to industrial equipment - BCC

Duration from 01.07.1983 to 31.12.1986

The project was aimed at relating the bulk handling characteristics of commercial coal grades to the coals' behaviour in industrial handling equipment.

Coal flow from silos and bunkers and through static or vibrated screens was identified as the main source of difficulties at industrial boiler sites, while coal adherence to items of equipment was a secondary problem. The difficulties were mostly of an intermittent nature and appeared to be related to abnormal levels of coal moisture and fines content.

The detrimental effects of coal fines and the importance of moisture and ash content were confirmed by studies on various items of equipment.

The bulk flow characteristics of industrial smalls coals were investigated using an annular shear cell. Predictions based on the measurements, expressed as a flow factor, showed reasonable agreement with experimental results, variations in the flow factor indicating that some coals change from free-flowing to cohesive when the free moisture content increases by only a small amount. It was shown that the interaction between coal and a mild steel hopper also varies with moisture content, and the study confirmed that flow in hoppers is improved by the use of ultra-high molecular weight polyethylene linings.

Correlations between various parameters were investigated with a view to establishing a simple and rapid technique for estimating the flow factor, and it was found that the latter could be determined with reasonable accuracy from the fines contents of washed and unwashed coals. The relationship between fines and surface clay was quantified, and this could form the basis of a quality control procedure for handlability at colliery washeries.

Tests based on coal compactability, and on flow from a small vibrated hopper or through different sized apertures were found to be of limited value in assessing handlability, and studies of the effect of particle shape and maceral composition indicated that neither of these factors is important.

Studies of adherence to the internal parts of a rotary valve showed that adherence varies with coal moisture and mineral matter (or, more probably, surface clay) content. It was confirmed that methylene blue absorption offers a possible means of determining surface clay. Such a test could be developed to give, in conjunction with a measure of fines content, a simple measure of coal flow and adherence characteristics, and hence of handlability.

It was shown that long-term, open air stockpiling of coal can have a detrimental effect on handlability.

7220-ED/806 Demonstration and evaluation of coal-water mixtures for industrial boilers - BCC

Duration from 01.09.1984 to 31.08.1987

This project dealt with an assessment of the preparation and combustion of coal-water mixtures (CWM) based on a range of UK coals. Preparation procedures were examined in order to identify the most appropriate processing route, and combustion trials were conducted to evaluate flame characteristics and ash fouling behaviour in a variety of test rigs.

It was demonstrated that CWM of acceptable rheological properties could be prepared by methods involving the wet milling of crushed coal or the blending of dry, pulverised coal: typically, the slurry solids content was 70% w/w. Appropriate dispersants were identified for the low-ash, washed coals studied. CWM prepared by wet blending was generally unstable, but certain additives were shown to be effective as stabilisers.

Attention was also given to the preparation of CWM from high-ash washery fines. In this case it was found necessary to develop a two-component additive system (one component being selective to the mineral matter, and the other to the coal itself) in order to achieve a satisfactory slurry. De-slimed Baum jig slurry was found to have similar characteristics to the corresponding low-ash coal.

Preparation procedures were also developed to incorporate limestone into CWM as a means of reducing sulphur dioxide emission during combustion.

On the basis of the procedures developed, a 250 kg batch and a 1 t/h continuous CWM preparation plant were designed and operated, both systems being capable of producing CWM by either the wet milling or wet blending route. Some 200 tonnes of CWM were prepared for combustion trials in the UK and France.

In order to identify the technical problems likely to arise when burning CWM in oil-designed boiler plant, a series of combustion tests was carried out to characterise the flames produced and to assess the behaviour of CWM fly ash in a boiler environment, particularly with regard to the slagging of heat exchange surfaces. There was no significant difference in the combustion characteristrics of CWM prepared by the two routes, and CWM prepared from high-ash froth flotation fines was burned with only minor difficulties. Measurement of gaseous emission levels from CWM and CWLM (Ca: S $\simeq$ 2: 1) flames showed similar NOx levels ($\simeq$ 280 ppm @ 6% Oz), whereas the respective SOz levels were 785 and 450 ppm: hence, CWLM offers a means of reducing SOz emissions in fine coal firing.

Ash deposition studies revealed the deleterious effect of using alkaline metal-based dispersants. Some CWM formulations gave light, friable deposits, but CWM prepared from coals with high slagging indices gave sintered, fused deposits which may be difficult to remove with conventional soot blowing equipment. However, deposition efficiencies for coal burned as CWM were generally lower than those for dry, pulverised coal firing.

7220-ED/807 Microfine coal combustion - BCC

Duration from 01.04.1985 to 31.03.1987

The project concerned an investigation of the combustion performance of microfine coal of nominal size characteristic 100% < 44 μm, i.e. finer than that of normal-grade pulverised fuel. Microfine coal size distributions were shown to differ in detail according to the type of mill used.

Evidence was obtained to demonstrate the following attributes of microfine coal firing:

- a reduced support fuel requirement for ignition and flame stabilisation purposes;
- a reduced flame length and increased peak flame temperature;
- a finer fly ash. Insufficient evidence was obtained to conclude that this would lead to reduced ash fouling of boiler convection tube surfaces;
- an increased furnace heat absorption associated with reduced gas exit temperatures. Experimental heat absorption profiles were compared with the predictions of a mathematical model that has the potential for calculating boiler de-rating on conversion from oil firing to fine coal firing.

The possible disadvantages of increased NOx emission levels and increased milling costs associated with fine coal were also assessed. In trials on a vertical shell boiler fired in the upshot mode through a staged burner, NOx levels were within the range 400 to 600 mg Nm^{-3} at 6% Oz.

In view of the high operating costs associated with fluid energy milling of microfine coal of mean size 6 μm (in contrast to mechanical milling which gives a mean size of 14 μm), it was recommended that consideration be given to the development of direct-fired mechanical mill systems which incorporate a classifier for the return of oversize coal for further grinding. By this means, fine coal flames can be 'tailored' to suit particular combustion requirements. The mill should be used in combination with a staged, swirled burner to provide reduced NOx levels and maximise the use of the available combustion volume.

7220-ED/810 Control of nitrogen oxides, sulphur oxides, hydrocarbons and particulates - BCC

Duration from 01.04.1985 to 31.03.1987

The levels of nitrogen oxide emissions from combustion plant depend mainly on boiler design, rather than on coal type, as indicated by the following table:

Typical emission levels from coal-fired boilers

Boiler Type	NOx emissions (corrected to 6% Oz) mg/m^3
Atmospheric FBC (shallow bed)	600 - 1400
Atmospheric FBC (deep bed)	400 - 800
Chaingrate stoker	300 - 500
Underfeed stoker	300 - 500
Spreader stoker	600 - 800
PF firing	700 - 2000
PFBC	300 - 500

Shallow bed FBC offers significant economies in construction and operation, but does so at the expense of higher emissions of nitrogen oxides and with greater difficulty in controlling sulphur oxide emissions. The purpose of the project was to investigate improved techniques for reducing NOx emissions from shallow beds and to determine the subsequent effect on emissions of sulphur dioxide and hydrocarbon emissions.

The work was conducted on five test rigs, ranging in size from 0.3 m square to 0.6 m diameter. It was shown that low NOx emissions are favoured by:

- smaller bed particle size and increased coal size. Coarse coals of size greater than 20 mm are likely to emit 25% to 30% less NOx than coal sized smaller than 10 mm. This can be attributed to the smaller surface to weight ratio of the larger coal, which will burn more slowly and generate lower particle temperatures. The impact of bed particle size can be even greater: a minimum 30% NOx reduction was measured on changing from coarse (1.3 mm mean size) to fine (0.4 mm) sand. This can be explained in terms of oxygen transfer between the bubble and particulate phase;
- the greater the bed voidage, as would occur with larger bed particles, the less the resistance to oxygen transfer and hence the greater the formation of NOx;
- reduced bed temperature and flue gas oxygen content;
- reduced coal nitrogen content.

It was demonstrated at test rig scale that optimising these operating conditions can result in emission reductions of up to 50%. The resultant effect on combustion efficiency was modest - a reduction from 97.5% to 96%.

Staged combustion resulted in a 35% reduction in nitrogen oxide emissions (the best location for secondary air injection being about 0.5 m above the bed), but this also gave a large drop in combustion efficiency - from 97% to 90% - due to solid carbon losses, rather than to emissions of CO or hydrocarbons. Efficiency is likely to be improved by grit refiring or by using preheated secondary air.

Ammonia injection was found to be an effective technique for reducing NOx emissions giving, in combination with air staging, a 52% reduction. Good results were also obtained with less hazardous materials, such as dilute ammonia liquor and solid urea. At the molar ratios used, emissions of ammonia at the stack were less than 20 ppm. Further work is needed to demonstrate that this technique will not have adverse effects on corrosion and fouling.

Sulphur retention in a bed of 0.25 m before fluidisation was only 40% at a Ca:S mole ratio of 3:1, but with a depth of 0.35 m and under optimum conditions for low NOx emissions, this was increased to over 60%.

UPGRADING PROCESSES

CURRENT RESEARCH CONTRACTS

Number	Title	Contractor	Duration
7220-ED/808	Minimising erosion in coal-fired boilers	BCC	01.04.85 31.10.88
7220-ED/809	Improving fine particle removal from flue gases in coal-fired processes	BCC	01.04.85 31.03.89
7220-EC/121	Untersuchung des Wirbelschicht-zustandes an einem 1:1 Kaltmodell einer grosstechnischen Vergasungsanlage	DEBRIV	01.04.86 31.12.88
7220-EA/813	Coal breakage characteristics in various forms of comminution equipment	BCC	01.06.86 31.12.88
7220-EA/816	Coal degradation in mechanical handling, transfer and conveying equipment for industrial plant	BCC	01.05.86 30.04.88
7220-EA/817	Disposal and utilisation of ash residues from pressurised fluidised bed combustion	BCC	01.04.86 31.03.89
7220-EA/818	Disposal and utilisation of flue gas desulphurisation residues	BCC	01.10.86 31.03.90
7220-EC/832	Production of industrial fuel gas for applications requiring high flame temperature and high emissivity	BCC	01.07.86 30.06.88
7220-EC/833	Development of gas cleaning systems for use in conjunction with industrial fuel gasification processes	BCC	01.07.86 30.06.89
7220-EC/702	Two-stage catalytic gasification of lignite	Thessaloniki University	01.02.87 30.09.90
7220-EA/821	Development of low cost coal handling	BCC	01.06.87 31.10.89
7220-EA/822	Industrial coal silos: outstanding problems	BCC	01.06.87 31.05.89
7220-EA/823	Surface active reagents	BCC	01.06.87 31.05.90

7220-EA/824	Development of coal feed systems for pressurised fluidised bed processes to eliminate the use of lock hoppers	BCC	01.06.87 31.05.89
7220-EC/835	Development of alkali metal compounds removal systems for use with hot particulate removal	BCC	01.06.87 31.05.90
7220-EC/837	Development of improved methods for the collection, transportation, control and utilisation of fine carbonaceous material	BCC	01.04.87 31.03.90
7220-EC/838	Development of an industrial gasifier for small-scale applications	BCC	01.06.87 31.05.90
7220-EA/304	Manutention des charbons difficiles	CERCHAR	01.10.88 30.09.90
7220-EC/316	Adaptation de petits broyeurs à la chauffe directe	CERCHAR	01.07.88 30.06.90
7220-EC/751	Control de fusión de escorias	ENDESA	01.03.88 28.02.90
7220-EC/752	Gasificación del carbón en lecho fluidificado circulante a presión	UPC	01.09.88 28.02.91
7220-EC/841	Fluidised bed coal gasification process for power generation	BCC	01.04.88 31.03.91
7220-EC/842	Trace constituents in industrial fuel gas	BCC	01.04.88 31.03.91
7220-EC/844	Sorbent handling on industrial sites for SOx control	BCC	01.07.88 30.06.91
7220-EC/846	The role of fuel additives to control environmental emissions and ash fouling	BCC	01.07.88 30.06.91
7220-EC/847	Wet ash removal	BCC	01.08.88 31.07.90

ECSC EXPERTS' COMMITTEE 'CHEMICAL AND PHYSICAL UPGRADING'

OBJECTIVES

The objective of this part of the coal research programme is to meet the continuing need for basic research on the nature of coal and on coal conversion and utilisation in order to provide support for R&D of a more applied nature and background information for the development of new processes.

CURRENT RESEARCH

(See list of research contracts)

There is a continuing interest in the development of standard analytical techniques for coal and coal products. This forms the subject of project 7220-EC/834 and is also included in project 7220-EC/123, a much broader investigation which, in addition, covers studies of coal conversion.

Successful work on coal hydropyrolysis is continued in project 7220-EC/206.

Much of the work in progress is concerned with aspects of high and low temperature carbonisation, and with the upgrading of the carbonisation by-products (projects 7220-EC/122, 7220-EC/327, 7220-EC/315, 7220-EC/317 and 7220-EC/318). (Some work on the relationship of tar quality to carbonisation conditions in the production of metallurgical coke falls under the responsibility of the Experts' Committee 'Coking of Coal')

Projects 7220-EC/839 and 7220-EC/840 deal with aspects of the production of carbon electrodes, an area where research is needed to ensure that, despite changing practices in the coking industry, coal tar pitch can continue to be a competitive raw material. The production of carbon fibres from pitch forms the subject of project 7220-EC/402.

Project 7220-EC/836 continues earlier studies of the behaviour of inorganic material in coal with a view to modifying the behaviour of such material. A similar study of the behaviour of mineral matter in the gasification of lignite is being carried out in project 7220-EC/124.

Three related projects address the problem of formation of oxides of nitrogen in coal combustion. In project 7220-EA/819 a study is being undertaken to determine whether the removal of light volatiles by mild solvent extraction or low temperature heat treatment can limit NOx formation, and whether additives can be used for the same purpose. Project 7220-EC/843 investigates the formation of NOx from combustion air, while project 7220-EC/845 looks at NOx formation from the point of view of improving burner design.

7220-EC/313 Copyrolyse du charbon et de residus hydrocarbones - CERCHAR

Duration from 01.06.1985 to 31.05.1988

The incorporation into coking blends of heavy hydrocarbon residues from the oil industry or from coal processing influences the yield of carbonisation by-products, and hence the economics of pyrolysis. The aim of the research was to determine which properties of such additives help to increase coal devolatilisation while improving coke quality. The classification of additives in terms of quality criteria should help the coke producer to make a choice.

Available additives were surveyed and listed according to their origin. They were characterised by standard analytical techniques, such as elementary analysis, mean molecular weight, infra-red spectroscopy, NMR, fractions insoluble in solvents, and by other forms of analysis to determine the hydrogen donor number, the hydroxyl index, chromatographic fractionation and extrography.

The carbonisation mass balance was determined to give the yields of coke, gas, tar and benzole.

Blends containing 5% to 15% of additives were prepared and tested in a range of reactors varying from a few grammes (tubular reactor) up to the 400 kg oven level. Mass balances were carried out on the Jenkner retort to obtain product analyses (gas, tar and benzole compositions, density, porosity, mechanical strength, reactivity and texture of coke). The improvement in coke quality resulting from co-pyrolysis was measured by microscopic analysis of the coke texture.

The use of additives always leads to an increased yield of by-products, in order to increase the value of tar, the latter needs to be enriched in light components. This can be achieved by using additives containing aliphatic and/or naphthenic compounds which give naphthalenes by the Diels-Alder reaction. Certain products from oil refining fall into this category.

Charge compaction also favours the production of tars rich in light components.

7220-EC/828 Chemical characterisation of coal and coal products - BCC

Duration from 01.09.1984 to 31.08.1987

The principal aim of this project was to apply new spectroscopic and chemical procedures to the analysis of coal.

Particular emphasis was placed on studying the chemical environments of sulphur, nitrogen and sodium, since these elements are associated with atmospheric pollution and plant fouling and corrosion problems. Significant new information was obtained.

Temperature-programmed reduction was used to study organic sulphur functionality in relation to coal rank. The variations in functionality observed are unlikely to be significant in combustion processes, but may have implications for pyrolysis, liquefaction and desulphurisation.

The average nitrogen content of a rank series of UK bituminous coals was shown to reach a maximum of around 85% carbon, dmmf. Variations in nitrogen functionality were studied by x-ray photoelectron spectroscopy.

Solid-state nuclear magnetic resonance spectroscopy was used to study sodium in coal. The sodium ion was shown to be fully hydrated and more or less rigidly bound to a single organic functional group at the pore surface. Sodium chloride was not detected, and was still only a minor component of dried coals. Low-temperature ashing destroyed the original sodium environment, confirming that it was not mineral. In addition to the sodium study, solid-state NMR spectroscopy gave information on the chemical environments of aluminium and carbon in coal.

Other techniques were used to probe the inorganic constituents of coal, particular attention being paid to differences between density-separated mineral matter and the corresponding low-temperature (plasma) ashes. This aspect of the work was undertaken to establish the extent to which low temperature ash may be taken as representative of coal mineral matter. The results suggest that certain changes to the mineral matter do, indeed, occur during plasma ashing. This was confirmed by Fourier transform infra-red spectroscopy, x-ray diffraction and solid state 27Al NMR spectroscopy. Thermal analysis-mass spectrometry was used to study coals and coal minerals under oxidising, combustion-related conditions, and this also revealed differences between density-separated mineral matter and the material obtained by low temperature ashing.

7220-EC/830 Pitch insolubles - their nature, properties and substitution - TIS

Duration from 01.10.1984 to 31.12.1987

Two examples of low-solids by-product tars from modern coke oven installations were distilled in the laboratory to produce pitches of properties similar to those of conventional electrode binders, apart from the low content of quinoline-insoluble matter.

Three further pitches were prepared in which the content of quinoline insolubles was boosted to conventional levels (8-12 mass %), in one case by dispersing carbon black in one low-solids tar prior to distillation, and in the second and third cases by air blowing a soft pitch, derived from the other low-solids tar, at elevated temperature.

These five experimental pitches and seven commercially-produced anode binder pitches were fully characterised using conventional anode binder specification tests including analysis for a wide variety of contaminant elements. Two pilot-scale experimentally produced pitches used in an earlier ECSC project were also examined.

Bench-scale test electrodes were produced from all 14 pitches using a prebaked-type anode formulation with petroleum coke aggregate obtained from an aluminium producer. The physical and reactivity properties of the test electrodes were measured.

The results indicate that low-QI binders prepared from modern coke oven by-product tars could probably be used to produce baked carbons having satisfactory performance as prebaked anodes for aluminium cells. If it is regarded as desirable to enhance the QI content of the pitches to match existing anode binder specification, addition of carbon black either to the tar prior to distillation, or to the petroleum coke aggregate when producing

electrodes, appears to be a satisfactory option. Air-blowing is regarded as a less satisfactory proposition for reasons connected with the rheology of the derived electrode pastes.

7220-EC/831 A study of the behaviour of ionisable salts during coal processing - BCC

Duration from 01.04.1985 to 31.03.1988

The presence of mineral matter and in particular of water soluble salt minerals in some coals is often associated with problems of deposits and corrosion when the coals are burnt. The aim of the project was to investigate the mode of occurrence of the ionisable salt minerals in coals and to study their release during combustion.

Three selected UK bituminous coals were used in the study. They and their separated minerals were fully characterised and the mineralogical composition estimated using a variety of conventional and advanced techniques. The coals were found to contain the same salts and minerals, but these varied in their relative proportions. No single analytical technique yielded a comprehensive analysis of the components.

The nature, extent and ease of removal of the ionisable salts were determined. The salts appear to be present mainly as ions absorbed on the coals' porous surfaces and can be substantially removed by aqueous leaching. Virtually all the sodium and chlorine can be removed if the coals are finely ground, ease of removal being controlled primarily by the nature of the coals' porous structure.

Ash fusion and high temperature microscopic examination of the ashes indicated that decreasing the salt content of the coals results in an increase in the ash melting point. In addition, increasing chlorine, sodium and calcium contents can be correlated with increasing ash fouling and slagging propensities.

The behaviour of the coals and their ashes under various thermal and combustion conditions and in a range of laboratory combustors was studied and the fate of the major inorganic salt mineral components determined. The importance of condensing chlorides and sulphates of sodium, potassium and calcium, and possibly low melting point eutectic mixtures, in providing an initial adhesive layer for the capture of impinging particles and causing deposit build-up on above-bed surfaces, was established. Such initial adhesive layers were significantly reduced for the coal with the lowest ionisable salt mineral content.

The consequences of varying some important combustion parameters, and the influence of certain coal pretreatments on the nature and extent of the deposits formed in laboratory fluidised bed combustors were evaluated. The initial deposits on above-bed surfaces were particularly affected by surface temperatures and by the use of sulphur sorbent bed materials. Coal blending and reduced chlorine contents were identified as possible methods of reducing both gaseous emissions and deposit forming tendencies.

Combustion of the coals in a pilot scale fluidised bed furnace confirmed observations made on the laboratory scale. The coal containing the highest ionisable salt mineral content showed the greatest tendency to form low melting point deposits. The major salt constituents present in the above-bed deposits were shown to be sulphates and chlorides of sodium and calcium.

CHEMICAL AND PHYSICAL UPGRADING

CURRENT RESEARCH CONTRACTS

Number	Title	Contractor	Duration
7220-EC/122	Vergleichsstudie der Schwelverfahren und Auswahl eines Verfahrens zur industriellen Entwicklung unter Berücksichtigung der Verwertbarkeit der anfallenden Produkte	KGSaar	01.07.86 31.12.88
7220-EC/327	Valorisation par post-traitement thermique du gaz brut dans l'optique d'une production d'hydrocarbures légers et de brais spécifiques	CERCHAR	01.06.86 30.11.88
7220-EC/123	Chemische und physikalische Veredlung von Kohle	StBV	01.07.87 30.06.89
7220-EC/124	Einfluss der Mineralstoffzusammensetzung von Braunkohle auf das Schmeltz-und Verschlackungsverhalten bei deren Veredlung	DEBRIV	01.12.87 31.01.91
7220-EC/206	Hydrogénopyrolyse sous pression: influence du prétraitement des charbons sur les rendements et les mécanismes de l'hydrogénopyrolyse	ULB	01.05.87 30.04.89
7220-EC/315	Etudes d'accompagnement de procédés d'utilisation et de conversion du charbon	CERCHAR	01.07.87 30.06.89
7220-EA/819	Basic studies of NOx formation and control	BCC	01.10.87 30.09.90
7220-EC/834	Characterisation of coals and coal products by solid-state NMR spectroscopy to aid conversion processes	BCC	01.10.87 30.09.90
7220-EC/836	The role of coal mineral matter in conversion processes	BCC	01.10.87 30.09.90
7220-EC/839	Bonding between binder cokes and filler particles in carbon and graphite electrodes	LCL	01.07.87 30.06.90
7220-EC/317	Pyrolyse industrielle: semi-cokes et brais	CERCHAR	01.07.88 30.06.91

7220-EC/318	Conduite de la cokéfaction et production de goudrons	CERCHAR	01.07.88 30.06.91
7220-EC/402	Produzione fibre di carbonio	CSM	01.07.88 30.06.90
7220-EC/840	Rheological performance of pitch binders	TIS	01.04.88 31.03.91
7220-EC/843	NOx formation in coal utilisation.	BCC	01.07.88 30.06.91
7220-EC/845	NOx and ash in PF flames.	BCC	01.07.88 30.06.90

ABKURZUNGEN - ABBREVIATIONS - ABBREVIATIONS

AITEMIN	ASOCIACION DE INVESTIGACION TECNOLÓGICA DE EQUIPOS MINEROS
BCC	BRITISH COAL CORPORATION, LONDON (UK)
BSC	BRITISH STEEL CORPORATION, GRANGETOWN (UK)
CERCHAR	CENTRE D'ETUDES ET RECHERCHES DE CHARBONNAGES DE FRANCE, PARIS (F)
CRG	CARBON RESEARCH GROUP, LOUGHBOROUGH CONSULTANTS, TECHNICAL UNIVERSITY OF LOUGHBOROUGH (UK)
CSIC	CONSEJO SUPERIOR DE INVESTIGACIONES CIENTIFICAS, MADRID (SP)
CSM	CENTRO SPERIMENTALE METALLURGICO, ROMA (I)
DEBRIV	DEUTSCHER BRAUNKOHLEN-INDUSTRIE-VEREIN, KÖLN (D)
ENDESA	EMPRESA NACIONAL DE ELECTRICIDAD S.A., MADRID (SP)
GAIZT.	ANTRACITAS GAIZTARRO S.A., LEON (SP)
HCC	S.A. HULLAS DEL COTO CORTES, MADRID (SP)
HUNOSA	HUNOSA E.N. HULLERAS DE NORTE, S.A., OVIEDO (SP)
HVL	S.A. HULLERA VASCO LEONESA, LEON (SP)
ICI	ICI EUROPA, KORTENBERG (B)
INIEX	INSTITUT NATIONAL DES INDUSTRIES EXTRACTIVES, LIEGE (B)
IREA	INSTITUT VOOR REDDINGWEZEN, ERGONOMIE EN ARBEIDSHYGIËNE, HASSELT (B)
MSP	MINERO SIDERURGICA DE PONFERRADA S.A., LEON (SP)
StBV	STEINKOHLENBERGBAUVEREIN, ESSEN (D)
SULCIS	CARBOSULCIS S.A., MINIERA DI NURAXI FIGUS, CARTOGHIANA (I)
ULB	UNIVERSITE LIBRE DE BRUXELLES (B)
UPC	UNIVERSIDAD POLYTECNICA DE CATALUNA, BARCELONA (SP)
WBK	WESTFÄLISCHE BERGGEWERKSCHAFTSKASSE, BOCHUM (D)

European Communities — Commission

EUR 12292 — ECSC coal research - Annual report 1988

J. K. Wilkinson, V. Luque

Luxembourg: Office for Official Publications of the European Communities

1989 — X, 152 pp. — 21.0 × 29.7 cm

Technical coal research series

EN

ISBN 92-826-0677-5

Catalogue number: CD-NA-12292-EN-C

Price (excluding VAT) in Luxembourg: ECU 12.50

The coal research activities of the European Coal and Steel Community during 1988 are summarized in this report. The research falls under two headings: mining techniques and coal upgrading. Subjects covered under the mining techniques heading are:

(i) roadway drivage systems,
(ii) mini gases, ventilation and climate,
(iii) methods of working and techniques of coal-winning,
(iv) mine infrastructure,
(v) modern management,

and under coal upgrading:

(i) coking of coal,
(ii) upgrading processes,
(iii) chemical and physical upgrading.

For projects completed in the course of the year the report summarizes the aims and main results. Projects on which work is in hand are represented by a progress report, and for projects started in 1988 a brief description is given of the aims.

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