

COMMISSION OF THE EUROPEAN COMMUNITIES

EUROPEAN COAL AND STEEL COMMUNITY

COAL RESEARCH REPORTS

**PROGRESS REPORT OF
COAL RESEARCH ENCOURAGED
BY THE COMMUNITY, 1972**

**Issue
No**

58

LUXEMBOURG 1974

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INTRODUCTION

The Commission of the European Communities promotes research in the coal sector pursuant to Article 55 of the ECSC Treaty.

The results of research projects are communicated to all interested parties by publication in technical journals, or in the 'Coal research reports', as well as in papers presented at technical congresses, symposia or information sessions. The corresponding

rules and procedures contained in the research contracts drawn up with the recipients of financial aid also ensure that 'interested parties in the Community' have access to the results of Community research.

This 'Report of activity in 1972' summarizes the projects carried out in the past year in the coal sector, as well as the more significant results obtained.

1.1. RESEARCH PROJECT 'FULLY MECHANIZED GATE ROAD DRIVAGE'

Steinkohlenbergbauverein, Essen

1.1.1. Partial project: EV 100 heading machine

After the general overhaul in the first half of 1972 the improvements introduced were tested in resumed operations at the combined mine Gneisenau, panel Kurl 3 of the Bergbau AG Dortmund. The improvements in the loading and conveying installation led to a low fault-proneness in the machine and to a consequent high utilization rate. Daily rates of between 9 to 11 m/day were obtained on a monthly average.

The improved support and transport back-up has not proved itself as yet. Here further changes are needed in design and technical methods. Improvements in the dust-suppression devices led to a higher degree of operating safety in the installation and better dust-suppression.

1.1.2. Partial project: VS 2 E heading machine

After reconstruction and improvements of the supporting installations the machine was used for driving a gateroad in the Ernestine seam. The undulating configuration of the seam called for frequent changes in the roadway inclination. During this it became clear that it is difficult with a tensioned machine to adhere to a set level and the set direction. Improvements are hoped for here from an added optical device to spread out the laser beam, which remains visible to the machine operator for longer during undulating drivage, and from an automatic cross-section cutting device as well as an improved cutting head. This is to be tried out in the near future. The combination of all supporting equipment and the automatic forward haulage of these machines has proved itself despite a few difficulties. The saving of one operator at the conveyor transfer point could be made. The operational run of the VS E heading machine was normally terminated on 25.8.1972 in the Ernestine seam. A further road drivage has not yet been settled.

1.1.3. Partial project: DRCL heading machine

At Emil Fritz colliery trials continued to reduce the supports effort in fully mechanized gate road drivage with the aid of Mönninghoff anchor borehole drilling equipment which had undergone several alterations and improvements. This made it possible to complete one anchoring operation in about 5 minutes in exceptional cases. But technical and operating defects still existed. The trials at Emil Fritz colliery had to be stopped in March 1972 due to increasing operational difficulties caused by geological factors. No other utilization of the machine was possible here. The supports trials are to be continued at the Rheinland combined mine of the Niederrhein Bergbau AG with a temporary powered support system in a DRCL heading.

1.1.4. Rock mechanics tests

In all heading machine trials the surrounding rock was investigated to obtain comparative values on rock hardness and wear. The numerous measurements give the first indications of the range of heading machine application.

1.2. RESEARCH PROJECT 'ROADHEADER'

**Centre d'études et recherches
des charbonnages de France**

During the second half of 1972 the experts from the 'drivages' working party attended tests of the cutting head and support. In view of what they saw at these tests they authorized the continuation of the research and the construction of the prototype, on the basis of the cutting method on test.

Two lines of work were followed in 1972, namely:

1.2.1. In the course of numerous manipulations of the cutting head and of the support, the technical features and reliability of these components were improved

In particular,

- the precision and speed of the transcription system whereby the machine is made to follow the movements of the display mock-up were improved,
- the drive system for the rotation of the cutting-head boom supports was strengthened, and
- defects in the various hydraulic circuits were corrected.

1.2.2. The study of the prototype's ancillary equipment was begun

namely:

- The loader: It was seen that the two side shovels took up too much room. It was eventually decided to use a central loading system, comprising a bucket loader plus an articulated conveyor.
- The rock-breaking tool: This is carried on the bucket loader; its purpose is to insert itself into the kerf and then splinter the blocks.
- The general structure of the machine; supporting wheels: The general structure of the machine has been reviewed, so that all electrics and hydraulics are carried on the machine, and so as to add supporting wheels on which the machine can be moved into the workings, or from one working to another.
- The hydraulics: These have been reviewed, so as to make them simpler and more reliable.

1.3. RESEARCH PROJECT 'MECHANIZATION OF GATE ROAD DRIVAGES AND DEVELOPMENT WORK IN COAL'

**Institut national des industries extractives,
Liège**

The following four roadheaders have been tried in the Campine coalfield to date: the Muniko at Eisden, the Westfalia at Waterschei, the Dosco at Beringen and the PK 9 at Winterslag.

The Muniko does well in coal but is unable to attack medium-hard rock (incidentally, this also applies to the Westfalia). The trials have been discontinued. The Dosco came into service in August 1971, and the PK 9 in June 1972.

1.3.1. the Dosco roadheader

The Dosco was first tried in a working in the '63-64' seam, where it drove 200 m, partly in an arch-shaped section and partly in a rectangular one. This first trial made it possible to assess the machine's cutting potential in fairly hard rock by the Campine's standards. The trial was also used as an opportunity of developing an efficient dust-prevention system. The rate of advance was 1.75 m per shift in the arch-supported section (articulated rail frames on timber side-members) and 2 to 3 m per shift in the bolted section, with 4 men in each case.

During the first half of this year this machine was then brought into service in a dip heading in the '55' seam. This dip heading is intended to provide access

to an advancing face in the future. The average dip is 11°, with a maximum of 15°, over 20 m. In spite of these very difficult conditions (the manufacturers had specified a maximum dip of 14°) the machine did very well, and the only two parts which had to be replaced were two steering pivots in the crawler track. 400 m were driven, of which 227 m were bolted. The rate of advance was 2 to 2.40 m per shift in the frame-supported section and 3 m per shift in the bolted section. Average monthly o.m.s. was 50 cm and 45.7 cm in the bolted and frame-supported sections respectively.

During the second half of this year the Dosco was put into service in a 400-m long development heading in the '61-62' seam, which has a thickness of 2.90 m.

The entire section was supported with metal arches on timber side-members.

The rate of advance during the last two months has regularly been in the region of 10 m per day for an excavated cross-section of 16.7 m².

In view of the good results which have been obtained (and which allow a rapid amortization of the machine) another two Doscos of the same type have been acquired by Beringen colliery.

1.3.2. the Russian PK 9 roadheader

The Russian PK 9 roadheader was put into service in a dip heading in the '70' seam at Winterslag colliery on 28 June.

The rate of advance was 3 m per shift with 4 men; the supports consist of TH arches. The dip of the heading is 9° and the seam is 1.25 m thick. The advance is slowed down by a considerable make of water (2 to 3 m³/h) from old overlying workings. The won coal turns into slurry, and this is difficult to evacuate with the machine's gathering arms.

The rock surrounding the seam contains a great many thin layers of highly-abrasive sandstone, and this makes for a high pick consumption. The rock beds in the roof are exceptionally hard; so much so that excavation in the roof has had to be abandoned altogether. The floor strata enclose a large number of flint and siderite beds which may be 10-cm thick in places (pick consumption has been at the rate of 8 to 10 per metre).

Having driven the dip heading, the machine is now driving the bottom road of a retreat face in the same seam. The roof of the seam consists of relatively hard strata, and it has therefore been decided not to cut it, and to set trapezoidal supports. Unfortunately the advance of the machine is being slowed down considerably by severe floor-heave in the road and by lateral pressure from the wall coal.

**1.4. RESEARCH PROJECT:
'IMPROVEMENTS IN CONVENTIONAL
HEADING TECHNIQUES'**

Steinkohlenbergbauverein, Essen

During 1972 partial tests of the overall project were carried out at 11 collieries. These are itemized as follows:

Company	Colliery	Operation
Bergbau AG Niederrhein	Friedrich Heinrich Pattberg Walsum	Drilling 1 Drilling 2 Supporting 3
Bergbau AG Essen	Carl Funke/ver. Poertingsiepen Gottfried Wilhelm	Drilling 4 Supporting 5
Bergbau AG Westfalen	Haus Aden Heinrich Robert	Drilling and supporting 6 Drilling 7
Bergbau AG Gelsenkirchen	Ewald	Supporting 8
Bergbau AG Herne/ Recklinghausen	Blumenthal	Supporting 9
Eschweiler Bergwerks-Verein	Erin	Drilling and Supporting 10
Gewerkschaft Auguste Victoria	Westfeld	Drilling and Shottfiring 11

The partial tests at collieries Auguste Victoria, Haus Aden, Friedrich Heinrich and Pattberg, concentrating on improved drilling techniques with jumbos, have been completed by mid-1972 and no longer form part of the overall project. Although it was possible to develop drilling cradles (or nacelles) and slushers to a certain point at the Auguste Victoria and Friedrich Heinrich collieries respectively, the defects found and identified with the crawler mounted jumbos at the Haus Aden colliery could not be remedied on the equipment available. The new design will incorporate these discoveries. The drilling cradles with their attendant drill arms at Pattberg colliery have not met the requirements made of them. Drilling cradles of this type are ruled out for underground use in the future.

The Mönninghoff 'portal' drilling platform could only be used for short periods so far due to the frequent alterations on the drill arms and carriages which had to be effected. So far, utilization has not yet yielded the hoped-for result.

The first underground use of the ladder-type drilling equipment had to be postponed due to operational replanning. Meanwhile some additional improvements on the drill rig are being made on the surface.

Tests on the 5-arm drilling platform at the Heinrich Robert colliery were not started until the second half of the year. The initial running-in problems should have been overcome by now.

In addition, thorough tests of drill hammers, rods and bits were carried out.

Now that the jumbos are equipped with the best drilling tools known, a further improvement in drilling performances may be expected.

As part of the supports improvements, trials were continued under 'roadway supports' testing. This involved the development of machines and techniques suitable for gunniting and backfilling and new steel and concrete support components, as well as equipment to simplify the supporting operation. Selective pre-trials were also carried out for future underground operation.

At Erin colliery the wet gunniting (König) machine is currently being used to construct a coal bunker for gunniting work. The design of the machine is not yet perfected. The concrete to be produced by it has already proved itself entirely as a support medium.

At collieries General Blumenthal and Haus Aden the conventional manual stone backfilling is being replaced by different backfilling devices which

provide a supporting concrete shell. Suitable sealing mats developed on the test rig were first used here.

At Walsum colliery an appliance (manipulator), first proved a test rig, has been used to mechanize the backfilling process. Its main application is to be with anhydrite stoppings.

At Auguste Victoria colliery shotfiring tests have begun, aiming to show the advantages of firing with large-calibre cartridges. In addition, accurate cross-section and strata-protective shotfiring is being investigated.

1.5. RESEARCH PROJECT 'IMPROVEMENT OF CONVENTIONAL DRIVAGE TECHNIQUES'

Centre d'études et de recherches des charbonnages de France

This research programme covers all improvements which concern the various stages in the operational cycle of a conventional drivage.

The programme was launched in July 1971. During 1972, the research which was conducted in the northern coalfields concerned the improvement of drilling performances and conditions; in the Lorraine, the research related to the evacuation of debris after shotfiring, to strata bolting in stonedrifts and to the drilling of drainage channels.

Research into drilling began with the development of a rail-mounted jumbo with one boom, which is fitted with a 100-kg Montabert H 50 hydraulic hammer drill. This is the Montabert 'Pantofore' (multi-head borer) which, as a first step, is meant for drivages with small or medium cross-sections. This hammer drill (which is far less noisy than the 30-kg pneumatic hammer drill, with a 2.8 times faster drilling speed), together with its space-saving rig, allows a very substantial improvement in working conditions and makes it possible to reduce the number and the space requirements of drilling tools. In a stonedrift with a cross-section of 12.5 m² and equipped with a 'Pantofore', 550 m have been driven at a daily rate of advance of 4.60 m and with a roadhead o.m.s. of 61 cm. There was a particularly marked reduction in maintenance (of the Pantofore) during that period. It is intended to extend the utilization of the jumbo to cross-sections of 18 to 24 m², in conjunction with rail or crawler-mounted carriers.

Another research project (this time in the Lorraine) has made it possible to specify the loading equipment

which is best suited in relation to the cross-section which has to be driven. This was found to consist of one or two Eimco shovel-loaders with side discharge onto a small armoured conveyor, and then a Thyssen belt conveyor suspended over the track of the loaded tubs. The 1000-litre tubs are turned on a specially adapted turntable; the 3000-litre cars are handled on a traverser which is fitted with a boxer.

The third research project concerns the mechanization of bolt setting in stonedrifts with medium and large cross-sections by means of a twin-arm bolt setting machine with a working platform which can be folded back. The time taken to set a run of 25 bolts has been reduced from 195 minutes (by hand) to 90 minutes (by machine).

Finally (still in the Lorraine), a machine has been developed to drill the drainage channels outbye of the roadhead; this has been done by combining the chassis of an Eimco 330 shovel-loader with a boom by which the debris can be collected 1 m below the haulage level and loaded into tubs. It is intended to subsequently try an identical prototype with crawlers or tyres.

1.6. RESEARCH PROJECT 'IMPROVEMENT OF CONVENTIONAL DRIFTING TECHNIQUES'

**Institut national des industries extractives,
Liège**

The introduction of reinforced-concrete panels has made it possible to mechanize lining operations when circular stonedrifts are driven in the Campine coal-field, and has regularly allowed a daily rate of advance of 4 m (3-shift working ; 4 men per shift).

With a view to further increasing the rate of advance to 6 m/d, INIEX has placed an order for a 200-m long belt conveyor suspended from two monorails. A gathering-arm loader will be brought into service: this will ensure continuous loading of the debris from a 2 m long clearing-up run, because a sufficient number of tubs to take all the debris can be slid underneath the conveyor.

The colliery engineers have adapted the panel-setting machine so that it now goes onto the gathering-arm loader. A third monorail will be used to move the panels from outbye into the roadhead.

2.1. RESEARCH PROJECT 'HYDRAULIC COALWINNING AND HAULAGE' II

**Steinkohlenbergbauverein, Essen
(Carl Funke colliery)**

During the second half of 1972 a daily disposable output of 1300 to 1400 t was achieved in the district where hydraulic working takes place. The target figure of 1500 t disposable output was reached on some days during November. An underground o-m-s of 5.3 t was achieved, despite poor geological conditions and teething troubles with the machines. Hydraulic working with sub-level caving may therefore now be considered a fully-developed winning method. The results show that this is an adaptable coal-getting system for semi-steep and steep seams, and one which can compete with level-seam methods as regards performance and also (given better geological conditions) as regards costs.

Teething troubles were mainly caused by the very high incidence of smalls; this created difficulties with partial preparation and with clarification. The high tectonic stress on the seams is the main reason for the unexpectedly high percentage of smalls.

Drilling with water-jet monitors and pillar working are now being further developed. Appreciable increases in performance can still be expected from this, because the number of rise-headings and winnings can be reduced.

2.2. RESEARCH PROJECT 'HYDRAULIC COAL HAULAGE AND HYDRAULIC WINDING IN DEEP SHAFTS'

**Steinkohlenbergbauverein, Essen
(Gneisenau colliery)**

A five-day trial with 650 t disposable output per day provided a conclusive demonstration of the hydraulic

haulage equipment's efficiency and reliability. The small bunkering capacity (only 40 t) proved to be a bottleneck, since the equipment could not be operated at optimum throughput with an irregular flow of coal from the face. Plans were therefore made for a bunker which is now being installed in the drainage road. Until this is completed, only 100 to 300 t disposable output per day will be transported; the haulage operation is handled by a fully-trained permanent team.

The screened coarse particles of > 60 mm (about 5% of the total throughput) are now transloaded from the level haulage into tubs, because the crusher's performance proved insufficient. This has prevented blockages being caused in the pulp pumps and pipelines by fairly large lumps and long, thin pieces of dirt.

The clarification of the return water (5 g/l) was unsatisfactory. It is now being clarified to < 1 g/l by adding flocculating agents, and because of the alterations which have been made to the settling pond.

Measurements of wear are continuing according to plan, but no definite findings are yet possible in view of the small throughput so far (approx. 30000 t disposable output).

2.3. RESEARCH PROJECT 'INTEGRATED MECHANIZATION OF WINNING, SUPPORTS AND STOWING IN THICK SEAMS'

Steinkohlenbergbauverein, Essen

2.3.1. Ploughing and pneumatic stowing – At Nordstern colliery

A new experimental face in the 'Zollverein 2/3' seam at Nordstern colliery was started in February 1972. The experience acquired in the previous experimental face was largely taken into account for the equipment

of the new face. Since then, the following experience has been gained and the following further developments have been pursued on that face:

2.3.1.1. *Winning*

An S2 plough with a ramp-type mounting was installed on the second experimental face, so as to get a comparison between various plough designs under the conditions pertaining in the 'Zollverein 2/3' seam. This lighter type of plough was mainly chosen because the floor on the new experimental face was quite soft. As a matter of fact, some 50 cm of bottom coal were left in the floor after a short time, so as to achieve a satisfactory coal-getting performance. Since then there have been no further difficulties with winning.

2.3.1.2. *Haulage*

The Halbach & Braun EKF3 chain-scraper-conveyor which was used instead of the Westfalia double centre-chain conveyor caused some trouble during the first few weeks. It only worked without any difficulty once the men on the face had learned how to handle the related intermediate anchorages properly, so that the conveyor was always sufficiently pre-tensioned. The conveyor's lateral coal-discharge equipment has also done well.

2.3.1.3. *Supports*

Systematic observations of the roof on the first experimental face had shown that the centre joints of the rows of roofbars were a cause of increased cavities in the roof. Joints which did not yield upwards were thereupon used on the second experimental face, and this brought about a genuine improvement. The roof on the new face was observed for a month, and it was found that the maximum base area of the roof cavity above the supports now amounted to 0.4 %, instead of the 20.3 % which had been observed in November 1971 on the first experimental face. The fact that the props' nominal loadbearing capacity has been increased from 60 to 70 Mp may also have had a bearing.

2.3.1.4. *Stowing*

As a further development of the side discharges which have so far been used for pneumatic stowing, a special design with an optionally-pivotable deflector flap has been used, with which the angle of discharge can be increased from 26° to approximately 45°. This design has made it possible to almost completely straighten the previously sinusoidal configuration of the stowing slope. The mobile pneumatic pipeline with side discharges has been further developed and

made more robust; this was done by reinforcing the couplings and collars and by enclosing the hydraulic components yet more effectively. A further improvement under this heading has been to insert ball joints into the face pipeline at intervals of roughly 30 m; these joints articulate under pressure, and they protect the line when it is being shifted, and make it more adaptable to variations in dip. These various measures have proved themselves in practice, and have made the mobile pneumatic pipeline more adaptable to the powered supports.

2.3.2. **Shearing, powered supports and caving**

2.3.2.1. *Surface trials*

The machine and the experimental equipment were delivered in January 1972, and trials began in February with the winning machine which is fitted with a cutting disc. The first phase of the trials took place in the 'soft' section of the artificial coalface on Bergbau-Forschung's mining-engineering test site at Essen-Kray (cf. last year's report). The trials were aimed at optimizing the cutting disc and its breaking tools. The following parameters were recorded in this connection: tensile strength of the chain, winch speed, shaft torque and power intake.

Whereas the principle on which the coal is won by the cutting disc came up to expectation, the readings showed high cutting-disc torques and an exceptionally high power intake.

These difficulties were mainly due to the fact that the properties of the artificial coalface are very different from those of real coal; in particular, there are no cleats, cracks and pressure partings to create a natural loosening effect. These unfavourable aspects of the artificial coalface were confirmed by comparative tests with a short, barrel-shaped drum. It nevertheless proved possible, in the course of comprehensive tests, to also optimize the performance of the cutting disc's wedge-shaped tool in the 'medium-solid' section of the artificial face, in accordance with the latter's requirements.

During the trials the tilt of the sloping coalface was altered from 84° to the maximum-possible angle of 76°, without any perceptible adverse effects on the machine's running stability.

In connection with the slip friction between the machine and the conveyor, the slip-stick effect created additional load peaks on the chain's tensile strength, and thus on the torque and on the power intake. It proved possible to avoid these additional load peaks (and the consequential permanent load

on all machine components) by applying rolling friction to the two face-side runners which bear the main weight of the machine.

Changing the cutting disc's r.p.m. also confirms the observation which applies to pure drum-shearing, namely that a lower r.p.m. of 62 min^{-1} is better than the higher figure of 95 min^{-1} .

The loading process of the cutting disc without a clearing plate was unsatisfactory at first; a substantial improvement was obtained by fitting loading helices, and the loading process of the cutting disc without a clearing plate is now better than that of the short drum without a clearing plate.

Before the first phase of the coalwinning trials on the artificial face had been concluded, the site was hit by a violent storm, with hurricane-force winds, on 13 November 1972. This destroyed Bergbau-Forschung's two open sheds, and the tests which had been proceeding there had to be temporarily discontinued. Since then, preparations and modifications have been carried out for further coalwinning and loading tests with a modified clearing plate.

2.3.2.2. The experimental face and powered supports

It became essential to conduct short underground tests to compare the results and experience gained on the artificial face with those acquired on a natural coalface. New facilities for such tests were obtained, at Rheinpreussen colliery, during negotiations with Ruhrkohle AG. It is intended to hold coalwinning tests of a few days' duration on a prepared face; this will be done early next March.

Since the shield supports which are manufactured by Bochumer Eisenhütte Heintzmann & Co. have also done well on the test site (on which the experimental face which is planned for 1973 is also to be operated), these manufacturers have meanwhile started the preliminary work for the development and fabrication of supports which will comply with the special conditions of the new winning method, and which will allow the integration of winning and of supports.

2.4. RESEARCH PROJECT 'A NEW STEEP-SEAM WINNING METHOD'

**Centre d'études et de recherches
des charbonnages de France**

Research began on 1 July 1971. The original aim was a new machine, to work in conjunction with

supports having hydraulic telescopic roofbars and with their side-members sunk into the stowed material.

Research on using the stowed material as an abutment for the supports had to be abandoned after tests. On the other hand, the following work is proceeding:

1. an investigation into the utilization of cable bolts as an abutment for the supports;
2. measurements of the forces transmitted from the roof to the supports;
3. trials are continuing with the 50 hydraulic telescopic roofbars which are now in service; these trials involve very comprehensive measurements. The technological aspects are satisfactory, and an order for 340 roofbars will be delivered in 1972.

Research into a new machine has been discontinued; the first stage is to develop supports in conjunction with the utilization of existing machines by improving the latter (measurements, regulating tests, trials on an artificial coalface).

2.5. RESEARCH PROJECT 'REMOTE MONITORING AND REMOTE CONTROL ON A SHEARER FACE'

**Centre d'études et de recherches
des charbonnages de France**

Research on remote control and remote monitoring on shearer faces (the subject of the second Agreement to be concluded between the ECSC and Charbonnages de France) continued during 1972 in the Schwalbach seam at La Houve colliery.

Ten chocks on a surface site were equipped for bank control in accordance with the system which was developed during the second half of 1971. They were then installed underground. The technological aspects are in order, but there is still the problem of cleaning-up between the conveyor and the chocks when the floor is soft.

The final accessories needed to instal remote-control equipment on the winch of a double ranging drum shearer have been delivered by Messrs. Anderson.

It is expected that a remote-controlled double ranging drum shearer will be installed underground early in 1973.

2.6. RESEARCH PROJECT 'AUTOMATED PLOUGH FACE'

Steinkohlenbergbauverein, Essen

During the period covered by this brief report, investigations relating to the project were carried out on the Westfalia gleithobel and the Klöckner-Ferromatik megahobel at the test site. The two ploughs were installed along the same artificial coalface, one on each side; they therefore had identical 'seam conditions'. The mock-up was 13 m long, 6 m wide and 1.25 m high. The 'seam' was solid enough to provide good ploughing conditions; the 'floor' was extremely soft.

There were no difficulties in steering the gleithobel with the control bit under the test conditions, neither was steering impeded by the greater amounts of 'coal' which could be won in the circumstances. The lifting jacks of the tilt control burrowed into the soft floor. Since these jacks already had relatively large footplates there did not seem much point in making them even larger. New lifting jacks were developed in collaboration with the manufacturers; they are fitted with jibs which are approximately 2 m long. The leverage exerted by these jibs reduces the plates' bearing pressure; this means that they no longer sink in, even when conditions are poor.

The steering of the megahobel, which has a baseplate, gave much more trouble than the steering of the gleithobel, which does not have such a plate.

The plough could not be steered at all when the bottom bit was set higher. The ridged core which was left in the floor was pushed aside by the plough's clearing plate on the return run. These cores are only solid enough if (as in the case of the gleithobel) the whole plough train is pushed up onto them slowly, under relatively slight surface pressure. This shows that height control by means of a control bit or a bottom bit requires a much more solid floor when the plough has a baseplate than when it has not.

It was only possible to steer the megahobel (with a baseplate) under the given circumstances by fitting a guideplate to the upper part of the plough; this plate bears against the coalface and retains the plough in the upper zone, as against the lower. The whole plough train is thus made to swivel in the direction of climb. The drawbacks of this steering method are that it is less effective than other systems and that it can only be applied in seams where roof-falls do not tend to occur. In the light of what has been learned so far, it has become very doubtful whether it is possible to make do with one steering method for all ploughs and for differing conditions.

2.7. RESEARCH PROJECT 'INCREASE IN FACE OUTPUT AND PRODUCTIVITY BY IMPROVED PLANNING AND MACHINE UTILIZATION RATES'

Steinkohlenbergbauverein, Essen

2.7.1. Partial Project: investigation of zone ahead of face

An improvement in the results of explorations into the zone ahead of the face using seismic waves is hoped for from a digital computer. Since the outlay for developing the flameproof housing for such a device is very high, extensive early investigations are needed to select suitable apparatus and methods for recording, transmitting and storing the measurement data.

To check penetration depth which may be achieved with digital registration of waves in the seam, comparative measurements with both digital and analog recording were carried out in a face some 2 m thick. Shot and geophone points were so arranged that up to 800 % overlap would be achieved. Evaluation of the field seismographs showed a fault at 300 m distance with the digital recording, while the analog recordings indicated nothing. Should these results be confirmed in drivage, the use of a digital device would provide increased effective reach by about 50 %.

To analyse the frequency content of the seam waves measurements were carried out at differing distances between the shot and geophone points, since the high frequencies which disperse better are more intensively absorbed in the coal with the increased distance travelled. For evaluation the seismographs were digitalized at 0.333 ms reading intervals, which corresponds to an upper frequency limit of 1000 Hz. The data obtained were fed through an electronic data processor; the evaluation is not yet completed.

With the aim of keeping the outlay for developing a flame-proof casing as low as possible, five ways of registering and transmitting measurements were devised. In this, both technical advantages and disadvantages, and the outlay in cost and time, were collated so as to obtain information for costing assessment.

2.7.2. Partial project: further development of components of face equipment

Investigations under the above research project covered the following specialized headings: plough installations, conveyors and drives.

The main focus of the investigations with the plough installations centre on further development in plough blades and the development of new height control devices for coal ploughs. To complement the previous investigations of individual blades, complete *pick sets* were investigated, depending on type of pick, pick geometry and lacing. In addition, the cutting, pressure and disrupting forces in the vertical direction were measured ('climbing' and 'dipping'). The tests are carried out in artificial coal faces of differing firmness and with different plough speeds. First evaluations showed that the impact of loading and clearing on the different force components was unduly great, because some of the cut material fell in front of the plough and was thus pressed under the plough body. The trial installation was then rebuilt.

Next to the lower plough rail a slit has been cut in the bottom plate for the entire length of the plough run and having roughly the width of the plough itself. Below this a double-chain scraper conveyor has been placed in a trench. After breaking out the cut material now falls directly onto this conveyor and is loaded out in the opposite direction to the ploughs movement. After this reconstruction the effects described no longer occur.

Investigations into *plough control* were carried out on two different plough installations, which were installed at opposite sides of a common artificial coalface; this guaranteed identical 'face conditions' in both installations. The firmness of the artificial winning face chosen was low and can be compared to easily ploughable coal with a very soft floor. Control trials produced different results in these conditions and with these two installations.

The Westfalia Lünen 'Gleithobel' showed up no control difficulties. The plough has no base-plate and runs on its own guides on the coalface side of the face conveyor. The floor is only touched by the tips of the bottom blades. When operating height control through control blades in the 'climbing' direction, the installation could be pushed onto the step in the floor left behind by means of pushing rams, although the firmness of the step was very poor. With tilting control the raising supports sank into the floor on the stowing side of the conveyor. In cooperation with the manufacturer new raising supports were developed which are equipped with jibs some 2 m long. By the lever action of the jibs the bearing pressure is considerably reduced and the sinking of the supports thereby prevented.

Control problems were considerably greater with the Klöckner Ferromatic Mega-plough. The ploughs base

plate embedded itself in the floor and the plough could not be controlled with the available devices. An attempt to control it in the 'climbing' direction by setting the base blade higher failed because the forward clearing plough pushed away the step cut by the bottom blade when travelling in the opposite direction. Successful control was only achieved once a newly developed guide runner had been attached to the top of the plough. This produced smaller cutting depths in the upper plough area than in the lower, causing a slowing movement towards 'climbing'. This type of control requires a high degree of firmness in the face and cannot be used in faces which are liable to breaking out.

As a preliminary to the further development of conveyors comparative investigations in simulated operating conditions are being carried out on the single-chain scraper conveyor, EKF2 type, and on a multiple-chain scraper conveyor to obtain evidence about their workability.

After functional tests on conveyors and measuring equipment the first trial period consisted of investigating the effect of differing chain pre-tensioning and load conditions on straight and recently moved conveyors. Tests in both idling runs and coal outloading show variations of the chain tractive forces in both installations which rise with chain pre-tensioning. The same pattern of variation is shown by the chain sprocket torque and the electrical output of the drives. The amplitudes of these variations, however, were greater with idling and light coal loading than with medium and heavy coal loading.

Apart from these dynamic oscillations, load displacements between main and auxiliary drives were found which repeated cyclicly with the chain turn-round time. The cause of this behaviour lies in chain strands of different pitch. By redistributing certain chain sections in such a way that chain strands of the same pitch ran over the two chain sprockets at the same time, it was possible to eliminate these periodic load displacements in both installations.

Investigations into *drive techniques* were carried out on an approx. 70 m long double-chain scraper conveyor with outside chains, PF 1/500 type. Chain forces, number of revolutions, torque and electrical power consumed were measured. The object of the investigations was to determine the start up and operating behaviour of the conveyor with differing load conditions and in extreme cases, such as blockages. These investigations were carried out with differing chain pre-tensioning and switch-on times of the two drives and the effect on start-up and operating behaviour established. The effect of the drive

design was established through tests with and without current couplings.

Test results have shown that the chain scraper conveyor represents a highly variable system from the drive viewpoint. Among parameters affecting this system are: characteristics of the drive motors and their reciprocating factor, elasticity of the chain assembly, friction values in the conveyor, chain pre-tensioning, the switch-on time differential of the drives.

The great variations in tractive force in the conveyor chain and the power variations in the drives lead to high loads on the parts of the installation. A further difficulty lies in the uniform load distribution on the two drives caused by the pitch tolerances of the conveyor chains and the characteristics of the three-phase asynchronous motors. For operating reasons no changes can be made either on the conveyor chain or the drive motors. The problem is only soluble by development in the field of components which allow the best adaptation between motor and face machine. New drive designs should develop in a way which achieves extensive protection of installation components, especially the conveyor chain, through suitable protection against overload, in addition to uniform load distribution.

2.7.3. Partial project: automation of plough faces

A device to establish the position of the coal plough in the face automatically, already developed by Bergbau-Forschung GmbH previously, was brought to effective readiness. It consists of:

- deriving from the system, the establishment of all adjusting and switch-off points and of driving the coal plough into the plough stable; determining the possibilities for incremental ploughing,
- deriving from the equipment, determining the value of the indicator and ancillary components, determining the maximum permissible casing dimensions as well as installation and assembly of the equipment.

The installation has been tested in several surface trials. The procedure required for acceptance for underground operation through the Berggewerkschaft experimental roadway at Dortmund-Derne has been initiated.

For control of face machines operational cycles and acceptable working procedures were first laid down, taking into account safety requirements. Parallel with this, individual electronic control groups were developed which now enable the entire system to be

readily assembled. A start was made in building up a compact monitoring and control installation for coal plough and face conveyor using the abovementioned control components.

After the successful completion of pre-trials with various pneumatic data collecting systems for keeping the face conveyor in line, a start was made in building up an installation for a whole face some 220 m long. Tests will begin towards the end of the year.

2.8. RESEARCH PROJECT 'HIGH-OUTPUT FACE'

Centre d'études et de recherches des charbonnages de France

The research programme consists of the following three parts:

- Improvement of face-end operations;
- Final development of on-face machine components;
- Elimination of bottlenecks on the face by organizational changes.

2.8.1. Improvement of face-end operations

2.8.1.1. On advancing faces

The two face ends which were installed in the Lorraine during the second half of 1971 on a pneumatically-stowed advancing dip face made it possible to drive both roads with the face machine (an AB with an FIDD jib).

2.8.1.2. Improving the ends of retreating faces

Two models have been produced of an anchoring beam for the tailgate face end, with which the AFC can be retained and snaked; one of them is a simplified version for roads with a smaller cross-section.

2.8.2. Final development of shearer components

Bench tests have been conducted by CERCHAR to study winning and loading with drums; these tests have demonstrated the influence which is exerted by r.p.m.

CERCHAR has also studied and field-tested a chainless system of propulsion (with claws), but this has to be further improved, particularly by using a special hydraulic power pack.

A 225 kW water-cooled rotary motor has been studied in the Lorraine, in collaboration with Messrs. SAGEM ; this motor will be delivered in 1973.

2.8.3. Organization

The two investigations which were undertaken in the Lorraine during the second half of 1971 have been

continued. The first concerns remote data-transmission between Folschviller colliery and the Merlebach computer centre. The second relates to computerized removal and re-installation of face equipment. Investigations are proceeding in the Blanzky area to pinpoint the factors which slow-down face output, and to suggest improvements.



3.1. RESEARCH PROJECT 'RADIO-ELECTRIC WAVE PROPAGATION IN UNDERGROUND WORKINGS'

**Institut national des industries extractives,
Liège**

3.1.1. INIEX/DELOGNE system

The laboratory has devoted its main effort to the patented INIEX/DELOGNE system and to developing its industrial application.

At Beringen colliery a coaxial cable has been installed in the roadways at the 789 m level together with radiating devices covering two sections 4 km each from the underground telephone station. A Y-phone was connected to the coaxial cable and it was found that it was possible at all times to communicate with an operator equipped with an X-phone who was moving in the roadway equipped with the INIEX/DELOGNE system. Since the installation early in the year the colliery management has continued to use the equipment for communications between the telephone station and locomotive drivers.

At Gardanne colliery in the Provence coalfield a cable and radiating devices were suspended in a coal outloading roadway equipped with three transporter cable belts in 'cascade' arrangement and a conveyor train with linear motor. The Y-phone base station was positioned underground a certain distance away from the shaft and connected by telephone cable to a low-frequency control panel installed on the surface. In these conditions the patrol man equipped with an X-phone and moving along 4.8 km of roadway can be called up from the surface and enter into communication with the central remote monitoring station. This installation was visited by members of the ECSC permanent group on 'Electricity' and by technical delegates from other French coalfields. In view of the satisfactory results the management of the Provence coalfield is now requesting us to take part in extending radio networks in the colliery, which will probably be effected during 1973.

For its part the Lorraine Coalfield is requesting us to carry out a trial of linking the INIEX/DELOGNE to X-phone transmitter-receivers and Y-phones for two different uses: one in a roadway, the other in the face.

On 15 January 1972 the Beringen colliery of the Campine Coal Mines put into service radio remote control of a monorail winch making use of the INIEX/DELOGNE wave guide line. Since the installation proved entirely satisfactory, the coal mine has reused the equipment once the working was completed to equip a new working. At the end of the year the coal mine decided to purchase a second set of equipment.

In all these installations the manufacture of radiating devices, the preparation of cables and their installation were carried out by the INIEX research team, which took all effective measures to improve understanding of the propagation of radio-electric waves in underground workings.

INIEX has granted a licence of its patent protecting the INIEX/DELOGNE system. The firm of SAIT Electronics of Brussels, which obtained the licence has started a design study with INIEX collaboration of the first industrial production line of radiating devices.

1972 can thus be summarized by listing a variety of industrial type of experiments and the start of commercial exploitation of the patent which had been taken out to protect the original idea of one of the teams' research workers.

In addition, INIEX has taken an active part in the conference on 'Automation in Coal Mines' organized at Luxembourg on 29 to 31 May 1972 by the ECSC. During the Round Table meeting on 31 May representatives of the mines inspectorate, research, designers and mine operators expressed the wish for an international committee 'Radio in the Mine' to be set up, whose technical secretariat would be at INIEX itself. Discussions are in hand with the ECSC to implement this.

3.1.2. INIEX/DERYCK-DE KEYSER system

With the collaboration of laboratory staff, Monsieur Deryck has continued preparing his doctors thesis on the twin-lead line used to support radio propagation in roadways. Numerous measurements in the Lanaye roadway support this thesis which will be publicly defended at Liège University on 25 January 1973.

3.2. RESEARCH PROJECT 'STUDY OF WAVE PROPAGATION UNDERGROUND

Centre d'études et de recherches des charbonnages de France

Following up our previous objectives we have directed our activity two ways: using the imperfections of a coaxial cable for roadway transmission and direct propagation across mining strata to establish a link between a rescue base and miners isolated by a rock fall.

3.2.1. Transmission in a roadway using a coaxial cable

We have started with the fact that a coaxial cable, whose braiding consists of non-coupling conductors, has a transfer impedance, i.e. that a coupling occurs between the interior and exterior of the sheathing. A theoretical study conducted by Prof Gabillard of the Lille Faculty of Sciences has shown that, with a coaxial cable propagation occurs in a so-called 'hybrid' manner which results from coaxial type transmission and uni-polar transmissions between the braiding and the roadway; the two types of transmission have differing propagation speeds due to the dielectric environment not being the same inside and outside the coaxial cable.

Tests were carried out in Provence with a KX4 coaxial cable to compare results of transmission by the hybrid method and that of the unipolar one between braiding and roadway.

It was found that uni-polar transmission with its reduction of about 80 db per km is preferable for distances below 750 m. On the other hand, beyond 750 m the hybrid method of transmission, with its reduction of 30 db per km, becomes more practicable. It should be noted that the 80 db reduction recorded in uni-polar transmission is very much higher than that measured during our first trials in the Nord Coalfield. These results highlight the effect of the resistance of the strata surrounding the roadway, which is much higher in the Provence Coalfield than in those of the Nord where we carried out our tests.

In addition, an experimental method has been developed by the Lille Faculty which makes it possible to study the transfer impedance of different types of coaxial cables on 10 m long samples.

3.2.2. Transmission through strata to communicate with miners isolated by a rock fall

Side by side with our study of wave transmission in roadways we have investigated the transmission of electromagnetic waves utilizing strata and a drilling pipe as a channel for phone communication with miners isolated by a rock fall.

A first theoretical study carried out by Prof Gabillard's team, borne out by tests in the Lorraine Coalfield, has shown that the most favourable frequencies for such a transmission lie below 50 kHz.

3.3. RESEARCH PROJECT 'CONVEYOR TRAINS'

Centre d'études et de recherches des charbonnages de France

Summary of work and results in 1972.

The characteristics of the conveyor train circuit with linear motors installed at a concentration stage in the Provence coalfield are as follows:

length of circuit: 2325 m
nominal speed of section displacement on the tracks in both directions: 7 m/s
Speed of return and loading: 3 m/s (or a loading throughput of 1560 TB/hour)
Speed of discharge: 2.3 m/s
– hourly throughput of one section: 130 tonnes gross for 4 sections mounted on the circuit.

The circuit has functioned operationally throughout the year servicing preparatory work for the new Etoile district. Its average daily transported load was close to 700 tonnes. The throughput will not reach 6000 tonnes a day until 1973 when the first longwall face of the new panel will have been started up.

A single conveyor section and a single shift manning the circuit would have largely sufficed to meet winning needs. But various tests and improvements have caused the circuit to be manned with 2 shifts and using two or three sections, priority being given to coal transport on one shift and tests and maintenance work on the other shift.

Incidents to report:

– *Traffic control:* on 13 March the front of an empty train buffered into the rear of a full train being unloaded. The cause is known and the correction made: the traffic control timing relays have been

backed — these have no 'memory' — by the interlocking of four thrusting positions at the rear of each section.

- *Control at low speeds*: the defects reported in 1971 in the thyristor variable transmission have been removed by changing the impulse amplifiers and various related improvements.
- *Braking*: some improvements have to be made to the brake-gear.
- *Linear motors*: the abnormal heating of the 10 motors which had to be replaced was caused, in the designers view, either by a fault in the isothermal control capsule or by ineffective insulation of the coil leads which has been successfully remedied.
- *Location detection*: it did occur — for two explained reasons — that the permanent detection magnets positioned at the front of the section came up against motors under voltage. This fault has been remedied by two modifications in the controls.

Other Items:

- Improvement in the section cycle time by installing an automatic lubricating system for the trains' movement bands at the discharge point.
- *Training of maintenance staff*: this has proceeded all the more effectively since the electrical engineers allocated to the circuit have not been hampered by the requirements of winning, the low throughput required of the circuit making for very flexible operation in view of the large stocking capacity available at the loading point.

3.4. RESEARCH PROJECT 'MECHANIZATION AUTOMATION AND RATIONALIZATION OF HAULAGE AND SUPPLY UNDERGROUND (TO INCLUDE MAN-RIDING)'

Steinkohlenbergbauverein, Essen

3.4.1. 'Materials, transport and Man-riding'

3.4.1.1. Overhead monorails and floor tracks

3.4.1.1.1. Development of a device to measure rope condition and tension for rope hauled systems

Bergbauforschung GmbH carried out measurements at three collieries on telephone and signal transmission systems starting from 100 kHz to establish the frequency range which would ensure interference-free transmission from below ground to the surface.

Signal transmission was found to be possible from 100 kHz. To prevent interference from rogue signals in the lines, the measurement signals were transmitted in modulated state and demodulated above ground. The apparatus involved has been finalized and is presently being constructed.

Tape apparatus has been developed for fixed-point measurements underground. The apparatus is at the moment being converted to intrinsic safety requirements and will shortly be handed over to the Mines Testing Station for passing on to the collieries.

The Rope Testing Station has in the meantime made a start on transducers to measure rope conditions and tension.

3.4.1.1.2. Examination of the 140 E rail and its connectors with a view to establishing limits of application

Investigations to date have shown that the standard 140 E rail and connectors can be used to replace the I 120 (strengthened) and I 140 strengthened used until now. The rail has in the meantime been cleared for underground use.

Earlier roll defects caused by excessive cooling speed were eliminated by adopting a different position of the rolled section over the cooling pit.

3.4.1.1.3. Investigation into hardmetal tipped brake shoes for brake trolleys and cars to establish the ignitability of CH₄ and air mixtures

Hardmetal tipped brake shoes on brake trolleys used in positive guidance rail systems strike sparks during brake application which can under certain circumstances lead to the ignition of CH₄ and air mixtures. The Rope Testing Station has accordingly built a surface test rig to establish the service range of this type of brake. The first tests under operating conditions have as yet not resulted in any explosions. Further gradations of CH₄ mixture are still being investigated.

3.4.1.1.4. Use of electronic modular systems for controlling winches, intrinsically safe drives and belt monitors

The intention is to replace the non-intrinsically safe controls of various kinds by standard electronic systems of the intrinsically safe type. These electronic units are to be built into standard type housings, and the entire control system will likewise be intrinsically safe. The advantages of these electronic units are as follows:

- improved maintenance and accessibility;
- simpler storage;
- faster fault finding;

- exceptional reliability;
- simpler wiring systems.

Bergbau-Forschung made a start on an intrinsically safe control box with standard components for a rope haulage winch at the beginning of November this year. This is due to be tested underground early next year.

3.4.1.1.5. Use of a positive ski-lift man-rider capable of negotiating curves at General Blumenthal colliery

The ski-lift man-rider, developed for powered man-riding in production workings, especially in inclined roadways, is in effect rope hauled, positively guided and can negotiate curved areas. Its continuous operating pattern makes for a high transportation capacity and the system is an effective alternative to man-riding belt arrangements.

The prototype, something like 250 m in length, is being tried out in a roadway at a gradient of 5 g (gon = degree in 400 degree circle (Trs.)). The tests revealed shortcomings on the bearings and chair clips. Once these have been remedied, the lift will be tried out in a rock incline at a gradient of 17 gon.

3.4.1.2. Own drives for levels

3.4.1.2.1. Use of a 100 h.p. diesel-hydraulic independent (own) drive at Friedrich Heinrich colliery

The Becorit diesel locomotive is now ready, with its various novel technical features such as electronic remote control, hydraulic service braking, hydraulic differential and powder extinguisher. One of the aspects considered was that of applicability for all independent (vehicles own) drives.

In-works inspection and testing of the hydraulics and electronics are now complete. Faults in the electronic control function and hydraulic motors have been eradicated. The drive is at present undergoing acceptance trials and design certification at the Rope Testing Station. The machine should go in underground this year.

3.4.2. 'Transfer arrangements for main shafts, staple pits, main/gateroad transfers and unloading points'

3.4.2.1. Staple pits

3.4.2.1.1. Use of transfer arrangements for level/vertical materials transfer points at Zollverein colliery

A time and motion study disclosed the problems involved in transfer of materials at staple pits and

revealed a number of possible technical and organizational improvements. The results produced by this study formed the basis of the requirements to be fulfilled by transloading equipment:

- modular principle in design;
- rapid assembly;
- universality;
- permitting parallel and shuttle movement or flow, and operated by one man.

These will be satisfied by a combination of a number of components to form transloading equipment suited to the particular staple pit conditions.

A prototype installation has been working since 1 July at Zollverein colliery. Tests to date have indicated that material transfers still take too long, the equipment is subject to stoppages and the construction too expensive. The prototype is therefore to be modified with a view to remedying these points.

3.4.2.2. Main/gateroad junction

3.4.2.2.1. Use of a transloading facility for central horizontal materials transfer duties at General Blumenthal colliery

Equipment developed in collaboration with SCHARF on the forklift and hoist table principle for transloading material from cars to floor tracks and monorails has been in operation since 1 July of this year. The one-man transfer equipment has worked without trouble until now.

Measurements carried out in August of this year showed that the throughput of the unit could be further increased by the incorporation of a bundled light source beamed at the arrest cam. A design is being worked out to these specifications.

To make the transfer between forklifts safer, new controls have been devised which involve one lever instead of the previous four. The new controls will be tried out early in 1973.

3.4.2.2.2. Use of centralized drive for several lifting beams in a central, level transloading station at Westerholt colliery

The proposed development of a central drive for monorail lifting beams is intended to improve materials transfer from cars on floor rails. This is necessary at heavy traffic transloading points such as gateroads where there is only one track as materials siding. The drive proposed is capable of raising or lowering several lifting beams at once. Individual actuation of the beams is also to be provided. The centralized drive for central flat transloading equipment is still in the development stage. Trials should start early next year.

3.4.3. 'Crushers, stageloaders, conveyors, mechanical shorteners/extenders'

3.4.3.1. Conveyors

3.4.3.1.1. Development of a continuous belt slit monitor at Bergbau-Forschung

The development of a continuous belt slit monitor to replace intermittent surveillance equipment used until now will pass through an intermediate stage which provides for quasi-continuous control. 100 m lengths of belt are to be monitored from a single point. The worst possible slit length amounts to 10 m per 100 m, including the belt overrun. Tests have started on a quasi-continuous monitor arrangement. At the moment conductor loops are being inserted in a 60 m test belt to ascertain possible interference from the inductance and capacitance effects arising in the belt. Different types of loop material are being checked in December of this year for impact strength (Bergbau-Forschung test apparatus). The electronic part of the monitor is still at the development stage.

3.4.3.1.2. Improved belt connections at Bergbau-Forschung

A test programme is being worked out which will take into account the type of loads applied to the belts and connections underground. Test belts used are those most frequently used below ground, two ply with PVC and rubber covers, with rated pull of 630 kp/cm of width. The first set of static trials of belts and connectors have already taken place. Dynamic loading (pulsating tensile and alternating bend loads) will be registered by apparatus which are partly still being constructed. The pulsating tensile test apparatus with fixed belt has in the meantime been completed and is being checked over for functional efficiency at the moment.

3.5. RESEARCH PROJECT 'MEASUREMENTS OF DYNAMIC LOADING ON SHAFT WINDING APPLIANCES'

Versuchsgrubengesellschaft mbH, Dortmund

3.5.1. Preparations for measurements on guides and buntons in the shaft

Mounting, cabling up and static calibration of recorders (strip tensometers) on guides and buntons.

3.5.2. Dynamic calibration of a guide panel

One complete panel (two guides and three buntons) was subjected to loading at various frequencies under a pulsator.

3.5.3. Installing photocells as point synchronizers within the shaft

The photocells provide synchronized time and location points on both record strips in the shaft and on the cage.

3.5.4. Erection of an automatic data recording facility

As it would take too long to evaluate the different measuring charts by hand, an automatic data recorder must be used with coupled calculator so as to evaluate the data in the required form and plot these accordingly. A start was made on programming the recording and processing functions.

3.5.5. Examination of cage guide rollers and conveyances

Today the high-capacity conveyances used in shafts run almost exclusively on rubber rollers. Continuous test programmes on the various types on the market are essential in order to establish load limits and optimum adjustment of these. A test rig was built which simulates shaft conditions, and six different types were tested on this. In the first series, the rollers were exposed to a constant load. A second series was started which provides for the large wheel to be fitted with a 5 mm high striker batten: this simulated the peak load arising at a guide transition point offset by 5 mm. Each test was described in detail in the technical half-yearly reports.

3.5.6. Measuring runs within the shaft

There are a great number of factors affecting the dynamic relationships between conveyance and guides in the shaft. Each factor has to be examined in isolation when building up the mathematical model. In order to establish the basic parameters for our test layout we measured the bends and inherent oscillation frequencies of the test cage in both horizontal coordinates at a number of different depths. An exciter was constructed to find the inherent oscillations. A jump of 5 mm was arranged on one guide transition within the shaft path used for measurements, and runs were made at various speeds and under various loads, followed by intermediate appraisal (still by hand as the automatic facility is not yet ready).

3.5.7. Plumblines measurements in the shaft

The quality of the guides controls the smoothness of the wind. Shaft guides are considered satisfactory when the guides are dimensionally true and vertical. Dimensions can be checked by feeler rollers simply enough, but deviations from vertical are more demanding. At the moment they are still found by point surveys. We are looking into the possibility of using lasers or a light curtain measuring system for this purpose.

IV

4.1. RESEARCH PROJECT 'STRATA CONTROL AND SUPPORTS'

Institut national des industries extractives,
Liège

4.1.1. Circular stonedrifts lined with reinforced-concrete panels

This technique continues to make headway in the Campine coalfield, and more than 15 panel-setting machines are currently in service. The method is used in all the Campine collieries. A daily rate of advance of 4 m is being achieved; this is with 3-shift working, 4 men to each shift.

The manner in which these drivages are organized at Zolder colliery is described in broad outline in Issue No 136 of the technical periodical 'Mines et Carrières'.

The total cost of driving a panelled stonedrift at Beringen colliery is Bfrs 20000 per metre, compared to Bfrs 32000 per metre for a stonedrift lined with concrete blocks. The new method is therefore cheaper by Bfrs 12000 per metre.

4.1.2. Back rippings in stone, lined with reinforced-concrete panels

In back rippings in stone in the Campine, the introduction of panels has allowed even bigger savings than in drivages in the solid; the average cost of a panelled back ripping is Bfrs 16700 per metre, compared to Bfrs 31000 per metre for a back ripping lined with concrete blocks.

In view of the fact that the savings are greater in back rippings in stone, 8 of the 11 panel-setting machines now at Zolder colliery are used in such workings.

4.1.3. Fabrication of the reinforced-concrete panels

The panels which are used are made at Beringen and Zolder collieries. Two entirely different methods are utilized at the two plants to produce the reinforcements and concrete components, but the cost price is similar.

Tests are now proceeding to compare the strength of rings made up from panels produced at these two plants, and to compare the behaviour of rings with 19 and 32-mm thick compressed-wood insets.

First results from these tests would appear to indicate that the strength of the panels has been reduced fairly appreciably by replacing the straps, which were wound round the longitudinal bars in spirals, with small bars welded to these bars at right angles.

The following practices are also being tested, the aim being to further increase the strength of the panels:

- (a) Replacing the smooth bars with twisted reinforcing pieces.
- (b) Placing the panels into watertight storage chambers immediately after fabrication, where they are kept in lukewarm water for a few days.
- (c) Reinforcing the concrete by means of steel fibres which are 0.15 to 0.50 mm in diameter and 20 to 35 mm in length. This process was recently developed in the United States and has been introduced in Belgium by Messrs Bekaert. Compared to non-reinforced mortar, the addition of these metal fibres (in a proportion of 2 to 4% of the volume of the mortar) has produced the following increases:

- compressive strength by 30 %
- tensile strength by 350 %
- bending strength by 200 %.

Two other series of tests are also being conducted; one to study a new type of tubing which is sunk into the concrete for the purpose of handling the panels, and the other to develop new and safer handling pivots.

4.1.4. Roadway maintenance in stonedrifts with metal frame supports

Two seams, surrounded by extremely soft and creeping rock strata, are worked at a depth of 1350 m in Pit No 19 of the Monceau-Fontaine Colliery Company.

Roadway maintenance in the stonedrifts is a considerable problem.

Floor-heave in these stonedrifts, which are less than 3 years old, is put at 20 cm per month; this means that a total depth of 5 m has had to be dented since the roads were driven. Maintenance is so extensive that it became essential to search for ways and means of reducing maintenance costs.

In 1971 INIEX acquired some guniting and injecting equipment; the trials which have been carried out have not proved satisfactory as yet. The roadway floors continue to lift. Attempts have also been made by INIEX to pin the floor with wooden bolts. The floor lifts much more slowly during the first few months after this has been done, but then heaves abruptly and rapidly.

Preparations have been made this year for three further trials; the first one commenced at the end of the year, and the other two are due to start early in 1973.

- (a) Lagging the frames with a continuous cushion of anhydrite or concrete. An extra 20 cm of rock is extracted along the entire circumference of the frames; wiremesh lagging is then placed against the outside face (the extrados) of the frames, and the horseshoe-shaped cavity is filled with anhydrite or concrete which is gunited with a special pump. The advantage of this lagging method is that pressure is evenly distributed over the whole frame, and also the elimination of any empty spaces between the supports and the rock which might have allowed the latter to creep.

After several fact-finding visits in Belgium and Germany we selected one of Messrs Putzmeister's 'Mixocret' pumps.

When the tests began, the plan was to lag an initial 50-m long section of stonedrift with anhydrite, and then to lag a second section with pumped concrete.

However, the very soft rock which is traversed by the road in question did not make it possible to limit to 20 cm the depth of the extra cut which was wanted along the entire circumference of the frames. Along one wall and in the crown of the roof the cavity which had to be filled with anhydrite often reached a depth of 50 to 70 cm. This meant that the quantity of anhydrite which had been ordered was only sufficient to lag a section of 22 m. The trials will continue with a pumped-concrete lagging.

- (b) Deep injection of resin along the circumference of the road. The aim is to create a resistant cylinder around the stonedrift (which is in soft rock). However, at first only the floor will be

injected; this is because preventive action against floor-heave is the major cost item at this colliery. The floor will moreover be reinforced with wooden bolts. Furthermore, solid or hollow metal bolts (the latter to be injected with mortar and resin) will be set into the walls at floor level; this is in order to prevent the walls from creeping.

- (c) Circular lining with panels in reinforced concrete. Following the success which this support method has had in the Campine as regards resistance to strata pressure and as regards the rate of advance, INIEX has hired a panel-setting machine, first to back-rip a stonedrift and then to drive a stonedrift in the solid (these two sections are situated in unrelaxed strata, whereas the previous trials took place in sections located in strata which had been relaxed through previous working).

4.1.5. Load-variation measurements in the solid coal ahead of a retreating face

INIEX has acquired some load cells, developed by CERCHAR, for the qualitative determination of the load variations which are exerted on the solid ahead of a producing face. These cells are introduced into boreholes which are drilled into the coal from roads ahead of the coalface.

In the first instance, we have placed four cells ahead of a retreating face in seam No 70 at Beringen colliery. This face has the peculiarity of being partly stowed and partly caved.

It has also been possible to find out the distance at which the high-pressure wave ahead of the face begins, and the position of maximum stress.

Beyond the maximum, pressure decreases rapidly and already cancels itself out at a certain distance ahead of the coalface. The results of these first tests are given in Table I.

In the light of these first results it will be seen that the pressure wave which precedes a stowed face makes itself felt at a shorter distance from the coalface than is the case with a caved face, but it continues to have an effect up to the immediate proximity of the coalface:

- on a caved face the 4 metres ahead of the coalface are already free from all pressure;
- even though measurements made with cells are, above all, qualitative and the first tests have not made it possible to state that the pressure wave which precedes a stowed face is quantitatively greater than the one which precedes a caved face.

Table I: Position of the pressure wave in relation to the coalface

Treatment of the goaf	Distance in relation to the coalface, in m		
	Appearance of the pressure wave	Maximum pressure	Cancellation of all stresses
stowing caving	7 10.20	2 6	between 0 and 0.80 4

4.1.6. Bolting in gateroads

Laboratory tests

Several trials with wooden and resin bolts have taken place in neighbouring countries, to prevent the presence of metal bolts in the floor from being a hindrance if any dinting has to be done.

The characteristics of these bolts have been established in laboratory tests. The tensile strength of polyester resin bolts reinforced with glass fibres equals and even exceeds the tensile strength of metal rods of the same diameter, but, on the other hand, they have less shear strength.

4.2. RESEARCH PROJECT 'PREDICTION AND CONTROL OF DEFORMATIONS IN THE MINE STRUCTURE'

Steinkohlenbergbauverein, Essen

Agreement concluded: 6.10.1972.
Period of agreement: 1.1.72. – 31.12.73.
Total expenditure: DM 4373 700
Aid granted: DM 2624 220

A technical half-yearly progress report (reference date 30.6.72.) was submitted to CEC and the Technical Committee for 30.9.72. As the agreement had not at that date been concluded, the first financial report will not be due until 31.12.72. reference date.

The research work in hand follows directly on the 'Applied Rock Mechanics' project which was completed on 31.12.71.

Rock mechanics:

The 'Strata Control Distribution' computer programme was used experimentally to aid the planning of winning at five collieries and has proved itself to date. Extending this to differing seam distances and strata conditions still requires testing and improvement. Yet its application in irregular deposits was

confirmed by analog tests. Work is in progress on other programmes for fault phenomena. Rock investigations provide the indicators for these calculations.

Roadway observations:

Statistical data recorded in 12 roadways included the effectiveness of anhydrite and 'Blitzdämmer' stoppings. Hand in hand with this went the laboratory work of testing the strength of this type of material.

In combination with existing tunnel and relief area construction, the effectiveness of thin, gunnited and back-filled layers was confirmed both in theory and on models.

Face observations:

Statistical recordings in the roof in 15 faces were largely instrumental in assessing or planning supports; other data served to interpret the relationship between rock pattern, roof deformations and coal sloping. Model tests complemented these recordings. During the period under review these were concerned with anything from the slip planes in the roof to strata behaviour during the starting up stage of the face; also the effect of differing support resistance in relation to steps in the roof.

Powered supports:

On the powered supports testing 6 designs newly developed or improved by manufacturers were tested. Assessment was made on the basis of requirements laid down jointly with support engineers and on a multiplicity of underground readings. Special measurements dealt with individual components, particularly roof-bar links and hydraulics components.

Shield supports:

The main effort is currently concentrated on new designs of shield supports. Extensive programmes on the rig tested 7 types of shield supports for differing loads and tests requirements. Investigations dealt

mainly with the danger of sudden forward movements with an uneven roof, stability during setting even in inclined conditions and the demands with uneven, one-sided loads of the kind which have led to damage underground recently. Utilization underground is being carefully watched and the results to date evaluated.

4.3. RESEARCH PROJECT 'FORECASTING AND CONTROLLING DEFORMATIONS IN MINE WORKINGS'

**Institut national des Industries extractives,
Liège**

Mechanization of bolt setting

The extension of strata bolting as a support method in drivages is being impeded by the slow pace at which the bolts are set.

A visit to the iron-ore mines in the Lorraine made it possible to see Secoma bolting jumbos (with and without turrets) in operation. The turrets enable one operator to drill the hole, to insert the resin cartridges and to introduce and tighten the bolt, all within some 2.5 to 3 minutes. On the other hand, a standard drilling carriage is used at the Saizerais mine; this requires the presence of two men, and they complete the whole operation in 1 minute and 40 seconds. This latter system would seem to be the more suitable method for the Campine, because it allows a better employment of the men on site.

Torque Tension (a British company) have just developed a drilling boom with a rotary drill; this makes it possible to drill, in a single operation, a 2.40-m deep vertical hole in the roof of a 2.8-m high trapezoidal road. Such a carriage costs Bfrs 540 000.

INIEX have hired a boom of this type. It has been placed on a gathering-arm loader at Beringen colliery.

This assembly has made it possible to drill a hole and set a bolt in 3 minutes and 30 seconds (in soft ground) instead of the 7 minutes taken with a stopper-mounted hammer drill. Nevertheless, improvements will have to be made so that the drilling machine can work in medium-hard ground.

4.4. RESEARCH PROJECT 'FORECASTING AND CONTROLLING DEFORMATIONS IN MINE WORKINGS'

**Centre d'études et de recherches
des charbonnages de France**

The research which has been conducted under this heading in the various French coal measures has made it possible to:

- *update the forecasts* which can already be made thanks to the results of earlier research,
- *extend these forecasts* to the as yet insufficiently-known area of thick and dipping seams,
- *define the means* of controlling deformations.

Roads

Eight practical experiments have taken place in stone-drifts to define the ways and means of two methods of controlling deformation, namely strata bolting and treatment of the face-side edge of roads.

The experiments relating to bolting (study of bolting density and of floor reinforcement) are still proceeding. The work done on the treatment of roadway edges (trials with chocks – of various degrees of rigidity and either hydraulically locked or not – and trials with anhydrite packs) has already shown that the best support is the one which is set as soon as possible after winning, and which bears as quickly as possible with the most rigidity on the caving side.

Two practical experiments in the Centre Midi coalfield have allowed us to extend our knowledge.

They have shown the extent of convergence during drivages (of the order of 1 m) and when the face passes (1 to 4 m); this convergence starts well ahead of the face and is largely caused by the loosening of floor coal.

Faces

Three practical experiments have been conducted during the first half of this year on faces in seams between level surrounding strata. The aim has been to diagnose the reasons for the trouble which has been encountered on difficult faces.

They have entailed the modification of some operational parameters (face length, load-bearing capacity of the supports, organization on the face), but the effect of these changes will only be tested during the coming months.

Incidentally, our knowledge now also covers thick-seam faces worked by sub-level mining.

The vertical and horizontal movements on such faces are considerable, and are related to major degradation of the coal on and above the face. The aim of the coal-consolidation trials which will be undertaken is to show whether consolidation allows the development of mechanization on such faces.

Finally, in inclined seams of steep and semi-steep coal measures, the key to the control of deformation and degradation is provided by a greater knowledge of the relaxed zone in connection with the first extraction.

Current research is aimed at getting to know the limits of that zone, and at studying the behaviour of supports which allow the mechanization of the winning methods which apply in such measures.

V

5.1. RESEARCH PROJECT 'FIREDAMP DEPOSITS AND EMISSION'

Institut national des industries extractives,
Liège

5.1.1. Firedamp-emission forecasts and gas-concentration measurements

Direct measurements of gas concentration in seams have been continued with a view to forecasting emission on level-seam faces in the Campine.

To quote one example, 'concentrations of 2.3 to 5.3 m³/t were recorded in the '63/64' seam at Beringen colliery.

Other measurements were taken in a development heading below the 825-m level in the 'Gros Pierre' seam at Ste-Catherine colliery (belonging to Charbonnages du Roton) in the Charleroi coalfield. The readings in that seam – which is regarded as containing very little firedamp – were 2 to 2.7 m³/t.

5.1.2. Firedamp emission on level-seam faces

Emission was investigated at the following collieries:

- (a) Hensies-Pommeroeul
 - 'Charles' seam, 710-m level, 'II East' face (specific emission = 7.5 m³/t),
 - 'Charles' seam, 710-m level, 'I West' face (s.e. = 14.9 m³/t).
- (b) Monceau-Fontaine, Pit No 14
 - '6 Paumes West', below the 1019-m level (s.e. = 67.4 m³/t),
 - 'Brose West', 1019-m level (s.e. = 84.7 m³/t).
- (c) Beringen (Kempense Steenkolenmijnen)
 - '63/64-N1-05' face (s.e. = 22.6 m³/t).
- (d) Zolder (K.S.)
 - '58/71a' face (no firedamp)
 - '22/59' face (s.e. = 72.5 m³/t)
- (e) Waterschei (K.S.)
 - 'L3-5B' face (s.e. = 79.6 m³/t),
 - 'L0-61' face (s.e. = 23 m³/t),
 - 'B8-49' face (s.e. = 16 m³/t).

- (f) Eisden (K.S.)
 - '28' seam, '0236' face (s.e. = 19 m³/t).

The investigations related particularly to the effect which is exerted on specific firedamp emission by operational planning, by the rate of advance and by production, and to the elimination of accumulated firedamp at the return end of retreating caved faces.

At Hensies-Pommeroeul, three measurement campaigns took place in the No II field (in the Théodore, Léopold and Charles seams, which are worked successively from top to bottom).

Specific emission was 56.8, 26.8 and 7.5 m³/t respectively. There was therefore a marked drop in s.e. in accordance with the descending order in which the seams are worked.

INIEX and CERCHAR have been in consultation to find a fuller explanation of the connection between firedamp emission and output or rate of advance, and to explain the discrepancy between various findings. The latter seems to be due, among other things, to the nature of the strata and to the consequential difference in the inertia of emission.

5.1.3. Methanometry, anemometry, remote-methanometry station

INIEX has been using G.T.M. methanometers since 1969. The collieries in the Campine have been equipped with this apparatus, which is prone to transmit under extraneous influences such as strays, static, etc.

The equipment of the remote-methanometry station at Zolder has been completed by the addition of A.T.M. 689 anemometers; this was done under special authorization, pending the Belgian mining authorities' normal approval of the apparatus.

5.1.4. Preliminary remote infusion of the solid and firedamp emission

The course of operations at Zolder colliery during 1972 did not allow any extensive investigation of the effect which remote pre-infusion has on firedamp

emission. Nevertheless, there was practically no emission on the remotely-infused '58/71a' face, but this was in a relaxed zone. The desorption-speed indices V_1 recorded in the seam were less than 0.1.

The greater moisture of the coal on site seems to be a result of the infusion of the overlying panel which was carried out through two boreholes 2 years before. This 'prehumidification' may partly explain why so little methane was found in the coal and in the air current on the '58/71a' face.

The '22/59' face, which had not been pre-infused, had a specific firedamp emission of $72.5 \text{ m}^3/\text{t}$.

The 'firedamp and dust' experiments are continuing on faces '52/71a' (s.e. $\cong 4.6 \text{ m}^3/\text{t}$) and '33/61' (s.e. $\cong 11.5 \text{ m}^3/\text{t}$).

5.1.5. Sudden outbursts

Seam classification according to liability to sudden outbursts has been continued by measuring the ΔP and V_1 indices on 3 faces at Hensies-Pommeroeul, on 4 faces at Monceau-Fontaine and on a face in the Campine.

5.1.6. Methane drainage in abandoned mines

Measurements and observations were undertaken mainly at the following mines:

- St-Albert and Ste-Marguerite (Charbonnage du Centre),
- Bois-du-Cazier.

A net volume of some $33 \cdot 10^6 \text{ Nm}^3$ was obtained at Charbonnage du Centre from February to the end of June 1972.

The gross flow drained at Bois-du-Cazier from August 1971 to June 1972 amounted to roughly $6 \cdot 10^6 \text{ Nm}^3$.

5.2. RESEARCH PROJECT 'CONTROL OF GAS EMISSION'

Steinkohlenbergbauverein, Essen

For the first year under review the following work was carried out under the five headings of the project:

5.2.1. Determining the effect of mining operations on the extent of emission

The mining factor of face-length was investigated in two faces of the Pattberg colliery and in three of the combined mine Grille/Grimberg 1/2. Measurements are completed and their evaluation has begun. In doing so it is also intended to analyse the mining factor of rate of advance. In two other Pattberg faces and in one at Waltrop colliery follow-up investigations were initiated.

5.2.2. Control of gas emission at face ends.

At two retreat workings at Niederberg colliery one was equipped with a 'bleeder' roadway and one with a low gas extraction system. The effectiveness of both systems is being monitored by measuring equipment. A third type of test consists of auxiliary ventilation using ducts as a means of controlling emission. The expert committee on ventilation of the StBV heard a paper relevant to this subject on 'Auxiliary Ventilation at the face end using ducting'.

5.2.3. Pre-drainage of winning faces

In four tests the residual gas content of the coal was established both before and after infusion. The results vary widely. In two cases infusion was seen to have no noticeable effect. In two other cases reductions in residual gas amounted to 18% and 74%. These tests are to be continued in other faces. In one face at Gneisenau colliery gas drainage tests in a seam were carried out and these are currently being evaluated.

5.2.4. Improvement of gas drainage in an overlying seam in a flat deposit

In one gas drainage system of a face at Rossenray colliery it was possible to gain information on the effects of low pressure and winning rate on CH_4 content, as well as the volume of gas/air mixture and firedamp concentration in gas drainage rises with the rate of advance in terms of time.

5.2.5. Establishing application prospects for gas drainage in inclined conditions

In order to achieve systematic progress on this partial project an agreement was concluded between Saarbergwerke AG and Bergbau-Forschung GmbH. The work was planned and started at Warndt colliery as intended.

5.3. RESEARCH PROJECT 'CONTROL OF FIREDAMP EMISSIONS'

Centre d'études et de recherches des charbonnages de France

5.3.1. Forecasting the specific emission

We have continued our research in this field with particular reference to level seams, by monitoring the results obtained from checks and by measuring residual-gas concentrations so as to get a clearer definition of the volume of the zone of influence (particularly along the floor).

We are also investigating the effect which the rate of advance has on the irregularity-coefficient of firedamp emission.

5.3.2. Controlling firedamp emission by drainage

We are monitoring the implementation of the rules which we have given for drainage on caved faces; this is being done by means of diagnostic measurements which are carried out in collaboration with the collieries. We are thus observing the course which is followed by the characteristic data of drainage installations in service, and we expect to draw conclusions from these observations with a view to optimizing the installation of drainage equipment.

We have finalized a computer programme for drainage grids, which is particularly helpful in solving the problem of meshed grids. This programme is now undergoing its first practical applications.

5.3.3. Miscellaneous

We have investigated the heterogeneous nature of firedamp levels on thick-seam faces which are worked by sub-level mining.

Finally, we have held six information sessions on fire-damp with 70 colliery engineers from the various coalfields.

5.4. RESEARCH PROJECT 'CONTROL OF FIREDAMP EMISSION' PROJECT

Institut national des industries extractives,
Liège

This research covers the following subjects:

- forecasting specific firedamp emission;
- a study of the natural laws of firedamp emission;
- a study of the effect exerted on specific firedamp emission by the rate of face advance;
- preventive action against accumulation of fire-damp at the return end of retreating faces;
- methane drainage (plus the related question of draining from abandoned mines);
- combating firedamp by preliminary remote infusion of the solid;
- participation in the 'process control of mine ventilation' project (mentioned for the record).

5.4.1. Firedamp emission on level-seam faces

Investigations have taken place at the following collieries:

- (a) Hensies-Pommeroeul
 - 'Jacqmain' seam, at the 710 level, face II East (this is the last face in a group of four seams which are worked in descending order).

- (b) Monceau-Fontaine, Pit No 25
 - 'Cinq Paumes' seam, face No 12 at the 1060 level (specific emission $\cong 75 \text{ m}^3/\text{t}$).
 - 'Cinq Paumes' seam, face No 2 at the 1090 level.
- (c) Beringen colliery (Kempense Steenkolenmijnen)
 - Face No 71, (s.e. $\cong 20 \text{ m}^3/\text{t}$) – (retreating face).
- (d) Zolder (K.S.)
 - Face 52/71a (s.e. $\cong 4.6 \text{ m}^3/\text{t}$) – (with preliminary remote infusion of the solid).
 - Face 33/61 (s.e. $\cong 11.5 \text{ m}^3/\text{t}$) – (preliminary remote infusion).
- (e) Waterschei (K.S.)
 - Face S5-55 (s.e. $\cong 70 \text{ m}^3/\text{t}$).
- (f) Eisdén (K.S.)
 - '28' seam, face 0236 (s.e. = $19.6 \text{ m}^3/\text{t}$).
 - '18' seam, at the 700 level, face 5147.

The investigations on these faces relate in particular to the effects which are exerted on specific firedamp emission by operational planning, rate of advance and output.

5.4.2. Retreating faces

Firedamp accumulation at the return end of retreating faces is a problem which has not yet been solved in a really satisfactory manner. Trials have taken place at Beringen colliery with a fan at the return end of the face, which draws off from the goaf (the Lorraine method).

5.4.3. Methane drainage

5.4.3.1. On faces

On one of the faces in the 'Cinq Paumes' seam (mentioned under Paragraph 5.4.1.) difficulties were caused by a considerable emission from the goaf along the bottom half of the reverse-slope face; this was in spite of drainage from the return airway.

Drainage holes have been drilled from the middle of the face; this has improved the situation.

5.4.3.2. In abandoned mines

Measurements and observations were mainly undertaken at the following mines:

- Charbonnage du Centre;
- Bois-du-Cazier.

Since the closure of the No 14 Pit at Monceau-Fontaine, the emission of residual firedamp has been measured in the airflow and in the drainage.

5.4.4. Combating firedamp by preliminary remote infusion of the solid

Experiments under the 'firedamp and dust' project have been continued on the following pre-infused faces at Zolder colliery:—

- 52/71a (specific emission $\cong 4.6 \text{ m}^3/\text{t}$);
- 33/61 (s.e. $\cong 11.5 \text{ m}^3/\text{t}$).

Under the experimental conditions which have been adopted, it takes at least 4 months of constant preliminary remote infusion to appreciably increase the coal's moisture over a distance of more than 200 m.

The Institute of Mining Hygiene has taken a particular interest in the efforts which have been made at Zolder colliery to give wider application to preliminary remote infusion. 16 panels have been (or are being) treated since March 1970.

5.5. RESEARCH PROJECT 'IMPROVEMENT OF CLIMATIC CONDITIONS ON THE FACE'

Steinkohlenbergbauverein, Essen

An extensive investigation into the effect which is exerted on the face climate by temporal variations in temperature and humidity was concluded during the period covered by the present report. The results of this investigation, including a new method of calculation to determine the attenuation of the amplitude of temperature variations in airways, are described in a thesis which was presented by Said A. Mohamed at Clausthal University of Technology in 1972. So far as the practising mining engineer is concerned, the most important results of the work lie in the graphs and simple equations to determine seasonal variations in climate when the airstream enters the face.

A measurement exercise lasting several weeks was again carried out to define heat parameters on mechanized faces, and this was done (for the first time) on a face equipped with cooling plant. The evaluations and calculations consumed a great deal of effort and money; they produced, *inter alia*, the following important findings:

- There is no significant difference in the equivalent heat conductivity λ_{aq} and the humidity parameter η_f on an air-conditioned face and on a comparable uncooled face.
- Not enough reliable parameters λ_{aq} and η_f have so far been available for intake gateroads with belt haulage. It was possible to establish some additional useable values in this connection; it was found that $\lambda_{\text{aq}} = 3 \pm 1.5 \text{ kcal/m h K}$ and that $\eta_f = 0.37 \pm 0.03$.

- The heat-conduction figures k on uninsulated cold-water pipes vary a great deal, evidently because the condensation on the outside surface varies. Values of $k = 14 \pm 2$ and of $20 \pm 2 \text{ kcal/m}^2 \text{ h K}$ were established for low and higher condensation respectively.

The experiments with air-conditioning techniques mainly related to the properties of air coolers in the presence of high dust levels. It was found that a considerable percentage of dust is precipitated and held in the coolers. Experiments with ribbed-pipe coolers, which operate below the dewpoint temperature, showed that a separation rate of up to 96% is achieved when the dust level is 100 mg/m^3 . If a cooler is to be largely self-cleaning it has to be kept completely wet with condensation water. This cleaning process can be assisted by spraying captured condensation water, or water from the cold-water pipes, ahead of the cooler.

Further development work concerned the improvement of water re-coolers. Here too, the heat-exchange surfaces have to be kept completely wet for high efficiency. It was demonstrated by experiments that the heat-exchange surfaces can be adequately wetted even at considerable depths, provided that the air speed and the quantity of sprayed water are sufficient. Heat-conduction coefficients of up to $117 \text{ kcal/m}^2 \text{ h K}$ were achieved during field trials with improved plant, whereas with older models the figure was only $75 \text{ kcal/m}^2 \text{ h K}$.

5.6. RESEARCH PROJECT 'PROCESS CONTROL OF MINE VENTILATION'

**Institut national des industries extractives,
Liège**

The present report only covers INIEX's participation in the research project since 1 July 1972.

INIEX's part is to investigate methanometry at Waterschei colliery, particularly in relation to the ventilation conditions in that mine, and also to establish and carry out a measurement and recording programme.

Pending the installation of a remote-monitoring system, firedamp-emission investigations have continued on 4 faces, viz.:

- Face L3-5B (specific emission = $79.6 \text{ m}^3/\text{t}$)
- Face L0-61 (s.e. $\cong 23 \text{ m}^3/\text{t}$)
- Face B8-49 (s.e. $\cong 16 \text{ m}^3/\text{t}$)
- Face S5-55 (s.e. $\cong 70 \text{ m}^3/\text{t}$).

The following remote-monitoring system has been selected:

- Measurement and drainage: A.T.M. anemometers, G.T.M. methanometers, 'Tricaptours' for drainage (eventually);
- Remote transmission: Funke & Hüster TF 24;
- Logging equipment: 'Analogic' data logger;
- Data acquisition and preliminary processing: IBM S/7;
- Graph recording: IBM 1627 plotter;

The logging-monitoring and recording programmes are now being written.

Obtaining a 1st class Certificate of Approval of intrinsic safety, to allow the equipment to be used underground, has caused a number of problems; these have been studied in collaboration with INIEX, with a view to making the necessary modifications.

5.7. RESEARCH PROJECT 'THE APPLICATION OF PROCESS CONTROL TO MINE VENTILATION SYSTEMS'

Institute of Mining Hygiene, Hasselt

5.7.1. Research at the Institute

- (a) In collaboration with Kempense Steenkolenmijnen's Waterschei colliery, the Institute has established a mathematical model (of the greatest possible accuracy) of that colliery's ventilation system.

This has involved the processing of data (relating to pressure losses and to the characteristics of

the biggest fans on site) which were compiled in the course of a great many measurement campaigns. The operation also covered Eisdien colliery, which will shortly be linked with Waterschei.

- (b) The Institute has participated in the preliminary studies concerning the selection of a teletransmission system for methanometric data, and in setting-up the link between this system and a computer (Analogic data-logger).
- (c) The Institute is now studying the extension of telemetry to ventilation (pressures and flows) and to climate (dry-bulb and wet-bulb temperatures).

5.7.2. Research at Louvain University (Department of Thermodynamics and Turbomechanics)

- (a) Professor Patigny's team is concentrating mainly on real-time and batch-bulk computer processing of ventilation, methanometric and climatic data. The programmes which are now being written include the automatic updating of the ventilation model in the light of the latest measurements, the detection of trouble-spots (airdoors left open, accidental obstructions, auxiliary fans switched-off, etc.), the calculation of fan operating conditions in accordance with specified requirements, the selection of specified airflow requirements in the light of firedamp emission and climatic conditions.

- (b) In addition to the above, the team has played an active part in developing the sequence of data-capturing — transmission — logging — preliminary processing — reading-in. It has also developed the control logic of the data-loggers, allowing for the random nature of the measurements which are transmitted by GTM-type methanometers, and it acts as the interface between the data-logger and the computer.

VI

6.1. RESEARCH PROJECT 'PREHEATED CHARGING OF COKE PASTES'

**Centre d'études et de recherches
des charbonnages de France**

During 1972, we have continued charging tests with preheated coal using the pilot plant installed at the Hagonage coking plant. Nearly 11 000 tonnes of coal have been treated requiring about 700 charging operations in the coking plants ovens.

A study of the various operational parameters of the crusher dryer and their effect on the characteristics of preheated coal has been successfully carried out during this period and the apparatus has worked up to normal throughput levels in satisfactory conditions.

To establish the impact of preheated coal on the different carbonization factors we have treated coal blends with high volatile (A) contents of 40 to 75 %. For each blend measurements and checks were made on the density of the charging, the pressure in the charge at the moment of charging, the temperatures of the walls and in the coke, the duration of firing and the quality of the coke obtained. These tests have enabled us to confirm on the industrial scale the results obtained in the pilot installation at the Marienau Experimental Station: increase in productivity of between 25 to 30 % and it is possible to obtain a coke suitable for steel making with a blend containing 70 % high volatile (A) coal.

6.2. RESEARCH PROJECT 'RAISING COKE-OVEN THROUGHPUT BY USING THINNER STRETCHERS'

Bergwerksverband GmbH, Essen

The group of research ovens was completed in the first half of the year and fired on 21 June. The ovens were heated over a period of three months to bring them to the required operating temperature of around 1100°C so as to commence coke production.

The first batch of coke was pushed on 21 September with an operating time of approximately 24 hours. The flue temperature was subsequently lifted to 1220°C and coking time reduced to 18 hours.

Firing adjustments were carried out under these operating conditions. The operation is not yet complete and is extremely difficult due to complexities involved in regulating the gas, air and waste gas. The group is therefore being run well below the full thermal load which means that the quoted figures of 1220°C flue temperature and 18 hrs coking time do not represent the increase in throughput afforded by the use of thinner stretchers. It has not yet been possible to measure the effect of various sizes of header on the heat transport patterns.

Recurring adjustment problems meant that the pneumatic regular valve adjustment curves had to be recorded several times over in collaboration with the manufacturer. After the heating system had been changed over, leakages occurred in the heating gas supply control valves. Efforts are concentrated at the moment on obtaining well adjusted combustion in the heating flues, optimum heat balance between the ram and coke sides and all-round functioning of the control and changeover equipment.

6.3. RESEARCH PROJECT 'IMPROVED PERFORMANCE IN COKE-OVENS BY PROGRAMMED, HEATED AND IMPROVED REGENERATOR'

Bergwerksverband GmbH, Essen

In conjunction with Project 16819/68-D the group of research ovens was completed in the first half of the year and fired on 21 June.

Once an operating temperature of 1100°C had been reached, the first batch of coke was pushed on 21 September. Together with the adjoining group of ovens, the research group were subjected to programmed heating and by using an improved regenerator it was possible to obtain a coking time of

18 hours. The heating was adjusted under these operating conditions. It became immediately apparent that the gas and air supply arrangements were exposed to unfavourable working conditions in the 18 hour coking time adopted in a high-performance oven battery which would eventually be working on 12 hour periods. It is almost impossible to obtain optimum supply to the individual burners using these relatively large sections in the horizontal gas channels and firing gas lines. The heating was therefore adjusted to a 16 hour coking time, and the pause between cycles extended so that in effect the heat supply situation corresponded to an 18 hour coking cycle.

To date problems have been exclusively on the electronic side ranging from limit switches with inadequate switching path to pulse interference in the programmer.

The improved regenerator has already shown its effectiveness as compared with the adjoining high-performance battery working on conventional heat storage materials. As the superior exchange capacity of the new material was used when designing the oven – the regenerator is appreciably lower – there is every reason to suppose that the higher specific exchange surfaces will be successful as both groups of ovens show similar waste gas temperatures.

The group is being fired without programme control until the 12 hour coking acceptance test.

6.4. RESEARCH PROJECT 'TESTS WITH A NEW REFRACTORY MATERIAL FOR COKE OVEN CONSTRUCTION'

Bergwerksverband GmbH, Essen

Research and development work on the use of new refractories with superior thermal conductivity for

coke oven construction started three years before the termination of the agreement at Bergbau-Forschung GmbH. Material which appeared to be suitable comprised:

- (a) low-iron magnesite, and
- (b) stone ('STARKIT') containing silicon-carbide.

After a first magnesite brick oven at the Technical University had to be re-lined due to damage after one year operating, the second magnesite brick oven gave excellent service over two years continuous operating. Research work uncovered some interesting information with regard to the effect of reaction conditions within the oven on the quality of the coke and by-products.

A third oven was lined in magnesite in November in order to clear up a number of technical questions relating to the quality of a suitable mortar and a spray substance compatible with the particular firebricks employed in the oven. This newly-lined oven will be used for a series of tests using different coal mixtures as raw material to be exposed to varied coking conditions.

Results to date justify the construction of a large scale testing facility and this has already reached the planning stage in collaboration with H. Koppers. The facility will include three ovens of real-life size (4 m height) at Prosper coking plant, lined with low-iron magnesite brick. With heat expansion in mind, the upper reaches of the regenerator partitions are made from forsterite whilst the lower partition areas are chamotte firebrick. Heating equipment is adjusted to 8 hours with a view to further use of programmed heating. Programme control will be based on temperatures in the upper reaches of one of the heating flues at a twin flue reversal point.

VII

7.1. RESEARCH PROJECT 'DECOMPOSITION OF AROMATIC SUBSTANCES USING DISSIMILATIVE NITRATE REDUCTION'

Central DSM Laboratory

Research into the decomposition of aromatic substances using dissimilative nitrate reduction is directly related to the growing need to solve environmental pollution problems. Currently dissimilative nitrate reduction as a method of anaerobic decomposition of wastes is the focus of interest.

We have already reported at length on enriching and isolation tests for micro-organisms which enable phenol and nitrate to be decomposed. The bacteria involved are probably of the *pseudomonas* genus. The pressure of nitrification required for phenol decomposition could be finally established.

The final proof was also found that the decomposition of aromatic substances is ultimately effected via the metabolism of the bacteria, using ^{14}C -UL-phenol and 1- ^{14}C -benzoic naphtha.

An investigation of cytochrome differential spectra of cells of pure cultured collective groups, which have grown with KNO_3 under anaerobic conditions, has shown that cytochrome C and B are present, as well as cytochrome A *pseudomonas stutzeri*.

A new peak in the spectrum at 460-470 nm with group 31 and the *pseudomonas st.* could be established. Phenol inhibits cytochrome reduction at 10^{-1} molar concentration.

Refreshing the medium is one method to reactivate a poorly decomposing culture.

The presence of NO_x -phenols in badly or well phenol-decomposing cultures has not yet been proved.

Phenol and nitrate decomposition in a continuous culture works excellently (95-99% effectiveness) with a dilution rate of $0.8 - 2.5 \cdot 10^{-3} \cdot \text{h}^{-1}$. The specific nitrate and phenol decomposition rates are, respec-

tively: $0.4 - 0.7 \cdot 10^{-3} \text{ mol NO}_3 \cdot \text{per g dry material. per h.}$ and $0.1 - 0.6 \text{ mol phenol. per g dry material. per h.}$ The extraction factor γ phenol amounts at most some 24-30 g dry material per mol phenol.

The P/ NO_3 ratio varies between 0.5-0.7 mol ATP per mol NO_3 .

The transition of a phenol decomposing culture under anaerobic denitrifying conditions to one under aerobic conditions requires an adaptation time of 1-2 days, after which an acceleration of the phenol decomposition occurs by a factor of 5 to 10.

It can finally be concluded that the decomposition of aromatic substances proceeds well under anaerobic denitrifying conditions but that many questions still remain unresolved.

7.2. RESEARCH PROJECT 'PHYSICAL AND CHEMICAL BENEFICIATION OF COAL AND ITS BY-PRODUCTS'

Centre d'études et de recherches
des charbonnages de France

Work continued at CERCHAR under each of the three main programme headings: special carbons, new products and improvement of conventional uses.

7.2.1. Special carbons

Since the quality of an electrode pitch appears to be basically linked to its aromaticity, attempts were made to make the measurement of this property more reliable by direct assessment through magnetic nuclear resonance. After the first tests with soluble fractures, a device has been designed and built enabling direct action on the pitch as a whole in its melted state.

Since the fight against air and water pollution is required to make great strides forward we have

restarted tests basing ourselves on previously executed fundamental research, applying coal-based active carbons to special instances of purification in both gaseous and liquid phases so as to show up the relationships between the physical and chemical characteristics and effectiveness.

7.2.2. New products

In the research on developing expanded granulates from the coal industry's waste, the nature and kinetics of gas emission at high temperatures was studied – oxygen, carbon monoxide, carbon dioxide and sulphur dioxide – and the effect of the degree of preliminary decarbonization on the expansion phenomenon.

7.2.3. Improvement of conventional uses

A batch of valuable results was obtained on the ignition of coal dusts following comparisons of pyrolysis with nitrogen and pyrolysis combined with oxydation in an oven with rapid radiation heating. This type of plant, also called fall oven, has been developed so that it ensures a constant heating rate as between tests and makes it possible to measure the maximum temperature reached by the particles. It is almost completed.

In petrography CERCHAR's work has proceeded both on basic research lines – diagnosis, nomenclature and definition of the brown coal (lignite) – coal demarcation – and toward forecasting of the mechanical quality of coke from optical data. This work forms part of an international effort.

In the study of spontaneous heating and self-ignition in coal an attempt was made to clarify the role of pyrites, thanks to an adiabatic test of great precision, pyrites in finely dispersed form appearing to be the root danger factor in humid conditions. Its action can be explained by the catalytic action of the ferrous salts resulting from its decomposition.

7.3. RESEARCH PROJECT 'NEW PROCESSES AND PRODUCTS'

Steinkohlenbergbauverein, Essen

The results of individual research tasks have been reported in this period at two round-table discussions, on 9 May in Paris and 16 November in Essen. The report in Paris was primarily concerned with the chemical properties of coal. In Essen the physical methods and technical developments were in the forefront.

In connection with the production of special carbons investigations were carried out into the use of active coke as catalysts. Here the absorptive behaviour of impregnated coke was mainly investigated. The model reaction used was the vinyl-acetate synthesis. Following up the possibility of using active coke for air and water purification, the regeneration problem was thoroughly examined, since the purifying prospects of such absorptions are of particular importance for economically effective application.

In the efforts to produce new materials from coal, the properties of hard coal material samples were examined after thermal treatment between 1000 and 2000 °C. It was found that this produced physical and chemical structural changes which clearly improve solidity. Certain additives make it possible to manufacture a filter-like material with specific pore size from such modified hard coal. The pore size of such materials approximates standard commercial fine filters. It is anticipated that it can be used for gas purification in addition to the planned separation of finest suspensions.

It was possible to conclude successfully the attempt to simulate the structure of hard coal by quantitative distribution of organic connections. Based on this work, the dependence of polymerization energies on the configuration 'operator' a^1 for different coal types was established in this period. In addition, the calorific value distribution of coals was simulated using defined organic substances.

Tests to influence the dissolution of coal and chemical reactions with hard coal using ultrasonic fields led, via the stepping-up of energy densities, to trials with an ultrasonic plasma. The first results indicate that this may open up a new approach to the high-temperature chemistry of hard coal.

Investigations into coal hydrogenation according to the H-coal process were extended to coals of differing degrees of carbonization.

In connection with the selective oxydization of coal, aimed at the oxydizing splitting off of sulphur-bearing heterocycles, a process was developed to systematically produce larger quantities of fractions enriched with sulphur-bearing connections. This enables better test methods to be employed which could lead to an earlier success.

The treatment of coal with differing degrees of carbonization under hydrogen with a heating rate of 5 °C/min up to a final temperature of 1000 °C makes it possible to identify different binding types of sulphur based on the dependence of hydrogen sulphide formation on the temperature.

The problem of producing hot, reducing gases from coke oven gas by intermittent combustion has led to extensive research into the basics of the reaction and the state of equilibrium under differing conditions. Also investigated were the effect of reactor geometry and the type of fuel feed.

In view of the technological behaviour of particular macerals, the coking capacity of 'Micrinite' was investigated. A precondition for this was a definite identification of its grain size and shape. For this the scatter capacity of an optical microscope does not suffice, but success was achieved by using a top light microscope together with the etching of grain boundaries. The first results have shown that 'Micrinite' does not soften when passing through the plastic zone.

Research work continued to establish the gas pressure occurring in horizontal chamber ovens when the tar seal is closed, and the advance calculation of coke properties during coking by the stamping method, by carrying out further calculations to verify operational results.

To determine the optimal coke size for blast furnace operation a system of equations has been developed which makes it possible to set specific layer densities depending on the raw material and the exact grain distribution and form.

During tests on pyrolysis and combustion of individual coal grains 3 ignition mechanisms were established: the time-separated ignition of volatile matter and the grain, simultaneous ignition of volatile matter and coal grain and ignition of the coal grains only. The type of mechanism is determined by the degree of carbonization of the coal used.

7.4. RESEARCH PROJECT 'NEW PROCESSES FOR OBTAINING INDUSTRIAL CHEMICAL COMPOUNDS FROM BY-PRODUCTS RESULTING FROM NEW COKING METHODS'

Université Libre de Bruxelles

7.4.1. Cracking under pressure

7.4.1.1. Isomerization of xylenes and xyleneols

This work has continued and was reported on in a paper submitted to the 16th Round Table at Essen in November 1972 by M. Bertau, entitled: 'Isomerization of xylenes and xyleneols'

7.4.1.2. Isomerization of Cresols

The Isomerization of para-cresol, previously transformed into phenolate, into ortho-cresol was con-

tinued. Isomerization rates of 20% in weight were obtained.

These transformations were studied at between 20 and 600 °C and under pressures of 1000 kg/cm².

7.4.1.3. Ammonolysis of phenols

The study of direct synthesis of aromatic amines, together with the degradation and isomerization of phenols through ammonolysis of phenolate hydrate was undertaken in 1972. Up to 35% amines were obtained in autoclave from para-cresol in ammonium hydrate.

This research will continue in the next years using other phenols and at temperatures and pressures which will make it possible to combine thermal degradation under pressure of heavy phenols and the corresponding synthesis of aromatic amines.

We expect to submit the first results of this work at the next Round Table planned for 1973.

7.4.2. Kinetic study of degradation and association reactions

7.4.2.1. Thermal cracking of cyclo-pentadene

The study of the pyrolysis mechanism of cyclopentadene and its contribution to the formation of aromatic substances has been the subject of a paper to the GAMS Congress in Paris in June and of a second at the 15th Round Table in Paris entitled: 'The Kinetics of thermal cracking of cyclo-pentadene'.

All the results of this research will be published as a doctor's thesis to be defended by M. Spielmann during the first 1973 term.

7.4.2.2. Aromating cracking of aliphatic hydrocarbons

The study of cracking heavy aliphatics present in pitch at low temperatures has enabled the aromatization mechanisms, which occur jointly with the degradation process, to be shown.

The thermal behaviour of decane and some other long-chain, aliphatic hydrocarbons has been studied. The study of the aromatization mechanisms of butane has been started and carried forward.

7.4.2.3. Kinetic study of pyrolysis reactions through mass-spectrometry coupled with chromatography in the gaseous phase.

The study of a pyrolysis installation linked to mass-spectrometry and chromatography was completed at the end of 1972. The entire installation has been ordered. It will come into service at the end of 1973.

From the middle of 1973 we will have a conventional installation of linked chromatography in the gaseous phase – mass-spectrometry.

The part specially devised for our research will not be completed till October or November 1973 and will probably not be used until 1974.

7.4.2.4. Study of the elementary mechanism of cracking of phenols marked by C¹⁴ and tritium

This research has been the subject of several previous publications. The latest results obtained in 1972 were presented to the 15th Round Table in Paris by Monsieur Bettens in a paper entitled: 'Interpretation of the thermal cracking mechanisms of ortho- and para-cresols, specifically marked by C¹⁴'.

M. Bettens will defend his doctor's thesis on his research in January 1973.

Other publications on this work will also be issued in 1973.

7.5. RESEARCH PROJECT 'FERMENTATION AS A MEANS OF PRODUCING CHEMICAL LINKS FROM COKING BY-PRODUCTS'

N.V. Nederlandse Staatsmijnen, DSM

Within the project framework 'Fermentation as a means of producing chemical links from coking by-products' an investigation into 'Feed yeast from brown coal carbonization water' was started in the middle of 1972. The first carbonization water made available by the research laboratory of the 'Rheinische Braunkohlenwerke' at Frechen contained less mono-

carbonic acid and more phenol and cresol than expected, while the carbon quantity was far larger than that required in the abovementioned links.

During yeast cultivation in this carbonization water such extensive precipitation was formed that the yeast growth could be observed neither spectro-photometrically nor gravimetrically but only microscopically. Nor could a separation of yeast and precipitation be effected.

Of the yeast types tested, *candida tropicalia* showed the best growth rate, a species known as capable of decomposing phenol.

A subsequent sample of carbonization water from the RBW contained no phenol and cresol but the quantities of mono-carbonic acids and disruptive links had not changed.

Because these linkages cause precipitation when ventilated, their elimination was tackled first. These disruptive linkages turn out to be polycyclic phenols, which it should be possible to remove either by oxydation or polymerization. It has not yet been possible to remove those constituents in such quantities that they do not have a disruptive effect on the monitoring of the growth rate during growth tests in shaker flasks.

At the same time the possibility was investigated of including hard coal carbonization water supplied by Bergbau-Forschung of Essen in the tests. This waste water, however, contained very small amounts of monocarbonic acids (less than 1 g/l) and large amounts of phenols and cresols so that yeast could not be cultivated in it.

To the problem of the disruptive effect of the polycyclic phenols, which can cause black or dark-brown colouring in the yeast, can be added that these links cannot be accepted because they are liable to be carcinogeneous.

VIII

8.1. RESEARCH PROJECT 'BROWN COAL COKING'

Deutscher Braunkohlenindustrie-Verein, Köln

8.1.1. Introduction

Within the framework of the above research project a total of 7 methods of manufacturing formed coke from brown coal were investigated. Highlights of the past year were the following:

- Completion of laboratory coking tests with brown coal briquettes produced without binders in indirectly heated retorts.
- Completion of laboratory coking tests with blended briquettes produced from brown coal fine coke and hard coal tar pitch or another binder in indirectly heated retorts.
- Formed coke manufacture from blended briquettes of brown coal fine coke, tarpitch and cakeable hard coal using a briquetting process at 120 °C.
- Formed coke manufacture from dry brown coal by activating the bitumen present through high-temperature briquetting.
- Full or half-scale briquetting tests to manufacture brown coal briquettes and fine coke briquettes to ensure a supply of suitable products for the half-scale formed coke test plant now under construction.
- Testing the techniques of application.

8.1.2. Results of research

8.1.2.1. *Formed coke manufacture from brown coal briquettes produced without binders*

8.1.2.1.1. Analysis of partial processes

To facilitate analysis of the partial processes the coking process up to 1000 °C was divided into 12 sections by coking in stages. Here five phases could be distinguished: pre-heating, dewatering, pre-degasification, main degasification and post-degasification. The processes within the individual

phases were analysed and discussed in relation to their impact on the mechanical, physical and chemical properties of the coking products.

8.1.2.1.2. Effect of briquette cooling on stability of formed coke.

The brown coal briquettes leave the briquetting press at a temperature of 60-80 °C, reaching their maximum mechanical stability only after cooling.

Coking tests have shown that briquettes used without cooling have almost the same coking stability as cooled briquettes, so that the cooling process can be dispensed with.

8.1.2.1.3. Effect of cooling off rate on formed coke stability.

Slow cooling off of the formed coke after coking does not appreciably improve the stability. It is therefore possible to cool the coke rapidly (13.5 °C/min).

8.1.2.1.4. Effect of retort dimensions

With a large retort diameter the temperature difference between outer jacket and retort centre is markedly greater. This leads to different heating up curves and, hence to different coke stability depending on the position of the briquettes in the retort in any tests. The relationships are being examined in detail.

8.1.2.1.5. Calculating the decisive factors affecting coke stability.

So as to define the importance of individual factors quantitatively, a step-by-step linear regressive calculation was undertaken. The interpretation of the regression equation shows that to obtain a high coke stability it is necessary to aim at the highest initial briquette stability and volumetric weight with the lowest water content and low heating up rate in the 110-230 °C and 230-450 °C temperature ranges.

8.1.2.1.6. Materials and thermal balance.

As a basis for planning the half-scale coking plant and possible future plants a detailed balance of quantities of material and a thermal balance for coking was worked out using the retort tests. One of the findings is that for 1 t formed coke 5.524 kg of run-of-mine coal are needed; also that the sensible and latent heat of the volatile matter exceeds the requirements of the coking plant, inclusive of drying the run-of-mine coal, by 2.78 Gcal/t of coke.

8.1.2.2. *Completion of coking tests using blended briquettes made from brown coal fine coke and mixed briquettes*

8.1.2.2.1. Analysis of partial coking processes

As in the tests with brown coal briquettes the coking of blended briquettes was also divided into partial stages by step-by-step coking. Overall there is a shift in the individual phases towards higher temperatures. This is explained by the fact that the individual components had already been exposed to higher temperatures. Here the coking process can broadly be regarded as a distillation process of the hardcoal tar pitch utilized as a binder.

8.1.2.2.2. Completion of tests with fluidized bed coke

The tests with fluidized bed coke were completed. Here the effect of natural fine grains (cyclone dust) was primarily examined. The compressive strength of formed coke deteriorates as the proportion of natural fine grains increases.

8.1.2.2.3. Tests with hearth-furnace coke

Following on the tests with fluidized bed coke, tests with a hearth-furnace coke which was a fine coke were carried out. This coke has a low bulk weight, a low volatile matter content and a high specific surface. The solidity of untreated briquettes and coke obtained were well below the corresponding results for fluidized bed coke, with comparable binder proportions and processing conditions. To obtain a compressive strength of $> 125 \text{ kp/cm}^2$ in coke a 40% proportion of binder, relative to the untreated briquettes, is required.

8.1.2.2.4. Tests with other binders

In addition to hard coal tar as a binder, tests are also conducted with residual resins from the petro-chemical industry and brown coal tar as binders. The same solidity could not be obtained with these binders as with hard coal tar pitch. For this reason the exclusive use of these binders is probably ruled out. In many cases, however, a part of the tar pitch can be replaced by these binders.

8.1.2.2.5. Calculating the decisive factors affecting coke stability

With the coking of blended briquettes a step-by-step regressive calculation was also used to determine the individual factors. An interpretation of the equation shows that the bulk weight and the specific surface of the fine coke used are of particular importance, as is the binder and water content of the blend. Particularly indicative is the correlation between the bulk weight of coke and the binder proportion on the one hand and the specific surface and the water content on the other. With a low bulk weight the optimum binder requirement is higher, while a large specific surface requires a higher water content.

8.1.2.2.6. Materials and thermal balance

As with brown coal briquette coking a balance of material quantity and a thermal balance was worked out for the coking of blended briquettes. According to this process, 4.905 kg of raw brown coal and 296.4 kg tar pitch or other binder are required for 1 t of formed coke. The thermal balance for coking, including drying produces a surplus of 2.7 Gcal/t of coke. These values only apply to a specific fine coke process and a certain blend ratio in the untreated briquettes and have to be calculated afresh for each particular case.

8.1.2.3. *Formed coke manufacture from blended briquettes of brown coal fine coke, tar pitch and cakeable hard coal using a briquetting process at 120 °C*

Research into the above was started later and is not yet completed on the laboratory scale. Results to date are as follows:

8.1.2.3.1. The mechanical stability of fine coke depends on the latter's properties. The mechanical stability of the single grain appears to be a decisive factor.

8.1.2.3.2. Standard coking coal with a 22% volatile matter content has proved to be the most suitable. In certain cases coal with up to 32% volatile matter can be used.

8.1.2.3.3. Tar pitch has only one function, that of ensuring adequate stability in the blended briquette; for this reason hard coal tar pitch can be replaced by residual resins from the petro-chemical industry or brown coal bitumen.

8.1.2.3.4. The grain size of the hard coal and the water content has little importance.

8.1.2.3.5. A reduction in the heating-up rate leads to improved quality in the formed coke. Using sand as a medium of direct heat transfer also has positive advantages. The best results to date were achieved with a blend of 55 % brown coal fine coke, 15 % hard coal tar pitch and 30 % cakeable hard coal. The compressive strengths of the coke obtained were around 150 kp/cm².

8.1.2.3.6. In order to suppress the swelling tendency of the hard coal components a sudden jump up to a temperature of 700 °C is required. Residual degasification should take place under careful heating-up conditions.

8.1.2.4. *Formed coke manufacture from dry brown coal by activating the bitumen present through high temperature briquetting*

The advantage of this method is that it enables non-briquettable brown coal to be formed even without a binder. Results to date are as follows:

8.1.2.4.1. The optimum temperature range for high temperature briquetting is 350-400 °C.

8.1.2.4.2. Low heating-up rates below this temperature range are beneficial.

8.1.2.4.3. With a grain size of 0-1 mm the optimum was found to be 1.200 kp/cm² depending on the forming pressure. With a grain size of 0-6 mm the compressive strength rose regularly with increases in forming pressure. Overall, the results with 0-1 mm grain diameter were considerably better. Coke compressive strengths of up to 250 kp/cm² were achieved.

8.1.2.4.4. Duration of pressure is also important.

8.1.2.5. *Full or half-scale briquetting tests*

8.1.2.5.1. Half-scale briquetting tests to manufacture fine coke briquettes from brown coal fine coke and tar pitch.

In the period under review 20 half-scale briquetting tests were carried out on a roller press of the Köppern firm at Hattingen. The blend consisted of fluidized bed coke with hard coal tar pitch as a binder. It was found that the results obtained in the laboratory could readily be transferred to a full-scale plant. Unlike the laboratory tests, poor solidity in the coke resulted if a high briquetting pressure was chosen.

8.1.2.5.2. Full-scale briquetting tests on a briquetting press to manufacture industrial briquettes for a half-scale coking plant.

The main aim in the tests was to reduce the solidity differences between the middle and outer briquettes of a bar consisting of three separate parts. Additional lateral sealing and a more uniform filling of the moulding channel achieved this in part. An increase in the forming pressure also raised the degree of solidity.

8.1.2.6. *Testing the techniques of application*

8.1.2.6.1. Flue gas desulphurization

Tests covered different brown coal cokes, showing marked differences between the various fine cokes. With a short residence time of the gas in the fine coke of one second, the specific surface is of little relevance. Tests have not yet progressed sufficiently to enable a comprehensive assessment.

8.1.2.6.2. Sintering tests with different iron ores.

Sintering tests at various steel works with appropriately differing blast furnace burdens have shown brown coal coke to be basically suitable as a sintering fuel, yet highlighting characteristic differences from the conventional fuels.

8.1.2.6.3. Tests with brown coal coke in electric smelters.

A test with brown coal briquetting coke in an electric down shaft furnace used in silicon-chrome manufacture could only show that there were no noticeable differences in the furnace behaviour and product quality compared with normal coke due to the small amount of coke available. Further tests will only be possible once the half-scale test plant is in operation.

8.2. RESEARCH PROJECT 'FORMED COKE'

**Centre d'études et de recherches
des charbonnages de France**

The prospect of directly using medium volatile coals for formed coke manufacture was first studied in the laboratory using Lorraine coal, with a 1.5 swelling index.

It was seen that to obtain a formed coke whose mechanical properties, in the laboratory, are similar to those obtained with briquette carbonization

according to the traditional MBNPC (85 % lean, 15 % fat), it is necessary:

- effectively to double the share of fat coal in the paste to values of 25 to 30 %,
- adopt a markedly slower heating rate in carbonization.

It has been found that if a fast heating rate is adopted, similar to that for briquettes on a lean coal basis, the size of the product carbonized would be irregular and the mechanical resistance of the resultant coke quite poor.

To confirm these results obtained in the laboratory a carbonization test involving some 100 t of briquettes fired with Lorraine (Faulquemont) volatile coal was carried out in our 10 t/d pilot plant.

To avoid the sticking of briquettes when carbonized the blend only contained 12% fat coal as a precautionary measure.

Compared with results obtained with pellets also made from no more than 12 % fat coal, it was confirmed that:

- the best results were obtained with a low heating rate. The oven capacity was only 400 K/hm² as against 700 standard.
- the resistance to crushing of the formed coke obtained was reduced. Only 30% of the pellets remained whose resistance was over 250 kg as against a 55 % standard result.

On the other hand, the MICUM and IRSID indices remained largely the same. Yet the apparent density was reduced to 1.09 as against 1.26 and the porosity rose to 42 % as against 32 %.

Consequently, the end product obtained had acceptable characteristics without having to go through the semi-coke stage.

In addition, the operation of the oven and the discharge of tars did not appear to pose any particular problems during the ten-day test.

At the same time we have directed research to other methods of manufacturing briquettes from blend formulas so as to try and increase the plant output and the mechanical resistance of the formed coke obtained.

To this end 2 series of tests were undertaken:

- Use of very small sizes and initiation of greater briquetting pressure than the conventional ones.
- Inclusion of a reducer in the blend of dry and fat volatile coal of the 10 to 20 % range. Tried out were:

coke dust, lean coal and a petrole coke with a 13 % volatile matter content.

Only the addition of petrol coke gave a favourable result. It made it possible to treat the briquettes at a fast heating rate, even for a 15 % proportion of fat coal in the blend.

Thus petrol coke can be a factor in improving productivity and mechanical resistance using the Faulquemont type of volatile coal.

During 1972 construction continued of a prototype carbonization plant with 4 units whose capacity is to be 120 t/day for the blend based on lean coal.

Tests of short duration have taken place since mid-October. Completion will last till the end of 1972 and the beginning of 1973.

8.3. RESEARCH PROJECT 'UTILIZATION OF WASTES'

**Centre d'études et de recherches
des charbonnages de France**

8.3.1. Light sands

Study of a method of producing light sands through the heating and expansion of shale grains falling into a flame in a counter flow. The vital problem is to prevent the grains from sticking to the oven walls. To study the possibility of confining the particles in the central zone of the oven during their fall, a hydraulic 1/10th scale model of an oven with a capacity of 10t/h has been built. On this model the number and position of burners spaced out on the opposite walls, the relative gas throughputs which will enable the solid particles to be confined on the oven axis and the quantity of solid material which can be treated are to be established.

Some data is becoming available on the effect of:

- the velocities of lateral liquid jets on the total flow,
- the lateral throughput in relation to the overall throughput on confining the grains on the axis.

Due to the considerable scale of the hydraulic model its running-in proved troublesome and threw up a number of problems which are now nearly all resolved.

It is still too early to be able to assess the effectiveness of an aerodynamic process being studied to confine solid particles on the oven axis; on this result the feasibility of the method of manufacturing light sands will be based on which we have worked during the period under review.

8.3.2. Expanded 5 mm granulates

The study of the expansion of coal shales and tests on the 1.5 t/h pilot plant built by the Nord Pas-de-Calais Coalfield have been continued.

The rotation speed of the expansion press has been measured to control the development of the slope of granules passing through.

Results achieved in the automatic control of the heating plant have been confirmed and improved.

Research has been done on the optimal thermal consumption, identifying the possible range of various granulates obtained in concrete manufacture.

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