The hydraulic hoisting of coarse coal from a depth of 850 metres

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SYNOPSIS

At the Hansa Mine in Dortmund, Germany, coarse run-of-mine coal, up to 60 mm in particle size, has been brought to the surface hydraulically from a depth of 850 m since November 1977. Hoisting is done by a three-chamber pipefeeder, by means of which up to 400 t/h can be lifted. The pipefeeder operates without problems, and has so far shown itself to be efficient and reliable.

Vertical hoisting can be carried out by water supplied from the surface, from underground, or from a surface water supply in combination with minewater from underground. Water that flows into the mine, which would in any event have to be pumped to the surface, can be utilized for hoisting operations. The energy costs per ton of coal for a lifting height of 850 m vary between 41 and 62 South African cents, and therefore lie within the range of costs that apply to conventional hoisting.

SAMEVATTING

Growwe onbehandelde steenkool met 'n partikelgrootte van tot 60 mm word sedert November 1977 by die Hansa-myn in Dortmund, Duitsland, vanaf 'n diepte van 850 m hidraulies na die oppervlak gebring. Die hysing geskied deur 'n driekamerpypvoerder deur middel waarvan tot 400 t/h gehys kan word. Die pypvoerder werk sonder probleme en het homself tot dusver as doeltreffend en betroubaar bewys.

Die vertikale hysing kan gedoen word met water wat vanaf die oppervlak, ondergronds of uit 'n waterbron aan die oppervlak tesame met ondergrondse mynwater, voorsien word. Water wat in die myn invloei, en wat in elk geval na die oppervlak gepomp sou moes word, kan vir die hyswerk gebruik word. Die energiekoste per ton steenkool vir 'n lighoogte van 850 m wissel tussen 41 en 62 Suid-Afrikaanse sent en lê dus in die kostebestek wat op konvensionele hyswerk van toepassing is.

Introduction

The decision to convert conventional mining sections of the Hansa Mine to hydraulic mining was taken by the Ruhrkohle AG at the height of the first energy crisis in 1973. The horizontal coal reserves had largely been mined out, and it was calculated that the extraction of coal from the remaining, steep deposits by means of high-pressure water monitoring would extend the lifetime of the mine by approximately eight years.

The project involved five facets of hydromechanical extraction:

(1) supply of high-pressure water for the hydraulic mining operations,
(2) hydraulic horizontal transportation of slurry underground,
(3) hydraulic vertical hoisting of slurry to the surface,
(4) water clarification underground and return of high-pressure water to the working face,
(5) processing of the run-of-mine coal slurry in the washing plant on the surface.

Fig. 1 shows a simplified layout of the equipment.

The two pump chambers, one on surface and one underground, are each equipped with four high-pressure pumps, which supply the mining sections with high-pressure water for the monitor guns, and also provide the water pressure necessary for vertical hoisting. The coal, which is mined by means of high-pressure water jets, flows in open channels through a screen–crusher installation that separates the oversize material (plus 60 mm), and then into a slurry basin.

A chain conveyor, having a variable-speed drive, in the slurry basin ensures a constant density and delivers the mixture of coal and water through the slurry pump. This pump, or series of pumps, transports the slurry via a horizontal pipeline approximately 2,8 km in length into the coal-slurry storage basin near the shaft. From here, the coal slurry is fed into another slurry basin for filling under low pressure into a three-chamber pipefeeder. The pipefeeder operates as a cyclic pressure vessel, hoisting up to 400 t of run-of-mine coal per hour in a single-stage lift to the surface.

Hydraulic Hoisting

Hydromechanical extraction with water jets was tried and tested many years ago, and was used successfully in mines in Canada, Russia, Hungary, and China.

In Germany, the method was tested in experiments that were carried out in various mines, but problems were encountered with hoisting because of the coarse run-of-mine coal with its high proportion of waste (40 per cent), and because of the heights to which it had to be hoisted. All attempts to overcome these problems with reciprocating pumps or slurry pumps connected in series were unsuccessful for technical or economic reasons.

The design requirements for the hydraulic hoisting system at the Hansa Mine were as follows:

(a) to overcome a difference of 850 m in height in one hoisting stage,
(b) to convey the coarse (maximum particle size up to 60 mm), valuable coking coal, keeping the expenditure on dewatering and processing within limits,
(c) to optimize the cost of vertical hoisting, i.e., by the use of as little water as possible.

These requirements could be met only by the installation of a high-pressure vessel — the three-chamber pipefeeder, which is the heart of the vertical hoisting system.

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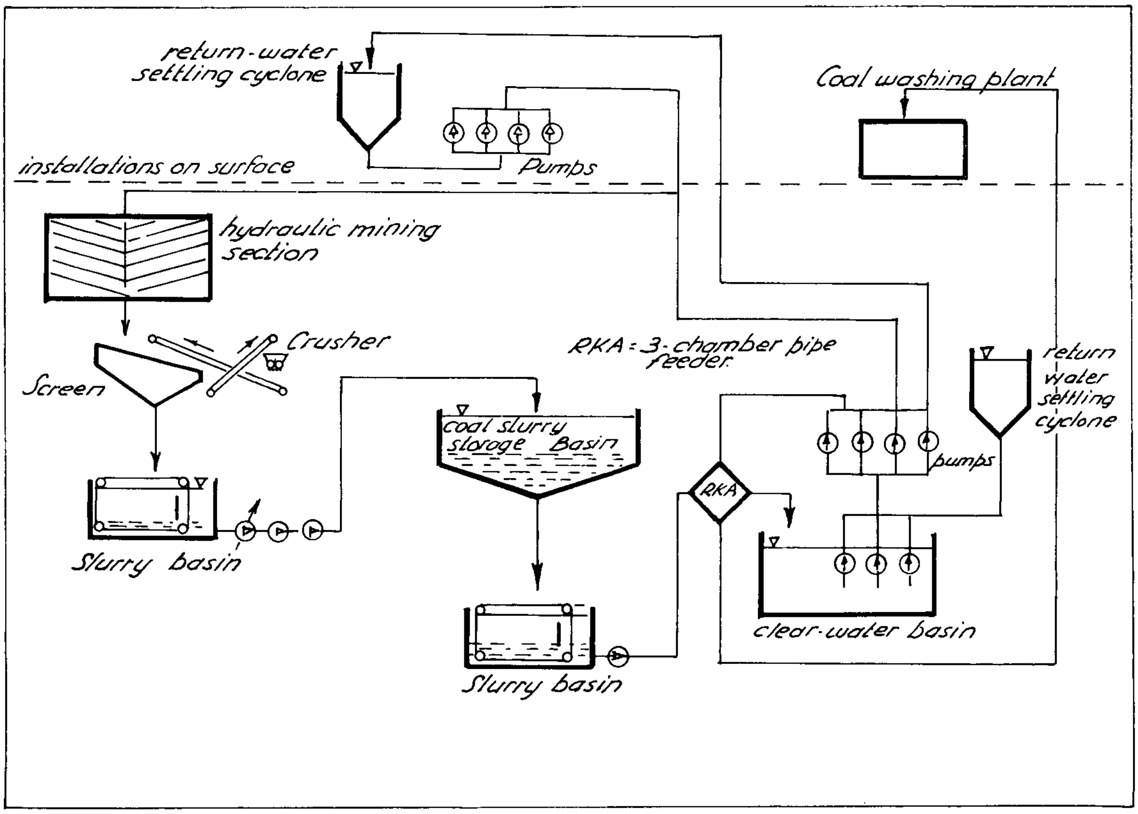

Fig. 1—Hydraulic mining and transportation system for coal at the Hansa Mine

Three-chamber Pipefeeder

Details of the three-chamber pipefeeder are shown in Fig. 2, including the slurry mixing tank with the water–solids mixture, the clear-water basin, the high-pressure and low-pressure pumps, and the pipefeeder with its three pipe chambers, each 350 m in length.

While chamber C is being filled with coal slurry from the low-pressure slurry pump at 3 to 5 bar, chamber B, which was filled in a previous cycle, is discharging at high pressure. For this operation, the high-pressure pump forces clear water under high pressure in the opposite direction into the chamber, and forces the slurry into the vertical hoisting pipeline. As a function of the conveying velocity and the length of the chambers, this working cycle lasts approximately 1 to 2 minutes; with the pipe loop at the Hansa Mine, it lasts approximately 80 seconds. Chamber A, which has already been filled with slurry and is still at low pressure, is in a waiting position. The main valves at the inlet and outlet sides are closed, and, before the conveying operation starts, the bypass valve to the high-pressure line opens to enable the build-up of necessary conveying pressure within the chamber. Then the main valve (which has been closed) opens, and the conveying operation starts. At that moment, chamber C terminates the conveying operation, and the main valves at the inlet and outlet sides of the pipe loop close. Then the bypass valve, which is connected to the low-pressure line, opens and decreases the high pressure within the chamber, which is then ready for the next filling operation.

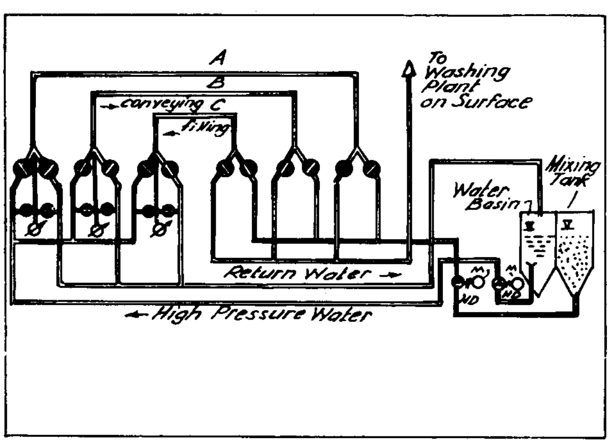

Fig. 2—Details of the three-chamber pipefeeder

The complete filling and conveying operation is conducted according to a definite programmed control scheme, and is monitored electronically by the action of limit switches on the valves, indicating the open or closed position.

The main advantages of the three-chamber pipefeeder are as follows.

(1) The water-solids mixture is fed continuously into one of the pipe loops and enters the hoisting pipeline continuously.

(2) After the conveying operation, the clear water from the high-pressure pump returns to the clear-water basin and is again available as high-pressure conveying water.

(3) Solids do not come into contact with the high-pressure pump so that multistage centrifugal pumps with high efficiency can be used.
(4) Wear-resistant plate slides are used.
(5) The system is controlled in such a manner that the high-pressure slide valves are moved only in the clear-water stream.

Regulation and Control of Density

The hydraulic transportation of a slurry containing as little water as possible can be achieved only if an optimum proportion of solids and water is maintained in the conveying pipeline and pipeline blockages are avoided.

The control method adopted at the Hansa Mine is illustrated in Fig. 3. The filling velocity of the slurry is measured by a flow meter in the clear-water return of the pipe feeder. This point has the same velocity as the filling pipeline and can therefore be used as a metering point, so saving the metering device from wear. The velocity of the conveying water within the high-pressure pipeline is detected immediately in front of the pipe feeder. A density-metering device is installed at the suction side of the slurry-filling pump and provides a feed-back circuit for the regulation of the speed of the scraper-belt conveyor, and thus for the control of solids addition. The density regulation is done automatically in accordance with a previously set desired value.

TABLE I

HYDRAULIC HOISTING OF RUN-OF-MINE COAL, HANSA MINE

General characteristics	
Hoisting height, geodetic	850 m
Planned output per day	5 000 t
Planned output per hour	250 t
Average waste content	30 %
Maximum ore size	−60 mm
Diameter of pipe	250 mm
Characteristics of the three-chamber pipefeeder	
Length of pipe chamber	356 m
Diameter of pipe chamber	250 mm
No. of hydraulic valves	12
No. of equalizing valves	6
Cycle time per chamber	80 s
Filling velocity	4,5 m/s
Output velocity	4,8 m/s
Characteristics of high-pressure pumps and motors	
Underground:	425 m³/h 120 bar
Power (inst.)	2 100 kW
Surface:	425 m³/h 40 bar
Power (inst.)	800 kW

Hoisting System at the Hansa Mine

Table I gives the most important characteristics of the vertical hoisting installation at the Hansa Mine. The installation is designed for a daily output of 5000 t of run-of-mine coal (corresponding approximately to a saleable output of 3500 t), which is hoisted to the surface in one stage over 850 m, with a maximum particle size of 60 mm.

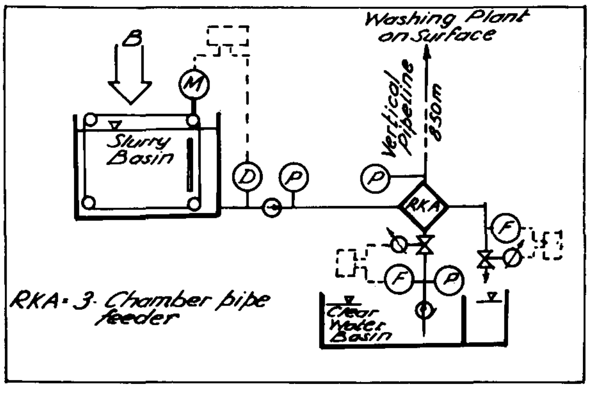

Fig. 3—Measuring and control instruments for the vertical hoisting of slurry at the Hansa Mine
B Run-of-mine coal slurry
D Density-measuring device
F Flowmeter
M Motor driving the chain scraper
P Pressure-measuring device

The installation was designed for an average transport concentration of 20 per cent, which corresponds to an output of 250 t/h, but the commissioning and start-up experience showed that material of relatively large particle size (60 mm) can be hoisted at a higher transport concentration. The output is now normally higher than 300 t/h, and outputs of more than 400 t/h have been achieved (Table II).

Table III shows the results for a normal hoisting day, taken after the start-up period of the mine. The output of 2132 t, which at that time came from only one mining section, was hoisted to the surface in 6,27 hours. An average waste content in the run-of-mine coal of 29 per cent gave a relative density for the solids of approximately 1,6.

TABLE II

SELECTED PRODUCTION FIGURES AT HANSA MINE

Date	Production t/d	Operating time	Output t/h	Waste %	Average density of solids	Transport concentration %	Average density of slurry	Remarks
	5 000	20 h	250	20	1,535	19,27	1,103	Planning, etc.
15.8.78	755	1 h 39 min	458	27,35	1,591	34,0	1,201	Highest output
20.10.78	3 544	10 h 17 min	350	28,42	1,600	25,9	1,155	Highest daily output
25.5.79	4 118	11 h 30 min	358	27,68	1,500	28,0	1,140	
24.10.78	2 245	8 h 07 min	277	33,29	1,640	20,0	1,128	Highest percentage of waste
3.11.78	2 741	8 h 12 min	334	21,61	1,547	25,5	1,139	Average daily production

TABLE III

RESULTS FOR A NORMAL HOISTING DAY, HANSA MINE

Hoisting production for 19.6.78		
Proportion of run-of-mine coal		
Coking coal	1 157 t	54%
Middlings	60 t	3%
Waste	535 t	25%
Coal sludge	380 t	18%
	2 132 t	100%
Coal and waste		
Coal		71%
Waste		29%
Relative density		
Coal	1,4	
Waste	2,5	
Run-of-mine coal	1,6	
Capacity of pipefeeder		
Output of run-of-mine coal	340 t/h	
Volume of slurry	850 m³/h	
Hoisting time	6,27 h	

The calculations shown in Table IV are derived from this value. The most significant is the transport concentration, which is given as 25 per cent. This corresponds to a water:solids ratio of 3:1, and an average slurry density of 1,15.

The three possible alternatives in vertical hydraulic hoisting, and the energy costs per ton of run-of-mine coal, are given in the following sections.

Alternatives in Hydraulic Vertical Hoisting

Hoisting Using Underground Water

Fig. 4 shows the engineering concept of vertical hoisting using water supplies from underground. The hoisting is achieved by the three-chamber pipefeeder. The mixture of water and solids is fed via the low-pressure slurry pump from the slurry basin into the pipefeeder. The vertical pipeline is 850 m in length, and leads direct into the washing plant on surface by means of a short horizontal pipeline. The high-pressure clear-water pumps, each with a capacity of 425 m³/h at 120 bar, are driven by electric motors that have an installed power of 2100 kW and are situated in a pump chamber underground.

TABLE IV

CALCULATIONS BASED ON THE HOISTING RESULTS OF 19.6.78

Output: Solids $M_s = 340$ t/h

Slurry $V_{Tr} = 850$ m³/h

Volume of solids

$$V_s = \frac{M_s}{S_s} = \frac{340}{1,6} = 213 \text{ m}^3/\text{h}$$

Transport concentration

$$C_T = \frac{V_s}{V_{Tr}} = \frac{213}{850} = 0,25 = 25\%$$

Proportions of water and solids (by volume)

$$\frac{V_f}{V_s} = \frac{V_{Tr} - V_s}{V_s} = \frac{850 - 213}{213} = 3:1$$

Average velocity of slurry

$$V_{Tr} = \frac{V_{Tr}}{A_{Pipe}} = \qquad = 4,82 \text{ m/s}$$

Average density of slurry

$$S_{Tr} = \frac{S_s \cdot V_s + S_F \cdot V_f}{V_{Tr}} = 1,15 \text{ t/m}^3$$

s = solids
f = fluids
Tr = slurry

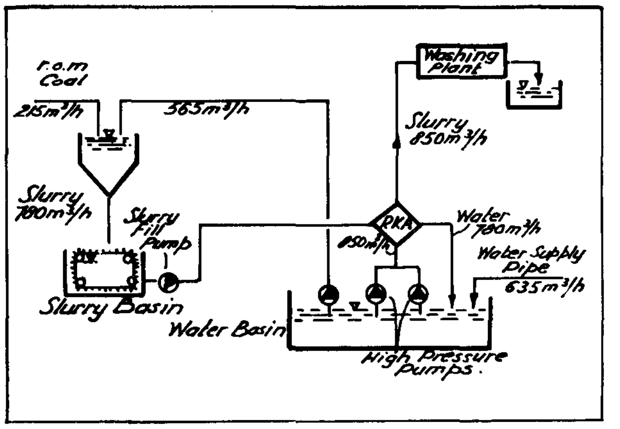

Fig. 4—Method of vertical hoisting using water from underground

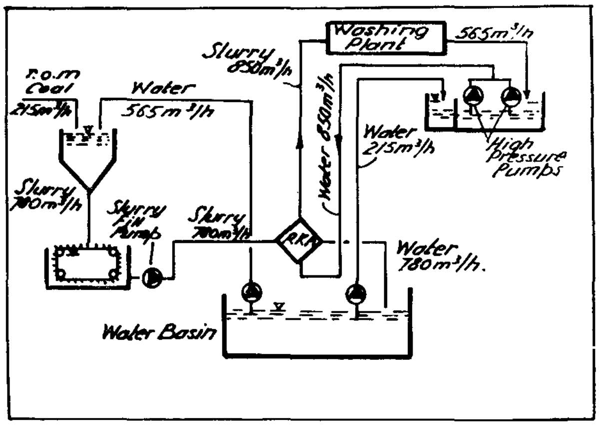

Fig. 5—Method of vertical hoisting using water from the surface

Hoisting Using Water from Surface

Fig. 5 shows the layout for vertical hoisting with water from the surface. The filling operation to the pipefeeder is done in the same way as for hoisting with water from underground. In this case, however, the high-pressure pumps are positioned on the surface and are connected direct to the three-chamber pipefeeder underground via a high-pressure pipeline in the shaft.

Whereas it is necessary to generate a pressure of 100 to 120 bar with the pumps installed underground, a water pressure of only approximately 40 bar is sufficient with a pump installation on the surface, because compensation has to be made only for the friction losses of the pipeline.

In this hydraulic hoisting variation, some high-pressure water remains underground, its volume being equal to the volume of solids it replaces in the pipefeeder during the hoisting cycle. At the Hansa Mine, this surplus water is fed to the clear-water basin and is available for the supply of high-pressure water to the monitors in the mining sections. If these sections do not need the high-pressure water, it is pumped, during a stoppage in hoisting, by one of the high-pressure pumps

TABLE V

COST OF ENERGY FOR THE THREE ALTERNATIVES IN HYDRAULIC HOISTING

	Water supply (340 t of solids per hour at a hoisting height of 850 m)		
	From underground	From surface	From surface and underground
Installed electrical power, kW			
Slurry fill pump for 3-chamber pipefeeder	250	250	250
Slurry feeding basin	130	130	130
Hydraulic equipment for 3-chamber pipefeeder	30	30	30
Slide valves, etc.	40	40	40
High-pressure pump 1	2 100	800	2 100
High-pressure pump 2	2 100	800	800
Booster pumps	160	160	160
Total	4 810	3 010	3 510
Effective power, kW	4 570	2 860	3 335
Cost per kW.h (Germany), DM	0,10	0,10	0,10
Energy cost per ton of run-of-mine coal, DM	1,34	0,84	0,98

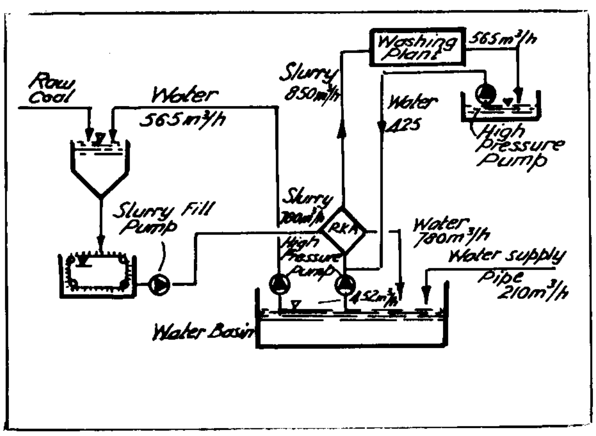

Fig. 6—Method of vertical hoisting using water both from the surface and from underground

underground through the hoisting pipeline into the water reservoir on the surface.

The general advantages of this variation are as follows.

(a) The high-pressure pumps, which have an installed power of only 800 kW, are located in an easily accessible area on the surface, where the conditions and available space are more favourable. In this respect, this alternative is comparable in principle with conventional hoisting by skip, where the winding gear is also placed on the surface.

(b) The capacity of the high-pressure pumps is small in comparison with the pump capacities needed for hoisting with underground water, and the investment and operating costs are favourable.

Hoisting Using Water from the Surface and from Underground

In the third alternative, which has proved itself at the Hansa Mine, the high-pressure water is taken from the surface and from underground. In this installation (Fig. 6), one high-pressure pump is situated on the surface, and the other is installed in a pump chamber underground. The prerequisite for such a combination is that the operation of the two pumps should be synchronized.

As with the other alternatives, the pipefeeder return water is used as a high-pressure water supply to the working face. However, water that flows into the mine, which would have to be pumped to the surface in any case, can be used in the hoisting operation. The advantages of this alternative are as follows:

(1) flexibility with regard to minewater inflows of varying quantities,
(2) the possibility of installing an economic hydraulic hoisting system in mines without water inflows,
(3) the economic aspects, particularly with regard to energy costs.

Costs of Energy for the Three Alternatives

As can be seen from Table V, the necessary power for the operation of the three-chamber pipefeeder, independent of the kind of hoisting used, is approximately 450 kW. Alternative 1, with two high-pressure pumps underground, requires installed power of 4810 kW. The effective power is approximately 4570 kW, which, in Germany at a price of DM 0,10 per kilowatt-hour, costs DM 1,32 per ton of run-of-mine coal.

For alternative 2, where water is supplied from the surface, the high-pressure pumps on the surface have a capacity of 800 kW each. However, an additional pump of approximately 800 kW has to be used for the return of surplus water, which accumulates in the mine as a result of the pipefeeder operation. The calculated cost, based on 2860 kW per ton of run-of-mine coal, amounts to DM 0,84.

Alternative 3, with high-pressure water supplied both from the surface and from underground, has a power demand of 3335 kW, which is just slightly higher than the 2860 kW for water from the surface (alternative 2). However, the additional water flowing into the mine can be pumped to the surface using the hydraulic hoisting system, so decreasing the volume of water to be pumped to the surface by the normal pumping system and thus effecting savings in pumping installations. The costs of energy per ton of run-of-mine coal amount to DM 0,98.

Summary

Since November 1977 at the Hansa Mine, coarse (up to 60 mm) run-of-mine coal has been hoisted hydraulically to the surface over a height of 850 m. The hoisting is carried out with a three-chamber pipefeeder, by means of which up to 400 t of run-of-mine coal can be lifted per hour in a single stage and transported to surface straight into the washing plant.

Since the commissioning and start-up periods, the three-chamber pipefeeder has been working without malfunction, and has proved to be an efficient and reliable hoisting installation.

A vertical hydraulic hoisting system can be operated with water supplies from the surface, from underground, or both from the surface and from underground. Mine water, which would in any event have to be pumped out, can be utilized for the hydraulic hoisting operations, so that a cost saving can be achieved.

This system relieves the load on the conventional hoisting equipment, and therefore increases the hoisted tonnage and the throughput capacity of the shaft.

Acknowledgements

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Face ends technology

The Institution of Mining Engineers has announced that they are sponsoring, in conjunction with The Association of British Mining Equipment Companies, the first Face Ends Technology Exhibition and Symposium, which will be held in the Conference and Exhibition Centre, Harrogate, Yorkshire, England, from 8th to 13th December, 1980.

All member companies of ABMEC are being invited to exhibit together with the Institution of Mining Engineers, The Mining Research Development Establishment, British Mining Consultants Ltd, the Health and Safety Executive (Safety in Mines Research Establishment).

The objective of this exhibition and symposium is to create a shop window for British Mining Technology relative to Face Ends and Gate Roads Systems. The exhibition will be of particular interest to graduates and students leaving university, technical colleges, and school, as it will give them an opportunity to see and hear at first hand the career prospects available to them throughout the mining industry.

Both the exhibition and symposium have the support of the National Coal Board. So that a complete exposition on this subject is given, the speakers at the symposium have been chosen for their expertise in developing and applying this technology.

All further information on FETEX '80 is available from Mr George Strong, Secretary of the Institution of Mining Engineers, Hobart House, Grosvenor Place, London SW1, England.

Geomechanics

The 29th Geomechanics Colloquy, which is being organized by the Austrian Society for Geomechanics, will be held in Salzburg on 9th and 10th October, 1980.

The themes of the four half-day sessions will be

1. Present-Day Engineering Geology
2. Geomechanical Problems in Dam Construction
3. Recent Experiences in Subground Engineering
4. Cases of Failure in Tunnelling.

Official languages will be English and German, with simultaneous translation of the papers and discussions.

Enquiries should be directed to the Austrian Society for Geomechanics, 5020 Salzburg/Austria, Paracelsusstrasse 2.