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# The influence of binder addition on the hydraulic transport of classified-tailings backfill

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**SYNOPSIS**

In certain underground stope-support applications, silicated backfill is favoured over the conventional classified-tailings backfill. This is due to the lower water run-off and high early fill strength associated with silicated fills. Little work has been done on the effect of binder addition on the performance of pipeline-backfill distribution systems. This paper examines the influence of binder addition on the hydraulic-transport properties of classified-backfill slurries.

**SAMEVATTING**

In sekere ondergrondse bestuttingstoepassings in afbouplekke word verkieselde terugvulling bo konfensionele terugvulling met geklassifiseerde uitskot verkies. Die rede is die verminderde afloop van water en die opvulselsterkte wat met verkieselde opvulsel geassosieer word. Daar is nog min werk gedoen met betrekking tot die uitwerking van bindstofbyvoegings op die werkverrigting van die terugvulpypleiding-verspreidingstelsels. In hierdie studie word ondersoek ingestel na die invloed van byvoeging van bindstof op die hidrouliese vervoereienskappe van verkieselde terugvulflodder.

## INTRODUCTION

Spearing and Smart[1] identified several shortcomings associated with backfill systems consisting of classified tailings:

(1) post-filling shrinkage of the backfill away from the hangingwall,
(2) low early strengths, especially in areas of higher stoping,
(3) run-off of water and solids,
(4) problems with the stability of the classified-backfill high wall, particularly for higher stoping widths.

Silicated backfill eliminates the run-off of water and solids (and, hence, post-filling shrinkage), and produces a placed fill of high early strength. There are two components in such systems.

(a) If no underground storage is used, the first additive, the **binder**, is added to the backfill slurry before it is discharged into a range; otherwise, the binder is added immediately after the last underground storage tank. The binder consists typically of a blend of ordinary Portland cement and pozzolans.
(b) Immediately before the placement, the **accelerator** solution is added to the backfill line by means of a non-return mixing nozzle.

An investigation was conducted to establish the influence of binder addition on the hydraulic-transport characteristics of classified backfill slurry. This paper describes and presents the results of the investigation.

## EXPERIMENTAL

### Pipeline Test Apparatus

The layout of the pipeline test facility is illustrated schematically in Figure 1.

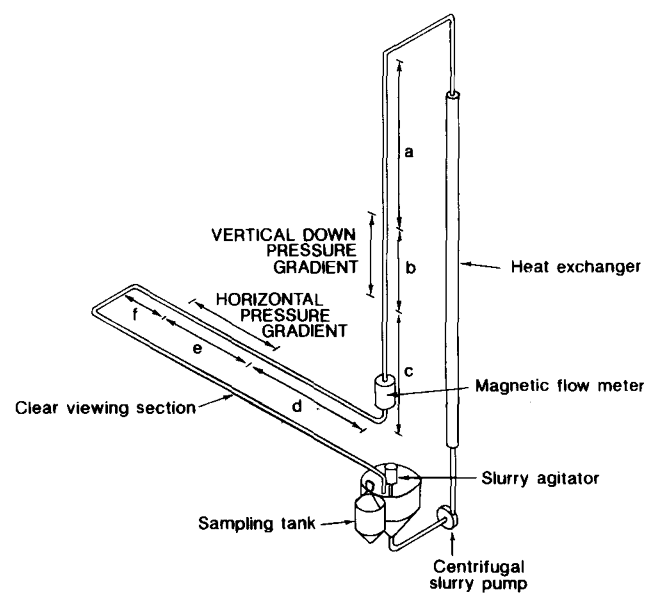


**Figure 1—The layout of the test facility**

The following measurements and observations are recorded during a pipeline test.

The **relative density of the slurry** is determined from the total slurry flow, which has been diverted to the sampling tank. The relative density of the delivered slurry is calculated from the mass and volume of the sample. For the highly concentrated backfill slurries considered in this paper, the relative density of the slurry (i.e. leaving the pipeline) and the *in situ* slurry relative density (i.e. within the pipeline) are taken to be equal.

The **flowrate of the slurry** is measured with a magnetic flowmeter. The output of the flowmeter is verified and calibrated by use of the sample tank. The flowrate is calculated from the duration and volume of the sample. The slurry flowrate is changed by variation of the rotational speed of the centrifugal pump used to recirculate the slurry.

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The **pressure gradients in the pipeline** are determined from differential pressure measurements made by the use of static pressure tapping located in the pipe wall. The pressures are recorded with differential pressure transducers, air-over-water manometers being used to calibrate and verify the output of the pressure transducers. Each pressure tapping is connected to a solids trap to ensure that the pressure transducers and manometers are isolated from the slurry.

The **slurry temperature** is measured with a temperature probe located in the slurry hopper. The probe is calibrated by use of a mercury thermometer. An inline heat exchanger is used to reduce the build-up of heat in the system and so maintain a constant temperature in the slurry during a test.

The clear section of pipeline permits the **slurry flow regime** to be observed, and allows the **stationary deposit velocity** to be determined visually.

The electrical output of the magnetic flow meter, pressure transducers, and temperature probe are recorded by use of a computer-based data-logging system.

### Test Procedure

The operation and test procedures for the pipeline tests are discussed in detail by Cooke[2]. The following is a brief description of the test procedure used for the backfill-additive tests.

(1) Material is loaded into the pipeline test rig until the slurry has the desired density.

(2) The slurry is pumped through the pipeline at a set mean mixture velocity. The pressure gradient in the pipeline is recorded to verify that the pressure gradient does not vary with time.

(3) The pressure gradient in the pipeline is measured for a range of mean mixture velocities and the stationary deposit velocity (i.e. the mean mixture velocity at which stationary particles are first observed within the pipe) is determined.

(4) The required quantity of dry binder is poured slowly into the hopper, and water is added to ensure that the relative density of the slurry is kept constant. The binder is mixed well with the backfill slurry by the action of the pump and the hopper agitator motor. The binder dosages are discussed in the next section.

(5) The slurry with binder added is pumped through the pipeline at a set mean mixture velocity. The pressure gradient in the pipeline is is recorded to verify that the pressure gradient does not vary with time.

(6) The pressure gradient in the pipeline is measured, and the stationary deposit velocity is determined for the mixture of backfill slurry and binder.

### Binder Dosages

The standard rate of binder dosage in the industry for a slurry with a relative density of 1,70 is 5,0 per cent dry powder by wet slurry mass. In practice, the required quantity of binder is mixed with water to form a mixture with a relative density equal to that of the backfill slurry prior to mixing. In these tests, the dry binder was mixed with the backfill slurry, and make-up water was added to ensure that a constant relative density was maintained in the backfill slurry.

The tests were conducted at slurry relative densities of 1,65, 1,70, 1,75, and 1,80. The binder dosage rates used for the tests (shown in Table I) maintain a constant binder-to-water ratio of 0,14 kg/l.

**Table I**
**Binder dosage rates**

| Relative density of slurry | Binder addition (% dry powder by wet slurry mass) |
|---|---|
| 1,65 | 5,4 |
| 1,70 | 5,0 |
| 1,75 | 4,6 |
| 1,80 | 4,2 |

As the relative density of the slurry is increased, the quantity of additive required is reduced, thereby reducing the cost of the additive used. In addition, the increased relative density of the slurry results in a less porous placed fill and, thus, in a backfill of higher ultimate stiffness.

## RESULTS AND DISCUSSIONS

The results presented are for a typical backfill slurry of classified tailings in a pipeline of 50 mm nominal bore.

### Stationary Deposit Velocity

The stationary deposit velocity as defined earlier is the mean mixture velocity at which stationary particles are first observed within the pipe. Figure 2 shows the variation of stationary deposit velocity with slurry density for the tests with and without binder. The effect of the binder addition is to slightly decrease the stationary deposit velocity owing to the increased mixture velocity.

### Flow Regime

Cooke[2], from pipeline tests with cyclone-classified tailings material, noted that the behaviour of the mixture changed as the relative density (solids concentration) of the slurry increased. Table II shows the various flow regimes identified and the associated relative densities.

### Pressure Gradient Versus Pumping Duration

Figures 3 to 6 show how the pressure gradient in the pipeline and the mean mixture velocity vary with time at a nominal set velocity with binder added. The variation of the

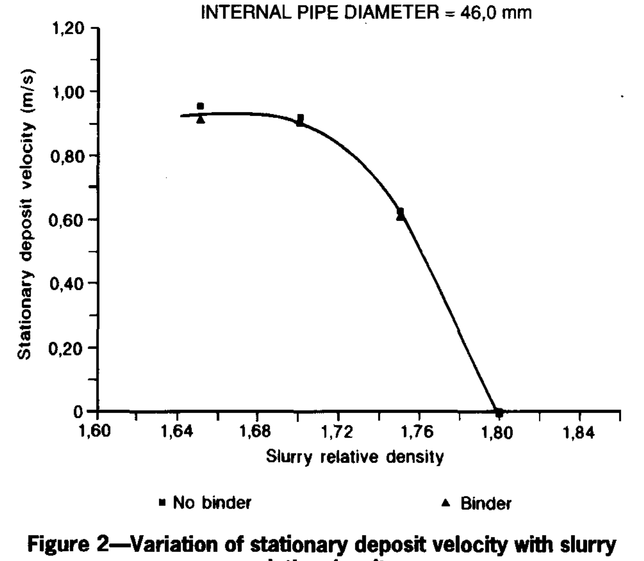


**Figure 2—Variation of stationary deposit velocity with slurry relative density**

**Table II**
**Slurry flow regimes**

| Slurry relative density | Flow regime and characteristics |
|---|---|
| 1,65 | **Heterogeneous.** The solid particles are suspended by fluid turbulence and interparticle contact. In a horizontal pipe, the flow regime is characterized by an increase in the concentration of solid particles towards the pipe invert. At high flow velocities, the mixture appears homogeneous (termed pseudo-homogeneous) owing to the uniform suspension of solid particles by turbulence. As the mixture velocity is decreased, particles settle, initially forming a sliding bed and then a stationary bed. The sliding bed is noted for 'pulse-like' movements, which are associated with the formation of dunes in the pipeline. |
| 1,70 | **Transition** between heterogeneous and dense-phase flow regimes. |
| 1,75<br>1,80 | **Dense Phase.** The concentration of solid particles equals or exceeds the concentration of freely settled (loosely packed) particles, and the dominant mechanism supporting the particles in the mixture is interparticle contact. The concentration of solid particles is uniformly distributed within the pipe. |

ratio of each individual data value to the mean value is plotted against the pumping duration.

Figure 3 shows that the pipeline pressure gradient is constant with respect to time for the test conducted at a slurry relative density of 1,65 with binder addition. Similar results are seen in Figures 4 and 5 for tests with binder additions at relative densities of 1,70 and 1 ,75 respectively. The greater fluctuation of the pressure gradient with time for the 1,70 slurry is associated with the transition from heterogeneous to dense-phase flow.

The variation in pressure gradient with time for the slurry of 1,80 relative density with binder addition is shown in Figure 6. The pressure gradient increases by 56 per cent over a 50-minute period, and the trend indicates that the pressure gradient will continue to increase with time. The test was not continued because the pressure difference was at the limit of the transducer span. The increase in pressure gradient can be attributed to rapid hydration of the binder within the slurry as a result of the binder-to-water ratio and the temperature of the slurry.

The ratio of binder to total water in the mixture was constant in all the tests. However, as the solids concentration was increased, the 'water demand' of the solid particles increased, and consequently the amount of water available to react with the binder was reduced. Thus, for this test, a critical binder-to-water ratio may have been reached that permitted the hydration reaction to occur rapidly.

When a constant slurry temperature is maintained while slurry is pumped through a closed pipe loop, the system's input energy is removed by the inline heat exchanger. As the relative density of the slurry increases, the energy required to pump the slurry round the pipe loop increases owing to the higher pressure gradients. At high slurry relative densities, the heat exchanger does not remove sufficient heat, and thus the slurry temperature increases.

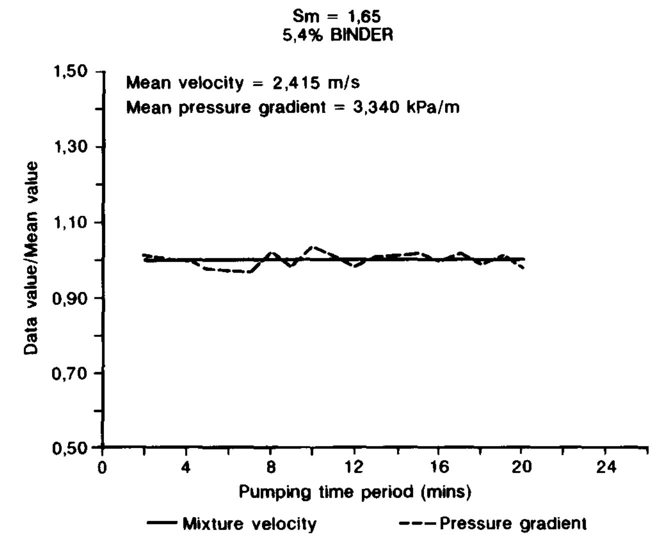


**Figure 3—Pumping duration versus pressure gradient at a slurry relative density of 1,65**

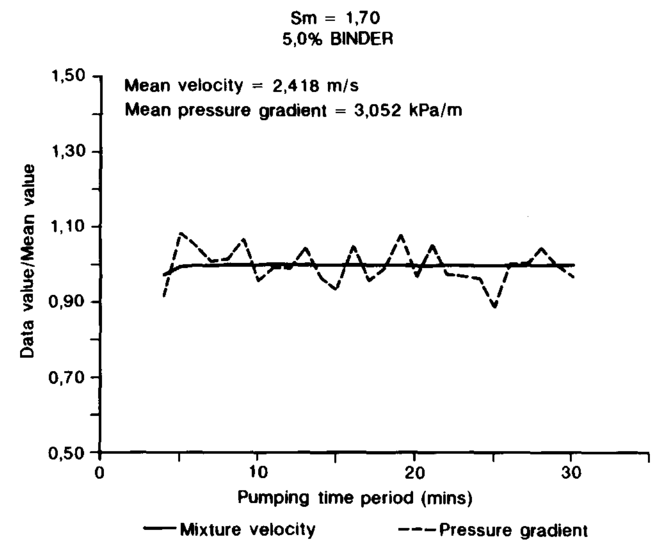


**Figure 4—Pumping duration versus pressure gradient at a slurry relative density of 1,70**

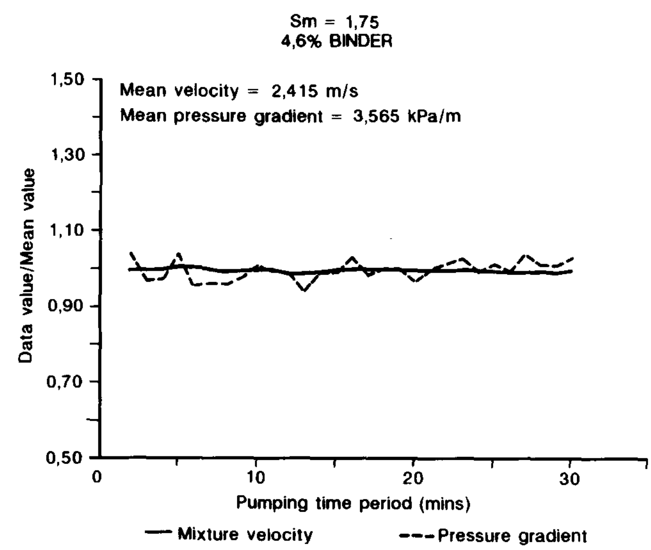


**Figure 5—Pumping duration versus pressure gradient at a slurry relative density of 1,75**

**Table III**
**Slurry temperatures**

| Slurry relative density | Mean slurry temperature (°C) |
|---|---|
| 1,65 | 25,6 |
| 1,70 | 27,2 |
| 1,75 | 29,9 |
| 1,80 | 34,3 |

The mean slurry temperatures for the tests with binder added are shown in Table III.

The slurry temperature in the last test listed may have been high enough to accelerate the hydration reaction, which would cause an increase in the pipeline pressure gradients.

## Pressure Gradient Versus Mean Mixture Velocity

Figure 7 compares the variation in pressure gradient with the mean mixture velocity for the test at a slurry relative density of 1,65 with and without binder addition. The addition of binder did not influence the pipeline pressure gradient in that there is no discernable difference between the two test results.

Figure 8 shows the variation in pressure gradient with the mean mixture velocity for the test at a slurry relative density of 1,70 with and without binder addition. The influence of the binder addition is to slightly decrease the pressure gradient at low mixture velocities, and slightly increase the pressure gradient at high velocities. This effect can be explained as follows.

At low velocity, the addition of binder assists the suspension of larger particles. Thus, the pressure gradient required to overcome friction due to the sliding bed (formed at low velocities) is reduced compared with that when the slurry has no binder.

At high velocity, the fine particles of the binder increase the viscosity of the vehicle portion of the mixture. Thus, at high velocities, at which the mixture rheology has a significant influence, the pipeline pressure gradient is increased compared with that when the slurry has no binder.

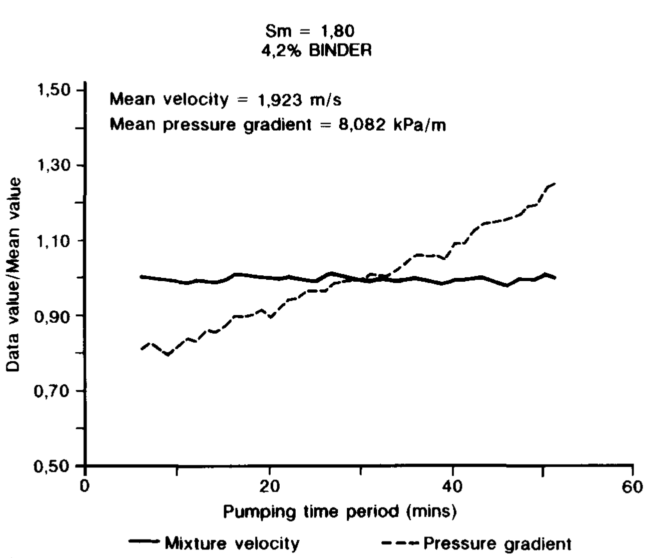


**Figure 6—Pumping duration versus pressure gradient at a slurry relative density of 1,80**

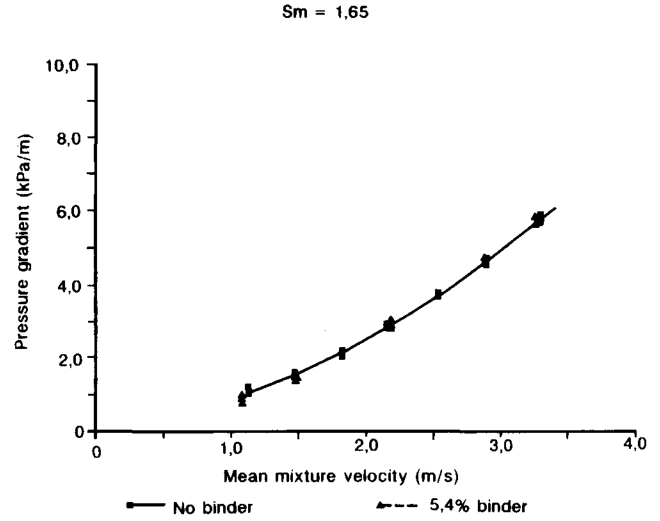


**Figure 7—Pressure gradient versus mean mixture velocity at a slurry relative density of 1,65**

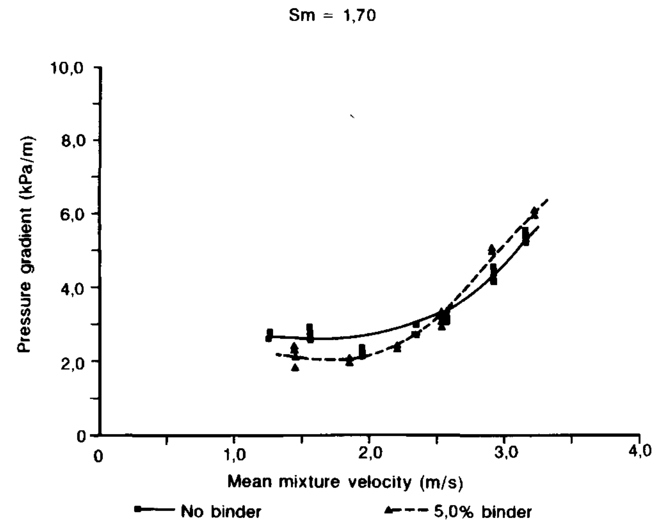


**Figure 8—Pressure gradient versus mean mixture velocity at a slurry relative density of 1,70**

Figure 9 shows the variation in pressure gradient with mean mixture velocity for the test at 1,75 relative density with and without binder addition. The influence of binder addition on the dense-phase flow regime is to marginally reduce the pressure gradient. This is probably because the binder assists in the creation of a lubrication layer between the particles and the pipe wall.

The variation in pressure gradient with mean mixture velocity is shown in Figure 10 for the test at 1,80 relative density without binder addition. The variation in pressure gradient with mean mixture velocity was not recorded owing to the continuous increase in pressure gradient, as shown in Figure 6.

## CONCLUSIONS

For the classified tailings tested, the influence of binder addition on the hydraulic transport characteristics for slurry relative densities of less than 1,75 is minimal, and will not significantly affect the performance of a backfill-distribution system.

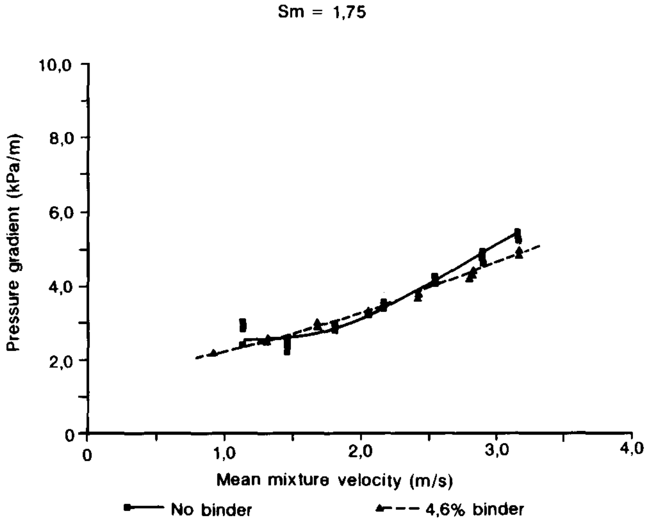


**Figure 9—Pressure gradient versus mean mixture velocity at a slurry relative density of 1,75**

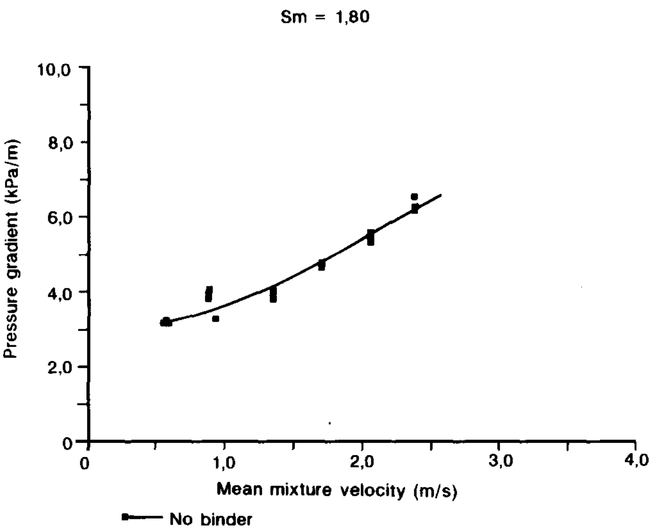


**Figure 10—Pressure gradient versus mean mixture velocity at a slurry relative density of 1,80**

The test conducted at a slurry relative density of 1,80 indicated a continuous increase in pressure gradient with time. The behaviour is probably due to rapid hydration of the binder within the mixture. The increase in the rate of the hydration reaction can be attributed to increased solids' 'water demand' and slurry temperature. With a view to the operation of backfill systems at higher relative densities, this phenomenon should be investigated further.

Backfill plants and distribution layouts for silicated fill systems should be designed to operate at a slurry relative density of 1,70 to 1,75 since this results in the following operational advantages:

- reduced pipe wear due to higher slurry relative density[3]
- reduced pipe wear due to the addition of binder[4]
- reduced additive cost and improved fill performance.

## ACKNOWLEDGEMENTS

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# Sasol Coal makes huge strides in the detection of dolorite*

Sasol Coal's Geology Department has developed a range of geological techniques for locating dolorite dykes and sills in coalfields well before mining takes place. One of the techniques, an adaptation of a standard oil-drilling technique, may rate as a world first in the coal industry. Another, seismic tomography, is believed to be a South African first.

The combined techniques provide sufficient information to enable mine management to plan the entire layout of a mine in advance, including the optimum location of shafts for accessing the coal. Enormous cost savings will be achieved as a result. In addition, the drilling adaptation, which enables the coal seam to be penetrated horizontally from surface, promises to revolutionize exploration drilling, with attendant cost savings.

## DIRECTIONAL DRILLING

The Geology Department recently completed a successful pilot test of the directional-drilling method when it penetrated the coal seam at Bosjesspruit Colliery—one of Sasol Coal's three underground collieries at Secunda. 'This test has established that it is a viable option', said Mr Chris Potgieter, Divisional Manager of Geological Services. He expects the new method to largely replace the existing conventional exploration methods of vertical drilling from surface and horizontal drilling underground. The test represents what is believed to be the world's first successful application of directional drilling from surface for coal exploration.

On a much larger scale, both in equipment and costs, the method is well established in the oil-exploration industry. The main challenge at Secunda was to reduce the cost of oil-drilling technology to such an extent that it would fit into colliery budgets. A low-cost wireless down-hole steering tool, developed in Australia, made a major contribution to the success of the project.

## SAVINGS

Mr Albert Hoffmann, a senior geologist at Sasol Coal, who initiated and closely assisted in the development of the new techniques, said the dolorite intrusions, which are a common problem in South African coalfields and are especially severe in the Secunda area, were the major reason for Sasol Coal's application of directional drilling and other available techniques in coal mining. Cost savings in mine planning and mine layout were another major driving force.

Savings of up to R20 million a year at Secunda Collieries through increased production and less frequent changing of sections can be achieved through the application of these techniques, which enable a mine to be planned as much as 20 years in advance.

## THREE MAIN TECHNIQUES

The main elements in this winning combination are

- aeromagnetic surveys
- directional drilling
- seismic tomography.

Aeromagnetic surveys, a geophysical method in which variations in magnetic properties are used to isolate the dolorites from the surrounding coal, provides a broad picture of the general location of intrusions in the coalfield. Sasol Coal started using this technique in 1990.

Directional drilling, probably the most useful single technique from the points of view of mine planning and cost saving, has been proved to be an effective method of locating intrusions in the coal seam well in advance of actual mining. Horizontal penetration of up to 1000 metres into the seam can be achieved with a single hole from surface.

Seismic tomography, which focuses on a specific portion of a seam to show the exact configuration of the dolorite intrusions, complements the broad picture established through the other two techniques.

In seismic tomography, detectors installed in a vertical drillhole in the coal seam register the impact of shots detonated in a neighbouring hole and give a clear profile of geological information between successive vertical boreholes. Thus, the exact location, thickness and shape of the dolorite intrusions can be established as further information needed in the planning of mining operations.

As with the directional-drilling method, Sasol Coal is believed to be the first mining group in South Africa to make use of this technique, which it has been developing since 1985.

* Issued by The Richmond Public Relations Group, P.O. Box 212, Melville, 2109 Transvaal.

# Technology and management in industry

The 1993 MIRO Annual Meeting will be held on 31 March at the Bloomsbury Crest Hotel, Coram Street, London, and will consist of a one-day Conference followed by the Annual Dinner.

The Conference will feature papers from ten invited speakers who are senior technical managers representing all facets of the industry.

Representatives from: American Barrick Resources, BRGM, British Coal, British Geological Survey, Cookson Group, Davy Process Technology, Lurgi GmbH, RTZ, and Shell will cover all aspects of the management of new technology, technology transfer, and technology and the market, from a European and a US perspective. The papers should be of particular interest to managers from the metals and minerals industry, but managers and research staff from all industries concerned with the introduction of new technology should attend.

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