J. S. Afr. Inst. Min. Metall., vol. 89, no. 12
Dec. 1989. pp. 387-394.

# Equipment alternatives for stoping in gold mines*

by A.G. DU PLESSIS†, D.G. WYMER†, and N.C. JOUGHIN†

**SYNOPSIS**

The use of a dense hangingwall-support configuration extending right up to the face would enable greater levels of safety and productivity to be achieved in stopes, and becomes a practical proposition if water jets are used for stope cleaning. Such an arrangement opens the way for extending the use of water hydraulic power to the whole stoping operation. This, in turn, can provide further productivity benefits and significant savings in working costs. With all the necessary equipment being available, such a system could be introduced immediately, although the designs of props and rockdrills are not yet ideal.

**SAMEVATTING**

Die gebruik van 'n digte dakstutkonfigurasie wat tot aan die front strek, sal dit moontlik maak om 'n groter mate van veiligheid en produktiwiteit in afbouplekke te bereik, en dit word 'n praktiese proposisie as waterstrale gebruik word om afbouplekke skoon te maak. So 'n reëling baan die weg vir die uitbreiding van die gebruik van hidrouliese waterkrag na die hele afboubewerking. Dit kan weer verdere produktiwiteitsvoordele en beduidende besparings van bedryfskoste inhou. Met al die nodige toerusting reeds beskikbaar, kan so 'n stelsel onmiddellik ingevoer word, hoewel die ontwerp van stutte en rotsbore nog nie ideaal is nie.

## Introduction

Currently one of the major impediments to the achievement of significant improvements in safety and productivity in gold-mine stoping operations is the degree to which good hangingwall support is possible with existing stoping equipment and configurations. This is particularly true for deep, narrow stopes and for those with a weak stratum in the hangingwall. The main problem is that the attainment of the desired support density at the face is compromised by difficulties in maintaining support close to the face and in cleaning blasted rock from around more closely spaced support.

In considering the use of improved stoping equipment and methods, therefore, the emphasis should be placed on approaches that facilitate, rather than detract from, good support. Alternative stoping equipment and suitable powering systems that can now make this possible are becoming available.

## Panel Layout and Equipment

A panel layout is depicted in Fig. 1. An essential feature is the use of closely spaced blast-resistant hydraulic props extending to within 1 m of the face before the blast. After the blast, the front row of props would be almost 2 m from the face, allowing a scraper to be run along the face. Once the face has been cleaned, and prior to the drilling of blastholes, props would be advanced to within 1 m of the face. At no time, therefore, would people be working in an area not adequately supported. Interlinked headboards would be used to increase the area of hanging supported directly and to help prevent dislodging during the blast. For adequate protection against rockfalls, a support resistance of up to 50 kN/m$^2$ would be aimed for.

Face cleaning would be carried out using hand-held water jets to move the blasted rock forward from between the props into the path of a scraper running along the face, as illustrated in Fig. 2. This method facilitates the use of closely spaced props, and has proved to be more versatile and labour productive than conventional cleaning. A further benefit is that the footwall is completely cleaned in this operation, and no additional sweeping of fines is necessary.

Use could be made of blast barricades mounted diagonally between rows of props, thereby containing the blasted rock while still allowing access for water jetting. Alternatively, backfill maintained relatively close to the face could provide confinement of the blasted rock.

Face rockdrilling equipment would have to be lightweight, compact, and easily manoeuvred in order to operate within the confines of space dictated by the support configuration. Hand-held rockdrills and thrustlegs are therefore proposed. The use of rigs or self-steered vehicles for drilling would not be feasible in this situation.

The adoption of an underhand face configuration, rather than a breast face configuration as shown in Fig. 1, could be advantageous, in that it could assist the water-jet cleaning operation and, if backfill were used, would keep the water used in the panel away from the fill.

## Choice of Stoping Equipment

Ideally, the hydraulic props would be lightweight to facilitate handling and installation, and would be sufficiently blast-resistant to allow for installation close to the face without having to be removed before the blast. Preferably, the hydraulic props should be powered by plain water. Existing hydraulic props require a hydraulic pressure of 20 to 40 MPa for setting. Depending on the type of hydraulic power source used, a pressure intensifier might be required to enable this pressure to be attained

* Presented at a colloquium entitled Equipment Alternatives in Underground Mining, which was organized by The South African Institute of Mining and Metallurgy and held in Johannesburg during September 1988.

† COMRO (Chamber of Mines Research Organization), P.O. Box 91230, Auckland Park, 2006 Transvaal.

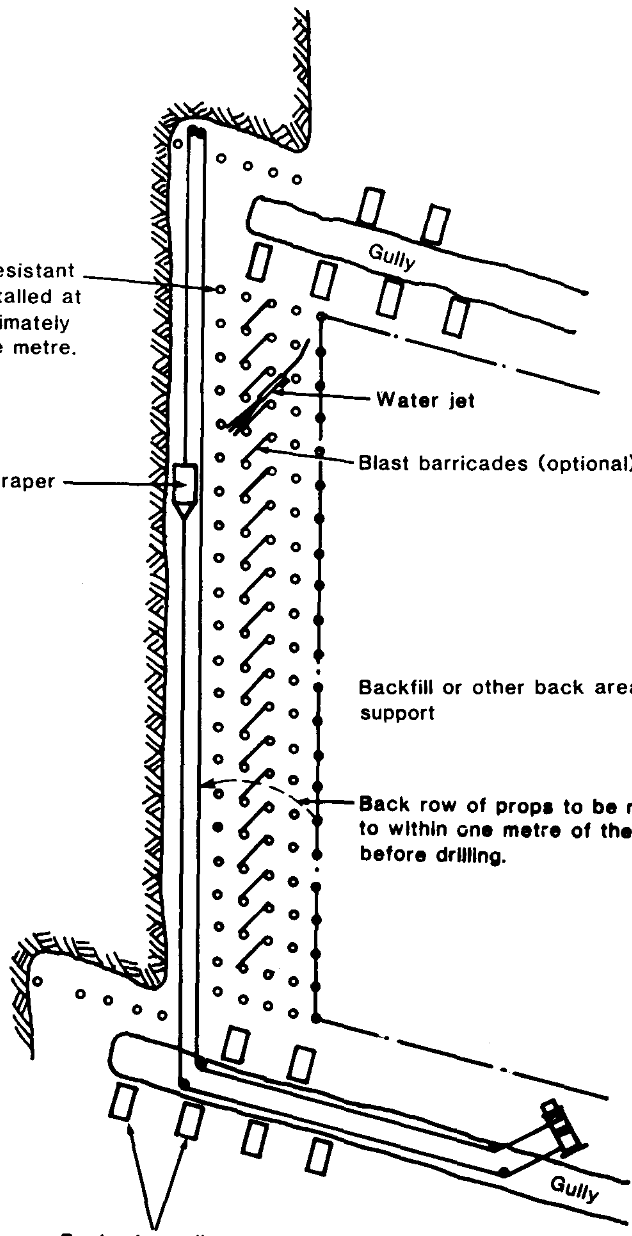


**Fig. 1—Panel layout with dense hydraulic-prop support, shown after a blast**

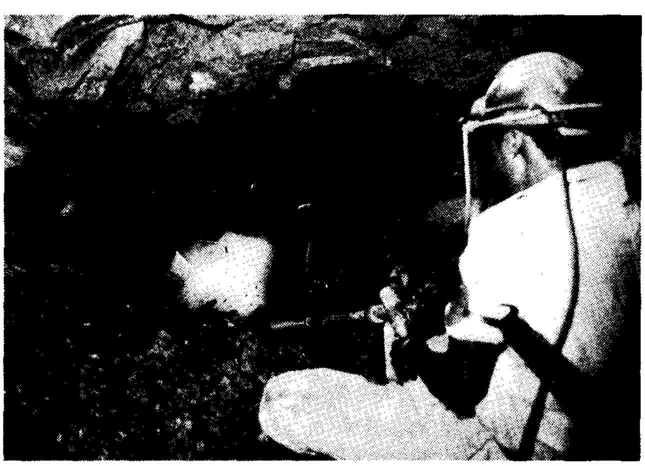

**Fig. 2—Water-jet assisted face scraping**

at the prop. Suitable compact intensifiers for insertion in the hydraulic supply line to the prop have been developed for this purpose. Water-powered blast-resistant props are available commercially, but the smallest version has a 200 kN setting force, making it relatively heavy and of unnecessarily high force for the dense support configuration proposed. In order to achieve the required support resistance, it is considered that a setting force of as little as 50 kN would be sufficient with a configuration of one prop per square metre. This would enable much lighter props to be used, which would be more easily handled than those available at present. Being of smaller volume, these props would require less water for setting. Therefore the intensifier, if required, could be even more compact than the version currently available. In addition to being designed for water powering, the props would need to exhibit sufficient resilience and robustness to avoid being dislodged during the blast. Few problems are foreseen in the development of such units, because the required technologies are well established.

The adoption of the dense support configuration proposed would greatly reduce the incidence of rockfalls at the face, and would facilitate improved productivity of the stoping activities. However, for severe rockburst conditions, it would still be necessary to use heavier props with setting forces from 200 kN upwards, possibly in combination with lighter, lower-force props.

Hand-held water jets for face cleaning have been the subject of a certain amount of engineering development to render them sufficiently safe, rugged, and reliable for use in stopes[1]. Suitable jetting guns are now available for use with water at pressures ranging from 9 to 18 MPa. Aside from making it possible to carry out face cleaning with the roof support system described above, the use of water jets enables much higher face-cleaning rates to be achieved. In trials conducted at Kloof gold mine over the past three years, average monthly cleaning rates of typically 20 t/h (scraper delays included) have been recorded using this cleaning method, approximately twice the average rate achieved elsewhere on the mine, where only face scrapers are used. The precise cleaning rates achievable obviously depend on panel length and on the condition and inclination of the footwall but, generally speaking, an improvement of at least 50 per cent can be expected. Labour productivity is also much improved because the scraper does not have to be rerigged during the cleaning operation, and because a separate activity to sweep fines is no longer necessary.

Conventionally, hand-held rockdrills and thrustlegs are powered by compressed air, but hydraulically powered versions operating on emulsion (98 per cent water) are now available commercially. These hydraulic drills are comparable in size and mass with compressed-air drills but, because their penetration rates are much greater, they are capable of achieving more than twice the number of holes drilled per hour. They are particularly effective in heavily fractured ground, and are environmentally much more acceptable because of reduced noise and elimination of fog.

The drilling performance of the emulsion-powered rockdrills has been measured exhaustively, and Table I shows some typical results obtained on various mines during a six-month period under a variety of production conditions[2].

The drilling rates given in Table I are more than twice those typically achieved with compressed-air drills. If full advantage is taken of this high performance, drilling labour productivities of up to 100 holes per shift can be achieved consistently with one drill. In practice, values as high as 160 holes per shift with one drill have been recorded on occasions.

The hydraulic emulsion for these drills needs to be supplied at a pressure of 14 to 18 MPa. Emulsion pumps capable of generating these pressures are available either in a conventional form, powered electrically, or in a form known as the hydro-transformer in which high-pressure water is used as the driving medium. Hand-held rockdrills and thrustlegs powered by plain water are under development. A prototype version is shown in Fig. 3, and versions are expected to become available commercially during 1991. With these, it will become possible to power the drilling operations directly from the same supply of high-pressure water as that used for props and water jets.

TABLE I
PERFORMANCE OF EMULSION-POWERED ROCKDRILLS USED FOR STOPING

| Production site | No. in crew | Steel length m | Bit rate mm | Average penetration rate m/min | Average drilling rate holes/h |
|---|---|---|---|---|---|
| A | 2 | 0,9 | 31 to 38 | 0,53 | 24,2 |
| B | 2 | 1,2 | 38 to 42 | 0,63 | 23,0 |
| C | 1* | 1,2 | 27 to 38 | 0,57 | 19,0 |

* The large stoping width at this site (2 to 2,5 m) made it possible to drill with a single operator

Fig. 3—Prototype water-powered rockdrill and thrustleg

A common feature of all hydraulically powered devices handled manually in stopes, including props, rockdrills, and water jets, is that they have to be powered through flexible high-pressure hoses connected to the powering installation. Standard hydraulic hoses do not survive well in the stoping environment owing to the susceptibility of the rubber cover to cutting and abrasion, and of the reinforcing wire to corrosion. Hoses of improved design and materials have been developed especially for this application, and are readily available commercially.

In any consideration of the equipment and its method of powering for the face layout shown in Fig. 1, the type of equipment to be used in the gullies should also be borne in mind. Gully equipment is essentially concerned with rockhandling; conventionally, the scraper winch is used for this purpose, but the continuous scraper and load-haul-dump vehicle (LHD) are alternatives[3]. All the options are fully compatible with the proposed face layout. Although scrapers are electrically powered at present, it is quite feasible to power them with high-pressure water, and a suitable scraper-winch drive based on a Pelton turbine has already been developed and proved, and is available commercially. If face scrapers are also powered in this way, the possibility then exists of powering the entire stope with water hydraulics. With this in mind, a range of ancillary devices (including items such as ventilation fans, watering-down guns, winch signalling bells, and blasthole cleaners) has been developed for operation on high-pressure water, enabling all external supplies of compressed air, electricity, and low-pressure service water to be eliminated from the stope if desired.

**Sources of Water Hydraulic Power for Stoping**

In recognition of the desirability of powering stoping machinery hydraulically, two alternative water-based hydraulic-powering technologies have been developed: electro-hydraulics and hydro-power.

In an electro-hydraulic powering system, high-pressure water or emulsion for the powering of stoping machinery is generated by electrically driven pumps. These pumps can comprise centralized installations that may serve a number of panels, or may constitute a distributed system, where they are located close to the working areas and are each sized to serve perhaps only one panel. The choice of system to be implemented will depend largely on the specific site and mine layout under consideration. A diagrammatic representation of a mine with a conventional compressed-air system is shown in Fig. 4, while Fig. 5 depicts an equivalent situation where electro-hydraulic power is used instead. It can be seen that the use of electro-hydraulics allows a simplification of the mine services infrastructure through the elimination of compressed-air reticulation to the stopes.

Since hydraulic rockdrills powered by plain water are not yet available commercially, any electro-hydraulic powering system for stopes will have to supply high pressure emulsion for this purpose at present. Conversely, water jets would be powered by plain water only. Props can be operated from either medium, although plain water is preferable. Separate electro-hydraulic pumping installations, supplying water or emulsion as appropriate, could be provided for the various items of equipment but, although technically viable, this would introduce unnecessary duplication of equipment.

An alternative approach would be to provide a single pumping installation operating on plain water, supplying props and water-jets directly, and supplying emulsion-powered rockdrills through hydro-transformers. Again, this is a technically viable approach, but the hydro-transformers constitute an additional equipment requirement.

A third option, considered to be the most attractive, is to provide one pumping installation that can be switched from water to emulsion as necessary, using appropriate changeover valving. In its simplest form, this approach is feasible only if rockdrilling and water jetting do not take place simultaneously. For the larger pumping installations this approach may not be possible, but the difficulty can be overcome by the installation of two or more smaller pumps instead of one large pump, and arranging for each to be operable independently on water or emulsion as required.

The alternative technology of hydro-power is based on the exploitation of the difference in elevation between the surface and underground workings of a mine to generate an underground supply of water at high pressure. This is then reticulated to the mining areas, where it is used to power stoping equipment directly, as well as to provide localized cooling and suppress dust. Versions of all the equipment necessary for the safe and reliable reticulation of hydro-power are available commercially, and system design processes have been developed[4,5]. Hydro-power, because of its inherent simplicity, represents an ideal powering source for the operation of the equipment required to implement the mining layout shown in Fig. 1. A hydro-powered mine is shown diagrammatically in Fig. 6, and it can be seen that a major simplification of the mine services infrastructure can now be achieved.

Since, for economic reasons alone, it is not feasible to add appreciable amounts of additives to the water in a hydro-power system, plain water is the only medium that can be considered. Thus, until water-powered hydraulic rockdrills become available in 1991, it will be necessary to use hydro-transformers for drilling operations, but all other equipment can be powered directly.

Equipment that can be powered by a hydro-power system has been developed to operate over a pressure range of 14 to 18 MPa, which corresponds approximately to the head available in a 1400 to 1800 m column of water. In many mines, only a lower pressure head may be available. In such cases, the technical feasibility and economic desirability of boosting the static pressure head available through electrically driven boost pumps has been established.

In the operation of a water hydraulically powered mining system, the implications for handling waste water both in stopes and mine wide are of obvious concern. However, theoretical studies[4,5] have indicated that conventional stoping operations powered by high-pressure water would require between approximately 0,6 and 1,8 tons of water per ton of rock mined. These theoretical figures have been confirmed by measurements taken in a stope operated entirely from hydro-power at Kloof gold mine. The water consumptions measured at Kloof for the items of equipment required for the implementation of the panel layout depicted in Fig. 1 are given in Table II.

TABLE II
MEAN WATER CONSUMPTIONS MEASURED IN THE HYDRO-POWERED STOPE AT KLOOF GOLD MINE

| Activity | Water consumption t/(t of rock mined) |
|---|---|
| Hydraulic drilling | 0,22 |
| Water jetting | 0,28 |
| Watering down | 0,03 |
| Blasthole cleaning | 0,07 |
| Prop setting | 0,01 |
| Total | 0,61 |

It is therefore apparent that the quantity of water required for hydraulically powered stoping is not very different from that normally required in conventionally powered stopes for cooling and dust suppression, and in fact will in many instances be considerably less. Therefore, any special provision for additional water supply, or for waste-water handling equipment and systems, would normally not be required.

Several economic feasibility studies in which the costs of water hydraulically powered stoping were compared with those of conventionally powered stoping have been conducted on various mines. The installation costs of

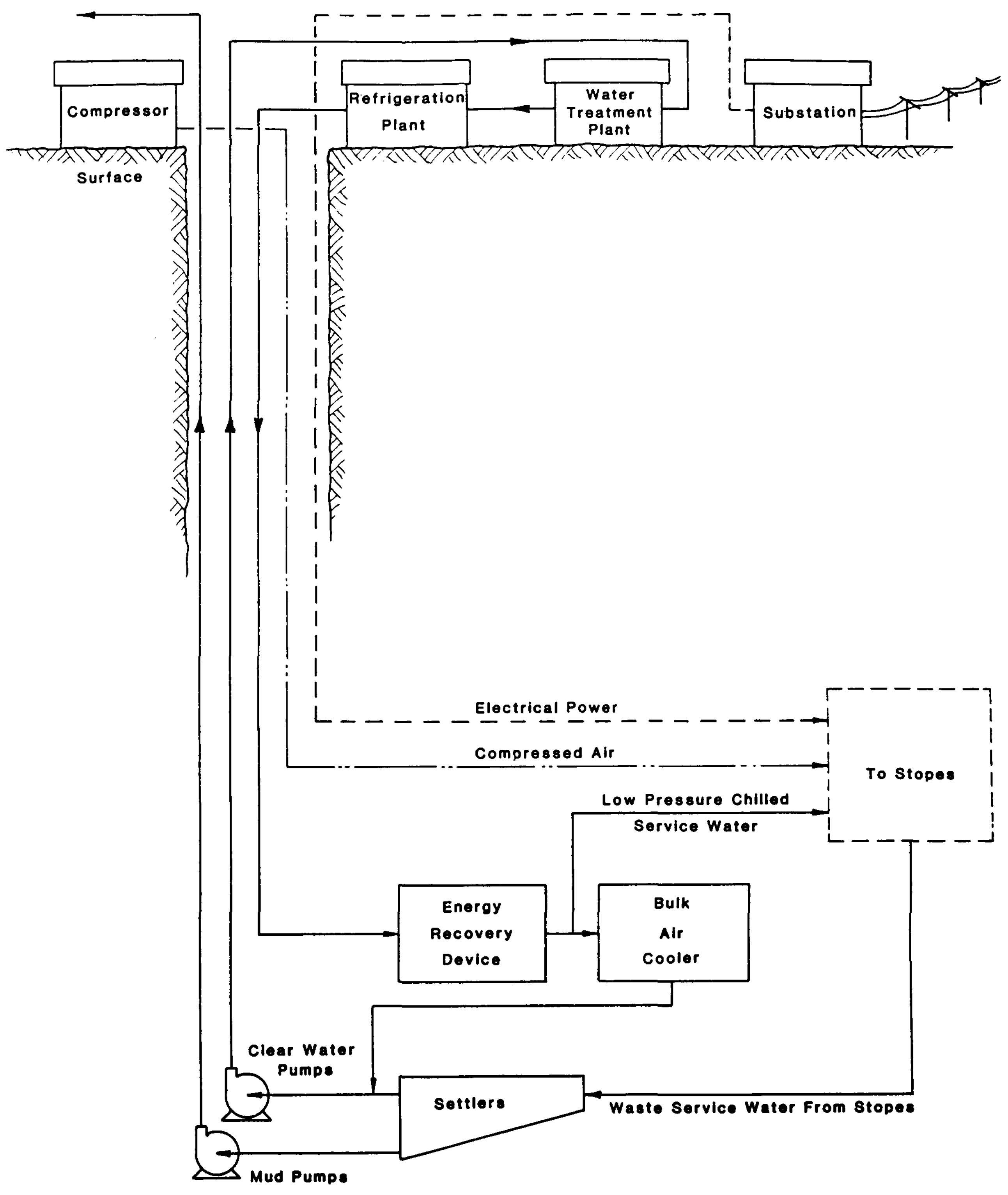


**Fig. 4—Basic stope powering and water reticulation in a mine powered by compressed air and electricity**

water powering systems were found to be strongly site-specific, but in every case the overall costs were significantly lower than those associated with conventional powering systems.

Rockdrills are the major consumers of energy in conventional stoping operations. The electric energy consumed on mines in the powering of compressed air rockdrills has been found to be at least 15 kWh per ton mined, much of this being dissipated in the form of air leaks and misuse. In contrast, measurements of electric energy conducted over many tens of thousands of holes drilled with electro-hydraulically powered rockdrills under similar production conditions indicate an electric-energy consumption of only 1,2 kWh per ton mined. If energy costs 5 cents per kilowatt-hour, this represents an annual saving of more than R1,2 million for a shaft system with

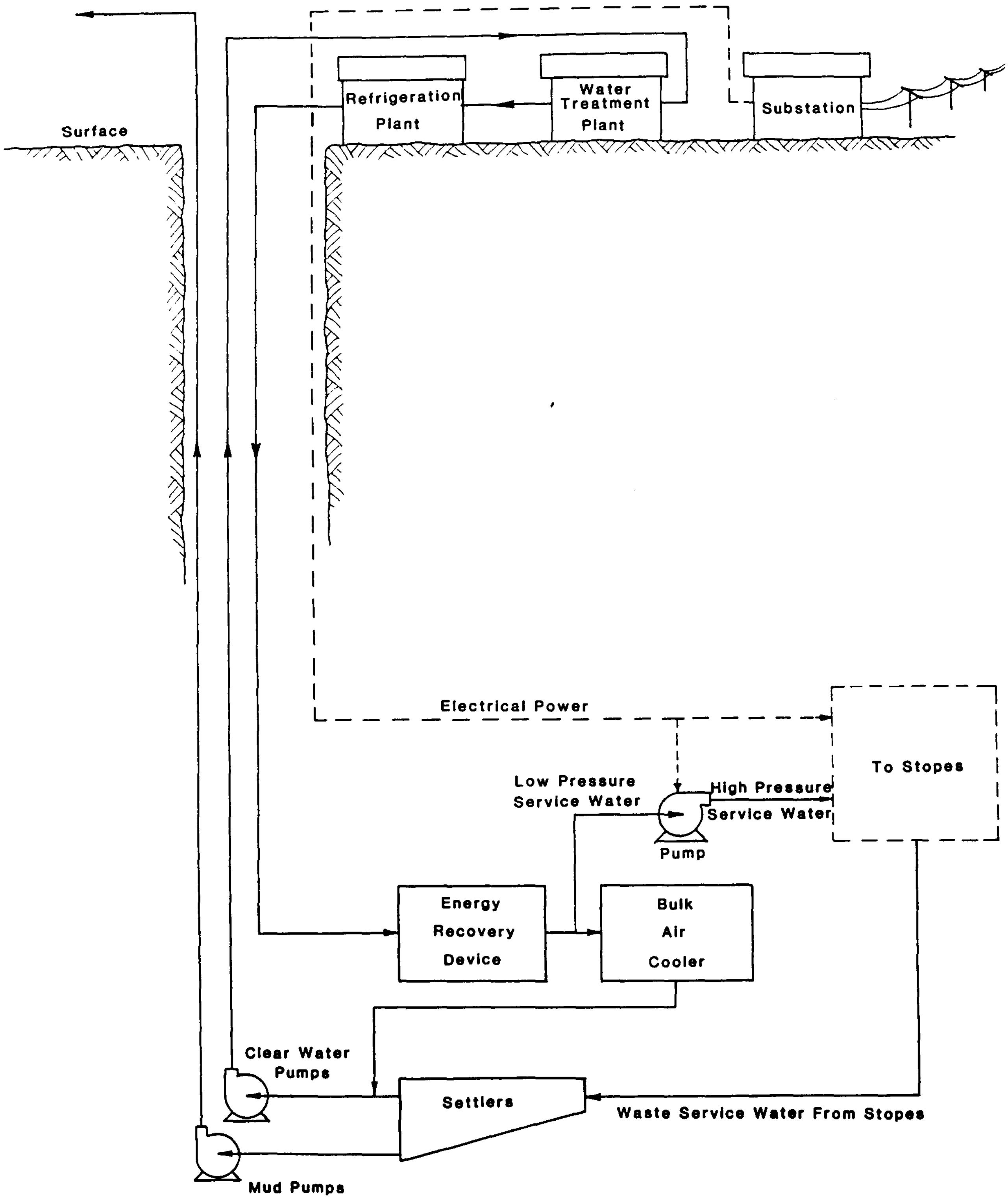


**Fig. 5—Basic stope powering and water reticulation in an electro-hydraulically powered mine**

a monthly production of 150 kt.

As would be expected, hydraulic rockdrills are more costly to maintain than are pneumatic rockdrills, but the fact that the drilling rates are typically doubled allows significant savings to be made in the labour costs for stope drilling. This, together with the energy savings mentioned above, results in a substantial reduction in the overall cost of drilling. The latest estimates suggest that the cost reduction is about 22 per cent.

## Conclusions

The use of a dense array of lightweight blast-resistant props installed close to the face provides a means by which the hangingwall support at the face can be signifi-

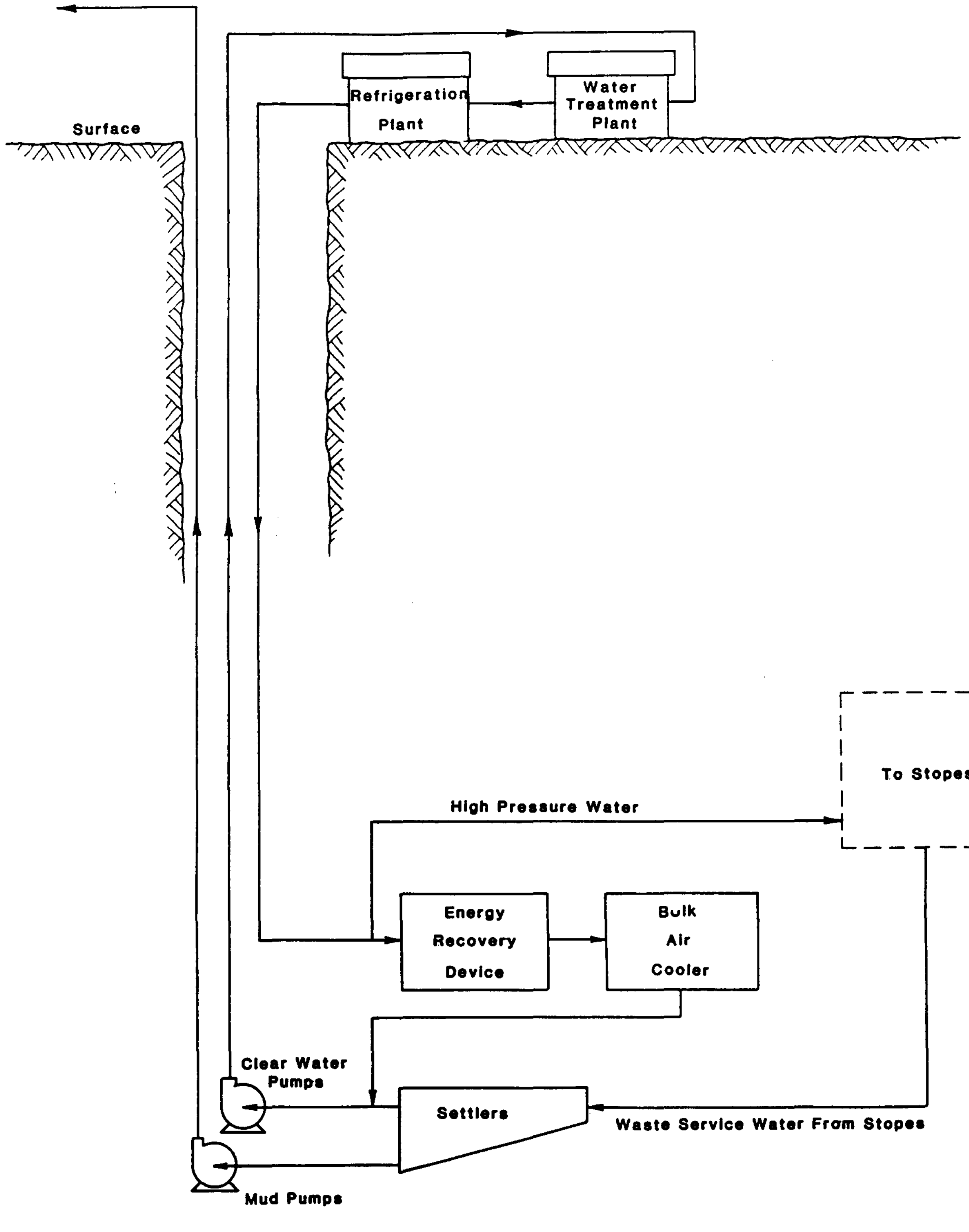


**Fig. 6—Basic stope powering and water reticulation in a hydro-powered mine**

cantly enhanced, thus enabling safety and productivity in the stope to be improved. The adoption of this arrangement is made possible by the advent of water-jet assisted face cleaning.

Proven equipment, compatible with the new support systems and with present-day gully-cleaning techniques, is available in the form of hydraulically powered pumps, water jets, and rockdrills. Therefore, the proposed panel layout could be implemented immediately. In addition to the productivity gains made possible by the enhanced hangingwall support, the adoption of the stoping equipment leads to the attainment of higher productivity because of faster cleaning and drilling.

Two alternative water-based hydraulic powering technologies suitable for stoping (electro-hydraulics and hydro-power) have been developed. Their implementation could bring about considerable simplification of the services infrastructure of mines, with the total elimination of compressed air, and even of electricity, being possible in stopes. Large savings in the costs of electric energy could also be achieved which, together with the productivity improvements described above, could lead to significant reductions in the overall costs of mining.

Two aspects remain less than ideal at this stage. Firstly, the existing blast-resistant hydraulic props are considerably heavier than they need to be. Secondly, the hydraulic rockdrills currently available are not fully compatible in that they are the only items requiring emulsion, rather than plain water, for powering. Every effort therefore needs to be made towards ensuring that suitable lightweight blast-resistant props and water-powered rockdrills are made available.

**Acknowledgement**

The work described in this paper forms part of the research programme of COMRO (Chamber of Mines Research Organization).

**References**

1. Pickering, R.G.B., and Wymer, D.G. Contribution to 'The use of high-pressure water-jetting in gold-mine stoping operations' by O'Beirne, D. *et al. Proceedings 12th CMMI Congress*. Glen, H.W. (ed.). Johannesburg, South African Institute of Mining and Metallurgy, 1982.
2. Hind, P.F., and Wymer, D.G. The development of hydraulically powered blasthole drilling systems for gold-mine stopes. Conference on 'Drilling Beyond Limits', Drilling Federation of Southern Africa, Johannesburg, Mar. 1988.
3. Byrne, O.S., Morris, A.A., and Pickering, R.G.B. Equipment alternatives for gully rockhandling in deep level narrow reef gold mines. Paper presented at Electra Mining '88 Colloquium 'Equipment Alternatives in Underground Mining', South African Institute of Mining and Metallurgy, Sep. 1988.
4. Brown, C.J., and Wymer, D.G. The engineering of water powered equipment for mine hydro-power systems. Paper presented at the Minemech '86 Symposium, Johannesburg, South African Institution of Mechanical Engineers, Sep. 1986.
5. Brown, C.J., Tupholme, E.R., and Wymer, D.G. The application of hydro-power to deep level mining. *GOLD 100. Proceedings of the International Conference on Gold.* Johannesburg, 1986. South African Institute of Mining and Metallurgy, 1986.

# Rock engineering

The South African National Group of the International Society for Rock Mechanics is to hold an international symposium at the Royal Swazi Spa, Swaziland, from 10th to 12th September, 1990. The title of the Symposium is Static and Dynamic Considerations in Rock Engineering.

This Symposium has been endorsed by the International Society for Rock Mechanics as an ISRM International Symposium, and it is the first time that an international symposium sponsored exclusively by the ISRM will be held in Africa. Accordingly, it aims to bring together rock-mechanics practitioners, consultants, researchers, engineers, and scientists from around the world to discuss advances in static and dynamic design in rock engineering.

### Static and Dynamic Design

Southern Africa is a developing region with a wide variety and abundance of mineral deposits. It is not surprising, therefore, that a very large and sophisticated mining industry has developed in the region. In addition, it is the location of several very large civil-engineering projects. The deep-level mines are well known for their dynamic and often violent behaviour. In contrast, the civil-engineering structures have to last for many decades. It is fitting, therefore, that a major symposium in the region should cover both areas of design—static and dynamic.

### Location

The Kingdom of Swaziland has been chosen as the venue for this symposium. Swaziland is a small African country known for the friendliness of its people, and for the relaxed facilities that it offers as a conference venue. It is easily reached by air and road, and is close to large mining and civil-engineering activities.

The Symposium will be held at the Royal Swazi Spa, at which hotel accommodation bookings have been made at favourable rates. The Royal Swazi Spa offers many recreational facilities, which include a casino and one of the finest 18-hole golf courses in Africa. Accommodation will also be available at two other hotels of international standard within walking distance of the venue.

### Papers and Themes

Prospective authors of technical papers should submit titles and abstracts of not more than 200 words to the Organizing Committee for consideration. These abstracts should relate to the following themes:

- Excavation in rock:
  - mechanical methods
  - explosive methods
- Dynamic behaviour of excavations in rock
- Long-term performance of excavations in rocks susceptible to deterioration.

### Tours

Three post-Symposium tours have been arranged to coincide with the completion of the Symposium and the commencement of the Electra Mining Exhibition, a bi-annual international event held in Johannesburg, South Africa. It is the largest exhibition of mining equipment in the world. It is scheduled for 17th to 21st September, 1990, and includes two colloquia: one each on mining and metallurgy.

The following tours are offered:

A. Surface mine tour to a very large open-pit base-metal mine and to a strip coal mine
B. Gold mine tour to the deepest mine in the world and to a mine using the scattered-mining method.

### Enquiries

Enquiries should be addressed to

Mr M. Faure
ISRM International Symposium
P.O. Box 5906
Johannesburg
2000 South Africa.
Telephone: (011) 339-4738 Fax: (011) 339-1821
Telex: 9-450083 SA.