

# Note: The practical application of microclimate cooling in an underground stope in a gold mine

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## INTRODUCTION

Although much information was available on the use of pre-frozen jackets as microclimate coolers in underground situations<sup>1, 2</sup>, no information was available on their performance under practical conditions in stopes.

The objectives of this study were

- (a) to determine the acceptability of the pre-frozen jackets to workers,
- (b) to observe the influence of the jackets on production,
- (c) to determine the costs involved in the introduction of microclimate cooling suits and to compare these costs with those of cooling the environment to acceptable levels, and
- (d) to test the microclimate garment for wear and tear over long periods.

## METHODS

Two freezer units, as described previously<sup>1</sup>, each of which was capable of holding and freezing 120 inner jackets, were installed in a cross-cut near the entrance to an experimental stope.

All the labourers working in the experimental stope were issued with pre-frozen microclimate suits every morning before they entered the stope. The stope was about 2 m high, and very little lashing was done in it because of the large-scale use of scrapers. For the duration of the experiment, the usual stope cooling and ventilation practices were discontinued, with the result that the stope warmed up considerably; twice daily temperature measurements indicated that the wet-bulb (W.B.) and dry-bulb (D.B.) temperatures varied from 34,2 to 35,5 and from 34,8 to 36,0°C respectively.

Initially, the Black labour com-

plement was expected to be 100 to 110 men, but only 60 to 94 workers were used. During March 1974, the labour force consisted of 60 men comprising 24 machine men, 12 winch drivers, 17 general workers, and 7 team leaders. The White miner and shiftboss wore their microclimate suits every day, as did the other supervisory and technical personnel who had to enter the area.

After 2 to 2,5 hours, the inner jackets were exchanged for newly frozen jackets at the entrance to the stope. The men wore these jackets for a further 2 to 2,5 hours or until the cooling effect of the jackets ceased, at which stage the jackets were discarded.

No physiological measurements were taken, but the labourers were questioned frequently about the effectiveness of, and their attitude towards, the pre-frozen microclimate cooling suits. The garments were checked weekly for signs of deterioration of the materials of which the suits were made.

Production figures for the experimental stope were obtained for the two months immediately preceding the introduction of microclimate cooling and for the first three months during the experiment. Production figures for the subsequent months of the experiment were not recorded as changes in operational conditions could have influenced the results.

## RESULTS

### Acceptability and Practicability

Most of the men (about 90 per cent), including the White workers in that area, spoke highly of the cooling and invigorating effects of the microclimate suits. In most instances, the jackets were taken off only when the cooling effect was lost completely. None of the personnel, except 5 to 10 machine men who worked in water and compressed-air spray, refused to wear them. These workers were

eventually persuaded to use the jackets because of a mines requirement that no one not protected by a microclimate cooling suit should enter the stope.

### Effect on Production

The effect of microclimate cooling on production is given in Table I. With 90 to 98 labourers during the two months preceding the experiment, the production varied between 2397 and 4167 t. The lower production rate during month 2 is attributed to the increase in the environmental temperature from 32,4 to 33,4°C W.B.

In the three months following the introduction of microclimate cooling suits, production varied from 3478 to 5199 t per month with 60 to 94 labourers, while the temperature increased from 34,2 to 35,5°C W.B. The low production during month 4 can be attributed to the low number of labourers. During both stages of the experiment, the production figures followed either the increase in temperature or the reduction in labour force. However, an average increase of 973 t in monthly production was observed after the implementation of microclimate cooling in spite of an increase of about 2°C W.B. Production remained high, even in the subsequent months during which only wear and tear were observed.

### Costs

The total capital outlay for the introduction of microclimate cooling is about 10 per cent of the costs involved in cooling the air by ventilation.

### Durability

The durability of the microclimate suits, especially that of the outer jacket, was shown to be most satisfactory. However, a few bad features became evident in the design and construction of the garments.

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TABLE I  
PRODUCTION AND ENVIRONMENTAL DATA

<i>Without jackets</i>	Labour complement (No. of men for 2 shifts)	W.B. temp. °C	D.B. temp. °C	Production t
Month 1	90	32,4	34,1	4 167
Month 2	98	33,4	34,2	2 397
Average	94	32,4-33,4	34,1-34,2	3 282
<i>With jackets</i>				
Month 3	93	34,2	34,7	5 199
Month 4	60	34,7	34,9	3 478
Month 5	94	35,5	36,0	4 090
Average	82	34,2-35,5	34,7-36,0	4 255
Production increase				973

- (c) After about four months of constant use, some of the inner jackets gave way at the shoulder section and had thus to be withdrawn from underground use.
- (b) The first set of vests did not last long before disintegrating because of rotting.

### DISCUSSION

Significant improvements have already been achieved in underground ventilation and air-conditioning practices, and further advances are still being planned for the gold-mining industry. Environmental conditions that favour the use of microclimate cooling, that is, temperatures exceeding 32,5°C W.B.<sup>1</sup>, should generally not be allowed to arise. Nevertheless, such situations do arise in emergencies when vital equipment has broken down or when the rock formation does not warrant the installation of expensive air-conditioners. The results obtained in this study show that microclimate cooling can be used advantageously in such situations.

The pre-frozen microclimate suits were well received and appreciated by the majority of the men who had to work under the conditions of very high environmental temperatures (34 to 35,5°C W.B.) in the experimental stope. The results obtained in the laboratory<sup>2</sup> indicate that body temperatures and heart rates should have been kept within permissible limits. No case of heat exhaustion or other heat illness

was reported from this area during the five-month period of the experiment.

Further proof of the success of the garment is reflected in the marked increase in production in spite of an increase in temperature of more than 2,0°C W.B. It is appreciated that production depends on many factors, but it should be recognized that it is normally impossible to achieve and maintain economic and safe production rates at temperatures of 34,2 to 35,5°C W.B.<sup>3</sup>. With microclimate cooling, not only was it safe to work under these environmental conditions but production actually increased by about 34 per cent, even though the average labour force was reduced slightly. This ability to work in extreme heat under microclimate cooling has been observed on several occasions: one involved the accidental opening of a hot-water (about 40°C) fissure during drilling operations; without protection it would have taken weeks to seal up this fissure, whereas, with microclimate cooling, it was achieved in three days.

Another significant advantage of microclimate cooling is its low cost. Initial and maintenance costs for microclimate cooling would be only one-tenth those of conventional cooling techniques. However, microclimate cooling should never be regarded as the only answer to hot underground environments. It is solely a procedure for use in emer-

gency conditions or as a temporary measure, under which conditions its use is strongly recommended.

Although the overall durability of the garment was very satisfactory, certain alterations and precautionary measures are essential. The outer jacket needs no alteration, but the inner jacket should be reinforced over the shoulder sections in order to prevent tearing at the seams.

The poor lasting qualities of the vests was entirely due to the growth of mould because the vests were washed and dried underground. This problem was greatly reduced by the use of a fungicide known as Steryscrub.

### ACKNOWLEDGEMENTS

The authors are indebted to the management and staff of Loraine Mine for their co-operation and assistance in this project.

### REFERENCES

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## O.F.S. Branch

Minutes of the General Meeting held in the upstairs lounge at the Harmony Country Club, Harmony G.M. Co. Limited, on Wednesday 12th November, 1975 at 4.00 p.m.

Mr G. J. C. Young (Chairman of the O.F.S. Branch) was in the Chair.

Also present were:

*Six Fellows:* Messrs A. T. Lewis (Committee Member), Z. J. Lombard (Committee Member), J. F. G. Lorenzen, A. N. Shand (Committee Member), D. A. Smith (Committee Member), and E. T. Wilson (Committee Member).

*Seven Members:* Messrs E. J. Dominy (Committee Member), B. J. Drysdale (Committee Member), H. M. W. Eschenburg (Committee Member), F. W. Kleinschmidt, N. Mayer, H. G. Mosenthal, and E. R. Penny.

*Nine Associates:* Messrs W. F. de Lange, J. R. Forbes, A. J. Johansen, D. R. Lings, A. R. F. MacDonald, R. R. Perkin, J. Scott, P. J. van der Bank, and C. P. Visser.

*One Graduate:* Mr P. S. Wentworth.

*Twelve Visitors.*

*Total Present:* Thirty-six.

### Welcome

Mr Young declared the Meeting open and extended a welcome to the members and visitors present.

### Minutes of Previous Meeting

The Minutes of the Annual General Meeting held on 30th July, 1975, were taken as read, and their adoption, proposed by Mr A. T. Lewis and seconded by Mr A. N. Shand, was carried.

### Matters Arising from Minutes

There were no matters arising from the minutes.

### General Business

No matters were raised under this heading.

### Main Business

In calling on Mr E. J. Dominy, Metallurgical Manager, Harmony G.M. Co. Limited, to present his talk and slide show of general interest on Canada, Mr Young remarked that, although Mr Dominy was a local member and therefore needed no introduction, he was sure everyone present was greatly

looking forward to seeing the slide show as Mr Dominy's trip to last year's Commonwealth Mining and Metallurgical Congress had roused much interest at the time.

In his address, Mr Dominy outlined what he considered to be the highlights of the Congress both from the technical and tourist points of view. This was followed by the screening of a series of exceptionally fine slides.

Mr A. N. Shand thanked Mr Dominy on behalf of those present.

Two short films were then screened:

- (1) 'Coal Gatherer' — opencast mining in Northumberland.
- (2) 'Northern Territory Mining' — mining expansion in Australia's Northern territory.

### Closure

The Chairman expressed his appreciation to the management of Harmony G.M. Co. Limited in making available the facilities provided for the Meeting. He thanked members and visitors for their attendance, and declared the Meeting closed at 5.20 p.m., after which refreshments were served.

## NIM reports

The following reports are available free of charge from the National Institute for Metallurgy, Private Bag 7, Auckland Park 2006.

### Report no. 343

*A mineralogical investigation of gold-bearing sulphidic ore from the Florence-Devonian Mine, Barberton.* (20th May, 1968; re-issued Dec. 1975).

Samples of gold-bearing sulphidic ore from the Florence-Devonian Gold Mine, Barberton district, consist essentially of quartz, sericite, chlorite, calcite, and small amounts of dolomite, muscovite, ankerite, and plagioclase as the non-opaque constituents. The main ore minerals present are pyrite and arsenopyrite. They are accompanied by medium amounts of pyrrhotite and small to

trace amounts of chalcopyrite, rutile, melnikovite-pyrite (gelpyrite), sphalerite, chromite, enargite, and gold.

Several of the above minerals, which are present in very small amounts, namely chlorite, dolomite, plagioclase, ankerite, melnikovite-pyrite, rutile, and chromite, have not been reported before in ore from the above mine. These constituents are not expected to interfere with the extraction of the gold.

The gold particles that were observed and studied in twenty polished sections made from ore of the above mine were enveloped or partly enveloped by sulphides, mainly pyrrhotite and pyrite, and in a few instances also by arsenopyrite. Some of the gold occurred in cracks or interstitially between sulphide crystals. Only a few free

grains were observed in the quartz. An estimate of the surface areas of the gold particles present in the ore suggests that about 75 per cent of the gold is included in the sulphides, whereas approximately 25 per cent occurs free (i.e., in the quartz).

The particles of gold generally measured less than 10 microns by 10 microns, but a few grains of 25 microns by 20 microns were also observed. However, the majority of the gold grains had diameters of less than 5 microns. Therefore, it can be assumed with a degree of certainty that fairly large numbers of sub-microscopic gold particles are also present in the ore, but their weight will not contribute significantly to the quantity of recoverable gold.

Because of the distribution of the gold, its small particle size, and the presence of considerable amounts of pyrrhotite, which act as a cyanide, it is thought that only a relatively small recovery of the gold could be expected by conventional cyanidation.

Fine grinding of the ore before cyanidation should improve the gold extraction considerably, whereas complete roasting should, theoretically, result in a much higher recovery.

#### Report no. 1384

*Flotation tests on samples of Canadian copper-zinc ores.* (12th Nov., 1971; re-issued Nov. 1975).

The results are given of laboratory tests on two samples of Canadian copper-zinc ores, one from the Lake Dufault Mine and the other from the Delbridge Mine. It is shown that the bulk-float process developed at the National Institute for Metallurgy is not directly applicable to these two samples. However, after some modifications had been made to the process, acceptable concentrates were produced from the first sample. From the other sample, only an acceptable zinc concentrate could be produced.

The results of a mineralogical examination of the two samples are given in the Appendix.

The differences between deposits, particularly in the 'activity' and floatability of the sulphide minerals, indicate that the bulk-float process cannot be of direct application to all copper-zinc ores but that it will have to be modified to suit the particular ore concerned.

#### Report no. 1488

*Extraction of rutile from Highveld smelter slags.* (28th Sep., 1972; re-issued Nov., 1975).

This report describes tests in which attempts were made, by additions of  $P_2O_5$  to synthetic slags and slags from Highveld Steel and Vanadium, to induce the rutile present in the slags to precipitate as a primary phase so that the rutile could be recovered.

Additions of  $P_2O_5$  of up to 40 per cent of the synthetic slag did not have the desired effect. Only when the  $TiO_2$  content of the slags (33 per cent) was increased to 40

per cent did the rutile crystallize as a primary phase after an addition of  $P_2O_5$  of 40 per cent. Similarly, larger additions of  $SiO_2$  than those determined in previous work were required to precipitate rutile from the slags ( $TiO_2$  content 33 per cent).

When the experiments were repeated on real slags from Highveld Steel, crystallization of the rutile did not occur. This difference in behaviour is attributed to either the FeO content or the difference in stoichiometry of  $TiO_2$  between synthetic slags and reoxidized plant slags.

#### Report no. 1499

*The production of medium-carbon ferrochromium.* (4th Dec., 1972; re-issued Nov. 1975).

In an attempt to produce medium-carbon ferrochromium, high-carbon ferrochromium was reacted with oxide melts containing the oxides of chromium and iron. These experiments were done in a laboratory furnace and in a 50 kVA arc furnace. It was found that the silicon content of the high-carbon ferrochromium decreased considerably, whereas the carbon content did not show any appreciable reduction. Higher concentrations of chromium and iron oxides in the oxide melt resulted in the reaction between the alloy and the oxide melt becoming uncontrollable and explosive.

#### Report no. 1521

*The dissipation of electrical power in the burden of a submerged-arc furnace.* (15th Feb., 1973; re-issued Nov. 1975).

Possible modes of electrical conduction in the submerged-arc furnace were investigated, and it is shown that electrical conduction can be ohmic or by arcing, depending on the temperature and the inter-electrode voltage.

Three-phase measurements of cell constants provide information on the various paths for ohmic conduction in the furnace, and the power dissipation along an electrode of a typical furnace is evaluated. It is shown that, if ohmic conduction applies, about 75 per cent of the power is dissipated in the bottom 300 mm of the electrode by delta and star conduction.

#### Report no. 1527

*The physicochemical properties of slags associated with the smelting of nickel sulphide concentrates.* (21st Feb., 1973; re-issued Nov. 1975).

The liquidus temperature, viscosity, and electrical conductivity of slags associated with the smelting of nickel sulphide ores were measured. These slags fall within the oxide quinary system  $CaO-MgO-Fe_3O_4-FeO-SiO_2$ , and have an unusually high content of iron oxide (30 to 60 per cent). The slags have low viscosities (0,2 to 2 P) and high conductivities (200 to 700  $Sm^{-1}$ ), and their liquidus temperatures vary between 1230 and 1400°C. These values differ from those found for local slags, whose iron oxide content does not exceed 25 per cent. The local slags have viscosities of about 3 to 5 P and conductivities of the order of 15 to 50  $Sm^{-1}$ . A change in the composition of the high-iron slags results in a decrease in conductivity to levels approaching those of local slags, but the viscosity is increased. The high-iron slags (with high conductivity) would not preclude the use of electric smelting furnaces; suitable transformers having lower voltages and higher currents could be used.

#### Report no. 1544

*The recovery of salable ferrochromium from material discarded by Ferrometals Limited.* (11th Jun., 1973; re-issued Nov. 1975).

An attempt was made to concentrate the ferrochromium contained in 'skrot'—a mixture of ferrochromium, slag, and other contaminants. It was found that screening at 2,5 cm, followed by hand-sorting of the oversize material, yielded salable ferrochromium. When the remainder of the skrot is crushed to material smaller than 1,2 cm, magnetic separation can be used to concentrate the ferrochromium. The overall recovery is expected to be greater than 80 per cent. The magnetic concentrate can be melted down in an induction or arc furnace, but additions of flux may be required.

#### Report no. 1547

*Physicochemical and thermodynamic properties of slags in the system*

*MgO-Al<sub>2</sub>O<sub>3</sub>-SiO<sub>2</sub>*. (23rd Aug., 1973; re-issued Nov. 1975).

The viscosity, specific electrical conductivity, and liquidus temperature of the slags were measured, and it was found that the variation of viscosity and conductivity with composition corresponds to trends predicted by simple structural models. However, the contours suggest that alumina partitions to approximately equal cationic and anionic fractions and that the liquid-oxide system, as such, is a regular solution. The activities of Al<sub>2</sub>O<sub>3</sub> and MgO derived on the basis of these assumptions appear to be in good agreement with previously published data.

#### Report no. 1548

*Physicochemical properties of slags in the system MgO-Al<sub>2</sub>O<sub>3</sub>-SiO<sub>2</sub> and their application to the technology of ferro-alloy smelting*. (13th Jul., 1973; re-issued Nov. 1975).

Smelting behaviour within an electric smelting furnace is considered, and a mechanism is proposed that depends on the slag formed.

The influence of the viscosity and conductivity of slags on smelting is examined, and these properties are measured for slags in the ternary system MgO-Al<sub>2</sub>O<sub>3</sub>-SiO<sub>2</sub> having an SiO<sub>2</sub> composition of 30 to 50 per cent and an MgO-to-Al<sub>2</sub>O<sub>3</sub> ratio of 0.5 to 2.0.

There is no simple method by which these properties can be optimized for furnace production. However, the individual effects of viscosity and conductivity on various aspects of the smelting process can be calculated.

#### Report no. 1553

*Characterization of the flotation properties of fluorspar from small-scale batch and pilot-plant tests*. (27th Sep., 1973; re-issued Nov. 1975).

Simulations of flotation-plant performance are to be made in a feasibility study of the development of a fluorspar mine on a low-grade orebody. Before these simulations can be done, the parameters describing the flotation characteristics of the ore must be determined experimentally and the model to be used in the simulations must be tested for its ability to predict the behaviour of the ore in a continu-

ously operating plant. This preliminary work is described.

The model was found to be a good description of the operation of the pilot plant, and indicated that a combination of lower feed rate and finer grinding should be investigated on the plant.

#### Report no. 1555

*The analysis, by atomic-absorption spectrophotometry, of matte-leach residues*. (2nd Oct., 1973; re-issued Nov. 1975).

Alternative methods for the analysis of matte-leach residues by atomic-absorption spectrophotometry were investigated.

For the determination of the platinum-group metals, gold, and certain of the base metals, a fusion with sodium peroxide, followed by the separation of gold by reverse-phase chromatography and of the platinum-group metals by ion-exchange, is proposed. The noble metals are then determined in a solution that is free of most base metals including the sodium present as a result of the fusion. Copper, nickel, iron, calcium, magnesium, and aluminium can be determined after they have been removed from the ion-exchange column. Arsenic, selenium, tellurium, antimony, bismuth, tin, silver, lead, manganese, zinc, and cobalt can be determined in a separate sample after dissolution by a sealed-tube method. This is also an alternative method for the determination of copper, nickel, and iron. Chromium is determined separately after fusion with sodium peroxide, and silver can also be determined in this way.

The laboratory method for these procedures is given as an appendix.

#### Report no. 1590

*The separation of osmium from ruthenium in hydrochloric acid solutions*. (18th Jan., 1974; re-issued Oct. 1975).

Tests on the most suitable method of separation are described. The following procedure was adopted as the most promising. After conversion to its bromo-complexes, the osmium is extracted into methyl isobutyl ketone, back-extracted with water, and determined spectrophotometrically with thiourea. A correction is made for the ruthenium that is

coextracted (18 per cent or less).

The method is applicable to solutions containing a maximum of 2 mg of ruthenium, and is also applicable to the separation of osmium from platinum, rhodium, iridium, and gold, and from palladium if that element is present in amounts not exceeding 100 µg.

#### Report no. 1606

*The electrical-resistance characteristics of the charge in the electric reduction furnace*. (1st Feb., 1974; re-issued Oct. 1975).

The electrical-resistance characteristics of furnace charges at Highveld Steel and Vanadium Corporation were investigated in the temperature range 200 to 1500°C. The variables considered were the types, proportions, and sizes of the raw materials, the degree of pre-reduction of the ore, the slag produced, and the use of sinter material.

It was found that the resistance characteristics of the charge depended mainly on the ore, modified primarily by its degree of pre-reduction and the reductant used. The resistance of the ore was comparable with that of the reductant in the temperature region 800 to 1100°C. In the high-temperature region, the resistance is influenced by the reactivity of the reductant. The slag influences the resistance in the reaction zone because the resistance of the slag is comparable with that of the smelted burden and that of the burden at lower temperatures. When sinter material is used, smelting occurs at a much lower temperature, which would result in lower tapping temperatures.

#### Report no. 1622

*The electrical conductivity of the charge in a ferrosilicon furnace*. (2nd Apr., 1974; re-issued Oct. 1975).

The resistance of various charges to a furnace producing ferrosilicon of 75 per cent silicon was measured. The reductants used were varied and were tested in the temperature range 500 to 1700°C.

The results indicate that, from the point of view of furnace resistance, Delmas and Arnot coals and char from Rand Carbide Limited would be the most suitable reductants for the process investigated. An increase in the coal content of the charge may also be beneficial.