Acclimatizing Men to Heat in Climatic Rooms on Mines

By C. H. WYNDHAM*, M.B., M.R.C.P., F.R.S.(S.A.) (Member) and N. B. STRYDOM*, Ph.D. (Member)

INTRODUCTION

Acclimatization of the labour force to heat is an integral aspect of gold mining in South Africa. A recent survey revealed that about 250,000 Bantu mine workers require to be acclimatized to heat each year. Until 1965 men were acclimatized by means of one of the Chamber of Mines methods (introduced by the Human Sciences Laboratory in 1953). This type of acclimatization was carried out underground where men shovelled rock in hot stopes under careful supervision. However, it has become increasingly difficult in the last few years for mines to provide underground the conditions of work and environmental heat required for adequate acclimatization to heat.

In examining an alternative to acclimatization in underground hot stopes, the Human Sciences Laboratory carried out a trial in 1965 of acclimatization in an air-conditioned climatic room on the surface of a mine. The new procedures developed from this trial have been so successful that there are today 26 climatic rooms on different mines. These rooms have been built following a design proposed by Mr Hodgson of the National Mechanical Engineering Research Institute[1]. Approximately 85 per cent of the total number of men being acclimatized each year are put through the new procedures in these climatic rooms.

This paper gives an account of the problems which arose and how they were solved, the inter-relationship between physical conditioning and climatic room acclimatization, the prodecures developed for elimination of labourers with low maximum oxygen intakes, and the advantages of climatic room acclimatization.

CLIMATIC ROOMS

The majority of the climatic rooms (twenty) have been built on the surface, but a number (six) of mines preferred to establish their acclimatization centres underground in order to decrease the initial costs involved in the construction of such facilities. These underground climatic rooms are usually located near shaft stations in redundant haulages and they can accommodate from 200 to 400 labourers, thus eliminating the need for multiple acclimatization shifts.

Figs. 1-4 illustrate various aspects of a surface climatic room.

PROBLEMS WHICH AROSE IN INTRODUCING CLIMATIC ROOM ACCLIMATISATION

There were four main problems which arose in connection with the introduction of the new method. These were:

(i) The type and rate of work to be used.

(ii) The air conditions required to obtain optimum acclimatization.

(iii) The duration of exposure to heat each day and the total number of days of acclimatization.

(iv) The methods of cooling labourers with high body temperatures.

Shovelling rock would have been the desirable type of physical work to employ, but the air-conditioned space required to accommodate large numbers of men and the difficulty in standardizing the work rate in shovelling led to the decision to employ instead the work procedure used by the Human Sciences Laboratory in acclimatizing men in the Laboratory. This is the lifting of the body weight against gravity when men step on and off a bench. It has the advantage that large numbers of men can work physically at the required rate in a relatively small space (120 men can be accommodated in an area of 70 ft by 21 ft) and the cost of construction and ventilation of the climatic rooms is thereby reduced. Also the work rate can be standardized by varying the height of the stepping benches in relation to the individuals' body weights.

The next problem was the air condition to be used in the climatic rooms. The Laboratory's research experience in acclimatization led it to choose an air temperature of 89°F (with the air almost saturated with water vapour) and an average velocity of air movement of 100 fpm. This air condition was combined with a work rate of 1,560 ft lb/min (oxygen consumption 1·0 litre/min) on day 1, and the work rate was increased gradually over the period of acclimatization to reach a work rate of 3,120 ft lb/min (oxygen consumption 1·6 litres/min) on day 9.

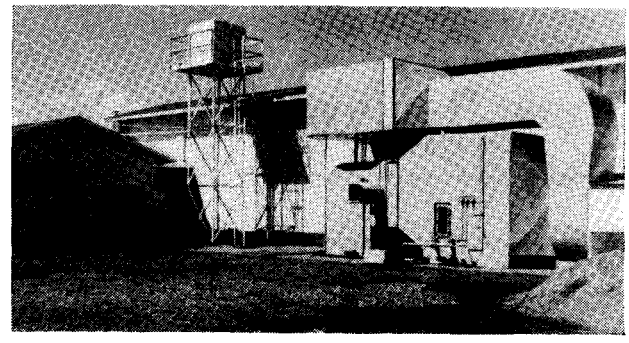

Fig. 1—Side view of a surface climatic room showing the machinery which automatically controls the temperature and humidity of the room

*Human Sciences Laboratory. Chamber of Mines of South Africa.

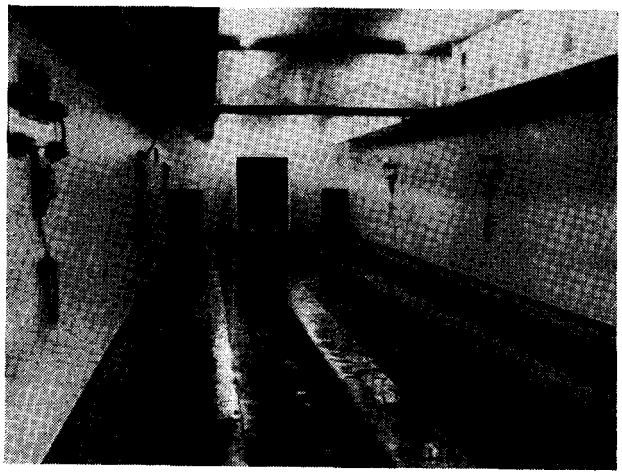

Fig. 2—Interior view of the climatic room looking towards the stepping timetable flanked by two urinals in the corners. The long rows of stepping blocks can each accommodate 50 labourers. Note the specially designed air ducts in the ceiling

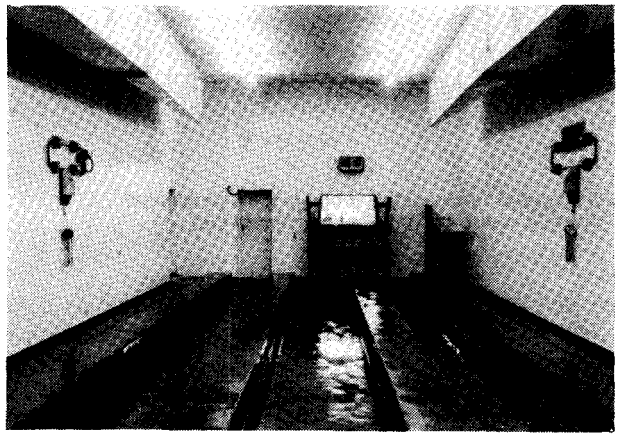

Fig. 3—View of the interior of the climatic room showing the long rows of stepping blocks, an outside observation port and the door giving access to the room. Note the tapering design of the air ducts

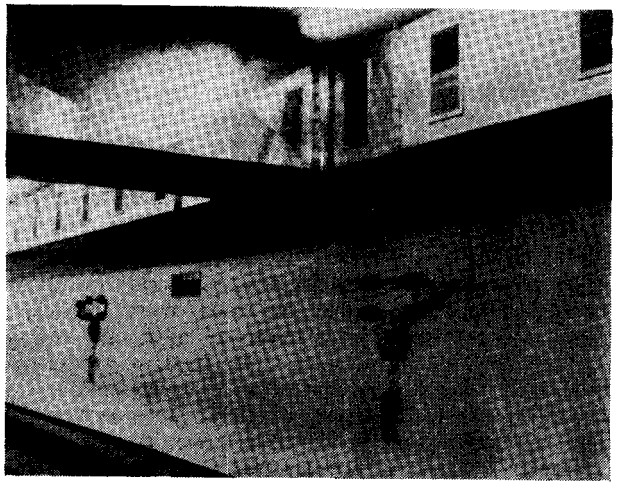

Fig. 4—A close-up view of the air ducts, temperature sensing unit and the electronic light metronomes inside the climatic room

For a work rate of 1,560 ft lb/min a better state of acclimatization is obtained with a wet bulb temperature of 93°F than at 90° or 96°F. However, such a combination of heat stress was not recommended for acclimatization in climatic rooms because, with this combination of work rate and environmental heat, the number of high temperature cases in the first few days of acclimatization would be relatively high. This would put a great strain upon acclimatization supervisors and might lead to their missing cases with excessively high temperatures—thus increasing the risks of heat stroke during the procedure. Also the low work rate would not be as effective in improving the physical conditions of labourers as the high rate used in the present acclimatization regime.

The present combination of work rate and environmental heat has proved to be very successful in acclimatizing men to heat. Recent research has shown that the level of acclimatization is as good as that achieved under Laboratory conditions, as is shown in Fig. 5. However, there is one important reservation in this regard. It has been found that at underground wet bulb temperatures above 91°F, novices and men who had not previously worked underground had higher temperatures, after climatic room acclimatization, than men who were accustomed to working in wet bulb temperatures in excess of 91°F. Novices should, therefore, first be posted to areas with wet bulb temperatures of 89° to 91°F for a period of two weeks to become adjusted to underground conditions *before* they are transferred to working areas with wet bulb temperatures in excess of 91°F. Also in underground centres, it was found that the heat produced by the men stepping increases the W.B. temperature from about 89°F in the front sections to about 91°F towards the back. This actually provides for better heat acclimatization but it also carries a somewhat higher risk of men developing heat disorders during the procedure. In order to decrease this risk these mines have been advised to move labourers towards the back every day and the heat stress is thereby increased gradually.

The third problem was the duration of exposure each day and the total number of days that should be used in acclimatizing men in climatic rooms. In the two-stage procedure, used underground in stopes, the minimum period required for acclimatization was 12 days. Earlier research at the Human Sciences Laboratory had shown, however, that under a more carefully standardized work rate and with close supervision it is possible to acclimatize men adequately in 9 days, and this was the total number of days chosen in the first year of the new acclimatization procedure in climatic rooms. Also, in the light of its experience of the physiology of acclimatization the Human Sciences Laboratory chose a period of 4 hours of work daily. Subsequent research showed that the period of daily work cannot be reduced to less than 4 hours without increasing the risks of men developing excessively high body temperatures. Further research demonstrated that the number of days of acclimatization can be reduced from 9 to 8 days without materially increasing the risks of very high body temperatures and this is the period recommended at present in climatic rooms. There are indications in recent research that it may be possible to reduce still further the period of acclimatization, but this requires confirmation.

The fourth problem was the cooling of men who became too hot. Research showed that it was not necessary to use the ancillary cooling methods employed underground, such as compressed air and water sprays, and that adequate cooling occurs by merely allowing

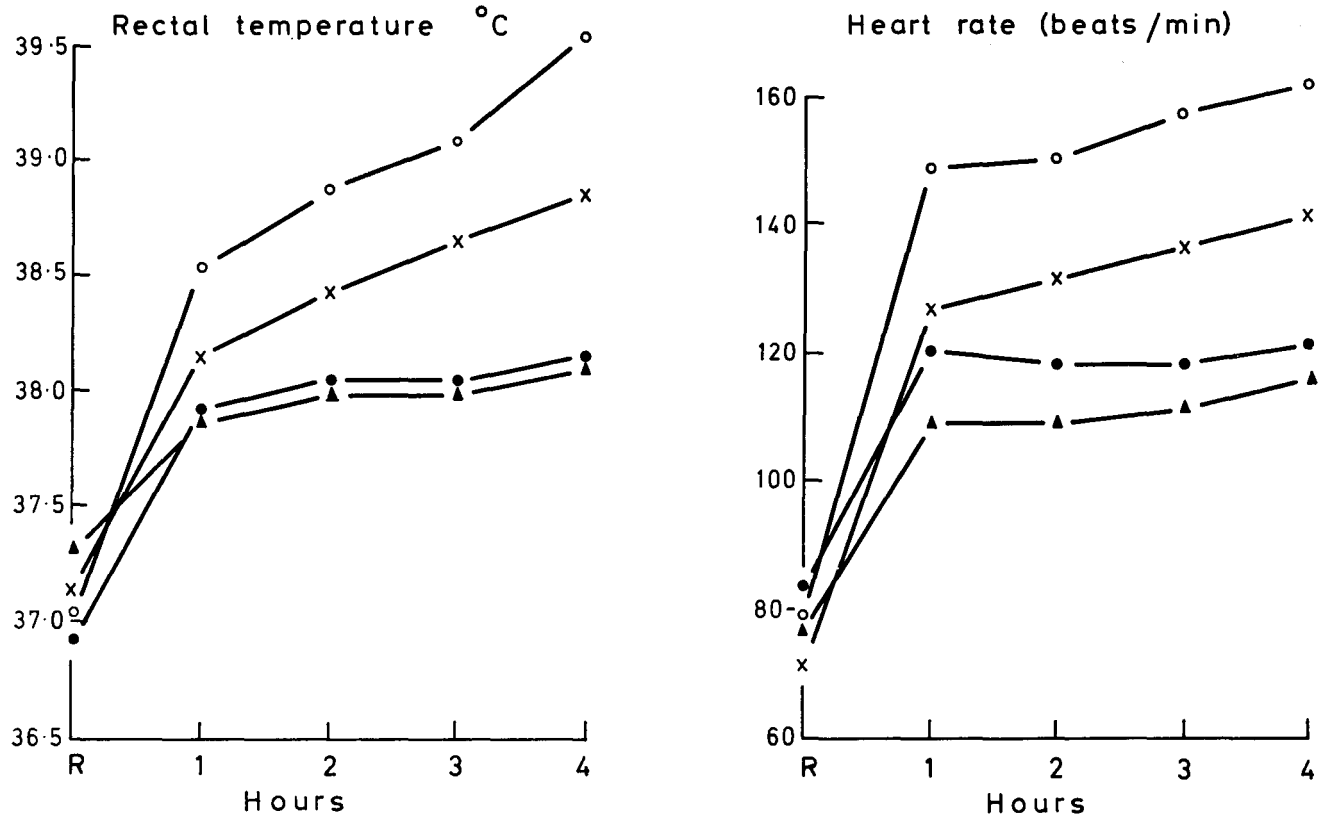

Fig. 5—A comparison between physiological parameters measured in unacclimatised (o), underground acclimatised (x), laboratory acclimatised (●) and climatic room-acclimatised subjects (▲)

the men to sit at rest inside the climatic room. Research also showed that the mean differences between oral and rectal temperatures in the climatic room was 1·74°F. compared with 1·22°F underground. The bigger difference in the climatic room is undoubtedly due to the high work rate compared with that employed in underground acclimatization. Work rate had previously been shown by Strydom *et al.*[2] to be the main determinant of the size of the differences. It was found that an oral temperature of 101°F, at which men are rested, can, in 1:100 instances, be associated with a rectal temperature of 104°F. This confirms the wisdom of the choice of an oral temperature of 101°F as the limit above which men should be stopped from working in climatic rooms and should be cooled to reduce the risk of hyperpyrexia.

PHYSICAL CONDITIONING

The inter-relationship between physical conditioning and acclimatization and the effect of the new procedures on the capacity for work was examined in a number of investigations.

A physical conditioning programme prior to acclimatization has the effect of improving the circulatory responses when men are first exposed to heat, but it has no effect upon their sweat responses. This is demonstrated in Fig. 6. However, pre-conditioning probably decreases the severity of the circulatory insufficiency and the possibility of heat collapse in the first few days of acclimatization, and may therefore shorten the period needed for acclimatization. This result could have useful practical significance if it were possible to introduce a safe physical conditioning programme right from the first day the men enter the recruiting depot in the tribal territories. Further research in this direction is indicated.

An hour of shovelling rock under cooler conditions than those pertaining in the climatic room had the effect of improving the state of acclimatization of the men undergoing acclimatization, judged by their lower rectal temperatures in the climatic rooms. It also ensures that the men are in a better physical condition and that they have some familiarity with the task of shovelling rock.

The physical condition of the men improved over the 8 days of acclimatization, judged by an average gain in weight of 2 lb and an increase in maximum oxygen intake from 2·39 to 2·82 litres/min. However, of even greater practical importance is the fact that whereas only 14 per cent of the men were capable of hard work on recruitment, this figure rose to 29 per cent after acclimatization; before acclimatization, 22 per cent of the men were capable of light work only and this figure fell to 7 per cent after acclimatization. The men also became more mechanically efficient.

The great improvement in physical conditioning undoubtedly occurs because the men work physically each day for 4 hours at a relatively high rate and, in fact, the last few days can be classified as moderately hard work being carried out at an oxygen consumption of 1·5 litres/min. Because of this, the question has been asked whether the procedure would not become unpopular because of soreness of muscles in the legs. To check on this point a detailed questioning of a large sample of men was carried out in 1967. This showed that about 5 per cent of men complain of sore

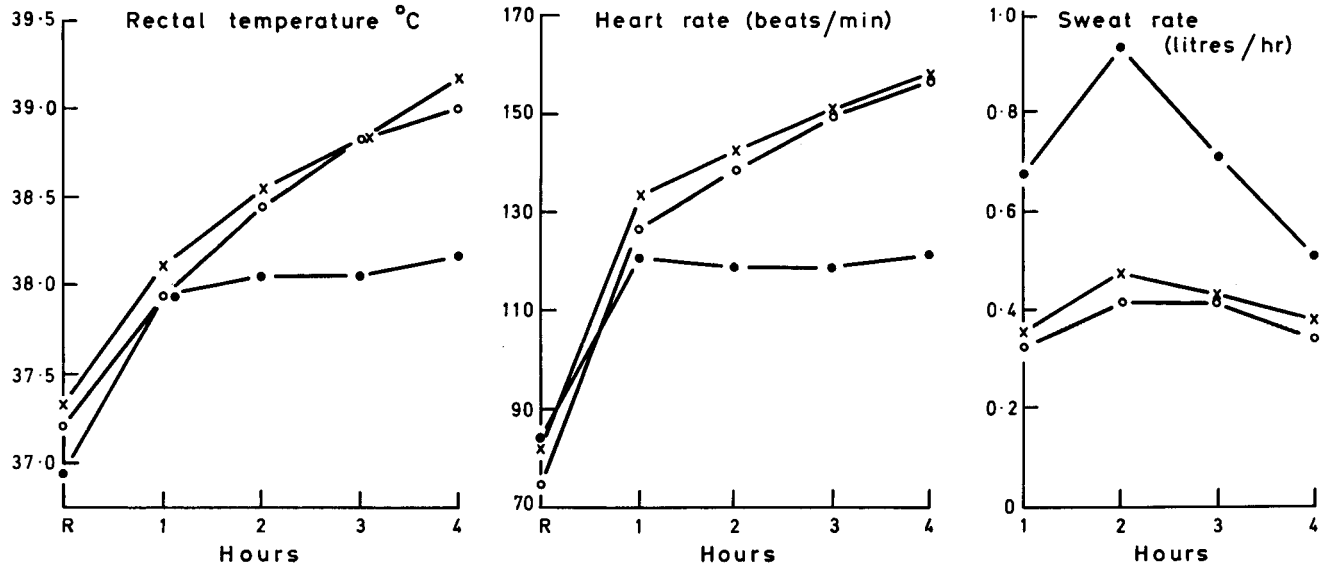

Fig. 6—A comparison of the state of acclimatision between subjects before training (x), after training (o), and fully acclimatised subjects (●)

calves on the second and third day, but by the fifth day the complaints are negligible and completely absent by the 7th day.

PHYSICAL WORK CAPACITY

An innovation in 1968 was the use, in conjunction with climatic room acclimatization, of a simple test procedure which was introduced in some mines in 1967 for measuring the physical work capacities of the men. This comprises ten minutes of stepping on and off a bench which is adjusted in height in relation to the man's body weight to give a work rate of 2,400 ft lb/min (equivalent to an oxygen consumption of 1·4 litres/min.) Men with heart rates above 140 beats/min after 10 minutes of work are considered to be unfit for underground work (shovelling and tramming) and are therefore not put through acclimatization procedures. This relieves the pressure on the acclimatization centres. It also classifies the men who should be eliminated from work in hot air conditions because of low maximum oxygen intakes. Such men have been shown in previous research from this Laboratory to be less tolerant to heat than those with higher physical work capacities[3].

ADVANTAGES OF CLIMATIC CHAMBER ACCLIMATISATION

The fact that acclimatization in climatic rooms has been adopted so rapidly and extensively in the gold mining industry is due to the decided advantages it has in the following respects:

(i) *Extra productive shifts*—the period has been reduced from the 12 days of the two-stage underground procedure to 8 days in the climatic room procedure. Comparable reductions have been made on the shorter procedures. This is an additional 4, fully productive, shifts from most of the 250,000 men being acclimatized in climatic rooms, or a total of about 1 million productive shifts per annum. One mine, with an underground complement of *ca* 11,000 Bantu, considers that it gains 30,478 shifts per annum and that the extra revenue is R31,088 per annum. The extra revenue accruing to the gold mining industry from the gain in extra productive shifts is considerable even if based on the relatively low estimate of R1.00 per man per shift.

(ii) The acclimatization is uniform for all men in that they all do the same amount of work for the same period each day, which was very difficult to achieve in working stopes underground.

(iii) The supervision is much more successful in that the men are concentrated in a relatively small, well-illuminated space and the task of stepping on and off benches is easy to standardize.

(iv) The detection of cases with excessive temperatures is simpler because of the frequent temperature checks and the greater ease with which the men can be observed.

(v) The treatment of cases with abnormal reactions to heat or with illnesses is much more rapid because there is no delay in getting the men to hospital.

(vi) Only 4 hours per day are spent on acclimatization; the remainder of the shift can be utilized for training the men in Fanakalo, and in safety or production procedures; the integration of training and acclimatization also results in a saving in time and a gain of productive shifts which one group estimates at 4 shifts per labourer.

(vii) In times of heavy influx the climatic rooms can be used for four to five shifts and can thus accommodate up to 1,000 men per day in the bigger rooms; this has eliminated the shifts previously lost while Bantu recruits were waiting to be acclimatized.

(viii) There has been a reduction in the load on busy shafts which one mine, with a complement of 8,000 labourers, estimates at 104 conveyance trips per month.

(ix) A certain amount of physical conditioning occurs.

(x) *Saving in manpower*—the number of European supervisors and Bantu bossboys employed in climatic room acclimatization has been *cut to one third* of the requirement in underground acclimatization. A recent survey shows that in the 26 mines using the new methods the ratios of supervisors to the number of men being acclimatized are:

1 European supervisor to 3,780 acclimatizees

1 Bantu bossboy to 430 acclimatizees

In the 8 mines still acclimatizing men underground by the Chamber of Mines methods the ratios are:

1 European supervisor to 1,340 acclimatizees

1 Bantu bossboy to 138 acclimatizees.

By the end of 1969 it is estimated that 238,000 of the 250,000 Bantu miners being acclimatized each year will be acclimatized by the new climatic room procedures and this will effect a saving in manpower of 100 European supervisors and 1,000 Bantu bossboys.

The direct financial benefit to the gold minjng industry of acclimatization in climatic rooms can be calculated in various ways but it is doubtful whether it is less than between one and two million rand per annum.

REFERENCES

1. HODGSON, T. and KERENS, G. J. J. G., 'The design, construction and calibration of a surface climatic chamber.' *Mine Ventil.* J. 19: 137-148, 1966.
2. STRYDOM, N. B., WYNDHAM, C. H., WILLIAMS, C. G., MORRISON, J. F., BREDELL. G. A. G. and JOFFE, A. 'Oral/rectal temperature differences during work and heat stress.' *J. Appl. Physiol.* (U.S.A.) 20: 283-288, 1965.
3. WYNDHAM, C. H., STRYDOM, N. B., WILLIAMS, C. G., and HEYNS, A. J. A. 'An examination of certain individual factors affecting the heat tolerance of mine workers.' *J. S.Afr. Inst. Min. Metall.* 68: 78-91, 1967.

Notices

P.W.D. ROSTER OF CONSULTING ENGINEERS

(*Extract from a letter from the Secretary for Public Works*)

In recent years a large number of professional engineers has entered the consulting field. Although the names of most of these have been placed on the Department's roster of consulting engineers either as a result of representations made by the South African Association of Consulting Engineers or by applying direct to the Department there are still some who seem to think that canvassing through an influential person is necessary to obtain commissions from the Department.

The Department's roster is open to all registered professional engineers who are suitably experienced to undertake consulting work and commissions are awarded strictly on merit. I shall appreciate it, therefore, if registered professional engineers who wish to be considered for commissions by the Department could be advised that they must apply, in the first instance, to be placed on the Department's roster.

On receipt of such an application a questionnaire listing all the information required by the Department will be forwarded to the applicants for completion and returning to the Department for record purposes. All names which appear on the roster are taken into account when a commission has to be awarded, due consideration being given to factors such as geographical position, seniority, capability and compatibility.

AMERICAN SOCIETY OF MINING ENGINEERS 1970 FALL MEETING AND EXHIBIT

The Secretary for Commerce has passed to us a letter received from the American Society of Mining Engineers, reading as follows:

"We would be delighted to have South Africa attend our meeting next year and to exhibit some of their mining equipment in our Technological Information Exchange. The 1970 SME Fall Meeting and Exhibit will be held in St. Louis, Mo., October 21-23, 1970, at the Kiel Auditorium. The AIME World Conference on Lead & Zinc Mining and Metallurgy will be an integral part of our meeting—and an added incentive to attend.

It should be understood that we discourage the showing of actual mining equipment and encourage the manufacturers and suppliers to send their engineers to man the booths. We hope that the exhibits will endeavour to put across their story by means of photographs, drawings, models and literature, rather than by display of prototypes of the actual equipment.

We will be happy to welcome manufacturerers from South Africa as well as the mining engineers who, from time to time, have registered at our meetings."

For further particulars, interested parties may write to the Society of Mining Engineers, 345 East 47th Street, New York, N.Y. 10077, U.S.A.