Factors Affecting the Mechanical Efficiency of Men Shovelling Rock in Stopes

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Discussion

M. J. Martinson* (Associate Member): This is another interesting paper in the series which the Human Sciences Laboratory is publishing on the physiological cost of the more strenuous manual tasks performed underground. As a mining engineer—albeit presently an academic one—this contributor is more concerned with the practical significance of the study in the field of stope cleaning than with physiological niceties, but before discussing some of the practical issues raised by the paper perhaps the authors would care to reply to lay comment on three physiological matters.

Firstly, in two places the authors make statements to the effect that the maximum oxygen intake of 'average' (*sic*) Bantu mine workers is 3·0 l/min. What do the authors mean by 'average'? Maximum oxygen intake in the individual is probably some function of *inter alia* age, physical fitness, state of health, ambient partial pressure of oxygen, diurnal and/or seasonal changes in metabolism, and possibly cumulative exposure to dust and other occupational contaminants. Since maximum oxygen intake is apparently such an important quality in manual labourers we ought to have a clear picture of its distribution in the entire labour force, and also know precisely how the individual's *quantum* is affected by factors such as those mentioned above.

Secondly, arising out of the same statements and ignoring the reservation implicit in the previous paragraph, is it correct to say that the 'average' Bantu mine worker has a maximum intake of 3·0 l/min? In the August 1966 issue of the *South African Journal of Science* four of the present co-authors reported the mean maximum oxygen intake of a random sample of 338 Bantu recruits of different tribes to be 2·63 l/min with a standard deviation of 0·542 l/min, and these figures were repeated in a paper published in the November 1968 issue of this *Journal*. Admittedly the mean maximum oxygen intake of the six subjects used in the present study was 3·05 l/min, but since they were selected on the grounds of previous shovelling experience they can hardly be regarded as being 'average' recruits.

Thirdly, it seems to me that the authors are perhaps a little uncritical in their acceptance of the '50 per cent of maximum oxygen intake' level of activity for endurance work. I am not unmindful of the evidence upon which this level is based, but I suggest that the evidence is at best tenuous and that the whole topic of fatigue and 'optimum' levels of productivity under conditions of high muscular activity and considerable psychological stress is a lot more complicated than would appear from the authors' ready acceptance of the 50 per cent level. Under present working conditions the question is largely rhetorical because it would need an army of supervisors to ensure that all members of a typical gang work at 'optimum' levels throughout the shift, but if individual performance should ever become more readily determinable the issue might become crucial to management and *malayisha* alike.

So much for physiological matters; now a few random thoughts on some wider, practical issues raised by the paper.

In the paragraph headed Material the statement is made that 'The mixture (of fine, medium-sized and bigger rocks) was considered to be representative of an average underground rock sample'. Elsewhere in the report the authors specifically draw attention to the effect of particle size on the oxygen consumption of men shovelling graded material, and intuitively one imagines that the size distribution of the material being shovelled would be highly significant in a study such as this. Presumably the authors were forced to assess size distribution subjectively because of the lack of objective data on the subject, and possibly the necessity for this assumption highlights how little we know quantitatively about any of the variables in stope cleaning systems. In this connection it may be remarked that although the present study was largely designed to show how dip and stoping width effect energy expenditure in shovelling, no data are given—nor, probably, are they available—to show how the industry's stoping tonnage is distributed in terms of these two factors. It seems to me that if the mining industry seriously hopes to improve stope productivity it must start by measuring the basic variables in existing systems.

Elaborating somewhat on the previous paragraph, there also seems to be a tremendous gap between the present study—and its predecessors—and the prospect of gainfully using the information so carefully garnered by the authors. It would be reassuring to hear from the authors that their work on the physiological aspects is being integrated in some master plan for increasing productivity of manual labour. This I fear is not the case, and if productivity has changed at all in recent years I would hazard a guess that the change has been brought about by random factors rather than by systematic engineering design. The Human Sciences Laboratory has worked extensively in stopes in the past, and possibly the time has come when it should widen the ambit of its operations to include engineering-type analyses of cleaning systems, with particular emphasis on the economics of rapid cleaning by manual labour. Perhaps experiments could be conducted with stakhanovite-type gangs consisting of men selected for their high maximum oxygen intake and superior motivation; these men might be offered special incentives in the shape of extra pay

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and rations, and wear distinguishing insignia which would serve as a pass for surface when their taskwork is completed.

Finally, I wish to raise a matter of principle arising out of the authors' statement that the results from this study can be used to determine 'optimum' (*sic*) levels of production from Bantu mine workers. It is not altogether clear what nuances the authors have in mind by putting 'optimum' in quotation marks, but presumably it is some sort of euphemism for 'reasonable maximum'. The South African mining industry must be unique in being able not only to measure the physiological reactions of its labour force under stress, but also in being able to lay down 'optimum' production rates based on these measurements. In an earlier paper from the Human Sciences Laboratory (the *Journal*, November 1968) it was reported that a significant number of labourers are presently working at oxygen consumptions in excess of 50 per cent of their maximum oxygen intake; if the day should come when standards set by the Human Sciences Laboratory can be enforced by management there should be appointed some sort of official ombudsman.

AUTHOR'S REPLY

Dr C. H. Wyndham (Member): Mr Martinson asks some very pertinent questions.

His first series of questions relate to the maximum oxygen intakes of the Bantu workers and our use of 3·0 l/min as the 'average' maximum oxygen intake. Mr Martinson is quite correct in his suggestion that maximum oxygen intake is a function of age and physical condition. It is also related to body weight. Our findings are that after the Bantu has gone through the physical conditioning of eight days of acclimatization then the mean maximum oxygen intake increases to a value which is close to 3·0 l/min and this improvement in physical conditioning is associated with a gain in mean body weight of about 7 lb.

We, at Human Sciences Laboratory, hope to persuade mine managers in the next few years to use the simple, rapid and accurate physical work capacity selection test in conjunction with acclimatization in climatic rooms. By this means mine managers could ensure that *all* men who go onto the shovelling of rock in stopes would have maximum oxygen intakes of 3·0 l/min and more. Such selection would solve Mr Martinson's problem with regard to our use of 3·0 l/min as the maximum oxygen intake of the 'average' Bantu and, perhaps, even more important it would ensure that no men with a low physical work capacity worked hard in hot conditions and are therefore liable to heat stroke.

Mr Martinson, in his second general point, has very perceptibely discerned our frustration at the failure of the gold mining industry to apply this information. We had hoped that the work study and production engineers in the mining industry would take this information, and similar information on the energy expenditure and mechanical efficiency of tramming rock at different speeds and with various loads, and work out a training manual for the two tasks and draw up a set of standard practices for the shovelling of rock in stopes and the tramming of it. The work study and production engineers have not done this.

My interpretation of their failure to do so is that they are frustrated and discouraged by the very negative attitude of the miners' to innovations in mining practices. This negative attitude is, perhaps the biggest single obstacle to increasing the productivity of the Bantu in the gold mining industry. It also frustrates much of the effort put into the training of Bantu in safety. If I am correct in my interpretation then it is high time that the industry makes a systematic study of the attitudes, motivation and aspirations of the miners with a view to uncovering the reasons for this negative attitude to innovations and, possibly, of removing the causes. Unless this is done it is possible that much of the effort and excellent research put into innovations in mining methods and machinery might come to nought.

We at the Human Sciences Laboratory would, therefore, welcome Mr Martinson's suggestions that a high level study group be set up in the gold mining industry to investigate the human and engineering problems of increasing productivity. Research and practical engineers, and physiologists and psychologists should be represented in the study group. This is no novel idea, 'Ergonomics' came into being in the industrially more advanced countries when they were faced with similar bottlenecks in their attempts to increase productivity and they, in a rational manner, got together the experts in the human and engineering sciences to try to solve the problems.

Notice

WATER YEAR 1970

The Water Year Office for South Africa has supplied a provisional list of scientific congresses and meetings due to be held during 1970 with "Water" as the main or secondary theme, as follows:

February: SARCCUS conference on "Water for Progress," Lourenco Marques.

March 16-20: Annual Congress, Institute for Water Pollution Control, Cape Town.

May: Possible S.A. Akademie conference on Cooling Tower Experiments, Pretoria.

May: Annual Meeting of Association of Municipal Electricity Undertakings, Potchefstroom.

May 27-29: Congress on "Water Resources of Natal", Durban.

June 29/July 4: Annual Congress, South African Association for the Advancement of Science, Cape Town.

July 2: Joint meeting of South African Association for the Advancement of Science and S.A. Akademie, Stellenbosch.

July: Winter School, Federation of University Engineering Students.

July: Youth Science Week. Foundation for Education, Science and Technology.

July 21-24: The South African Tunneling Conference.

September: Proposed SARCCUS conference on water in Nature Conservation, Skukuza.

November 16-20: International Convention on "Water for the Future", Pretoria.