J. S. Afr. Inst. Min. Metall., vol. 84, no. 2.
Feb. 1984. pp. 45–49.

The Furry Caterpillar: a new technique in the managerial control of gold mines

by M. SPLAINE*, S. J. BROWNER†, and M. A. FIELD‡

SYNOPSIS

In the field of operational control, Shewhart Control Charts and Cusum Charts have long been available to management. These techniques provide help by detecting rogue values of a control variable and changes in the underlying mean of that variable respectively.

This paper describes a new technique for identifying changes in the trend of a control variable, particularly when that variable is subject to large inherent variance.

SAMEVATTING

Wat bedryfsbeheer betref, beskik besture al lankal oor Shewhart-beheerkaarte en Cusum-kaarte. Hierdie tegnieke help onderskeidelik met die opspoor van afwykende waardes van 'n beheerveranderlike en veranderinge in die grondliggende betekenis van daardie veranderlike.

Hierdie referaat beskryf 'n nuwe tegniek vir die identifisering van veranderinge in die tendens van 'n beheerveranderlike, veral wanneer daardie veranderlike onderworpe is aan 'n groot inherente variansie.

Introduction

Operations research is generally directed towards an interpretation of the behaviour of process variables to assist managers in the effective control of their operations.

For many years, managers and quality-control engineers have used Shewart Control Charts and, more recently, Cusum Charts to monitor the behaviour of processes[1]. Both these techniques have sound bases in mathematical statistics, and their use is widespread throughout the technical world. A control chart is intended to show when a variable is significantly outside its operating range on either side of a target mean value (Fig. 1), whereas a Cusum Chart is meant to show when there has been a significant change in the underlying (perhaps 'target') mean (Figs. 2 to 4). Thus, these two techniques have complementary roles in the field of quality checking and control.

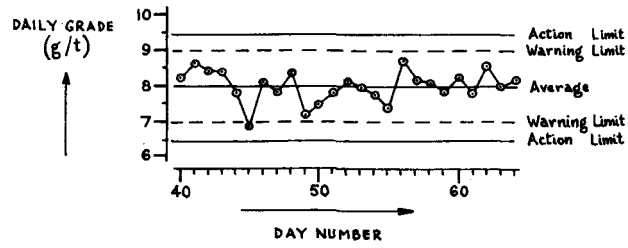

Fig. 1—Conventional control chart (Shewhart Chart) for daily grade with constant underlying mean value

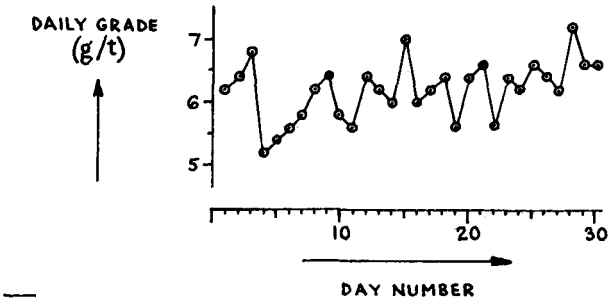

Fig. 2—Chart of daily grade with changing underlying mean value

Neither technique is particularly suited to show that there is a gradual change in the mean value of a key variable. Such change is particularly prevalent in the mining industry, for example in mine call factor, costs per ton, and gold head grade to the mill. Such variables are normally monitored by the plotting on a graph of regular observations, a moving average of those observa-

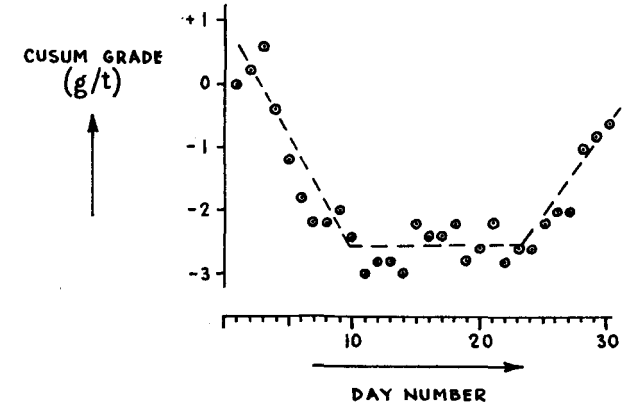

Fig. 3—Cusum plot of daily grades as given in Fig. 2

* Head of Management Sciences, Gold and Uranium Division.
† Head of Management Sciences, Welkom Section.
‡ Head of Management Sciences, Vaal Reefs Exploration and Mining Company.
All of Anglo American Corporation of South Africa Ltd, P.O. Box 61587, Marshalltown 2107, Transvaal.

SA ISSN 0038–223X/$3.00 + 0.00.

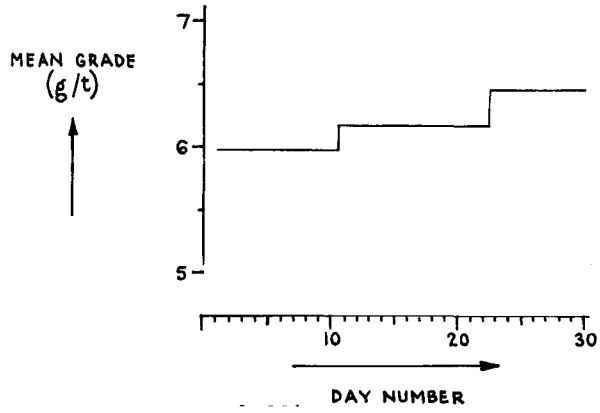

Fig. 4—Manhattan Diagram derived from Fig. 3.

tions and, sometimes, an exponentially weighted moving average. The averaging procedures smooth out some of the fluctuations in the individual observations, making it easier for a manager to see trends through time when they occur. Whenever such a trend can be seen by eye, it is important for the manager to know whether or not it is a significant trend; otherwise, he may take action to correct something that is not really happening.

The standard statistical technique by which the significance of an apparent trend can be tested is that of simple linear correlation analysis between the key variable and time[2]. This analysis yields a value for r, the correlation coefficient, for which there are tables giving the chance that that value would occur even if there were no real trend. The manager then has an objective measure of the chance that a real trend exists, or a measure of the statistical significance of the trend. Unfortunately, the above analysis must be carried out on a stated number of observations for the interpretation to be valid. In general, the manager does not know when the trend may have started, and it often happens that his interpretation is different for different numbers of observations in the set used in the analysis.

Furry Caterpillar Diagrams

As an answer to this problem, the following procedure was devised. For daily gold head grades, values were stored for two months' worth of days, the earliest in the list being dropped as each new day's value was added. Each day, the correlation analysis was carried out for all possible sets of continuous numbers of days' values, working backwards in time from the current new day. The least number of days' values in a set must be 3. Then, for all the sets with a significant value of r, the appropriate straight line representing each trend was drawn on a graph of head grade against time. Although 2 months' worth of values were examined, the lines were drawn only for the most recent month on the graph.

Fig. 5 is an example of such a graph (called a Furry Caterpillar Diagram) for a particular day (no. 75) during a continuous sequence of runs. For the 28 days shown, it can be seen that a sequence of falling head grades was

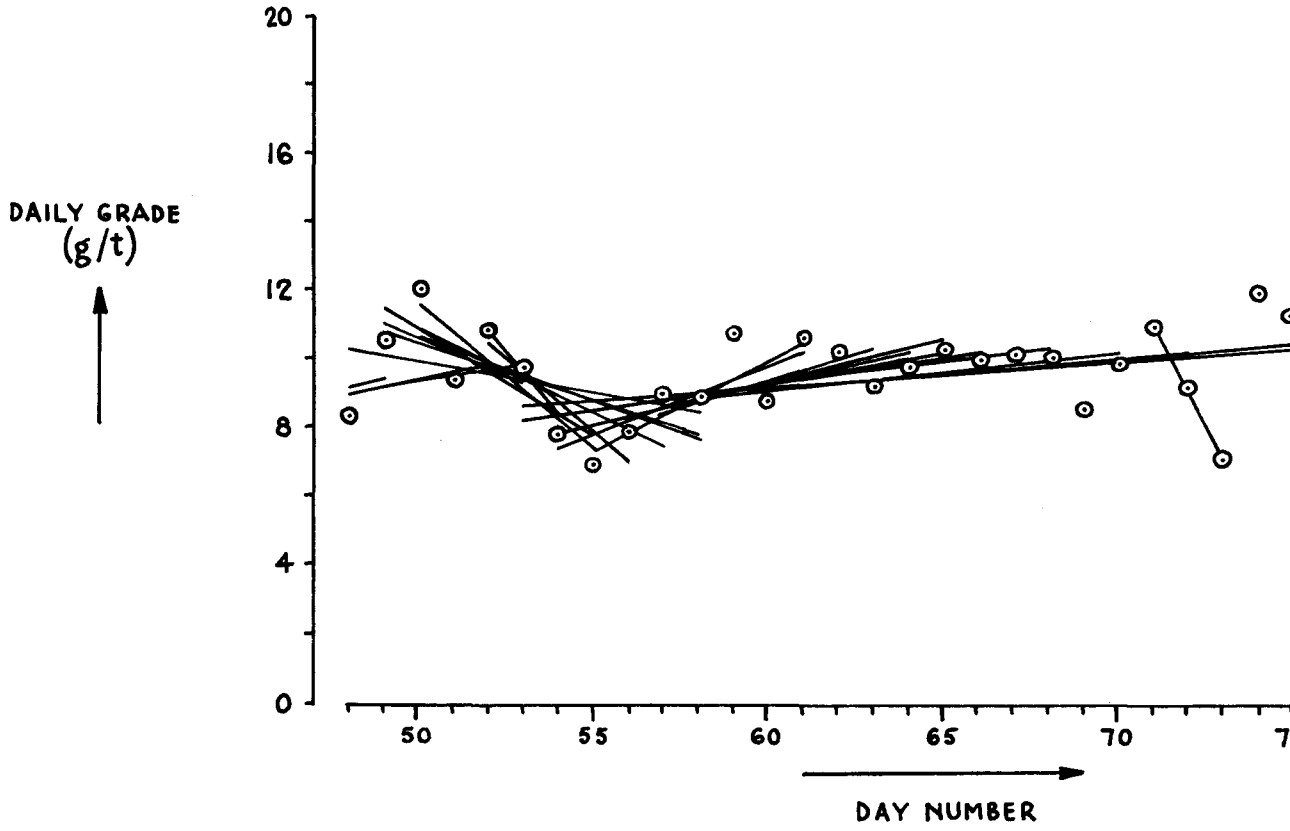

Fig. 5—Furry Caterpillar Diagram of daily grades, day 75

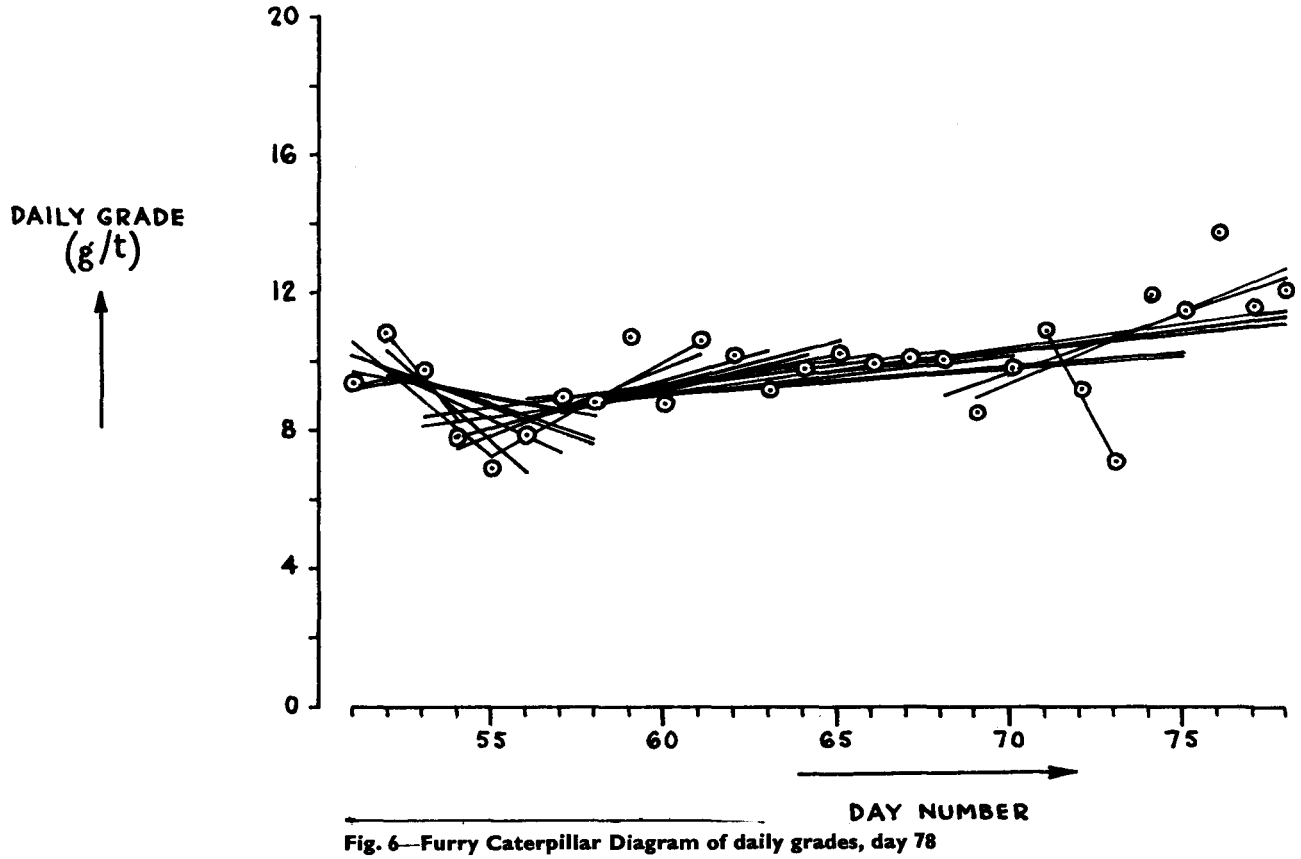

Fig. 6—Furry Caterpillar Diagram of daily grades, day 78

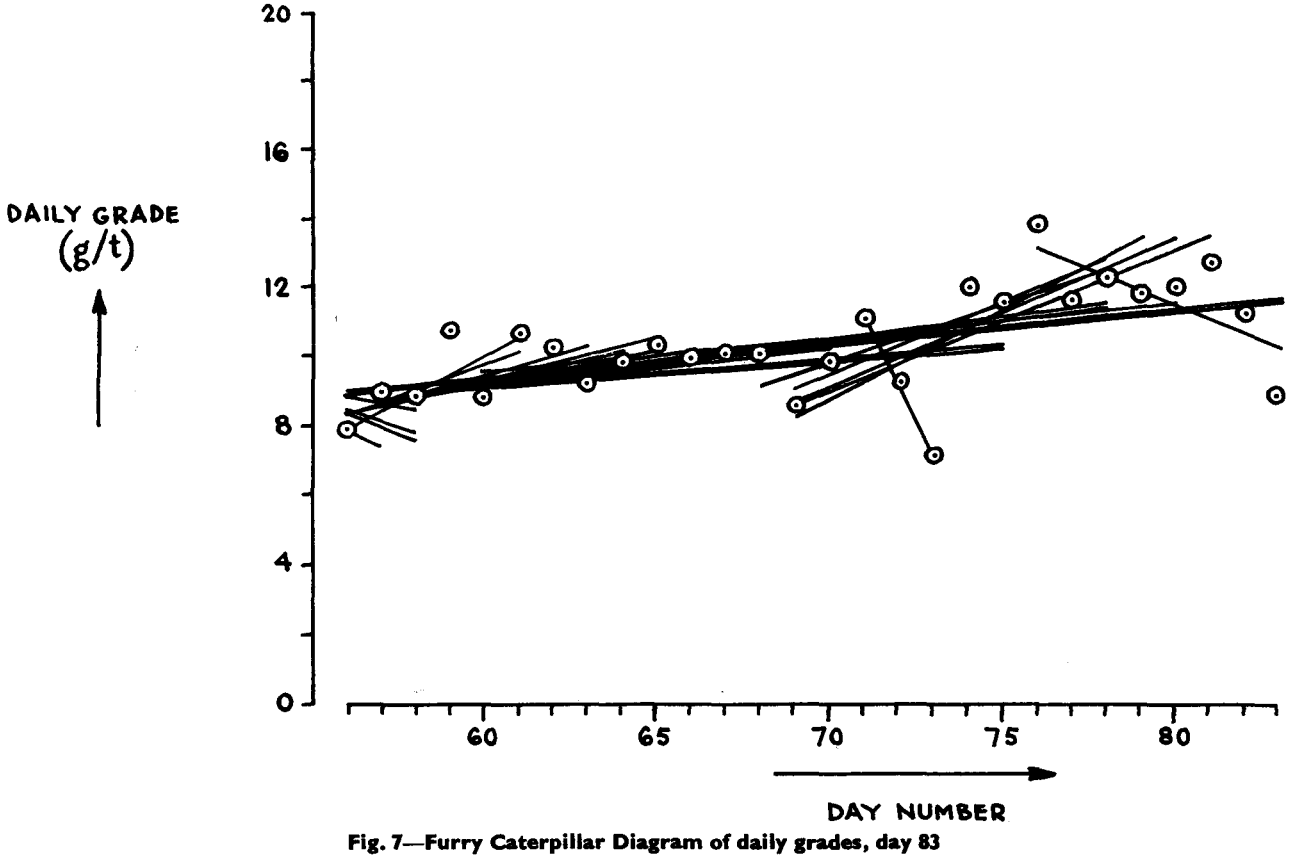

Fig. 7—Furry Caterpillar Diagram of daily grades, day 83

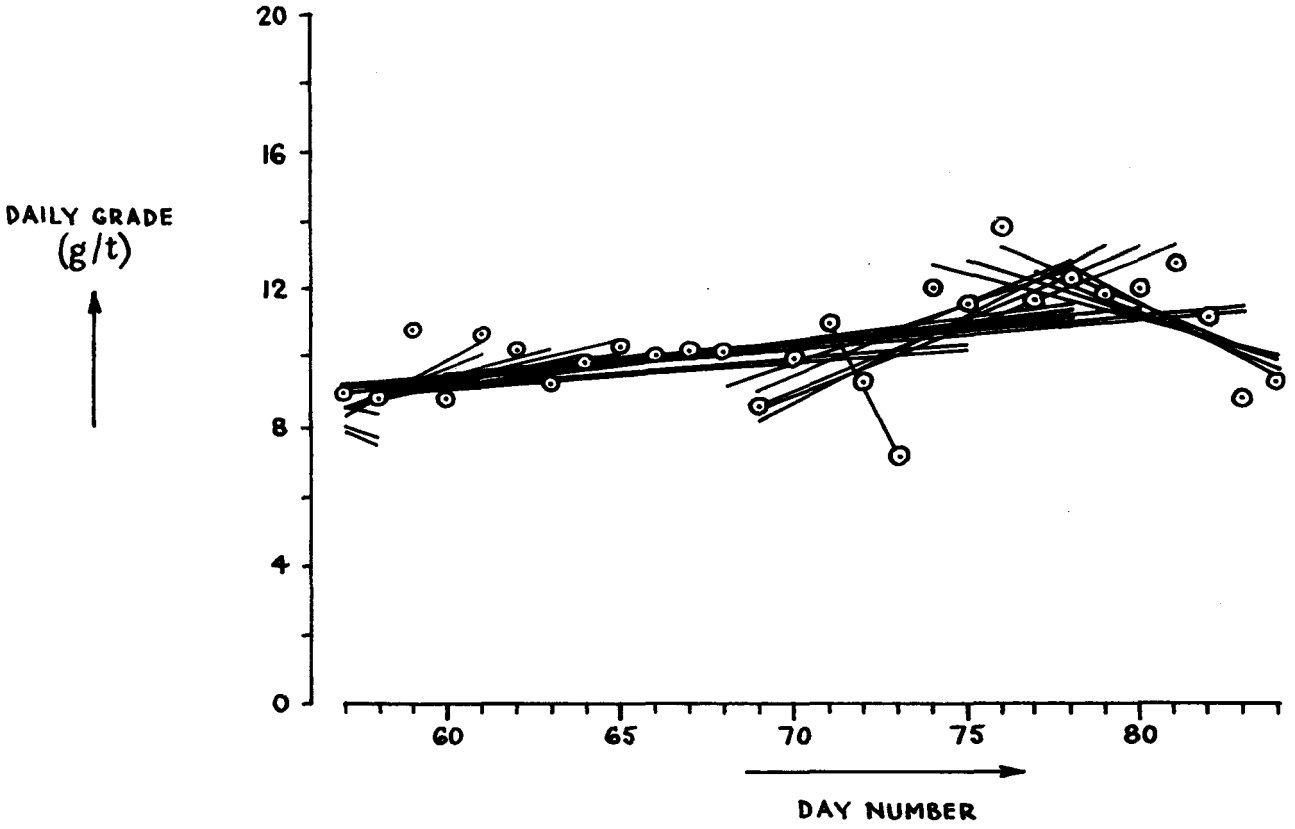

Fig. 8—Furry Caterpillar Diagram of daily grades, day 84

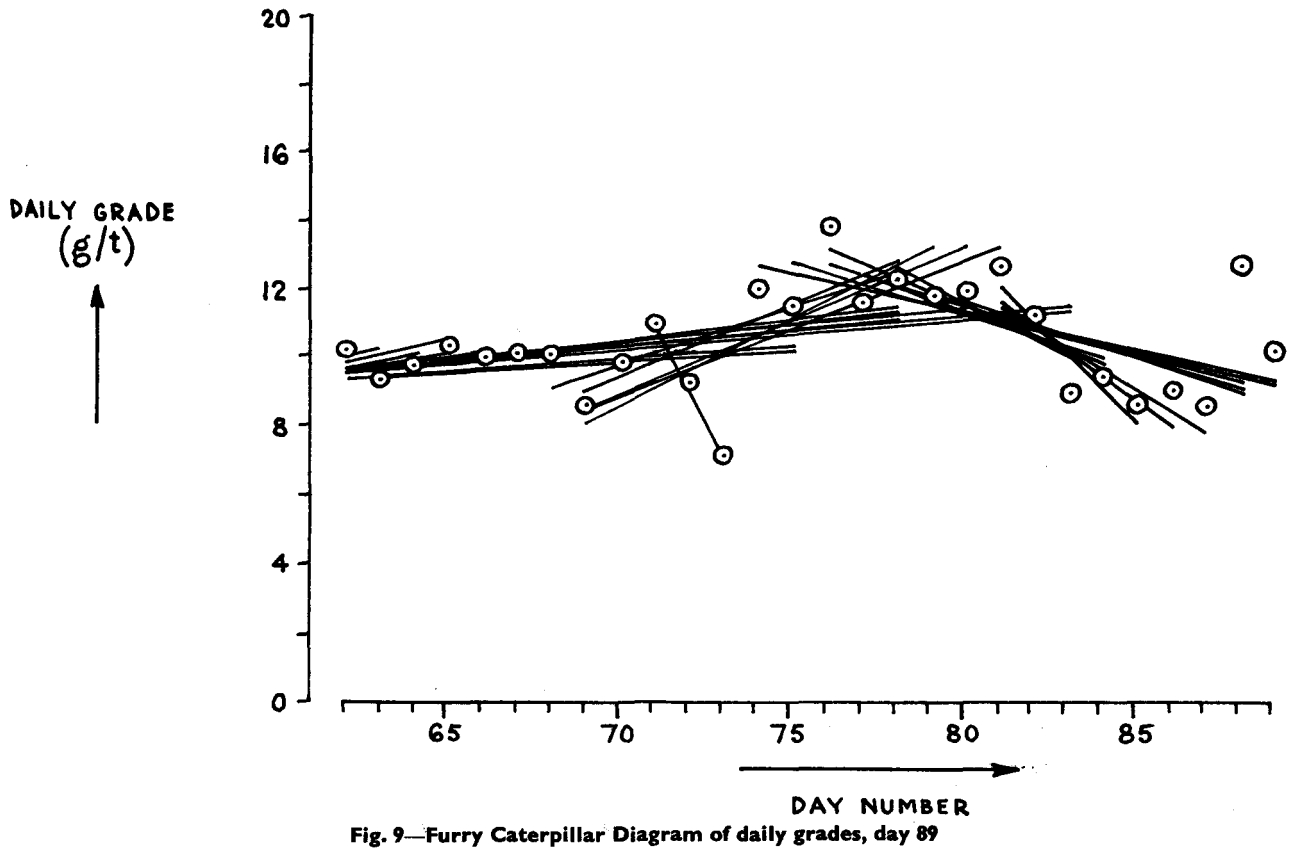

Fig. 9—Furry Caterpillar Diagram of daily grades, day 89

followed by a sequence of rising head grades, which started after about day 55. Two of the lines showed some evidence that the rising trend was still operating up to day 75, but the falling trend line from day 71 to day 73 gave warning that a reversal might have started at about day 71. Fig. 6 shows the position 3 days later, where it is clear that the reversal was not confirmed and that the rising trend was still operating. Fig. 7 shows the position another 5 days afterwards, when there was a falling trend line from day 76 to day 83, again giving warning that a reversal might have been starting. Fig. 8 shows that, on this occasion, only 1 day later than Fig. 7, the reversal from rising to falling trend was confirmed, there being five significant falling lines. Six days after Fig. 7 the number of falling lines had grown to 13, as shown in Fig. 9.

All these lines were significant at the 98 per cent level (i.e. there was a 2 per cent chance of being wrong when believing that a trend was real). However, since each data point has been used many times over, there is no accepted interpretation within mathematical statistics of the whole Furry Caterpillar Diagram. In all the cases examined so far, whenever turning points have been identified by eye from a Furry Caterpillar Diagram, subsequent *t*-tests on the difference in slope between each such pair of data points have always revealed highly significant differences ($0{,}001 > p$). In practice, this diagram provides a straight-forward routine way of assessing data that may contain trends in time. Moreover, potential trends that turn out to be real are confirmed to the eye within very few time intervals.

Application of the Technique

The procedure described above for Furry Caterpillar Diagrams has been coded for the Infogold computer system, along with those for producing control charts and Cusum Charts with their appropriate Manhattan Diagrams. Thus, the three separate monitoring methods, known as GOLDWATCH, can be invoked on a regular basis for any measured variable, the latter being input via a terminal at a mine and the subsequent output being available at that mine if required.

Acknowledgement

The authors thank the management of the Gold and Uranium Division of Anglo American Corporation of South Africa for permission to publish this paper.

References

1. MURDOCK, J. *Control charts*. London, Macmillan, 1979.
2. DAVIES, O. L., and GOLDSMITH, P. L. *Statistical methods in research and production*. London, Oliver & Boyd, 1972.

Alluvial Tin

The SEATRAD Centre will organize an international seminar on mining techniques for alluvial tin deposits, to be held in September 1984. The seminar will focus mainly on gravel-pump mining and dredging techniques, which are commonly used in Southeast Asia for the mining of alluvial tin deposits.

The gravel-pump tin-mining sector in Southeast Asia is currently facing two major problems: declining grades of ore, and high costs of energy for the mining operation. As a result, there has been an increasing trend for large-scale operation using bigger pumps, diesel engines, and motors, as well as earth-moving equipment, to excavate and transport the material. New problems arise, particularly with regard to high interest rates and volatile metal prices. There is therefore a need for the review of the present situation, for the discussion of the advantages and disadvantages of large-scale operation and use of earth-moving equipment, and for the proposal of improvements or new methods that can result in lowering the cost of tin production.

In the dredging sector, there is a need for the design of dredges of high capacity and for deep deposits, in view of the lower grade of ground being worked, as well as the discovery of the deep alluvials. With increasing costs of energy and spares, there is also a need for improved efficiency and for the testing of new materials that may have better wear-resistance properties.

It is therefore timely that an international seminar should be organized to bring together gravel-pump miners, dredge operators and designers, equipment suppliers, and researchers in order to discuss the problems, exchange ideas, and propose improvements. It is envisaged that the seminar will be divided into two sessions: the first on gravel pumping, and the second on dredging techniques. Papers would be presented at the sessions, and ample time allotted to discussions on each paper, as well as a panel discussion at the end of each session.

An exhibition of mining and mineral-processing equipment, particularly for use in alluvial-tin mining, is also being planned.

A one-day field trip will be organized to a gravel-pump mine and dredge near Ipoh, Malaysia.

Information on registration, exhibition, and other details of the seminar are available from The Director, SEATRAD Centre, Tiger Lane, IPOH, Malaysia. Telephone: Ipoh 05-559366; Cable: TINCENTRE, IPOH.