An analogue system for the early detection of fires in gold mines*

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SYNOPSIS

After a brief account of the differences between the control of underground fires and those on the surface, the paper describes the analogue detection system used on the mines of the Anglo American Corporation of South Africa Limited.

The system comprises Spanair gas analysers, Becon combustion-particle detectors, a telemetering system, a surface signal-recording and-processing system, and an alarm system. The use of the system is described and illustrated.

SAMEVATTING

Na 'n kort verslag van die verskille tussen die beheer van ondergrondse brande en brande op die oppervlak beskryf die verhandeling 'n analoogopsporingstelsel wat op myne van Anglo American Korporasie van Suid-Afrika Beperk gebruik word.

Die stelsel bestaan uit Spanair gasanaliseerders, Becon verbrandingspartikel-opspoorders, 'n telemetriese stelsel, 'n oppervlaksein-opname en -verwerkingstelsel, en 'n alarmstelsel. Die aanwending van die stelsel word beskryf en geïllustreer.

Introduction

An all-analogue fire-detection system that is used in South African gold mines has been described fully by Van der Walt *et al.*[1]. That paper is recommended to anyone wishing to know the technical details of the system. The present paper describes, in non-technical terms, the use of the system, and starts with a brief account of the main differences between the control of underground fires and those on the surface.

Control of Mine Fires

For underground operations, air is caused to flow down a shaft, through all the workings, and up a return air shaft. A shaft system serving an area of, say, 9 km^2 with workings at a depth of, say, 1,5 km may require only about 50 combustion particle detectors backed up by 6 gas analysers to detect any fire effectively. For a similar area on surface, many hundreds of detectors may be necessary to obtain the same degree of coverage. In an underground situation, the detection is more positive since the products of combustion must pass along confined passages and so over a detector head if the latter is placed in the workings on the return-air side of the fire area. The time of detection depends on the velocity of the ventilating current and the distance from the fire to the detector head. This distinct advantage of early positive detection of underground fires is of major importance in reducing the attack time, i.e. the time from ignition of the fire to when water is first hosed onto it or until the fire area is sealed.

For surface fires in areas serviced by municipal fire brigades, there is a South African Bureau of Standards code of practice, which includes the following paragraphs relating to one component of overall attack time—attendance time. The relevant sections read as follows:

2. *DEFINITIONS*
   2.1 *Attendance time*
   The time interval between the receipt of the fire call by a fire brigade and the arrival of the fire unit(s) at the fire (i.e. turn-out time plus travelling time).

4. *ORGANISATION OF FIRE SERVICES*
   4.2.3 *Attendance times*
   The efficiency of a fire service is judged largely by the attendance times that the fire brigade is capable of achieving. The attendance times should not exceed those shown in Table I.

TABLE I
ATTENDANCE TIMES AT FIRES

1	2	3	4
Class of Brigade	Fire-risk Category	Attendance Times*, minutes	
		1st Attendance	2nd Attendance†
Professional	High-risk Moderate-risk Low-risk	5 7 12	6 9 —
Semi-professional	Moderate-risk Low-risk	7 12	9 —
Retained and Volunteer	Low-risk	12	—

* Although these attendance times are the same for all classes of brigades protecting areas falling into the same fire-risk category, the area protected by a semi-professional, retained, or volunteer brigade is more restricted than that protected by a professional brigade (see Table 2), thus allowing for a longer turn-out time for semi-professional, retained, and volunteer brigades.

† Times for reinforced units.

For mines to achieve anything like the attendance times shown in the table, permanent fire-fighting teams providing a 24-hour coverage would be required. Up to now, mines have not had such a service but have relied upon highly trained teams of experienced men drawn mainly from mining, engineering, and ventilation disciplines to be available when called upon to fight fires. The attendance time for these teams includes time to assemble, to check kit, and to proceed underground to the correct level in the shaft and along the haulage-way to the scene of the fire.

Comprehensive plans must be prepared for all fire-prone areas underground so that the attendance time can be limited. To reduce the attack time, immediate action must be taken when the alarm sounds, and radio call-out facilities should be employed to notify the men in the stand-by team.

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Analogue Detection System

Before the installation of the analogue detection system and detailed emergency plans, the estimated attack times in one gold mine for fires starting immediately after the main shift ranged from 195 minutes, to 540 minutes for certain remote and isolated areas. This mine had divided the underground workings into 78 areas each of which could be sealed off without affecting the production in the other areas. With such long attack times, there was little chance of extinguishing a fire with water, and the fire area had therefore to be sealed off. Since the installation of analogue detectors and detailed emergency planning, the attack time has been reduced to such an extent that the fire-fighting teams are able to attack the fire directly in most, if not all, of the accessible areas.

The system developed by Anglo American Electronic Laboratories with the close co-operation of the mines comprises the following:

(i) Spanair gas analyser,
(ii) analogue Becon combustion-particle detector,
(iii) telemetering system,
(iv) surface signal-recording and -processing system,
(v) alarm system.

The Spanair carbon dioxide analysers are usually installed in return airways to monitor complete ventilation districts (Fig. 1). They therefore act as a backup to the Becon detectors, which are installed near the working faces (Fig. 2).

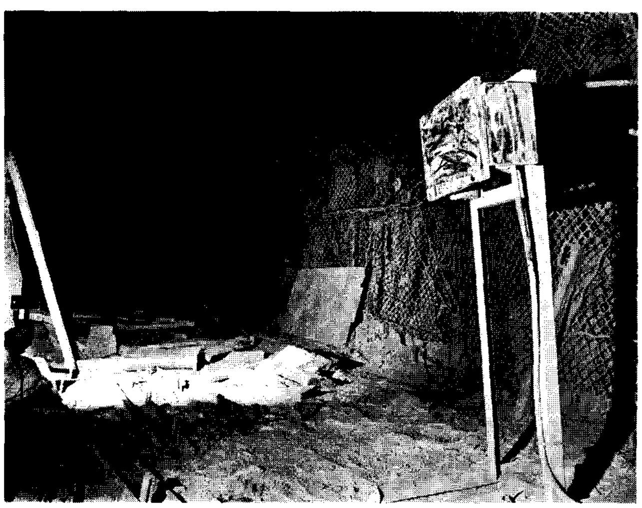

Fig. 1—A Spanair gas analyser in a return airway

The telemetering system consists of a 64-channel frequency-division multiplex network especially developed for mining conditions that transmits the analogue outputs from the analysers and detectors to a surface signal-recording and processing system. The underground telemetering electronics system is housed in sealed fibreglass boxes as shown in Fig. 3, and the surface installation is shown in Fig. 4.

The type of record most acceptable to mines is one that shows the past record and present status of all the signals in such a way that they can be easily read and understood. The five circular chart recorders shown in

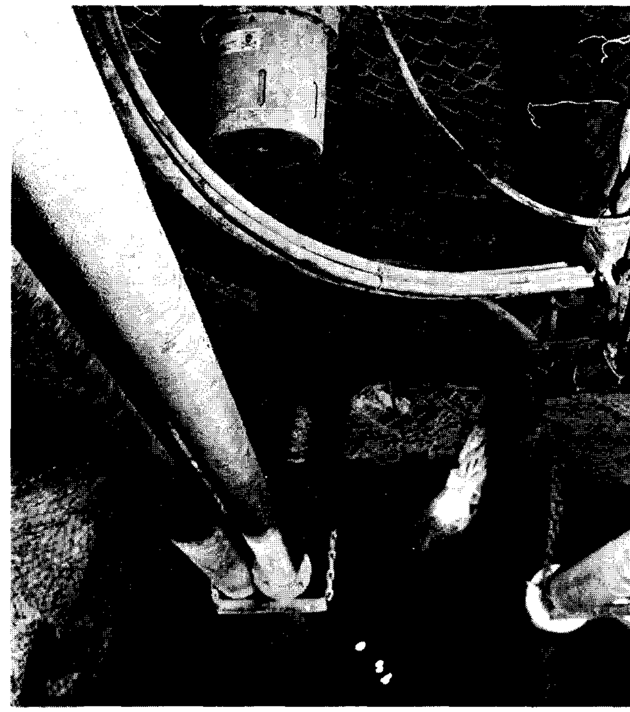

Fig. 2—A Becon detector installed near the working face

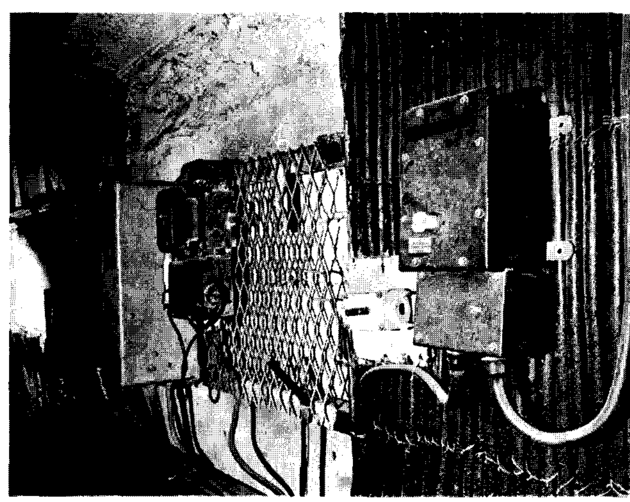

Fig. 3—The underground telemetering electronics system

Fig. 4 are for the Spanair analysers, and the three drum recorders are 24-channel 'dot' recorders for the Becon detector. A typical printout of the dot recorder is shown in Fig. 5. These graphs are in twelve different colours, with a dot and circle trace in each colour to make up the 24 channels. It is therefore possible by close examination of the chart to determine which channel indicates a fire. However, as the pens are concealed, one has to pull out the paper to see the instant recordings. Fig. 6 shows a bank of separate 7-day chart records for both the Spanair analysers and the Becon detectors, which is preferred to the dot recorder system.

The additional cost is more than compensated for by the ease with which checks can be made and instant readings observed. From a typical Spanair chart (Fig.7),

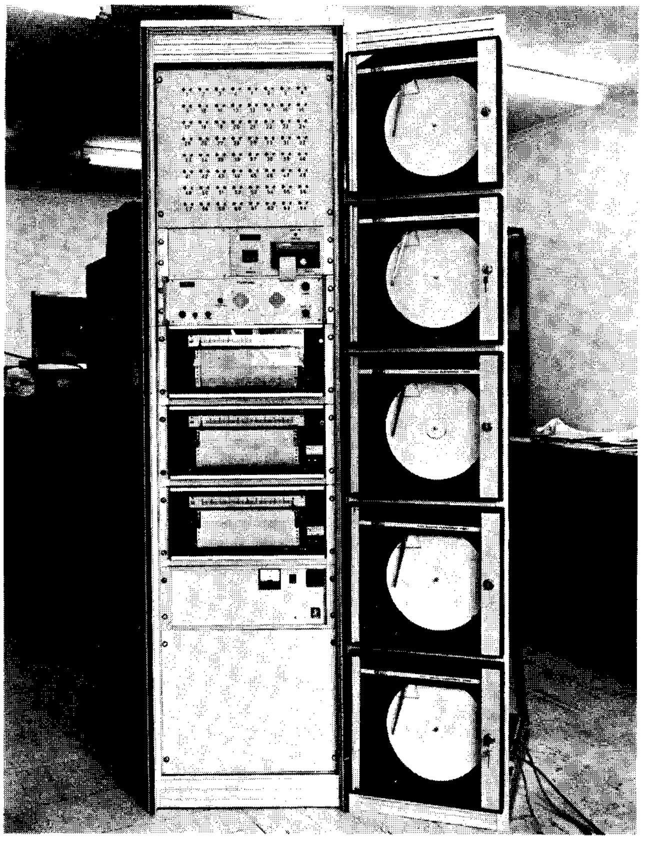

Fig. 4—The surface telemetering electronics system

the effect of workers exhaling carbon dioxide and the effect of the blast can be seen. Immediately before the blast, the concentration of carbon dioxide returns to normal with all employees out of the mine, and then a high concentration of carbon dioxide develops as a result of blasting operations, with a fairly constant daily delay for conditions to normalize. The time the night shift enters and leaves underground can be seen from a careful study of the chart, and later the main day-shift is more clearly shown by the depression in the chart each day. In Fig. 8, a small fire that broke out during blasting operations is very apparent.

Fig. 9 is a seven-day analogue record of a Becon detector under normal operating conditions showing scheduled and unscheduled blasting. The record also shows slight variations in the Becon ouput at times when mining activity takes place. These are attributable to the presence of diesel locomotives.

In addition to the above recorders, use is made of a three-channel standby recorder that is capable of a better time resolution than the seven-day circular chart recorders. The output of any Becon detector or Spanair analyser can be switched on to one of the channels of this recorder whenever an alarm is given. These have proved most beneficial for the monitoring of fire-fighting operations since any changes in the concentration of carbon dioxide or combustion products are highlighted immediately.

Also incorporated in the system as a standard item is a digital printer that records each alarm by channel

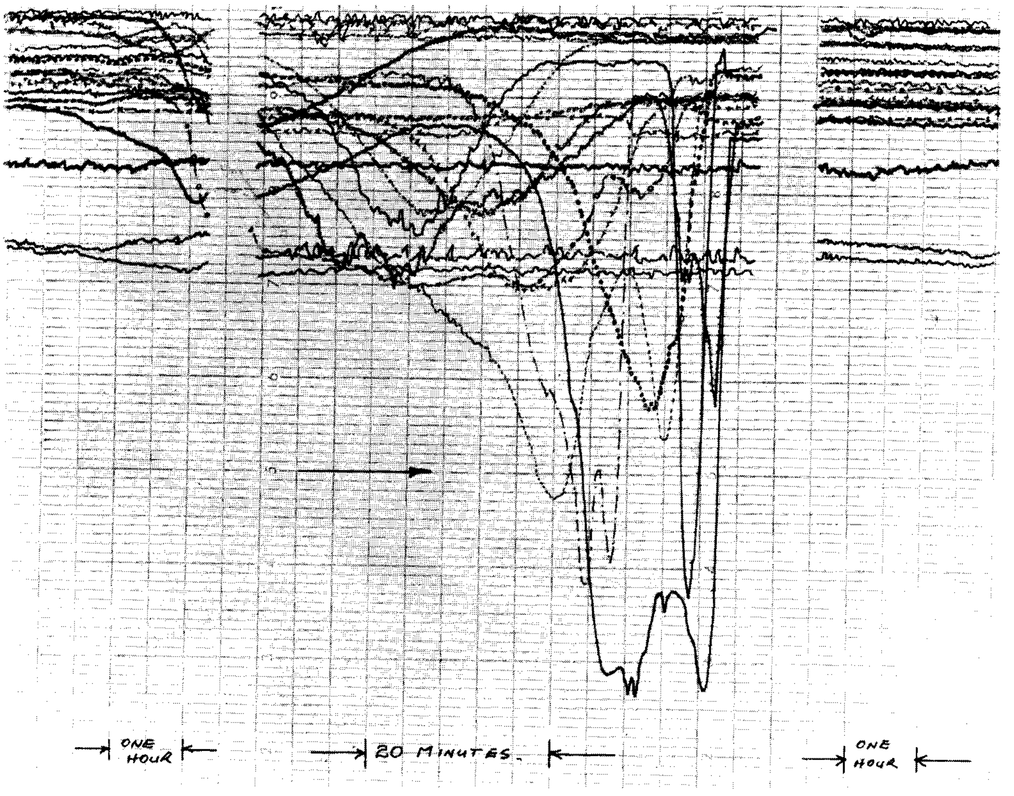

Fig. 5—A typical printout of the dot recorder

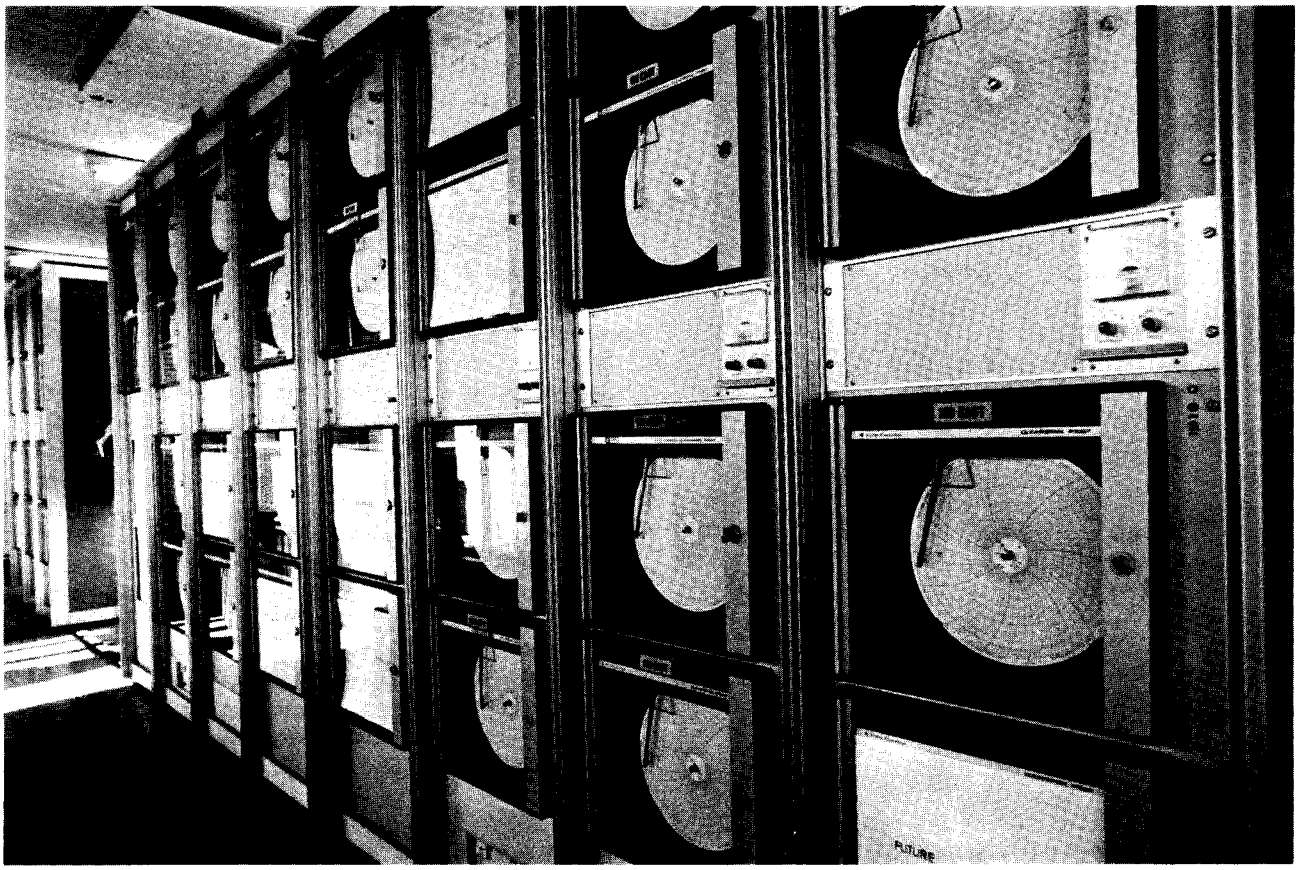

Fig. 6—A bank of separate 7-day chart records for the Spanair analysers and the Becon detectors

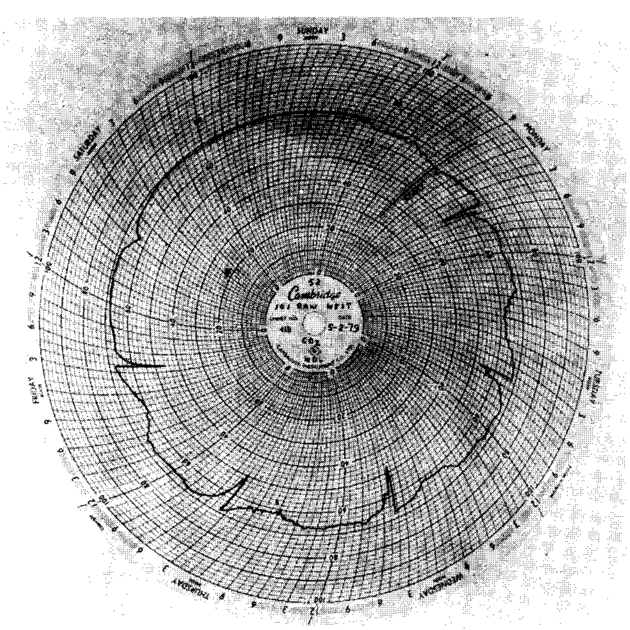

Fig. 7—A typical Spanair analyser chart

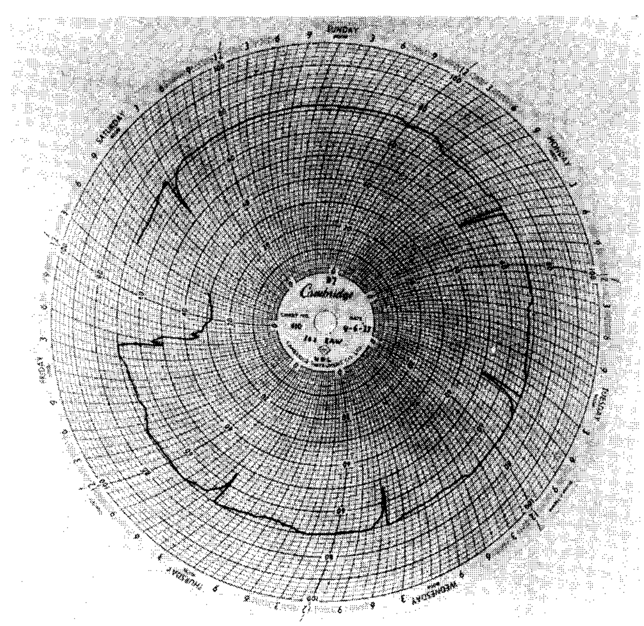

Fig. 8—A Spanair analyser chart showing the outbreak of a small fire during blasting

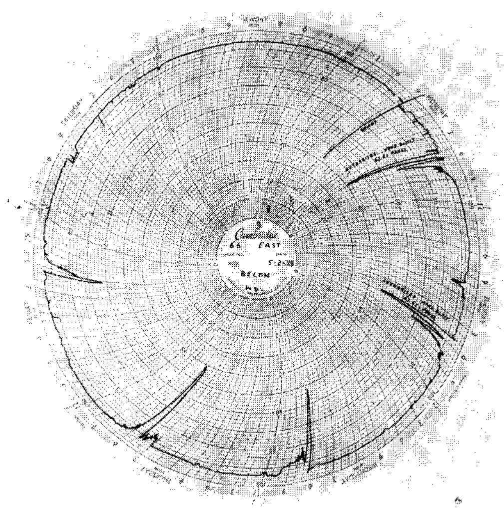

Fig. 9—A seven-day analogue record of a Becon detector

number and the time of day when the alarm started (+) and when it stopped (−), as shown in Fig. 10. This short strip covers the period from 16h55 to 17h08 during blasting operations. Channel number 51 is seen to have started recording at 16h56 and stopped 6 minutes later at 17h02. Channel number 55 recorded from 17h00 to 17h02. Channel number 52 started recording sometime before 16h55 (not shown), stopped at 17h02, restarted at 17h03, but stopped again at 17h07. In practice, these printouts are referred to only when checking for abnormal activities. The alarm system is relied upon to alert the controllers, and in this regard it has proved most reliable.

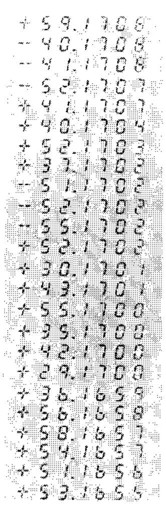

Fig. 10—A typical printout showing a record of each alarm

There are four alarms that can be set on surface to give full protection. The 'tracking' alarm – a rate of change of signal – differentiates between slow diurnal variations and aging drift in the outputs of the Becon detectors and Spanair analysers from the faster change-in-output signal that results when fires break out and during blasting. It also permits greater alarm sensitivity than previously.

At fixed time intervals of 10 minutes, the analogue output signal is sampled and held; a fixed (but pre-adjustable) value, usually 2 per cent of full scale, is then subtracted from it. This alarm level is held for the next 10 minutes before updating. When the analogue signal decreases faster than 2 per cent in 10 minutes, the alarm level is crossed, so providing the alarm signal. Bi-colour channel lights, which can be seen at the top of Fig. 4, are fitted to the surface console. In the quiescent state, the light is green; in the alarm state it alternates between green and red, and an audible alarm sounds.

This tracking alarm is backed up by a fixed alarm, the setting of which is beyond normal variations (excluding blasting) in the analogue ouput signal. The method of alarm is the same as for the tracking alarm. There are also low-level and high-level alarms, the former to warn of a major failure in the system such as a cable break, and the latter to protect the unit from any extraordinary high outputs due, for example, to some component failure.

As most fires are associated with blasting operations, centralized blasting from the surface is recommended if the maximum benefit is to be derived from the detection system. The daily routine for the duty mine overseer once the shift is clear is to check that no channel is recording abnormal conditions. He then gives instructions to blast electrically from the surface and observes all the channels recording blasting operations. In practice, as the audible alarm sounds for each channel, he acknowledges it by pressing a button and the visual alarm continues until the concentration has returned to normal. The audible alarm is automatically re-instated when the visual alarm is cancelled. Should the alarm restart for a channel that has already completed its cycle during blasting operations, a fire must be suspected and this can be confirmed by a study of the chart recorders. The duty mine overseer should remain in the control room until all the alarm signals have ceased, i.e. until all the channels have returned to normal.

Conclusion

It is recognized that fires result from breakdowns in management controls, and that the prime objective in every fire-prevention programme is the prevention of ignition. However, no matter how hard one strives to maintain effective controls, there is always a possibility of failure on the part of individuals to adhere to standards. Consequently, mine managements must plan to limit the losses caused by any non-standard action. It is for this reason that the detection system described is now standard equipment on all Anglo American gold mines. It has proved most reliable and successful in helping to reduce fire losses.

Acknowledgement

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Reference

1. Van Der Walt, N.T., Bout, B.J., Anderson, Q.S., and Newington, T.J. *J. Mine Vent. Soc. S. Afr.*, Jan. 1980.