THE REDUCTION OF PROCESS HAZARDS BY PLANT CONDITION MONITORING

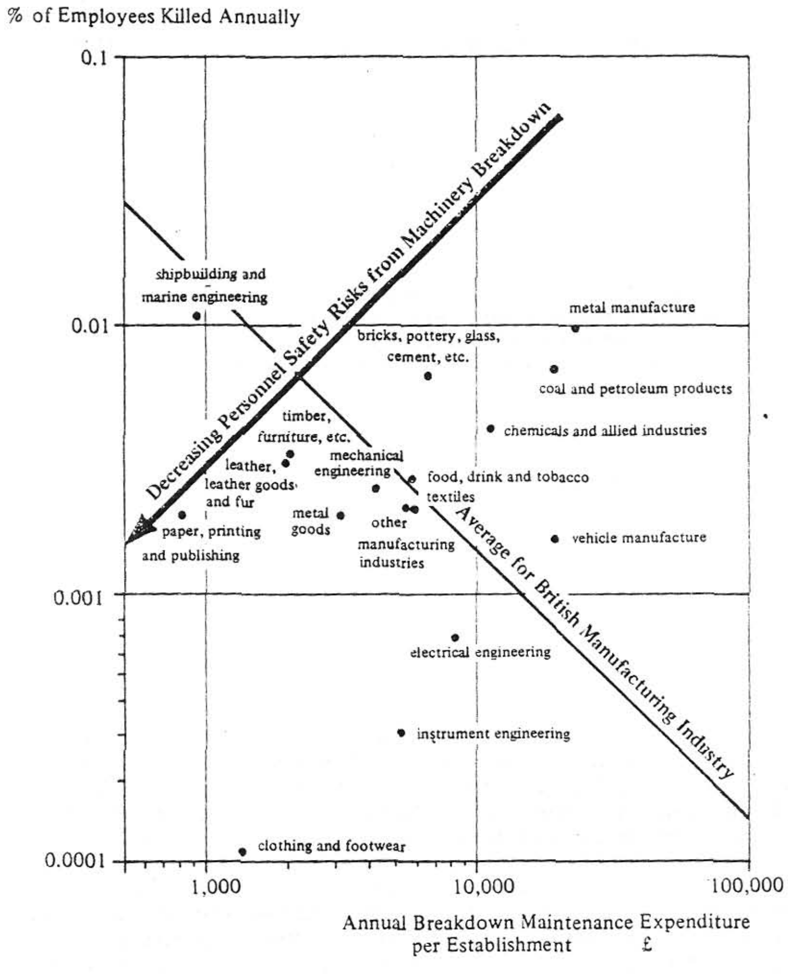
M.J. Neale*

Process hazards can arise from the deterioration of plant and machinery and this paper discusses the methods which are now available for determining plant condition so that failures can be anticipated and appropriate action taken.

As a starting point it is useful to consider those industries in which these techniques are likely to be particularly useful in terms of hazard reduction. One way of assessing this situation is shown in Figure 1 which indicates the percentage of employees killed annually in various industries. This is plotted in this figure against breakdown maintenance expenditure, to give a guide to those industries in which the safety risk is likely to arise from mechanical breakdowns. Industries which have an above average risk, in these terms, are those towards the top right hand corner of the diagram, and these industries, are those in which condition monitoring of their plant and machinery could have a major effect on safety. This is distinct from other industries, such as shipbuilding, where there is a high risk, but where this probably arises from other hazards such as dropped objects. Hazards of this kind can probably be reduced better by other methods such as the wearing of hard hats and protective clothing.

The kind of industries which have most to gain in terms of safety from the condition monitoring of their plant and machinery are those such as oil refining, chemical processing, and the manufacture of metals, plastics and ceramics. The plant and machinery which is likely to be particularly appropriate for monitoring, will be that which operates at high pressures, temperatures and voltages, or which contains dangerous working fluids or high inertia high speed components.

*Michael Neale & Associates Ltd, 43 Downing Street, Farnham, Surrey.



THE INCIDENCE OF PERSONNEL SAFETY RISKS IN THE BRITISH MANUFACTURING INDUSTRY

FIGURE 1

The principles of condition monitoring

It is unusual for an item of plant or machinery to fail suddenly and catastrophically without any advanced warning. There is usually some deterioration of performance or signs of wear, leakage or vibration, which indicates that all is not well.

The general principle of condition monitoring involves the selection of some appropriate indicator of the machine condition, which can be measured at intervals. This measurement is recorded and is then usually plotted on a graph, against time in service, to indicate whether deterioration is occurring, as shown in Figure 2. If, however, the operators are very familiar with the machine and its various failure modes, it may be possible to check its condition from a single reading, which is then compared with known and established criteria for that particular machine in its operating situation.

The object of the condition monitoring activity is to achieve a lead time or advanced warning of failure to enable the machine or plant to be taken out of service in a planned manner. Failures in service can then be eliminated and the maintenance operation can also be much more efficient, because the necessary spares and skilled labour can be standing by to do the job.

The advantages of condition monitoring from the point of view of safety and also of the economics of plant operation are shown in Table 1.

The methods which are available

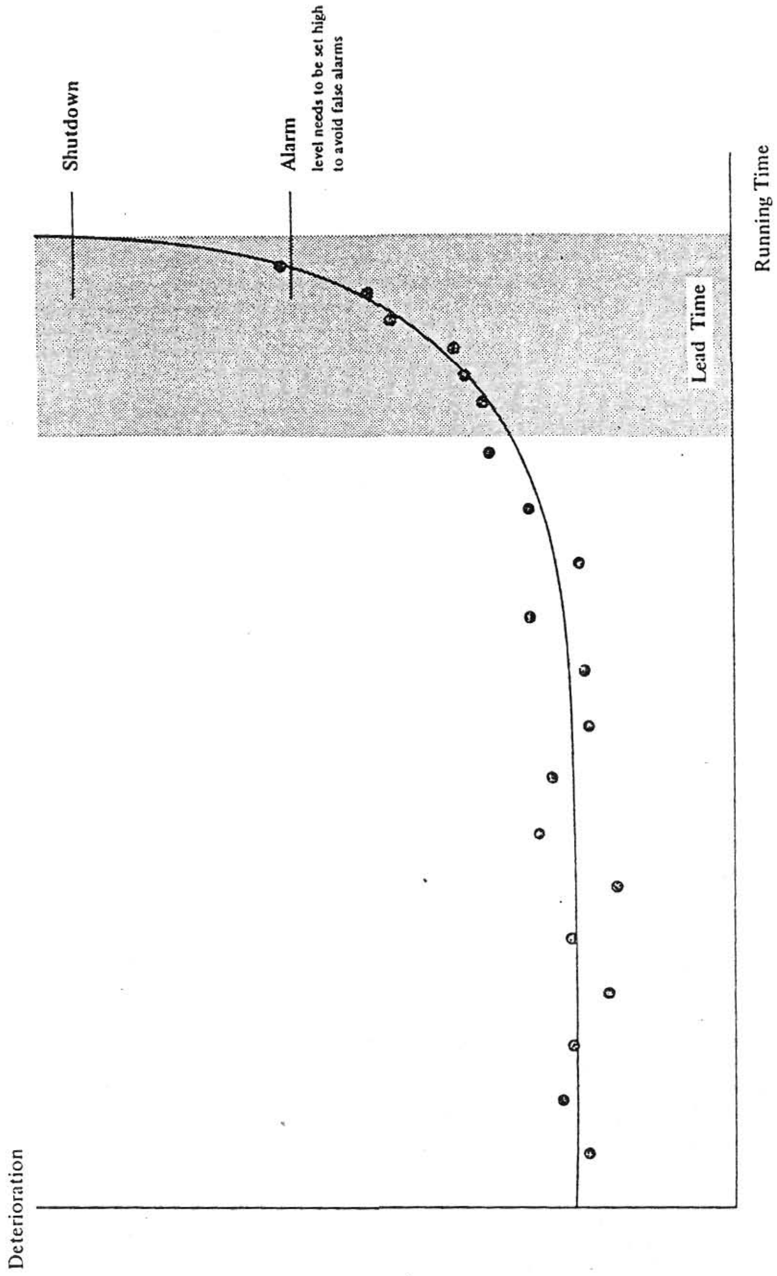
There are five basic methods used at present for monitoring the condition of plant and machinery and these are:-

1. Visual monitoring.
2. Vibration monitoring.
3. Wear monitoring.
4. Performance monitoring.
5. Corrosion monitoring.

All these methods really involve an extension of long established machine minding practice by the application of modern technology.

In visual monitoring improved instrumentation enables concealed internal parts to be inspected. Some machines such as aero engines are now designed with special access holes to allow many key components to be inspected with boroscopes. Photographic or surface imprint recording is also widely used to show trends in the change of the condition of surfaces.

In vibration monitoring the simplest measurements involve recording the overall level of vibration in terms of smoothness and roughness, but very useful methods of analysis are also now available to determine the general source of the vibration and even the determination of its actual cause.



THE REGULAR MONITORING OF DETERIORATION TO
GIVE ADVANCED WARNING OF FAILURE

FIGURE 2

	ADVANTAGES OBTAINED		METHODS BY WHICH CONDITION MONITORING GIVES THESE ADVANTAGES: Lead Time	METHODS BY WHICH CONDITION MONITORING GIVES THESE ADVANTAGES: Better Machine Knowledge
SAFETY	*Reduced Injuries and* Fatal Accidents to Personnel caused by Machinery.		*Enables plant to be* stopped safely when instant shut down is not permissible.	*Machine condition*, as indicated by an alarm, is adequate if instant shut down is permitted.
OUTPUT	Increased Machine Availability	More Running Time	Enables machine shut down for maintenance to be related to required production or service, and various consequential losses from unexpected shut downs to be avoided.	Allows time between planned machine overhauls to be *maximised* and, *if* necessary, allows a machine to be nursed through to the next planned overhaul.
		Less Maintenance Time	Enables machine to be shut down without destruction or major damage requiring a long repair time. Enables the maintenance team to be ready, with spare parts, to start work as soon as machine is shut down.	Reduces inspection time after shut down and speeds up the start of correct remedial action.
	Increased Rate of Net Output			Allows some types of machine to be run at increased load and/or speed. Can detect reductions in machine efficiency or increased energy consumption.
	Improved Quality of Product or Service		Allows advanced planning to reduce the effect of impending breakdowns on the customer for the product or service, and thereby enhances company reputation.	Can be used to reduce the amount of product or service produced at sub-standard quality levels.

THE ADVANTAGES OBTAINED BY THE USE OF CONDITION MONITORING

TABLE 1

The monitoring of wear debris involves the principle that since the working surfaces of machines are washed by their lubricating oil, any deterioration in these surfaces should become evident from the occurrence of wear particles in the oil. These particles may be ferrous and large enough to adhere to removable magnetic plugs in the oil return lines, or they may be very small and only be detectable by spectrographic analysis or detailed microscopic examination of oil samples.

Performance monitoring may involve the monitoring of the performance of a complete machine such as a pump by comparing pressure and flow at its output and relating this to its operating speed, or it may involve checking component performance by, for example, measuring the temperature of a bearing to ensure that it is performing its required function of transmitting load between moving surfaces without excessive friction.

Corrosion monitoring applies mainly to stationary plant such as pressure vessels and piping systems and is concerned with checking the rates of corrosion of these components from the inside due to the materials which they contain. Some of the simplest methods involve techniques such as the drilling of sentinel holes part way through the wall of the vessel, which leak when the contents corrode part way through the wall. The holes are small and are plugged, after a leak occurs, with tapered pins. Other methods of corrosion monitoring involve the insertion of coupons of material, via some readily removal access arrangement, which can be checked for their own corrosion rate so that this can be used to indicate the likely corrosion rate of the main components.

In the case of the first four methods of monitoring which are applied primarily to various forms of rotating plant the way in which they are used is that the existence of a problem is usually detected from the general level of the measurement, and its rate of change, while the nature of the problem can generally be determined from a more detailed analysis of the measurements obtained. This is outlined in Table 2.

The methods of monitoring described in Table 2 are in effect a mechanism of communication between a machine and a monitoring engineer. It will be observed that the visual method of monitoring in relation to the others, requires negligible technological back up. This is because the necessary analytical facilities already exist within the human observer. The lack of these natural analytical facilities in the other three methods of monitoring is the reason why more complex technological facilities and methods need to be applied.

The various methods used for the condition monitoring of plant and machinery are all of considerable technological interest and the skills involved in using them are rapidly developing. On many machines it is now possible to anticipate failure many tens of hours in advance and in some cases many hundreds of hours. One of the best established areas of application of these techniques has been on the civil air lines where, as a result, the incidence of in flight engines failures has been reduced to negligible proportions.

Monitoring Method	Detection of Problem Existence by Measurement of Level	Determination of the Nature of the Problem, by Analysis of the Measurement		
Visual monitoring	Overall appearance	Colour	Shape	Texture
Vibration monitoring	Overall vibration level	Frequency content	Signal waveform	Signal statistics
Wear debris monitoring	Amount of debris	Size distribution of debris	Shape of the debris	Chemical composition of the debris
Performance monitoring	Rate of output	Uniformity of rate of output	Quality level	Uniformity of quality

THE GENERAL APPLICATION OF MONITORING METHODS TO THE DETECTION AND DEFINITION OF MACHINE PROBLEMS

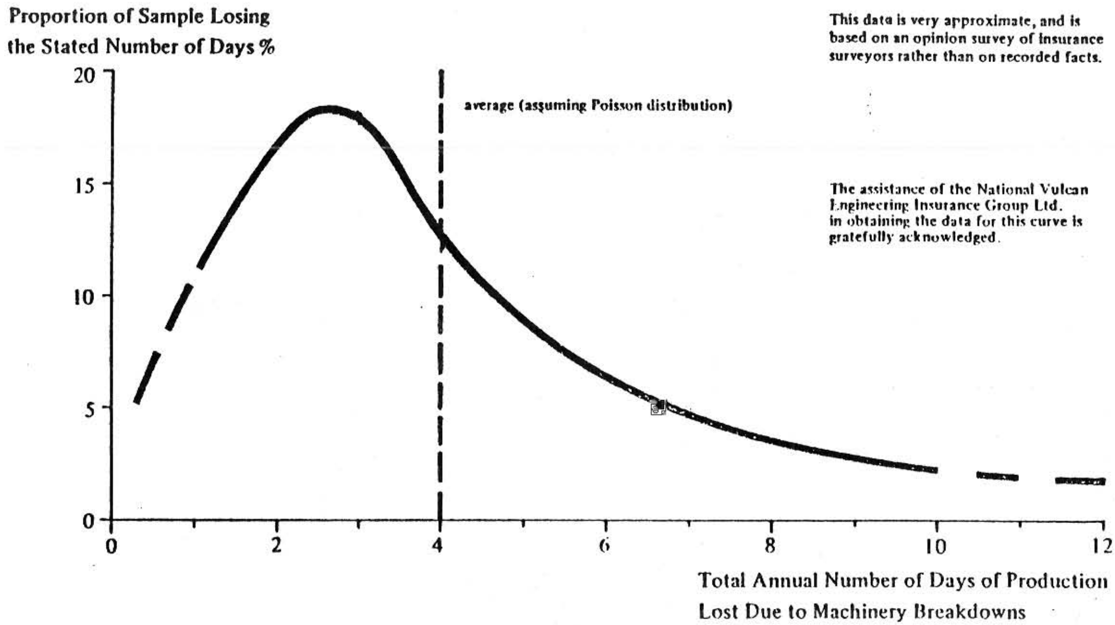
TABLE 2

Applying the techniques in industry

It is always easier to get new ideas applied in industry if they can show a distinct economic advantage, and condition monitoring can do this by reducing the extra costs which can arise from consequential damage, and by increasing machine availability. The situation of plant breakdowns in British Industry is shown in Figure 3 which indicates a mean value of 4 days lost output per year. Since the added value output of British Industry is about £200 million per day this suggests annual losses of about £800 million. These cannot all be recovered by condition monitoring because not all machinery is suitable for it and the main applications are in capital intensive industries. However savings of the order of £250 million a year are probably possible.

In addition to this the increased safety that would result would be a major added bonus. Present users have found that for general application it is worth spending about one percent of the capital value of a plant to set up a monitoring system. When, however, safety is a particular added advantage, it has been found worthwhile to spend more, and in many cases organisations have spent up to five percent of the capital value of the plant in these circumstances. The optimum method of applying the techniques will vary from one company to another but the key factors are the selection of the items of plant which it is essential to monitor, and then the selection of a few optimum methods of monitoring which can cover the various failure modes which are anticipated. The exercise requires the close co-operation of the operating and maintenance staff and it is generally advisable to obtain external advice in the planning and initial implementation stages. This advice may be obtained from independent consultants, or if the application is very well established, adequate advice may be obtainable from the suppliers of the monitoring equipment.

Condition monitoring is an excellent example of a situation where an action to improve industrial safety can at the same time give rise to useful economic savings.



This data is very approximate, and is based on an opinion survey of insurance surveyors rather than on recorded facts.

The assistance of the National Vulcan Engineering Insurance Group Ltd. in obtaining the data for this curve is gratefully acknowledged.

THE INCIDENCE OF PRODUCTION LOSS DUE TO MACHINERY BREAKDOWN

FIGURE 3