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Conspectus

IN THE FOCUS

Preventive Maintenance

The capital scarcity in general and extreme paucity of foreign exchange in particular make it imperative for the developing countries like India to prolong the life of their productive apparatus. What is even more important is to keep them in a good health for the unhindered growth of production. If one analyses the major causes of underutilisation of capacity in Indian industries, it would not be difficult to conclude that lack of an effective maintenance system is perhaps the single most important factor responsible for the present low capacity utilisation. And yet, leaving apart a few pleasant exceptions, there seems to be a general apathy, if not aversion, about the need of an effective maintenance system. What is to be lamented is not the ignorance about the latest techniques of preventive maintenance like Predictive Maintenance, Tribology etc., but the status of "Second class citizen" given to the maintenance. Maximum utilisation of capacity cannot be achieved unless due recognition is given to 'Preventive Maintenance'. The purpose of bringing this problem in the focus of this issue is not only to highlight its importance but also to apprise the industry of some latest developments in the field of maintenance. — *Editor*

Predictive Maintenance

Predictive Maintenance consists of techniques to diagnose the exact condition of equipments by means of on-stream, nondestructive testing system, thereby avoiding shutdowns. It can be done with new tools of maintenance, which, even though are complicated, but, if properly used, can be of great value. Preventive Maintenance in modern chemical industries can be planned and their frequencies scheduled optimally, if correct forecasting of equipment behaviour is done on rational and scientific data. It, therefore, becomes imperative to monitor equipment condition regularly to forestall failures. This paper deals with this aspect of Predictive Maintenance, that is inspection and monitoring and the application of a variety of new devices and techniques that have been developed for this purpose ....S. Ghosh P.R. Srinivasan (Page 269)

India's Economic Policy: A Critique and An Approach

Addresses itself mainly to the policy makers. The twin objectives are, first, to analyse some critical segments of the Indian economy, and second, in the light of this analysis, to recommend some basic policy changes in order to correct faulty policy postures and improve the economy's performance. It focusses on short-period changes and aims at policies calculated to give early rather than late results. While accepting fully the ideological premises and politico-economic objectives of India's policy, it exposes how ill calculated are the policy instruments to achieve these objectives......... A. M. Khusro (Page 17).

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Growth with Justice is an undisputed objective of progressive ideologies but the achievement of this objective by translating it into policies and the management of programmes accordingly is the biggest task that needs careful consideration. To achieve the basic objectives many programmes have been adopted in the past developmental plans, the focus of all of which was to increase production and to distribute income fairly among all the classes. Yet it has been observed that 'growth with social justice' in India remains an unresolved problem for generations to come because of difficulties of establishing a co-ordination among federal democracy, welfare state, mixed economy and traditional society. The reconciliation of liberty with equality in a society of authoritarian family and caste-occupations as well as achieving fraternity in a nation of diversities, is not merely the function of plans and policies ....V. Jagannadhan (Page 37).

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Control and Measurement of Maintenance Effectiveness

The success of any maintenance programme depends upon proper integral planning. By establishing a maintenance cycle with a permanent plan, it is possible to control and measure the maintenance function and from the data collected, an analytical approach to maintenance can be introduced. The touchstone of the success of any maintenance programme is how effectively it has increased the productivity of the equipments by decreasing down-time in particular and overall cost of production in general. This can be measured by a set of ratios which may be called as 'Maintenance Indices'..........V.K. Kapoor (Page 305)

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The rapid advance in technology has also revolutionised techniques like thickness gauge, minearscope, ultrasonic flaw detector, ultra leakage detector, temperature indicators etc. The new concepts like 'Industrial Tribology' and 'Terotechnology' are finding their way into the managerial book of knowledge. Cumulatively, they have ushered a new era in the field of maintenance. The greatest advantage of these new techniques lies in the fact that they eliminate the change factors in industrial breakdowns and put the whole maintenance programme on a more solid ground. The paper shows the way how these new techniques can be used with benefit in carrying out an effective maintenance programme.........S.K. Kalra (Page 316)

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... maintenance has rightly been equated with ...d management for the simple reason that the ...ains arising out of an effective maintenance system are so enormous that no management can afford to ignore it. Yet, unfortunately, a review of the existing situation in Indian industry would reveal that maintenance is, by and large, a relatively neglected area of management. The author has identified a number of hurdles—psychic and others, informulating and implementing an effective preventive maintenance system. Once these hurdles are identified, it is to be hoped that corrective action would follow ......R.M. Garg (Page 325)

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The traditional notion that innovation affects economic relationships and productivity through their bearing on the unit input requirements of the resources involved needs broadening to encompass concomitant changes in the kinds and quality levels of such resources, on the quantity and quality of other resources, on market potential and quality of products and on the resulting output mix. Productivity in the economy cannot be effectively evaluated within a framework which assumes that innovation arrives from extra economic space and their effects are limited to input-output ratios and that attendant changes in the nature of inputs and outputs products and factor prices can be ignored. For providing more effective guides, a more thorough knowledge of the course encountered at each stage of exaggeration and in each sector of the economy is required. To comprehend the richness of technological change there is a need to have specialised knowledge of industries.........S. Venu (Page 369)

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With Season's Greetings

Yours truly

EDITOR

Predictive Maintenance

Siladitya Ghosh P.R. Srinivasan*

There has been an awakening to the importance of maintenance. Definitely, there is a salutary change in attitudes and a belated recognition of the importance of maintenance. Everyone now seems to realise that investment in sophisticated plants will not pay unless these plants are given the best of maintenance attention. With the rapid growth in technology, the plants on which we are now dependent for achieving our targets of production are totally different from what we have been accustomed to in the past. A shutdown for maintenance of one of the modern plants would mean complete stoppage of production during the period. In the older plants, if one stream went out of production there was another to maintain at least partial production. This new situation arising out of anxiety to keep up with modern developments and to take advantage of the economics of scale has consequently placed on us a great responsibility—the responsibility to ensure the largest number of stream days in each plant every year.

Preventive maintenance in the new high-volume single stream plants no longer means disassembling equipments routinely for inspection. Now it means diagnosing the exact condition of the equipment by means of on-stream, non-destructive testing. The objective is the avoidance of unnecessary shutdowns. This is called predictive maintenance.

Predictive maintenance concept involves a new philosophy that is changing the whole picture of industrial maintenance. This new approach has two fundamental rules; the first is : "Don't do it (unless you have to)". The second, which is closely related, is : "if you have to do it, then do it a better way."

Performance of work that should have been avoided or deferred has always been a major component of maintenance cost. On the other

* The authors welcome comments or suggestions on the contents of the article. Fuel Efficiency and Technological Services Division of National Productivity Council can extend their consultancy services to concerned organisations relating to problems covered in the paper.

hand, failure to perform maintenance work, when it is needed, has also been a major cost consideration due to equipment damage that could have been avoided.

The idea behind the new maintenance philosophy, then, is to perform maintenance work at the proper time. The new tools of modern maintenance work is needed—and just as important—to know when it is not needed. These tools are far more complicated than those in the usual maintenance tool box. But properly used, they are also potentially far more valuable.

The purpose of this article is to unfold the revolution in trouble-predicting and trouble-shooting test instruments. In the last ten to fifteen years, and particularly in the last few years, new instruments and new combinations of old instruments and trouble shooting have come at an increasing rate—so fast, in fact, that few plant maintenance departments have been able to keep uptodate. Today there are instruments for accurately checking everything from the slipperiness of tile floors to the density of the exhaust fumes from the plant's diesel trucks.

The New Tools

An effective preventive maintenance programme requires a sound base of data for assessing plant and equipment condition and detection of conditions of deterioration, before they erupt into trouble. For, we can plan preventive actions and schedule their frequencies optimally only on rational and scientific data that enable forecasting equipment behaviour and performance. In addition, in many of the modern chemical process industries, the safety hazards and penalty costs of failure can be great. It is, therefore, necessary to monitor equipment condition regularly to forestall failure. Predictive maintenance deals with this phase of maintenance activity—inspection and monitoring largely on-stream.

Each of the new devices or techniques permit detection of abnormal conditions that are outside the range of human senses, and display findings so that anomalies can be analysed and, if necessary, action can be taken.

The simplest of these new tools enhance visual perception. In this area are penetrants for visual detection of flaws or cracks. Optical aids for magnifying or illuminating flaws also fall into this classification, as do

Fibrescopes that extend visual perception into otherwise inaccessible places such as the inside of a tube or vessel or even around bends in tubing or piping.

The more complex tools involve converting various forms of energy into electrical impulses and displaying the results. Meters, oscilloscopes, video-displays, are common forms of display. Alarms, automatic shut-down and a variety of other action devices mey also be used with the new tools. Sensed signals may be transmitted in a number of ways—by wire, by radio waves or sonar waves, for example. A number of techniques even provide automatic interpretation through image enhancement, amplification and, of course, cumputer analysis.

Many of the new methods are an offshoot of the revolution that began with the transistor. High gain, high efficiency, low-cost stable amplifiers, high-accuracy solid-state voltage reference elements, tiny but precise crystal filters, and a wide range of sensors derived from the space programme are a few of the components that have provided the base on which instrument manufacturers have developed one after another new analysis and test sets. There is no evidence that development of new instruments has reached its peak.

The new tools available for use in the maintenance fucntion are generally classified into two distinct fieids. One is the monitoring of vibrations in rotating machinery, such as compressors, turbines, fans, and blowers. The other field is checking for corrosion and erosion in pipes and vessels by non-destructive testing methods. We can further classify them as follows :

1. Vibrations and Frequency Analyzers
2. Metal thickness measuring instruments
3. Locating cracks in metals
4. Noise measuring instruments.

Inspection By NDT Methods

The two most widely used tools for the on-stream checking of corrosion and erosion in pipes and vessels, detecting of flaws in materials, and inspecting of welds are ultrasonics and radiography. The other methods useful for maintenance inspection, especially in chemical process plants, are the following :

1. Magnetic Particle Examination

2. Dye-Penetrant Examination

3. Eddy-current Probe.

The first two, viz., ultrasonics and radiography are particularly useful for on-stream inspection to survey wall-thickness of vessels, piping etc., to determine the progress of attack due to corrosion/erosion and to isolate vulnerable areas for periodic checking.

Magnetic particle and dye-penetrant inspection are simple methods to detect surface and sub-surface flaws like cracks. They are useful in inspection for fatigue cracks in machine parts like shafts, piston rods, C-rod ends, nozzle attachments of vessels as well as stress-corrosion cracks in vulnerable areas of process vessels and piping.

Eddy-current testing is specially useful in examination of heat exchanger tubes, which are not accessible for inspection from the outside, to detect evidence of corrosion damage.

In addition, there are other sophisticated techniques like thermography, which makes use of infra-red sensing for detecting of hot spots in high temperature equipment. Temperature is in many cases an external evidence of trouble and monitoring temperature in key points can help in identifying developing trouble and its possible causes.

Ultrasonic as a Maintenance Tool

Sound, a form of harmonic energy transmitted in wave patterns, can be sent through various materials to detect abrupt changes in homogeneity. At ultrasonic frequency, sound can be very useful in detecting imperfections in high density materials.

The application of ultrasonic work in the field usually falls into two separate catagories :

1. Flaw detection in new equipment, such as piping, pressure vessels, and welded seams, during or shortly after fabrication.

2. Maintenance testing in the plant during operation or during shutdown periods.

Ultrasonic instruments are of two types, the resonance type and the pulse-echo type. In the resonance type, the instrument consists of an electronic oscillator which transmits electrical energy of a constant ultrasonic frequency to a crystal (transducer), which converts this energy into mechanical pressure waves which travel through the thickness of the material examined at a constant velocity. The pressure waves are reflected back from the opposite surface. Since the velocity is constant, the time taken for a wave to traverse the thickness and back is a function of the thickness to be determined. If frequency of oscillation is adjusted to a value at which a wave is propagated from the transducer at exactly the same instant that the previously reflected wave has arrived back, resonance occurs and the time interval between recurrent cycles is directly proportional to the thickness, the resonant condition is detected by the instrument by virtue of the increased power required to drive the oscillator. Any interruption in the sound wave will appear on the read-out device, possibly indicating a discontinuity in the tested material.

In the pulse-echo type instrument, electric pulses are generated instead of continuous waves as in the resonance type. The electric pulses are transformed into ultrasonic waves, which are beamed into the material by means of piezo-electric transducer. These ultrasonic waves travel through the material under inspection and are reflected from the back surface (back echo) or from any internal discontinuity or flaw (defect echo). These echoes are indicated on a cathode-ray tube screen. Variances in reflection time indicate a discontinuity in the tested material. Longitudinal wave (straight-beam) inspection is used for detecting laminar discontituities, i. e. discontinuity parallel to the surface, while shear-wave (angle-beam) inspection is used for detection of transverse defects like cracks. By moving the probe or search unit over the surface, the entire volume of material can be probed for defects or flaws or for determination of thickness.

Advantages and Limitations of Ultrasonics

Some of the advantages of ultrasonic include :

* Very deep pentration is possible.

* It is usually fast, dependable, easy to operate and may be automated.

* Results are immediately known and indications may be displayed in a variety of read-out techniques.

* Highly accurate and sensitive results are possible.

Some disadvantages :

* Contact or immersion is required.

* Techniques can be limited by geometry of the part or flow orientation, or density of the material.

* Internal conditions may mask results.

* Technique cannot be used on all materials.

* Some techniques are highly interpretative and require close correlative information.

Radiography : Popular Tool

Radiography primarily depends on the great penetrating ability of X-rays, gama-rays and nuclear particles. There are many different radiographic techniques such as fluoroscopy, Xeroradiography, three-dimensional and colour radiography, flash or high-speed radiography, Vidicon radiography, etc. But the common workhorse for maintenance applications is X-ray and gama-rays that have travelled through the material or equipment to be tested.

X-ray examination of various components began several years ago. Until World War II, all X-ray work had to be done with high-voltage X-rays and associated equipment. This limited portability and the ability to work in the field. After World War II, a radio-active source of gama rays became available. This made it possible to expose X-ray film in the field without the necessity of heavy and bulky equipment.

X-rays are most commonly produced in a vacuum tube by electron bombardment of dense materials. Gama rays are essentially the same as X-rays but come from the nucleus of unstable isotopes as the atom tries to gain equilibrium after nuclear decay. These rays are usually of higher frequency and have more penetrating ability than X-rays. The radioactive isotopes are normally contained in a protective device (camera) and remotely controlled, to expose and withdraw the radiation source as desired.

In this method, the metal to be inspected is placed between a source of X-ray or gama rays and a photogtaphic film. Due to differences in the absorption of rays by cracks, voids, non-metallic inclusions etc. compared to solid homogeneous metal, the flaws are indicated in the developed film as darkened areas against the lighter appearance of the adjacent sound metal. Absence of flaws and uniformity of thickness will produce pictures (radiographs) of uniform shade.

Though radiography is mostly used for inspection of newly constructed equipment—welds, castings, forgings, etc., it can also be used in service inspection of operating equipment to detect cracks, excessive thinning or other serious internal flaws. Portable equipment is available for field inspection. Typical applications include testing of sheets, tubes, rods, forgings, castings, welds, seams, lamination honeyeomb, brazing, assemblies, and pressure vessels.

Advantages and Limitations of Radiography

The advantages of radiography include :

* X-rays and gama rays give high penetration and can detect internal anomalies such as irregularities of density or geometry.
* Both have a photo read-out and, therefore, a permanent record.

* Both have a high sensitivity.

* X-rays allow good control of energy levels.

* Gama-rays can be provided by physically small sources and be put into small cavities for interior shots.

The disadvantages are :

* This technique requires rigid safety controls.

* Both are relatively expensive.

* Both require well-trained technicians in production and interpretation of radiographs.

* Technique is dependent on flaw geometry or orientation.

* X-rays require relatively elaborate facilities.

* Gama rays are limited to one energy level per source.

5

Electromagnetic Testers

A number of new maintenance-related tools evolved from research and development work on electromagnetic waves, practically all segments of the electromagnetic spectrum—from long-wave raido to X-rays and gama rays—are included in this class of equipment. Techniques in the field are developing to a point where fatigue can be detected early, before the actual failure occurs.

One of the methods—radiography—has been dealt. The other two methods that have received a great deal of attention from maintenance organisation, are infra-red heat detection and eddy current.

Infra-Red Heat Detection

The use of infra-red pictures, or thermography, is emerging as a promising new tool for monitoring operating equipment. This heat-detection technique has been popular with utility companies for several years. The chemical industry in USA is now applying infra-red scanning (by a TV camera) to show live pictures of the temperature differences on the surfaces of objects or pieces of equipment. A typical picture will vary in shade from the darker, low-temperature surfaces to very light high-temperature surfaces. Distance of the camera from the object may be as much as several hundred feet with no effect on the highly accurate readings. And using a known heat source for calibration permits accuracy to within one-half degree from 22F. to more than 3,600F.

The principal applications have been in detecting hot spots in lines, leaking relief valves, furnace coils, reactors, process valves, heat exchangers, etc.

The necessary equipment can be expensive :

$70,000 or rental of about $2,000 a month are typical in USA. Also, visual access is required for the picture and there is limited experience in applying this technique, as well as a limited number of manufacturers.

Eddy Current

When a conductor is placed in a magnetic field it generates a secondary field. If the primary magnetic field is created by an electromagnet using alternating current, an alternating magnetic field is created in and around the conductor. This induces an alternating voltage within the conductor. The resulting current follows a circular path and is termed an "Eddy Current."

Various sensing devices may then be used to measure four significant properties of the conductor (or test object). These properties are electrical conductivity, magnetic permeability, density, and geometry (including surface and subsurface discontinuities). Further, the distance from the primary magnet and the conductor, or an irregularity within the conductor, can be accurately measured. If the intervening space contains a nonconductor, the thickness of that material is measured.

A very useful application of the eddy current tester is in the inspection of non-magnetic exchanger tubes for defects and thinning. As the electromagnetic pick-up (probe) is moved through a tube, the variations in the tube-well are indicated by impedance in the inductive reactance field around the probe, which is indicated on an electronic recorder and recorded on a strip chart. As the probe passes through a tube, the recording pen oscillates across the centre-line of the moving chart. This oscillation results from changes in quality and thickness of tube well surrounding the probe as it moves. The chart centre line is taken as the reference for normal tubing and any deflection of the trace to either side indicates a deviation from normal.

Other applications include checking variations in wall thicknesses, longitudinal seams and cracks, pits, porosity, metal analysis, lack of bond, and thickness coating. Apart from tubing, it is used on items such as bar stock ball bearings, wires, welded parts, and flat or sheet stock.

Advantages and Limitations of Eddy Current

Advantages include :

* Can be designed as a high-speed automated test.
* Contact with the specimen is not required.
* Conductors can be tested through insulators.
* It is an exceptionally sensitive test.
* High-speed testing and automated operations may be conducted by operators having little skill.
* No pre-cleaning or post-cleaning is required.

On the minus side :

* Limited to electrical conductors or materials backed by conductors.
* Somewhat limited depth of penetration.

* Interpretation may be difficult due to possible false indication arising from many variables.

Dye–Penetrant Examination 6

This is also a non-destructive method of locating small flaws in metals such as cracks, pores and laps which are open to the surface. The method consists of supplying a red penetrant dye to a clean area, removal of penetrant which has not entered flaws and spraying on a white develop which brings out the entrapped penetrant showing up as red indications on the white background. The characteristics of the red marks such as the rapidity with which they develop and final size and shape are excellent clues as to the nature of the flaws. The rate of bleeding is an indication of the width and depth of the defect, while the extent of bleeding is an indication of the volume of defect.

A variation of the above is the fluorescent method which makes use of a fluorescent penetrant, which glows under a high intensity ultraviolet light. This method is more sensitive than the visible penetrant method and very fine surface imperfections will be defined by the glowing fluorescent penetrant.

Apart from detecting surface-flaws, the penetrant method may be used to detect leaks in vessels or tanks. These methods are suitable for detecting cracks due to corrosion, fatigue, etc.

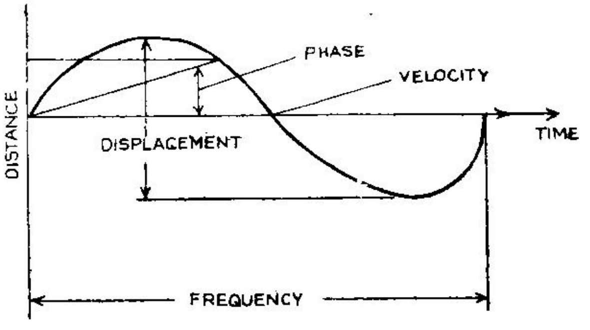
Vibration Monitoring and Analysis

During the past fifteen years, the application of vibration measuring and analysing techniques to maintenance of machinery has gained wide acceptance.

All mechanical systems vibrate. Vibration is one of the "side effects" of machine operation. While other side effects such as heat and noise may also be present and available for measurement and analysis, vibration has been used very successfully in improving the maintenance man's knowledge of equipment conditions.

Vibration is the motion of a machine or machine part moving back and forth from its resting place. The total distance of movement is known as the peak-to-peak displacement or amplitude. The number of cycles of this movement over a given period of time is known as frequency. The third characteristic of vibration is the phase of vibration which is the position of the machine part at any given instant with reference to some fixed point. The fourth useful characteristic of vibration is velocity or the speed with which the position is changing, that is the peak velocity of the movement in the natural position. Fig. 1 indicates these four characteristics of vibration.

Fig. 1



When a machine is operating normally and according to design, it will produce a certain "vibration signature". Deviations from this normal pattern of vibration may require maintenance attention. Principal causes of abnormal vibration are : (a) imbalance, (b) misalignment (c) worn bearings, belts or gears, (d) aerodynamic or hydraulic forces, and (e) reciprocating forces.

Each of the above characteristics of vibration gives significant information about machinery condition. Amplitude and velocity tell how much vibration is present, or in terms of the condition of the machinery, how good or bad its condition may be—increase of amplitude or velocity signifies worsening condition. The frequency of vibration tells what is causing the vibrations and is therefore the most important characteristic we measure by comparing the frequency of vibration to the rotating speed and multiples of rotating speeds, the particular part causing the vibration and the trouble with that part can be pinpointed. Phase is used in detecting and correcting imbalance.

A vibration analyzer is capable of measuring the displacement (amplitude), the frequency, and the phase of vibration. When vibration occurs at several frequencies, the analyzer must be able to separate one from another to measure the characteristics of each. The size of the vibration analyzer varies according to the depth of analysis required. Vibration probes are permanently installed on operating equipment and vibration characteristics are monitored continuously, permitting diagnosis of operating problems.

It is important in vibration analysis to first establish the basic vibration pattern for the monitored machine. This is often done by obtaining readings for amplitude, frequency and phase at the time of machine installation. Once the individual characteristic vibration patterns are established, monitoring can recognize changes. Standards for vibration exist and are being defined for many types of equipment to provide uniform acceptability levels. It is better to specify vibration characteristics as a part of the equipment ordering procedure.

Vibration analysis can reduce costs by in-place balancing, early detection of trouble, elimination of damaging failure, evaluation of new and repaired equipment as to quality and proper installation, and specific knowledge of what replacement and repair needs to be made. It is a relatively inexpensive technique.

However, variations in process equipment and installations make it difficult to relate vibration data to any uniform standard. Also, while changes in vibration patterns are quickly detected, it may require some sophisticated analysis to determine what caused the change.

Table 1 gives a summary of the principal causes of machinery vibration and their identifying characteristics.

Predictive Maintenance

For installing a vibration monitoring programme there are essentially six basic steps :

1. List critical machines.
2. Determine each machine's condition and normal vibration.

3. Select check points.
4. Determine frequency of monitoring.
5. Establish acceptable vibration limits.
6. Establish a recording system.

1. *List critical machines :* Critical machines are those failures which involve high penalty costs (e. g. machines without standby spare capacity) or serious hazards to safety (e. g. high pressure compressor systems, equipment handling lethal or inflammable fluids).

2. *Determine each machine's condition and normal vibration :* This helps to establish by comparison with other similar machines in good condition what are the normally acceptable vibration characteristics for monitoring. At this stage, it is necessary to design a suitable Vibration History form, providing essential machinery data (name, speed, HP, etc.) with a sketch showing general arrangement, location of bearings, couplings, gears, check points, etc. Fig. 2 shows a sample Vibration History form.

3. *Select check points :* Check points should be selected for vibration monitoring after a careful analysis of possible causes of trouble with the particular machine. Points selected should be those likely to show increased vibration when trouble is present. Normally, check points will be located at or close to the bearing housing of the machine. The initial vibration study during the first step will help locate points where maximum vibration readings are observed. Finally, check points selected should be clearly marked by a spot of point with a punch mark for clear identification for future checks.

4. *Determine frequency of monitoring :* This should be based on a judicious assessment of frequency of likely trouble, the nature of the machine and its function, resources available. Some machines like large high-speed turbines, centrifugal compressors may need daily check. Others, like pumps, fans and blowers and similar units may need only weekly checks. In the early stages, checks may be done too frequently to guage the development of the trouble, but generally, experience and past maintenance record help to establish a reasonable optimum frequency for each machine.

5. *Establish acceptable vibration limits :* Absolute vibration limits indica-

VIBRATION ANALYSIS DATA SHEET B-103 DATE

☐ Noise Vibration Analysis of : 1 water feed pump

Test conditions—Normal

For ....

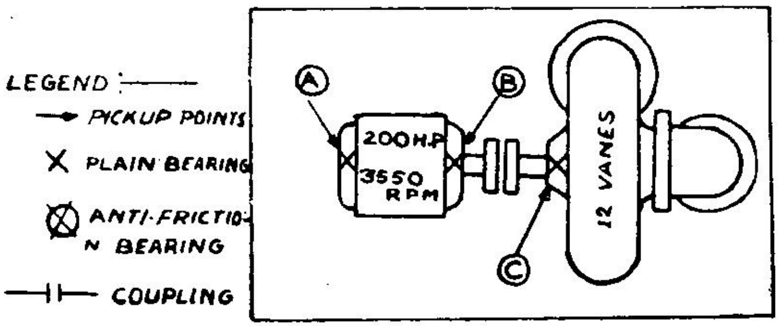
....

....

Mechanalysis equipment

Used : Model 350

Performed by :— J.H.T.



Pick up		Filter Out				Filter in		
		Noise	Displ.	Velocity		Vel.	Vel.	Vel.
Point	Pos.	dB(A)CPM	Mils.' CPM	In/Sec	CPM	3550	7100	43K
A	H			.40	3550	.38	.03	.01
	V			.26		.22	.02	—
	A			.40	3550	.37	.02	.01
B	H			.44	3550	.40	.04	.03
	V			.28		.24	.04	.01
	A			.48	3550	.43	.05	.02
C	H			.50	3550	.44	.07	.03
	V			.32	3550	.30	.04	.02
	A			.55	3550	.50	.06	.02

Fig. 2 : Vibration Analysis Data

(Source—Machinery Vibration Monitoring—SOUND AND VIBRATION, November 1971).

ting a clear demarcation between what is acceptable and what is not, are not available. Past experience and accumulated data on a large number of machines, however, provide a helpful guide in grading the performance of machinery by serverity of vibration.

Figure 3 shows a Vibration Severity Chart. The Chart indicates limits of vibration for various grades of performance—from 'extremely smooth' and 'smooth' through 'good' and 'fair' to 'rough' and 'very rough' at the other extreme. These limits will require modification to take account of factors like safety, penalty cost of failure, etc. in any particular plant. 'Service factors' have been worked out for various classes of equipment, which are used as multipliers of the measured vibration level to obtain 'effective vibration'. It is compared with the acceptable limits of the Vibration Severity Chart Service factors used for equipment in a refinery or chemical process plant and is shown in Table 2. But the important point in the monitoring programme is to identify the source and extent of the trouble or fault, before it is decided to shut down the machine.

6. *Establish a recording system :* The recording system, while being as simple as possible, should provide adequate information on performance of each machine included in the programme over a period of time. PM data sheet for each machine would contain the information shown in the sample form in Fig. 4.

At this stage, it is necessary to point out that merely having a vibration recording system is not enough. The recorded data has got to be interpreted; this would help in deciding the frequency of monitoring and ultimately reducing the maintenance downtime.

Conclusion

Predictive maintenance techniques discussed here cover only the more commonly used ones that have already contributed to improved maintenance knowledge. Others, many of which are being used and added to the list of useful maintenance tools with increasing frequency, include eddy sonics, magnetic particles, electrified particles, filtered particles, brittle coatings, liquid crystals, photo-elastic coatings, and accoustic emissions. The list is still incomplete.

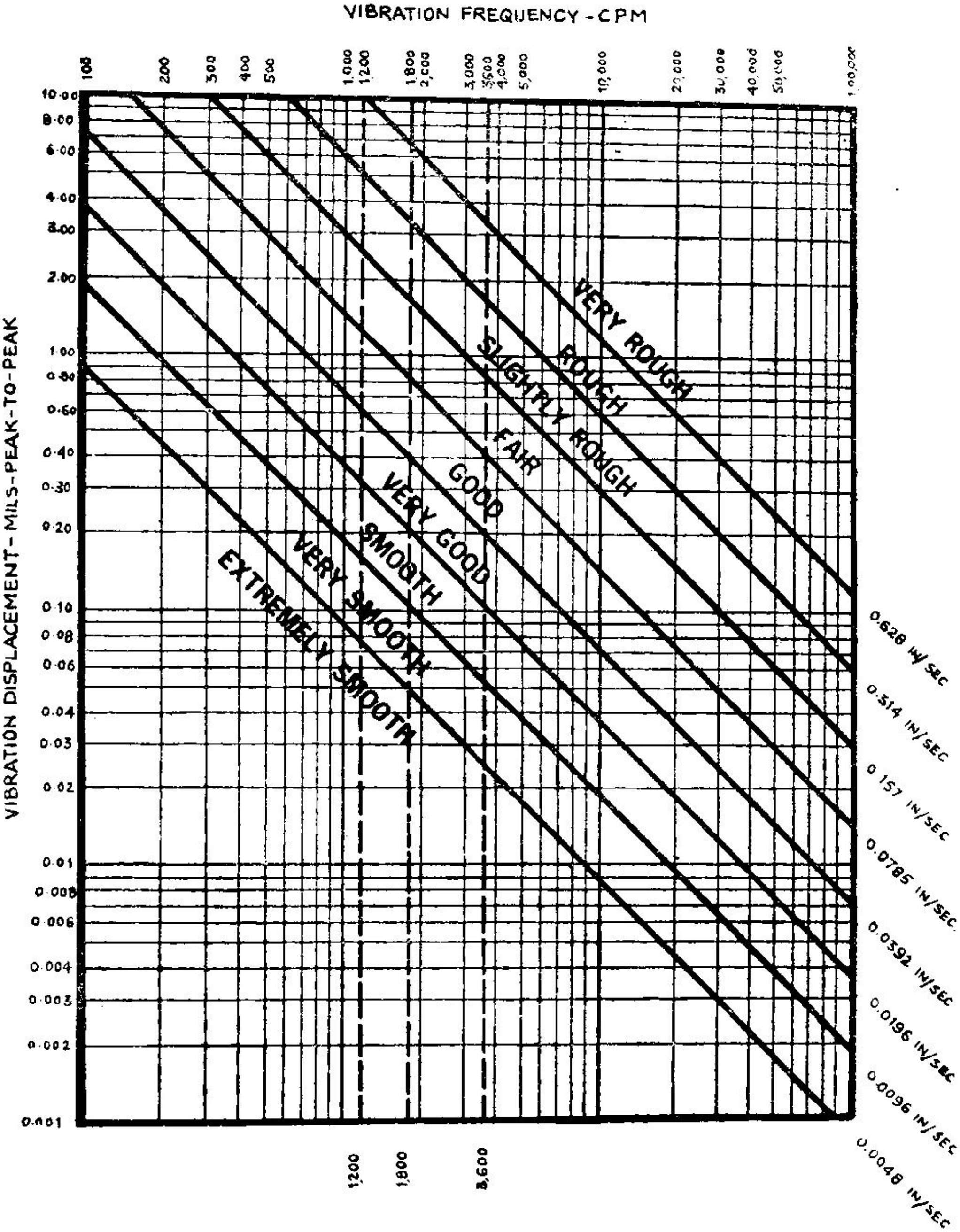
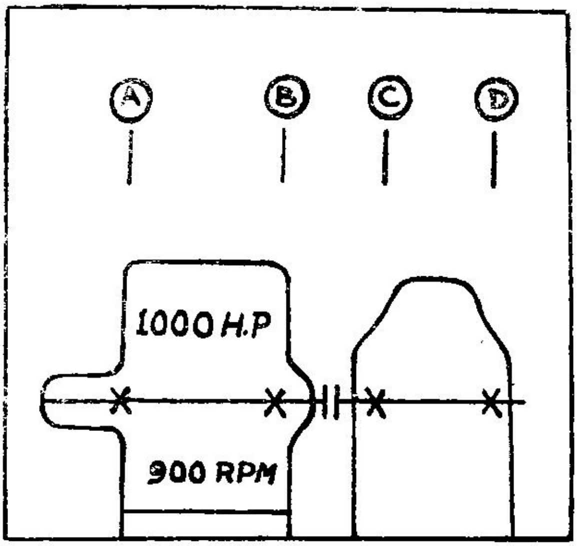


Fig. 3 : General Machinery Vibration Severity Chart



Machine : Main Pump '2

Component : Motor + Pump

Vibration Tolerances		Lubrication	
A. . . .	B 4.0	A. . . .	B. . . .
C . . .	D. . . .	C. . . .	D. . . .
E. . . .	F. . . .	E. . . .	F. . . .

Location :

Pump House

Checked Date	By	House keeping	Packing condition	( ) Lubricated						Vibration amplitude —Mils (.001-IN)						Remarks
				A	B	C	D	E	F	A	B	C	D	E	F	
Feb.										.4	.9	.7	.5			Use horizontal bearings.
Mar.										1.0	.8					
April										1.0	.85					
May										1.0	.75					
June										1.5	.9					
July																Down for new packing.
Aug.										1.9	2.1	1.8	1.5			Check shipment.
Aug.										1.3	.9					
Sep.										1.2	.9					
Nov.										1.2	.7					

Fig. 4 : Preventive Maintenance Data Sheet

(Source—Preventive Maintenance Using Vibration Analysis. By : Colin Nicholls. Mechanalysis International, London).

The maintenance manager faces today two major challenges associated with the new technology. The first is one of appreciation. It is not always easy for the man, who learned to use this hand to detect bearing-heat problems and the end of a screwdriver to "feel" vibration, to understand and appreciate that the new methods can improve his performance and knowledge. The new tools do not seek to indict his past methods. They simply recognize that the techniques of the past were based on sound maintenance know-how and seek to extend that application to points that human senses do not detect. The challenge to appreciate the purpose and place for this new methodology must start with training in what the tools are and the purpose they attempt to serve.

The second challenge of the new technology is one of application. The tools are not available in the country. A few companies have started manufacturing them ; no liaison is established between the manufacturers and the users. Most of the manufacturers are small in size ; they do not offer excellent training programmes. Most of the preductive maintenance tools are yet to be imported. Another source is National Aeronautical Laboratory which provides assistance for vibration monitoring. A list of instruments and suppliers has been prepared by the authors, and concerned parties can have it from NPC, on a request to Exective Director.

Whereas the sheer number of new tools and the rapidly increasing rate of availability creates a problem for a maintenance manager in the U.S.A., the problem for the Indian maintenance man is just the opposite—the non-availability. However, with the increasing awareness of the possibilities and with greater intercommunication with the users, the manufacturers and the service orgainizations like National Productivity Council of India, the situation would improve for the better.

Acknowledgement

1. TROTTER, Chemical Engg. Deskbook, Feb. 26, 1973.

2. ROSE, Proceedings of the Seminar on Fertilizer Plant Maintenance, USAID, New Delhi.

3. BLAKE, Hydrocarbon Processing, January, 1964.

Table 1

A Typical Vibration Identification Chart

CAUSE	AMPLITUDE	FREQUENCY	REMARKS
Imbalance	Proportional to imbalance. Largest in radial direction	I X RPM	Most common cause of vibration
Misalignment couplings or bearings and bent shaft	Large in axial direction 50% or more of radial vibration	I X RPM usual 2 & 3 X RPM sometimes.	Best found by appearance of large axial vibration. Use dial indicators or other method for positive diagnosis. If sleeve bearing machine and no coupling misalignment, balance the rotor.
Bad bearings antifriction type	Unsteady—use velocity measurement if possible	Very high several times RPM	Bearing responsible most likely the one nearest point of largest high-frequecy vibration
Eccentric Journals	Usually not large	I X RPM	If on gears, largest vibration in line with gear centres. If on motor or generator vibration disappears when power is turned off. If on pump or blower attempt to balance
Bad gears or gear noise	Low—Use velocity measure if possible	Very high gear teeth time RPM	
Mechanical Looseness		2 X RPM	Usually accompanied by imbalance and/or misalignment
Bad drive belts	Erratic or pulsing	1,2,3 & 4 X RPM of belts.	Strob light best tool to freeze faulty belt
Electrical	Disappears when power is turned off	I X RPM or 1 or 2 X synchronous frequency	If vibration amplitude drops off instantly when power is turned off cause is electrical
Aerodynamic hydraulic forces		I X RPM or number of blades on fan or impeller X RPM	Rare as a cause of trouble except in case of resonance
Reciprocating forces		1, 2 & higher orders X RPM	Inherent in reciprocating machines can only be reduced 6 design charges or isolation

Table 2

Machinery Vibration Service Factors

(MP Blake —"New Vibration Standard for Maintenance, HP and PR, January, 1964)

Single stage centrifugal pump, electric motor, fan	1.0
Typical chemical processing equipment, non-critical	1.0
Turbine, turbogenerator, centrifuga lcompressor	1.6
Centrifuge, stiff shaft, multi-stage centrifugal pump	2.0
Miscellaneous equipment, characteristics unknown	
Centrifuge, shaft-suspended, on shaft near basket	0.5
Centrifuge, link suspended, slung	0.3

NOTE : Effective vibration = measured peak to peak vibration multiplied by service factor.

—Values are for bolted down equipment ; when not bolted multiply the service factor by 0.4

—Vibration is measured on bearing housing, except as stated.

Problems of Productivity : Equipment Replacement

L.N. Maheshwari

The success of an enterprise, particularly of a competitive one, depends on a whole range of factors, their relative importance varying widely from one type of industry and operation to another. In some lines a company may be able to move up because it has better research facilities, better product design, better sales organisation, better advertising, better financing, better personnel or better trade connections than others—even though its capital equipment is inferior. In other lines, capital equipment will be strategic, if not a dominant area of competition. A firm of lawyers will hardly sink because of the conditions of its typewriters, desks, and filing cabinets, but a Steel Company will be ruined by failure to keep its equipment competitive and it is so with most industries, particularly the capital-intensive industries.

Capital formation is not a polite game which can be carried on *ad infinitum*, once the machinery is installed. Replacements do not meekly and decorously await, like dutiful heirs, the natural death of the existing assets. It is a ruthless and cut-throat struggle in which new capital goods rob the functions of the old. Displacement function is frequently due to the competition of new goods quite different in character from the old. The functions of the horse and buggy have been appropriated by the automobile. The airplane displaces the ocean liner. Nylon supersedes natural silk.

Once we grasp this dynamic character of the process of mechanical displacement or transformation, the term "replacement" seems inadequate. It is too weak, too passive and too suggestive of the notion that new facilities merely fill a vacuum left by the demise of their predecessors. For this reason we should, if possible, avoid the word entirely, using instead such expressions as "displacement", "re-equipment" or "re-mechanisation". The term "replacement", of course, has the advantage of common usage, a consideration by no means negligible.

Depreciation Policy and Replacement

Although, authorities on equipment policy are by no means unanimous on the point, the general view is that replacement decisions should not be influenced by the book value. Anyone who has sold industrial equipment is aware, however, that this rule is often honoured in the breach. Nobody would like to "take a loss" on the disposal of assets with substantial remaining book value, and their replacement is handicapped accordingly. Right or wrong, rational or irrational, this prejudi exists and must be reckoned with. Inadequate depreciation may be due to either improper methods of distributing depreciation over the service life or to excessive estimates of life expectancy of the asset. In either case we get higher book values than what we should have and a consequent drag on modernisation and improvement.

The impact of depreciation policy on replacement sometimes takes a slightly different form. Even when the management entirely ignores the remaining book value in its re-equipment decisions (or thinks it does) it is not uncommonly influenced by a vague feeling that capital assets ought to be kept in commission over the service life, assumed for depreciation purposes; hence this period becomes a kind of magnet, drawing replacement policy to it, not rigidly or invariably to be sure, but with subtle and persistent attraction.

Replacement is affected by depreciation policy, in still another way, through the influence of the latter on the supply of funds available for capital purposes. To the extent that capital expenditure is influenced by the volume of depreciation accruals, depreciation policy becomes an important factor affecting replacement. The extent of this influence is, of course, impossible to measure but it must be substantial. There is, however, unanimity of opinion that extraordinarily low rates of depreciation adopted both for book and tax purposes, have unquestionably contributed to the technological backwardness of industry in the country. While both these considerations argue for the improvement of depreciation policy, there are other reasons for such improvement which have nothing to do with replacement. Depreciation accounting is a subject by itself and let us not get lost in it at the moment.

If all durable goods were as good as new to the end, requiring no maintenance, collapsing finally all at once in a heap of junk—and if they were not displaced before the end of their physical endurance by improved substitutes, the problem of when to replace them would be as simple as the problem of when to replace electric lamps. It so happens, however, that these conditions are rarely met. The majority of durable goods require during their service life a flow of maintenance expenditure, which as a rule runs irregularly with age and use. Most of these suffer a deterioration in the quality of their service as time goes on. Moreover, in a dynamic technology they are subject to competition of improved substitutes, so that the quality of their service may decline relative to available alternatives even when it does not deteriorate absolutely. Where these complicating factors are present replacement does not await the ultimate physical collapse of the asset concerned—indeed in many cases this point is never reached if the parts are renewed piecemeal as they wear out—but is controlled instead by economic considerations.

There is a wide-spread tendency to think of replacement as the filling of a vacuum left by the physical collapse or deterioration of existing capital goods, and hence to underemphasise the dynamic effect of external technological and economic changes. Physical deterioration is still an important factor in limiting service life—varying widely in significance from case to case—but in modern world external changes must be given even greater weight. With the heightened tempo of scientific and technical progress, capital goods are increasingly pushed out of service or displaced rather than merely replaced after they expire from physical decay.

Functional Degradation

Consider for a moment, the case of the electric lamp. It could be used as good as new, until its function suddenly stopped. It is clear that the lamp was not replaced functionally until after its failure. Its failure left a functional vacuum which the successor lamp filled.

Consider now, by contrast, the life-history of a locomotive. It began in heavy main line service. After a few years, the improvement in the design of locomotives made the unit obsolete for that service. It was thereupon relegated to branch line duty where the trains were lighter, the speeds lower and the annual mileage was also not much. For some years it served in that capacity but better power was continuously being displaced from main line duty and "kicked down stairs" on the branch lines, and eventually our old locomotive was forced out at the bottom, to become a switcher in one of the marshalling yards. But the march of progress was relentless and in the end, thanks to the combination of obsolescence and physical deterioration it would end up on the inactive list. For some years more it lay around idle most of the time, but pressed into service during seasonal traffic peaks and special emergencies. Finally at long last, the bell tolled and it passed out of the scene to the scrap dump.

While the failure of the electric lamp left a functional vacuum to be filled by its successor, the retirement of the locomotive was merely a belated recognition of the fact that it was already dead from a functional standpoint. Unlike the electric lamp, which maintained the full integrity of its original service to the end and which was functionally replaced, therefore, after retirement, the locomotive was replaced while it was still in service. Its final retirement was merely an aftermath of replacement.

Now most capital goods fall somewhere between these two extremes. They suffer a partial displacement of their function during their life, with the remainder displaced at the retirement. Typically, they undergo during their active careers an irregular downgrading of function that reflects this partial displacement. Production equipment is sometimes resold in used condition, generally going to lower grade uses registering less precision and reliability and less continuous service. Even when it is held until final retirement, by the first buyer, it tends to gravitate with increasing age into low precision operations and intermittent service, winding up frequently in merely protective or standby capacity.

The debasement of function over the life of a capital asset may be either quantitative or qualitative. That is to say, there may be a decrease in the amount of service rendered as the unit ages or a deterioration in the quality of the service or both. A combination of the forms of degradation is characteristic of most types of movable productive equipment, whereas for buildings and other structures qualitative degeneration is predominant.

Qantitative Degradation

For obvious reasons, the measurement of decline in the amount of service rendered—in terms of hours worked or miles run per year, for example—is easier than the measurement of decline in quality. Where a machine can be shifted as it ages to jobs of lower continuity and intensity, either within the same ownership or by sale in the secondhand market, quantitative degradation of function is highly probable.

Now it must be obvious that the decline of service intensity with age does not just happen; it is, in fact, a reflection or manifestation of the growing qualitative superiority of service offered by available substitutes or alternatives for the existing asset. This superiority may reflect an actual deterioration in the service of the ageing facility, or merely an improvement in the currently available alternatives without such deterioration, but in any event a gap opens up servicewise, between the asset and its competition, making it vulnerable to displacement. Naturally, its vulnerability is the greatest, other things being equal, in high intensity assignments in which the greater capital charges incident to new facilities can be spread over a larger production. Such assignments are usually the first to go. Where tasks of lower continuity are available, the ageing asset nominally sinks into intermittent employment, in which it can defend itself against the wolves of competition.

Qualitative Degradation

The retreat into jobs of lower service intensity is not the only means by which ageing facilities maintain their hold on life, they prolong their existence by also finding work of lower quality, in which the service superiority of new and better substitutes is less important. Thus a machine tool that has lost, some of its original precision, but is otherwise serviceable, may gravitate towards assignments for which the requirements are less exacting, or a bus that has yielded the cream of its service as a tourist carrier may be relegated to a short-route service.

Capital goods are 'kicked down stairs' in the scale of service not simply because new facilities are developed that can perform better or cheaper the same service rendered by existing units. The service itself may be outmoded by the progress of the arts or by changes in demand. Thus the war of machines is not merely or even primarily a struggle for the privilege of performing a pre-existing function or service, though occasionally this is the only thing at issue; it is a more complex affair in which the improvement of the service itself is often the most effective and lethal offensive weapon. The ability of a challenger to perform a superior function can dislodge an existing asset quite as well as its ability to perform the same function in a superior manner. Both factors continue to intensify the ceaseless aggression of the new against the old.

What is replacement ? It is the displacement of capital goods from their function or service. It is correct to say that a capital asset is replaced as often as its current job or work assignment is taken over by a successor. Certainly it is immaterial in principle whether it is the asset's last function or its first that is taken away from it, or whether, upon displacement it finds an alternative service or goes at once to the scrap yard. It is immaterial also whether its next assignment, if any, is in the same ownership.

Primary and Secondary Replacement

If replacement is the functional displacement of an existing facility, it may occur, obviously, without the acquisition of any new asset by the same enterprise. The function of the displacement facility may be either taken over or superseded by the service of other equipment in the same ownership. In many types of enterprises such inside or 'secondary' replacement is provided without new acquisitions (primary replacement); it occurs in fact whenever functions or job assignments are reshuffled among the existing units. It follows that replacement policy is much broader than acquisition policy. Its task is not simply the procurement of new facilities which can economically take over the functions of existing equipment; it is the assignment of the existing equipment itself to secure the highest service at the lowest cost. Replacement policy should ensure that all facilities in service are able to defend their functions against economical displacement by any challenger, whether outside or inside the same ownership. It must be obvious that the considerations governing primary replacement, by new commitment of capital, are quite different from those governing the functional reassignment, or reshuffling of assets already owned.

The Relativity of Obsolescence

Since replacement is the functional displacement of an existing asset, it follows that the obsolescence of that asset must be defined in terms of its relation to its job, not in terms of age or decrepitude as such. It is obsolete for the job when it is economically replaceable. Obviously, it need not be obsolete for all other jobs; indeed there may be many in which it can successfully defend its tenure. Obsolescence is thus a matter of relativity, not an attribute of the asset itself. This is a point worth emphasising in view of the widespread tendency to associate obsolescence simply with age.

When to Replace Equipment

Deciding when to replace equipment is a universal (and much debated) problem. Nevertheless, many of the methods are based on misleading over-simplification. Occasionally, too, they contain basic and important errors of theory which hide real issues in capital investment or raise false bogies. Replacement investments are often made without any reference to a rate of return criterion. Instead replacements are made according to preordained schedules or they are postponed until they become 'must' or they follow some one of the cost rules. It has to be admitted that economists have not contributed much to the solution of this problem. The pure theory of replacement has become an elaborate exercise in mathematics, where profit maximising plans are determined for a variety of abstract problems, such as the optimum life span for an infinite chain of identical replacements.

Apart from these replacement formulae, being too complex for the average executive, they yield different results when applied to the same set of facts : hence it is often more difficult to decide, which formulae is correct. For these reasons it is not surprising that elaborate mathematical procedures for timing replacements have only a limited currency in industry. They yield in practice to a simpler application of 'business judgement' aided frequently by a simple rule of thumb test that happens to be favoured by the management concerned.

Certainly there can be nothing wrong with the application of business judgement to this problem, indeed it is widespread. No magic formula exists or is in prospect by which decisions in this field can be delegated to a clerk with a calculation aid. Replacement is rarely the installation of a new unit of plant or equipment identical with the one removed—if it were only that the clerk might suffice—but is more likely to be the substitute of an improved and often radically different unit or combination of units. The more dynamic the technology concerned the more numerous and varied the alternatives. The less adequately will any mathematical formulae fit the case, the greater must be the reliance on personal judgement.

Since the use of full-fledged replacement formulae is comparatively rare, but the use of conventional rule of thumb tests of replacements very common, it is important to examine these shorthand aids to managerial judgement. Do they make sense ? Can they be justified on theoretical grounds ? Do they command general acceptance ? Many a management make replacement decision without the benefit of a rule of thumb. The answer is 'hunched' sometimes after much weighing of the pros and cons, sometimes with little more analysis than one might devote to the replacement of a pair of shoes. Whether the decisions issuing in this fashion from the managerial forces are better than those obtained by the application of a customary rule depends, of course, on the quality of the institution—and the nature of the rule—in each case. No general answer is possible. The point is that by either procedure management is really shooting in the dark. Hence the need for some reliable guide to the management in replacement decisions to ensure productivity of the capital.

Organisation of Equipment Policy

It must be made clear at the outset that there is no one 'best' set up for the administration of equipment policy. There are too many variations to reckon with; the size of the Company, the nature of the operation, the character and condition of the facilities, the personalities in management, and so on. Good organisation for a large concern may not be so for a small one, and a system (or even the lack of it) that works satisfactorily in one case may be bad in another regardless of size. There is, therefore, no organisation chart or blue print to offer. We should rather concentrate on the functions that good organisation must perform, leaving the structure to be worked out by each management in accordance with the peculiarity of its own situation.

Since the grand object of equipment policy is to take timely advantage of all profitable re-equipment opportunities, the prime organisational aim is to ensure that management, including top management is apprised promptly and fully of these opportunities. It is essential that the executives who make the equipment decision have available at all times systematic and comprehensive information on the situation. Nothing less than this can constitute good organisation.

Need for Specialisation

If management is to have a timely and comprehensive coverage of re-equipment opportunities, there must be somewhere in each enterprise an official (or in larger concerns a staff) charged with responsibility for keeping the equipment situation under surveillance and for marshalling and transmitting the necessary data. It is a popular illusion that replacement analysis is something any mechanically minded individual can do. On the contrary, it is a difficult art calling for special training and experience. It should, therefore, be in the hands of specialists.

The object of specialisation is not merely to provide more complete re-equipment analyses; it is to centralise the function of analysis itself. This does not mean that all re-equipment proposals should originate from the specialist. On the contrary, suggestions may come from line operating officials, such as foremen, master mechanics, engineer, works manager, departmental heads, etc. It means only that they should clear through the specialist who should make the formal analysis in co-operation with the operating men. He should, of course, have authority to originate studies and proposals on his own initiative.

It is quite natural that a large proportion of ideas and suggestions for re-equipment should originate from regular production executives who are close to the firing line and it is desirable to preserve the decentralisation of initiative. It needs to be supplemented, however, by the more systematic and continuous vigilance of a specialist. The regular operating executives are often too busy getting maximum production from the equipment they already have to give sufficient time and attention to the evaluation of alternatives, especially when existing equipment is physically sound. In this case, its replacement is likely to turn on developments external to the plant; hence not under daily observation, such as for example, the appearance of improved substitutes. These developments are hard for the operating man to keep up with and it is even harder for him to find the time to investigate them. The specialist, on the other hand, must make it his main business to keep informed.

It is not only in his superior knowledge of current mechanical alternatives that the specialist should have the advantage over the average operating man, he should be better informed also on Company plans that affect equipment decisions. It is obvious that equipment policy cannot be intelligently executed severed from such plans. Expansion may be contemplated in one line of production, contraction in another. New products or the redesigning of old ones, may be in the offing. The reshuffling of activities among different plants may be under consideration. The specialist can be kept informed of matters such as these when it may be neither practicable nor desirable to inform all the operating men likely to originate suggestions on re-equipment.

Need for Systematic Review

However desirable the decentralisation of initiative in the origination of re-equipment proposals might be, it leads, in the absence of a specialist, to haphazard, unsystematic coverage of the field. Suggestions go up on a case-by-case basis, with the result top management at no time gets a complete picture of equipment situation. Many rely apparently on the hope that the spontaneous, unorganised initiative of re-equipment proposals by the operating executives will provide top management with the information needed to maintain productivity of the plant and capital invested.

A great many of the concerns that do have a set up for the review of their facilities such as an "Industrial Engineering" and "Engineering and Development Department" or the equivalent, are not getting the results they think they are getting. In some cases this is due primarily to the failure of the reviewing specialists to employ a rational analytical technique, in others it reflects chiefly a lack of aggressiveness in prosecuting the review. Usually it is a combination of both. The fact reckoned with. There is, however, an important defect in this set up of which top management is often unaware, that is, the "law of anticipated reactions". The technical executives who prepare and send up re-equipment proposals do not enjoy having their recommendations rejected. It appears to reflect on their judgement and is, in addition, a waste of time. They begin presently to guess what top management will O. K. and to limit their proposals accordingly. As a result, only sure-fire cases go up. The top office finds itself making few rejections but this is because it is out of touch with the real thinking of the men in the shop. It is no longer challenged, as it should be, by their judgement. Thus protected, it may infer from the paucity of requests for new equipment that mechanical situation is excellent while, in reality it is the reverse. Another way of playing safe by technical executives is to 'pad' the equipment budgets with proposals which can be cut without affecting productivity, as a favour to reviewing authorities.

Budgetting

Even though the law of anticipated reactions is ignored in the submission of re-equipment proposals, it must be obvious that their review on a case-by-case basis can hardly provide top-management with a comprehensive and systematic knowledge of its equipment situation. Now does it permit the advance planning and control of capital expenditure.

Real planning and control in this field presupposes two things—(i) a comprehensive inventory of re-equipment opportunities; (ii) an estimate of the annual loss in each case from not taking the opportunity. With this information before it, management can make a budget that means something; without it, it can only shoot blind. If good budgeting depends on good analytical technique, it is clear that it depends equally on the continuous and systematic review of facilities discussed earlier.

Post-Audit

Re-equipment decisions are made necessarily on the basis of certain projections for the future. These projections are, of course, never realised exactly. As seen in retrospect they are sure to be more or less wide of the mark. This makes it desirable as part of the equipment policy, to have a regular post-audit of replacements to see whether the expectation that entered into the original analysis shows any general or systematic bias. If this post-audit shows a prevailing tendency either to overestimate or to underestimate the advantages from replacement, future projections can be shaded to correct this bias. There is no test like actual experiment.

Conclusion

The failure of the industry to recognise the economic demise of its productive facilities and to accord them timely burial can have deplorable consequences for the country as a whole and may properly become a concern of national policy. No country can contemplate with equanimity, the failure of its industry to keep abreast of technology. It deprives the state of power and security and robs the citizen of the advance in living standards to which he is properly entitled. When private enterprise develops a predilection for antiques as instruments of production it can expect sooner or later to come under the critical scrutiny of the State. Examples of such state intervention to raise productivity of private industry could be found in Great Britain and France immediately after the war.[1]

In this connection it may be profitable for us to know what one such "Working party" said about the state of British Industry immediately after the World War.

"It is necessary if the trade is to enjoy robust health that firms should readily know to rebuild, renovate and re-equip at each stage of progress as soon as it becomes commercially practicable to do so. Unless the will is strong in this direction there develops an increasing tendency to be satisfied with short-term profits and to hold on to the old buildings and to old equipment to the bitter end, in the meantime building up no adequate resources for replacement, when allowance is made for present-day building costs. It is possible in this way for an almost hopeless position to arise in the industry, without there being any general recognition of what is happening. There is more than a danger,

1. c.f. "Working Party" Schemes sponsored by Sir Stafford Cripps in Great Britain in 1945.

in our view, that this has happened or is happening today in a large section of the trade. We cannot press too strongly upon the industry that it should take steps without delay to take stock of its present position, collect and face courageously the facts and figures, which could not but show, in our opinion, that a change of policy is overdue, and devote itself whole-heartedly to the fulfillment of a re-building and re-equipment plan such as would put the whole industry on a thoroughly modern basis."[2]

2. Report of the Working Party on Jewellery and Silverware. p-29.

Control and Measurement of Maintenance Effectiveness

V.K. Kapoor

Measurement of maintenance is a complex, nevertheless, an important factor for any management. While the production can be rated in terms of output of any particular machine, no analytical yardstick is available for maintenance operation, and consequently, the basic concept of maintenance is vague.

The basic function of maintenance department in most of the industries is firstly, to ensure repair of equipment under breakdown in shortest possible time, and secondly, to introduce certain check lists etc. to prevent breakdown of machine to maximum possible extent. But the question persists in the minds of managements, as to how to evaluate maintenance as a function, and what are the methods possible for controlling it within narrow limits of efficiency. This gains more importance in view of modern sophisticated machines, wherein any breakdown can lead to a considerable dislocation in line production and enormous loss in terms of output due to machine breakdown time. So maintenance is not a question of records, check list, inspection schedules and the like, or a question of working a machine or putting into order, when it breaks down. On the contrary, it is a matter of involving continuous attention so that machine does not go out of order. This involves a different attitude towards the whole concept of maintenance.

Under the conditions existing in India, it could be said, with exceptions, that we could even afford to keep maintenance men idle, if at all, but not the equipment as the unit labour cost forms a lesser significant part in total unit cost, compared to fixed charges in mechanised and higher capital cost industries. Maintenance is already an expensive item, especially considering the complicated and sophisticated equipment of today. On an average and under good conditions, the cost of maintenance of equipment during its life-time is equal to or exceeds its purchase price. With some equipments, this cost may reach two or three times the purchase price. Such expenses are justified only if it helps in attaining the main objectives of maintenance, i.e. increased productivity of equipment and decreased downtime and overall cost of production and safeguarding the equipment itself. This can be achieved only if maintenance is planned carefully and rationally. As such, an enormous cost reduction can be achieved if maintenance efficiency and cost are controlled within the tolerable limits. It is said that a good maintenance is a good management. The success of any maintenance programme depends upon proper integral planning. By establishing a maintenance cycle with a permanent plan, it is possible to control and measure the maintenance function and from the data collected, an analytical approach to maintenance can be introduced.

The essential pre-requisites of an effective maintenance programme are:

Work Order System

Work order control is a system by which every type of maintenance job done, whether minor or major in scope, is definitely covered by a standard written form which shows that the work is needed, is adequately described, is properly approved, is issued by proper authority and provides a record.

The work orders are classified into the following categories :

(a) *Emergency Work Order* is given by production man to the maintenance department to take up an emergency breakdown which may result in serious loss of production. This work is taken up immediately by maintenance department. The production man justifies his emergency on a work order form and formal approval and cost calculation is done later. Emergency work orders should not exceed 5% of the total maintenance.

(b) *Minor Work Orders* are issued when labour hours are estimated to be less than four hours and/or money involved is estimated to be less than Rs. 100. This is issued for non-routine minor repairs. The originator issues two copies. One copy is sent to maintenance foreman. The cost against this work order is charged collectively by maintenance department. The total man-hours for one type of work like welding etc. for a period are taken together for calculation of cost. Similarly, cost of material used can be accounted.

(c) *Major Work Orders* are issued for authorising in writing any normal, non-repetetive work requiring over four hours of labour and/or money involving more than Rs. 100. These work orders are filled in by the production man in four copies. The originator keeps one copy for his record. Three copies are sent to maintenance department. The maintenance clerk retains one copy and two copies are sent to maintenance engineer. The maintenance engineer sends these copies to section maintenance foreman. The foreman goes to the place where the job is to be undertaken. The foreman then marks an estimate of cost regarding man-hours and materials. He will also confirm whether the complete material required is in hand or is to be procured. After making these estimates, the foreman sends these copies to maintenance engineer. The maintenance engineer, after thorough checking with the help of costing section, sends these to originator. After going through the estimate of cost labour and time involved, the originator decides whether the work is to be taken up or not, depending upon the production commitments. These copies are then sent to maintenance department for necessary action.

The advantage of this work order system is that detailed analysis is made for all the maintenance jobs, and time and cost calculated. By introducing this system, any maintenance department can, in due course of time, establish his working standards in terms of labour hours, individual material cost etc., which goes a long way in effectively controlling the maintenance function.

(d) *Equipment Work Order* is placed by maintenance department for ordering spare parts, materials etc. from different sections.

With proper work order control system, labour requirements to meet all demands of repair can be rightly ascertained. Equipment requiring maximum and costliest maintenance is revealed and indices for improving work performance can be adopted.

There are some plants where although a good work order system exists, no efforts are made to estimate the time requirements of the job or plan and schedule the work-load a day in advance. The maintenance foreman takes about an hour each moring to go through his order file and assign the day's work to 30 men in his labour force. Thus 30 valuable hours are first lost each morning before the work could be started. Then, some men cannot start or finish some of the jobs assigned to them as they lack materials or spare parts for which advance planning has not been made.

Thus, it is very necessary that having determined the work-load requirement from work order system, daily scheduling and weekly forecasting must be done.

The initial approach to work scheduling is on daily basis. By scheduling, supervision learns how close its estimated work in hours is to be actual, the work-load pending against the available man-power, and kinds and types of interruptions and their influence on scheduling effectiveness. On this planning, the maintenance supervision has a record of each day's work, which can be used as a base for improvement and correction.

Weekly forecasting is done once a week, after meeting with different sections. All the co-ordination between different arms of maintenance department is discussed and implemented. Any work left unfinished is added to the next week's schedule and reason for delay recorded.

A simple chart for weekly forecasting can be made as follows :

Men	*Monday* *Work Order No.*			*Tuesday* *Work Order No.*			....
Group A	501	503	...	...	...	...	....
Group B	...	...	...	...	...	...	....
Group C	...	...	...	...	...	...	....
Group D	...	...	...	...	...	...	....

The estimate time is based on the available data from previous recordings which can be suitably modified, depending upon the situation.

In addition to this, a monthly statement of work orders can be prepared, giving the details of labour hours and material spent for a particular machine or section :

Monthly Work Order Statement

	Emergency	*W/Orders*	*Minor*	*W/Orders*	*Major*	*W/Orders*	*Equipment W/Orders*
Section	Labour Hours	Material Cost	Labour Hours	Material Cost	Labour Hours	Material Cost	Lab. Material Hours Cost

Though it is difficult to provide a yardstick for ratio of types of work orders because conditions and plants vary considerably, the above statement will pinpoint the areas requiring maximum attention as well as give the correct picture of maintenance efficiency. If more time is spent on emergency work orders, it is clear that standard of maintenance is low and more money should be spent on preventive maintenance or overhauling.

Categorisation of Equipment

Maintenance is basically a means to advance the economic merit of an equipment. It is economical to do preventive maintenance on that equipment where the loss resulting from lowering of equipment performance or interruptions resulting from equipment breakdown is larger than the expenditure on preventive maintenance. On the contrary, if the loss is smaller, preventive maintenance is uneconomical and breakdown maintenance will be more economical.

The equipment can be categorised as follows :

Factors	*Points*	*Weight Coefficient*	*Total*
Production (P)	1 to 5	10	50
Quality (Q)	1 to 5	9	45
Cost (C)	1 to 5	9	45
Delivery Schedule (D)	1 to 5	7	35
Safety & Morale (SM)	1 to 5	6	30

Depending on this categorisation, the grading of equipment can be done as follows :

A Grade	—	164 — 205	Points
B Grade	—	123 — 163	,,
C Grade	—	82 — 122	,,
D Grade	—	41 — 81	,,

The type of maintenance for different equipment is planned on above basis.

Maintenance Records

Records occupy a pivotal position in any maintenance programme as they guide and direct the various steps in any planned maintenance. The following records should be kept by maintenance engineer :

(a) *Lubrication Schedule* will show the recommended lubricants, lubrication points, interval of lubrication etc.

(b) *Inspection Schedule* will show the dates of inspection, results and recommendations.

(c) *Spare Parts Card* will show the list of essential spares, their stores index, their annual consumption and replacement.

(d) *History Card* for each machine will give the age of machine, details of major breakdown etc.

Optimum Man-Power

Since maintenance is basically a trained and skilled group, its effect on overall cost of labour is quite substantial. The ratio between maintenance personnel and production group is always a subject of discussion in industries. No conclusive data is available to Indian industries at present. In western countries, with high degree of sophistication, the production operators, who are basically unskilled persons, are reduced while maintenance force is increased. In an important plant in

Germany, the ratio of maintenance man-power to production man-power has changed from 1:12 to 1:4 during the last ten years, primarily due to high degree of sophistication on the machines.

In India, in many industries, the strength of maintenance force is based on the rule that the expenditure required for the maintenance is directly proportional to the volume of business done, and an arbitrary sum is kept aside every year. This budget is set without regard to existing maintenance load and is unrealistic. A better method followed in many industries is to calculate the maintenance man-hours required as revealed from work orders received during a certain period and to estimate the man-power of respective skill from the data available. The type of man-power can be segregated as unskilled, semi-skilled, skilled or specialised skill man-hours. This results in properly sized work force, balanced in craft skill. This also leads to good supervision and worker morale because logic and objective analysis is used to size the work force. However, it is very essential that the maintenance force must be adequately equipped with proper tools. Effectiveness of maintenance force will be greatly influenced by how well they are equipped. Continuous efforts should be put in to see that new methods which simplify the work and improve the overall efficiency of maintenance are involved.

Control of Maintenance Cost

Normally, maintenance cost is calculated as the sum total of cost of breakdown maintenance and preventive maintenance. The cost of down-time of equipment—a very vital factor in maintenance cost analysis, is often ignored. With the rapid mechanisation and three-shift operation of equipment, the cost of downtime is getting more and more important. The cost of downtime embraces :

(i) Direct cost of material due to lost production.

(ii) Idle labour hours lost.

(iii) Cost of defective components produced.

(iv) Interest on idle equipment.

The total sum in respect to cost of breakdown, maintenance, preventive, maintenance and cost of downtime is called *controllable maintenance cost.* The most effective level of maintenance is where the controllable cost is least.

Measurement of Maintenance Effectiveness

Many techniques exist which can be used to determine the efficiency of work-force. They are generally based on the principle of determining work content contained in the tasks to be carried out and comparing the actual performance of work-force with them. These techniques, in themselves do not provide any control of maintenance work. Control of maintenance work will always remain the prime function of maintenance supervision. The technique of work measurement, however, does provide the necessary information for supervision to determine how many men they need and whether efficiency of work is at the acceptable level.

Work measurement is a management technique for improving the effectiveness of doing craft work. Briefly, it entails developing standard methods of performing various job elements and establishing elemental time standards, against which work efficiency can be measured. Several renowned companies in U.S.A. and Europe have developed work measurement programmes which are showing good returns on investment. The national survey figures of America indicate that the maintenance labour effectiveness is in the range of 50%. However, many companies, through the application of work measurement technique have increased the effectiveness of their labour-force to as high as 80%. In India, we do not have any figures, but it can be safely said that it is much less than 50%. What can be the reason for such low efficiency? Are the workmen unwilling to work, are they lazy? In my opinion, the low efficiency is primarily due to lack of application of scientific methods by the management. Experience has shown that the major factors which reduce the efficiency of work-force are :

(a) Improper or insufficient tools and equipment;

(b) Inefficient location of materials and equipment;

(c) Improper co-ordination between departments, leading to poor planning and scheduling of shut-downs;

(d) Material shortages and poor material control;

(e) Inadequate transportation facilities;

(f) Inadequate engineering;

(g) Inadequate supervision;

While it is generally agreed that the standards reach their maximum usefulness when associated with a wage incentive plan, even without a wage incentive plan their application can materially reduce and control production and service costs through improved planning. Because of non-repetitive nature of many maintenance tasks, it is not economical to establish an individual standard for each job as it is performed. In such case, standard data are used. Since the compilation of standard data through various time studies is a long and expensive process, individual companies cannot justify the cost of developing their own complete sets of maintenance standards. However, several standard data manuals are available, which have been developed by various major companies in the U.S.A. and western countries. Individual companies can benefit from these data and can suitably modify them to suit their individual conditions.

A set of separate personnel can be recruited and trained in interpretation of standards and methods improvement. The work measurement technique can be applied as follows :

All work orders will continue to be issued on existing forms. Each foreman will now separate his work orders into two groups; those requiring more than four hours of labour and those requiring upto four hours of labour. The latter can be handled in the usual manner, while the former will come under work measurement. Each job requiring more than four hours is discussed by the foreman and craft measurement analyst. Together, they visit the job site and agree on the method to be followed. At this point, analyst takes over all the paper work and leaves the foreman the responsibility of supervising the actual job. All the design work like sketches, component size etc., are furnished by design office. The analyst breaks the jobs into elements for agreed methods and adds the necessary allowance and arrives at standard time.

Work Sampling

Work sampling is a statistical technique, which is used for comparing the performance of any activity from time to time and locating the areas of delay or inefficiency for that activity. The procedure consists in taking the snap readings of preselected factors on random basis. The number of samples can be determined depending upon the required probability of error. Any measurement before and after the introduction of new methods can indicate whether the efforts are beneficial or not, and what are the probable factors giving hindrance to the desired activity.

The number of factors which can cause delay in maintenance work has been mentioned earlier. These factors can be tabulated and snap round can be taken by an independent person, who will plot the graph of the observations made by him.

The results can be tabulated as follows:

Characteristics	Snap Reading - (in Hours)									
	1	2	3	4	5	6	7	8	9	10
Improper tools & equipment										
Bad location of materials and equipment										
Improper planning & scheduling										
Material shortage										
Bad transportation facility										
Inadequate skill										
Outdated methods										
Miscellaneous delays										

The above chart will pinpoint distinct areas, which contribute to the delay and inefficiency of the maintenance group. The management can take corrective action in the required areas.

This method has been extensively employed in the author's factory and has given encouraging results.

It may be mentioned that the work-force must be aware and suitably oriented well in advance for the purpose of studies being undertaken. If the workman is not taken into confidence, any results obtained will be questionable.

Indices for Measuring Maintenance Effectiveness:

(1) Frequency of breakdown $= \dfrac{\text{Total hours spent on maintenance last month}}{\text{Total hours spent on maintenance in the current month}} \times 100$

(2) Breakdown maintenance index $= \dfrac{\text{Total hours spent on breakdown}}{\text{Total man-hours available}} \times 100$

(3) Level of maintenance $= \dfrac{\text{Total hours spent on scheduled maintenance}}{\text{Total man-hours available}}$

(4) Equipment availability Index $= \dfrac{\text{Actual running time of equipment}}{\text{Total running time available}} \times 100$

(5) Man power index $= \dfrac{\text{Man-power strength last year}}{\text{Man-power strength in the current year}} \times 100$

(6) Maintenance cost index $= \dfrac{\text{Total cost of maintenance}}{\text{Total cost of production}} \times 100$

(7) Yearly maintenance cost index $= \dfrac{\text{Total maintenance cost for last year}}{\text{Total maintenance cost for current year}} \times 100$

The above set of indices provides a handy tool in the hands of management to measure the effectiveness of maintenance.

Maintenance Engineering : A New Concept

S.K. Kalra

Maintenance of equipment in industry can be broadly classified into three aspects : (i) Managerial aspects, (ii) Economic aspects, and (iii) Engineering aspects.

In Indian Industries, during the last decade, the management has realised the importance of maintenance function as a tool to reduce production costs. There is an overall awareness of Preventive Maintenance systems, Predictive Maintenance systems and Planned Maintenance systems and whenever you meet maintenance executives in the plants, they take pride in discussing the type of maintenance systems they have in their plants and the display charts for equipment maintenance. The terminology of Tribology and Tero-Technology are finding their way into the managerial book of knowledge. But the actual situation in majority of the industries on the shop floor still desires much to be done. Most of these terminologies remain limited to the status symbol of executives and discussions in seminars, conferences and technical journals.

As far as the economic and engineering aspects of maintenance are concerned, our industries have still a long way to go. In many industries, to get a realistic picture of the cost of various maintenance activities, is a Herculean task as they don't have proper costing system of maintenance work. And unless one knows the cost of the activities, it is difficult to improve the economic performance of maintenance functions. In engineering industries, though the industries have come out of the oil-can and spanner image of maintenance, there is still a wide gap in maintenance engineering practices in our industries, as compared to similar industries in some of the advanced countries in Europe. The use of simple devices, sophisticated instruments as an aid to better maintenance engineering for objective inspection of equipment, has been a well-established fact in the advanced countries. In these countries they are able to predict and plan 80%

to 90% of the maintenance activities, thus practically eliminating the unplanned stoppages.

Maintenance Concept :

This paper is intended to introduce a new concept in maintenance engineering which comprises three essential features :

(i) Failure analysis

(ii) Creative thinking, and

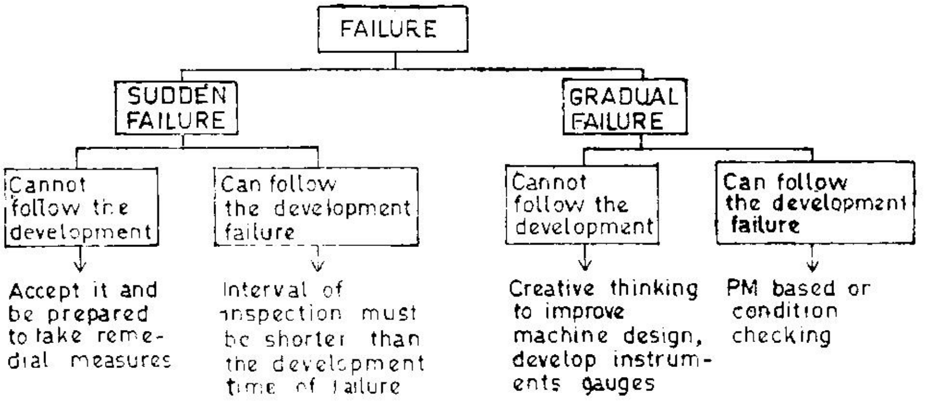
(iii) Use of instruments and aids for objective condition checking.

The basic philosophy behind this concept is that first an analysis should be made to understand the equipment and its components, their behaviour during operation and analysis of types of defects and failures which can happen due to normal wear and tear. Then the technique of creative thinking and brain-storming should be applied to devise simple methods, ways and means to measure wear on components and take corrective measures as a planned repair before the failure has taken place. Further sophistication in maintenance engineering can be built up through the use of instruments and aids for objective condition checking to predict and plan maintenance activities and avoid failures. In this new concept, I have listed the use of these instruments and aids as the last item as most of these are very expensive and the industries must look into the economics of these before investing their capital. These may be very useful for large process industries where they can have a wide application and result in enormous savings in operation and maintenance cost, while for the small and medium size industries, the approach of creative thinking may be reasonably objective.

Failure Analysis

The terms "Defect" and "Failure" have been used in this paper frequently. It is necessary at this stage that these words should have an explanation. "DEFECT" means, that the original qualities in a component have changed to such an extent that the original function of the component cannot be expected or obtained. "FAILURE" means, that a component has a defect, which influences upon function to such an extent, the function does not meet the demand or ceases.

There are, of course, different kinds of both defects and failures, some of them are coming slowly, meaning there is a certain Defect or Failure Development time. In many cases it is possible to reveal the presence of a Defect, before it has developed so far, that the component fails. In many other cases the developing time is too short, and the detection is not possible before the failure is a reality.



The objective of such type of analysis should be to bring most of the failures from left-hand columns to right-hand columns in a phased manner. A happy situation of maintenance in the industry will be indicated when most of the failures fall in 'A' category and least possible in 'D' category.

When making plans for PM it is of the greatest importance to know about the different types of defects and failures, that may be expected in the components. However, the first fact is that any machine is built up of components and that the PM must be based on knowledge about the components. The enviroment, meaning both the combination of components in a machine, as well as the environment around the machine during operation, climate, load, atmosphere, humidity, etc. of course, has influence on the development of both defects and failures, but the PM must be based first on the basic needs of the components, their qualities under normal conditions". The actual PM of a component should then be checked and corrected to environmental conditions.

The initial PM programme of component inspection should be made on the basis of one's own experience and technical knowledge about the behaviour and characteristics of components, manufacturer's instructions or help from specialists in the field. A periodic review of the PM programme is absolutely essential to revise PM schedules on the basis of behaviour of equipment and analysis of types of defects that develop in that particular environments. Thus development and improvement of a PM programme is a continuous process in the industry and maintenance executives have to make continuous efforts to improve this function.

Creative Thinking

The condition checking methods of equipment can be divided into two groups :

- — Subjective checking methods (inspections) utilizing the human senses, feel, smell, see, listen. An experienced inspector will be able to make a qualitative assessment of the condition of equipment like bearing temperature by feeling, sound of gear box by listening, tension in the chains, V-belts etc., by seeing, and take remedial measures.

- — Objective checking methods to enable to get quantitative measure of wear and defects by measuring the change in qualities of components. It is possible to measure wear by establishing the rate of change in measurements. In this case also defect development time may be estimated or even calculated, if two measurements are taken sometime apart.

The technique of creative thinking can be very usefully employed to convert subjective condition checking methods into objective ones. Very simple devices can be made for objective condition checking of wear on V-belts, slackness in chains, wear on chains, etc. To illustrate this point three simple methods are described on the next page.

In many industries cyclones are used in pneumatic transport plants. In separating the material from the air the material glides along the curved surface inside the cyclone. In most cases this will cause wear of the sheet steel plate and sooner or later the plate becomes so thin, that it breaks and the material is blown out. To prevent this from happening many manufacturers mount wear plates inside the cyclone. But this material also wears out and must be replaced.

The natural phenomena for inspection of wear plate will be to stop the plant, make a man enter into the cyclone and inspect it for wear. This operation is sometimes both difficult and dangerous.

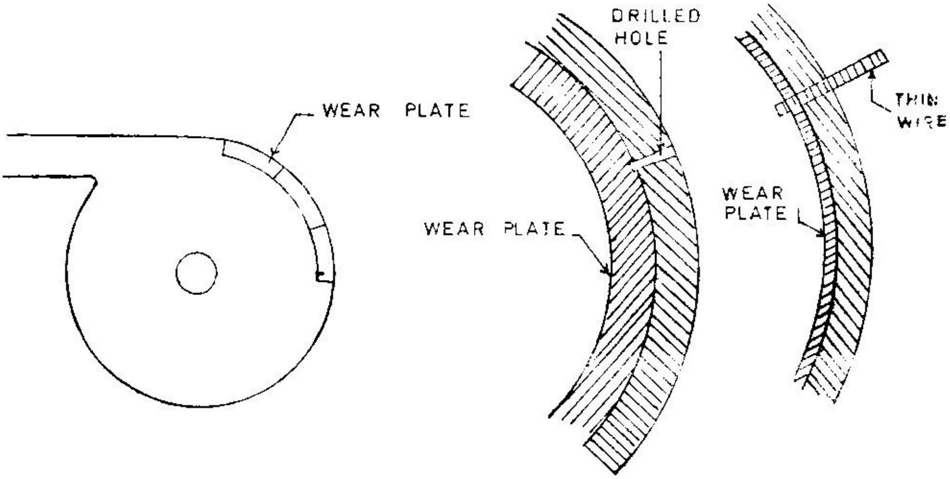


Fig 1 Fig. 2 Fig 3

By drilling a small hole from the outside, through the outer plate and a short distance into the wear plate it is possible to inspect, or rather check, the wear plate by inserting a piece of thin wire in the hole from the outside. If it goes through, the wear limit is exceeded and the plate has to be replaced at the next stop. The depth of the hole in the wear plate should correspond to the wear rate from the time interval between two inspections.

The movement of spring suspended machine components can be checked as shown below. A pencil and a piece of paper are all that are needed.

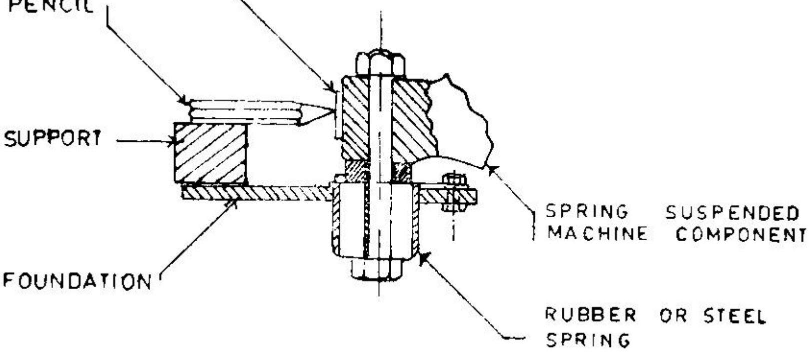
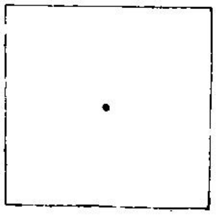


Fig. 4

If the component moves with a fairly high frequency, a center punch mark can be used. When the part is moving the mark will describe some sort of figure as indicated below :



Mark at rest

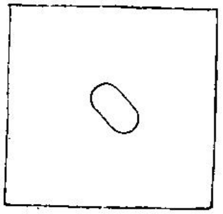


Figure caused by mark during motion

By fixing the movement limits for the mark during motion, the effectiveness of spring can be measured and replacement planned before actual failure.

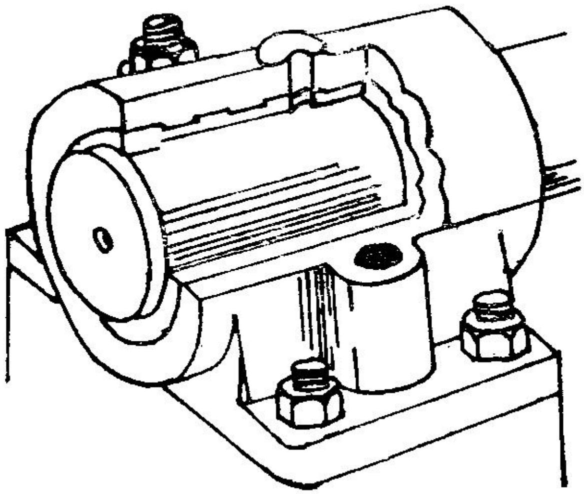


Fig. 5

Plain bearings usually have a long lifetime, provided they work under normal conditions and get the right lubricant. Even if working under ideal conditions such bearings wear and the play will become too large to allow a good lubricant film. Sometimes it is possible to lift the shaft against an indicator, sometimes it is possible to arrange a test point as indicated in the sketch attached. (Fig. 5)

By following the change of play with an indicator, it is possible to get a measure of wear. Of course, the reading must be done when the shaft is stopped but gives an accurate indication of the wear. A limit can be established and the lifetime predicted.

Use of Instruments and Aids for Objective Condition Checking

In advanced countries much sophistication has been built into the maintenance engineering through the use of electronic, ultrasonic, magnetic and Radiography principles. Listed below are some of these instruments which can be advantageously used in large process industries, resulting in enormous cost savings.

Thickness Gauge: The Branson Caliper 99 is an inexpensive, light-weight ultrasonic thickness guage. It provides instant non-destructive thickness readings with an accuracy of ± 0.1 mm from one surface. Typical applications include measuring thickness of machine parts, tubes, pipes, flat stock, pressure vessels and ship hulls.

Minearscope 500 : It multiplies the power of ear many times and virtually eliminates outside noises and makes it possible to hear even the faintest signal of danger. Warnings of wear and failure are made audible long before they can become serious enough to cause machine damage. It can save thousands of Rupees by locating worn bearings and bushings, chipped, pitted or dirty rollers, balls or races, misaligned shafts and broken or chipped gear teeth.

Ultrasonic Flaw Detector : This can be very efficiently used for detection of very small flaws, cavities, shrink holes etc. which are not readily detected by other means. This instrument is very useful for detection of blow holes in castings, fatigue cracks in steel plates, axles and other steel parts, cracks produced during heat treatment of metals, flaws in welded joints, sheets, tubes etc. It also has an added advantage that only one surface of the material to be tested need be accessible.

Ultrasonic Leakage Detector : The instrument can indicate the ultrasonic noise generated by a gas leak. It works with high frequencies, e.g. 35,000 - 45,000 c/s that prevents the disturbances from machine noise to influence on the indications.

Temperature Indicators: The contact thermometers work with high safety and are simple to handle. They are very useful for measuring temperatures of bearing surfaces, gear boxes and meters etc. The instruments are available in different measuring ranges as follows:

A	− 50°C	to	+ 1240°C
B	− 50°C	to	+ 200°C
C	− 50°C	to	+ 360°C

The infra red thermometer indicates the average temperature of an area from a distance. A cheap type of thermometer has an elevation of 15:1 which means that if it has to indicate a point 15″ away it indicates the average temperature of an area with a diameter of 1″.

There are numerous other types of instruments, like Endoscopes for carrying out inspections in gas tank, tubes in heat exchangers, cylinders in engines etc., Vibration meter for measuring the amplitude of vibrations, stroboscope for inspection of moving or rotating components. These can be usefully utilised for objective inspection of components to predict failures before they actually happen.

Conclusion

Thus the new maintenance concept which is a combination of component failure analysis, creative thinking and use of sophisticated instruments for equipment inspection can be economically applied to suit the requirement of different types and sizes of industries. Thus large process industries should preferably have their own plant engineering cell adequately trained and equipped in the use of these modern instruments and can effect large savings in plant operation by preventing breakdowns, while the smaller companies can take the help of outside consultancy, like the National Productivity Council where a beginning is being made in these services through its Plant Engineering Cell. However, knowledge about their own equipment and its components in the industry and a continuous approach of creative thinking to devise simple and better methods for objective condition checking are basic essentials for every industry, be it large or small, if they want to cut down their operation costs through more effective maintenance.

Hurdles in Implementing Preventive Miantenance System

R.M. Garg*

All management systems are essentially aimed at optimum utilisation of the resources at the disposal of an enterprise. 'Preventive maintenance' is one of the systems which aims at maximising the effectiveness of the resources in the nature of plant, machinery and equipment. The term 'PM' is a familiar concept in Indian industries since long. Among the engineering personnel of the industries, this is also a common subject of discussion. Of late, symposia are being organised on this subject to make concerned people know and realise the importance and objectives of this method.

In a layman's language, 'PM' is "maintenance to prevent breakdown", which means to attend and repair the machines or equipments before breakdowns occur. Breakdowns may be classified broadly into two groups:

(1) Controllable breakdowns, (2) Uncontrollable breakdowns.

Preventive Maintenance aims at (i) eliminating the controllable breakdowns and (ii) minimising the frequency and severity of the uncontrollable breakdowns. The system ensures an awareness on the part of the plant personnel as to what breakdowns could arise and perhaps when they could expect them. To be forewarned is to be forearmed : all the necessary precautions can be taken and before the breakdown occurs, repairs can be scheduled to set things right again in time. The objective of this paper is to detail what 'PM' can do as a system and the hurdles that will be encountered in implementing and maintaining the system.

Preventive Maintenance system can achieve the following for an industry:

(I) Increase productivity ;

* The author wishes to thank Mr. K.N.N. Swami, Office Manager, Asbestos Cement Ltd., Podanur for his co-operation in preparing this paper.

(ii) Less downtime of plant and equipments, thus increasing production. (In a continuous process plant, loss of time in starting and stopping is great) ;

(iii) Increase life of plant and machinery ;

(iv) Fewer number of spares required to be maintained ;

(v) Avoids installation of reserve or stand-by equipments ;

(vi) Standardisation of stores and items and thus reduction in inventory possible ;

(vii) Manpower planning feasible ;

(viii) Budgeting the yearly expenses become feasible ;

(ix) Can adhere to delivery schedules to customers by maintaining production programmes ;

(x) Lower costs of maintenance ;

(xi) Prevention of accidents and destruction or damage to materials and equipment ;

(xii) Avoids irritation and frustration at all levels.

The various hurdles in implementing and maintaining this system are as under :

1. *Lack of proper attitude towards planned working :* To do a job in a systematic way and planned manner can be either an inborn habit of a man or should be instilled in him at a young age.

While planning a job, certain questions arise in one's mind and one should be capable of analysing them. Questions such as (i) Why one is doing this ? (ii) When should one do this ? (iii) Will it be economical? (iv) Whether the method followed is correct ? (v) What would be the implications ? (vi) Who could be a proper man to do it or help ? One should answer for developing a correct attitude towards planned working. There are a few who possess a proper attitude towards planned working. For others, 'PM' system provides a partial aswer, and consequently, helps in the better implementation of 'PM' System.

2. *Human tendency to resist change :* People by and large resist change and it is more so,

(a) if work methods have been standardised and man becomes habitual of doing the job in a particular way ;

(b) If the man is not aware of the implications of change, it creates fear in one's mind ;

(c) If the workload on him has been static for long periods, he resists any change in workload ;

(d) If the chances of his benefits are nil even though he is convinced that he is not a loser, his mental make-up revolts against change.

The introduction of 'PM' system calls for changes and readjustments in routine work. The responsibilities are better defined. Actually, this may not increase either the workload or responsibility, but since the man commits his work in writing through various records and the conception of individual responsibility is crystalised by removing ambiguities, fear develops in the minds of those who are not sincere and so they resist.

Further, it is an accepted fact that by doing any job in a systematic and planned manner, the waste of time can be avoided, the man-hours can be reduced and since jobs are scheduled to be done during normal working hours, the overtime will be reduced. This is a direct loss and therefore is the biggest factor which make workmen resist the system as a whole. However, if the system is thrust upon, the delaying tactics or undeclared go-slow tactics are adopted and workmen try to sabotage the schedules and the whole system.

3. *Obstacles in Implementing 'PM' System :* The existing uneducated plant workers who have learned the jobs or acquired the skills in respect

of existing machines by doing the jobs repeatedly over a long period of their working life, thus are incapable of repairing the newer or more sophisticated machines and, hence, the need for recruitment of skilled hand arises.

Under PM the jobs are required to be done more skillfully in lesser time and more precisely which calls for knowledge of drawings, measuring instruments and basic education.

During change-over period, i.e. the state of changes from breakdown maintenance to 'PM' when the level of breakdown will come down to minimum, the total number of jobs to be attended in scheduled periods are more and thus require more number of hands.

The analysis and planning of maintenance jobs call for a systematic recording and collection of various data and information. These records serve costing purposes even better. Usually, these information are concerning lubrication, planned maintenance, equipments, history, spare parts, consumption and stocks, developing import substitution, manpower employed, equipments down-time etc. These records serve as a basis for a systematic evaluation of repair and renewal alternatives.

This technical recording which does not exist under breakdown maintenance set up and when introduced under 'PM' system calls for extra or increased staff in maintenance department.

All these mean recruitment of highly skilled workforce in the department. But the new recruitment is resisted by existing workforce because their chances of promotion are reduced and resented by management because the labour strength increases. Even if the company's economy can sustain such increase in labour strength, the management does not agree to do so for obvious reasons.

4. *Impatience on the Part of Management :* 'PM' system is a long-term policy matter. It may take few years to achieve the goal and see the results in big and complex units. In majority of cases the Plant Engineer proposes to the management to introduce PM system. But the management does not have the patience to await the results and, if things go slower than expected the management takes

decision of banning the setting up of 'PM' system and withdraw the sum allotted for it. This is out of my experience in some Indian industries.

5. *Lack of Motivation :* Motivation means something which induces a man to work effectively and efficiently. The motivating factors can be rightly related wiih human needs and psychological factors. According to an American Social Psychologist—'the human being who is missing everything in life will linger for food, water, somewhere to live with his family and the like rather than safety, esteem and knowledge".

In India, labour and lower supervisory and clerical staff earn a little more than subsistence level, barely enough to cover their needs and thus an urge to earn more money is uppermost in their minds. Incentive in the form of money is supposed to be one of the best motivating factors. For a maintenance crew there have been certain bases adopted for implementing incentive plans :

(a) Maintenance performance measurement, using the "Universal Maintenance System".

(b) Production output

(c) Percentage downtime registered

(d) Merit award.

It has been universally accepted that due to wide variety of jobs and conditions, it has been impossible to set standards which would represent the exact time required by the maintenance worker to do each job; also if at all any such efforts are done under UMS, they are very costly and time-consuming and just out of question in near future for Indian industries. Further this needs perfect preventive maintenance system and work measurement system.

In some industries the incentive plans for maintenance personnel, are related to the production output. Although this is the easiest method, it has many drawbacks and has failed to improve efflciency of maintenance personnel.

The maintenance performance can be equally easily related to plant and equipment downtime hours due to planned repairs and breakdowns, or, in other words, loss of production in hours due to any of mechanical or electrical reasons.

Usually, for increasing downtime a normal complaint from maintenance personnel comes as plant or machines not being operated and handled properly, operational people being careless etc. But, such quarrels can be avoided by better and proper record keeping as desired in PM system and by implementing equally attractive and effective incentive plans for operational personnel, I feel in Indian conditions it should be a workable solution.

In merit award system, some merit factors are defined and the workers are rated periodically by committee formed for this purpose only. Each merit factor carries some points. The individual number of points obtained in rating are converted to the amount of money he will receive until next review. The worst part of this system is that no individual who is rated low will remain satisfied and keep confidence in the judgement of the committee and therefore the system becomes utter failure.

6. *Non-availability of proper spares and drawings :* When new plants are purchased and installed, the management economise and do not purchase many important assembly drawings and dimensional drawings. The effect is that in the absence of any such dimensional drawings of spares, the PES are not able to keep the spares ready unless they get some opportunity when they can open the equipment and sketch for themselves. Thus, irrespective of planning, the schedules of planned repair fail and job planning becomes impossible.

7. *Scant regard for maintenance work :* Operational personnel have scant regard for the efforts and skills of maintenance personnel and envy them. In case of breakdown of a machine, an operational personnel would stop working and wait for a maintenance personnel to set the machine in order even though he is a better man to give information. The management tolerates this, because it is they who spread the feeling through their own officers that operational people are those who give production only.