Cost effective predictive maintenance

These programs can be a reality in every plant

BY B.C. HOWES, B.R. LONG AND V. ZACHARIAS

A good predictive maintenance program generates savings for your plant in several ways, including reduced parts and labor costs through prevention of wrecks, reduced over-time through better scheduling of maintenance tasks, and reduced down-time. The savings generated in these areas are obvious, and generally accepted within the industry.

The number that is critical to the overall profitability of the mill, however, is the net benefit, defined as the difference between the savings generated and the cost to generate these savings. This paper will discuss how savings generated and net benefit diverge, and will attempt to provide a framework for evaluating alternative predictive maintenance approaches.

Two broad categories of machinery can be identified: machinery on which failures occur so rapidly and are so catastrophic that permanent monitoring is required, and machinery on which increasing vibration is a sufficient indicator of a potential problem and provides enough warning to allow repairs to be made in a timely fashion. This paper is limited to a discussion of maintenance on the second category of machines.

It is assumed that we are discussing plants with a significant amount of equipment. As a minimum, let's use Plant XYZ, with 400 machines, 10 possible readings per machine, a total of 200 000 hp and a maintenance budget of $4 000 000 per year.

The maintenance task today
Maintenance of rotating equipment is part of the bottom line. No longer can we think of maintenance equipment and personnel as an unnecessary expense. In order to maintain your position in this competitive world, you must build an effective maintenance program from the ground up.

Evolution of maintenance: The evolution of plant maintenance is shown by the time line in Fig. 1. Start at the bottom with old-time or technologically backward plants. Maintenance philosophy was *Run it until it quits*. Eventually, better methods were developed. Moving up the time line, more and more effort is put into maintenance planning and prediction, resulting in more effective but not necessarily more cost effective maintenance.

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Current practice: Most maintenance experts in the pulp and paper industry recognize that some form of preventive maintenance is cost effective, and therefore desirable. However, you will find that even among this group, varying levels of preventive and predictive maintenance programs have been achieved.

Some plants combine preventive and on-time maintenance. This approach leaves most of your maintenance personnel available for making repairs, but it has several disadvantages. You can introduce problems during unnecessary overhauls, you will have unexpected failures, and your tradesmen will work more maintenance hours than necessary.

Further up the scale, some plants have a vibration inspector doing spot checks. Occasionally, he connects and identifies a problem before it is critical. More often, the hit and miss nature of this approach means that he misses.

Parallel and often superior to spot checks is periodic inspection of machinery by rotating equipment specialists with sophisticated diagnostic equipment. This approach has the effect of wasting the time of skilled people. Job satisfaction is low and the program tends to fall by the wayside.

Periodic, planned vibration checks on every piece of equipment, combined with trending of results, produce the greatest benefit. Periodic checking and trending can be done manually, by designating as many people as necessary to take readings, record them, graph them, and analyze the results. Properly done, the manual method is effective. The problem is that the job is tedious and time-consuming, and sooner or later, it doesn't get done well enough to produce good results. When the results are not good, the time is not justified, so the program is abandoned.

Thus we come to the state-of-the-art; an automated system of periodic planned vibration checks on every piece of machinery. A computer keeps track of all the machines, test-points, and recorded data. A portable instrument is used to take readings, and it remembers them until they can be transferred back to the computer. Trending and historical analysis are done by the computer.

The automation dramatically reduces the tedium of the job. Fewer people are required to collect data, because using the instrument is so much faster than collecting data by hand. The computer takes over trending and anomaly detection. All you have to look at each day is the anomaly report, and from there, you can concentrate on the identified problems.

All of the more advanced systems generate significant savings, but the net benefit associated with each program requires more consideration.

The economics of maintenance

Savings generated: Figure 2 illustrates in a qualitative way the savings available from a range of maintenance programs, some time after the program has matured.

The resources expended on the program, including people, equipment and training, are shown by the horizontal axis. The program cost curve is the total cost of the program; it increases linearly with the resources expended after the initial start up has been completed.

PRESENT TIME – TECHNOLOGICALLY ADVANCED MILLS

AUTOMATED PREDICTIVE MAINTENANCE
WITH DIAGNOSTICS AS APPROPRIATE
(survey everything: computer records & trends)
(use skilled workers to identify solutions)

↑

TRENDING
(comparisons over time—even more worthwhile)

↑

PERIODIC MANUAL VIBRATION CHECKS
(takes a lot of effort, but OK when it works)

↑

ROUTINE VIBRATION DIAGNISTICS
(skilled inspector checks because it's Monday)

↑

SPOT VIBRATION CHECKS
(hope you check the unit that needs it)

↑

ON-TIME MAINTENANCE
(regular overhauls based on running hours)

↑

PREVENTIVE MAINTENANCE
(visual inspection, regular lubrication, etc.)

↑

BREAKDOWN MAINTENANCE ONLY
(no attempt to prevent or predict problems)

EARLIER TIMES – TECHNOLOGICALLY BACKWARD MILLS

Fig. 1. Advance in maintenance practice.

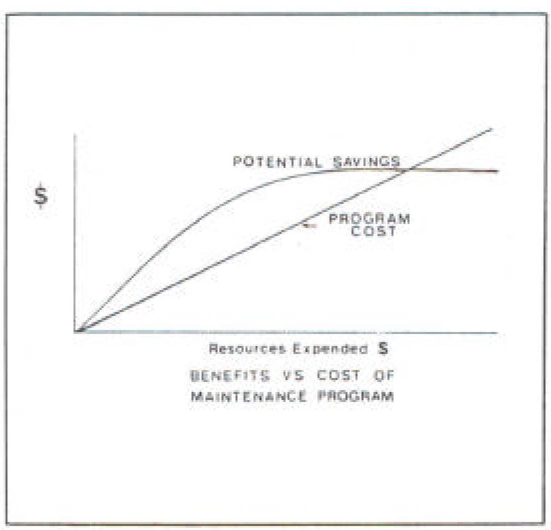

Fig. 2. Savings generated by preventive maintenance programs after maturity of program.

POTENTIAL SAVINGS =

+ savings in parts
  (no unnecessary replacements)
  (less consequential damage)
+ savings in labour
  (overhauls as needed, not on-time)
  (easier repairs)
  reduced over-time)
+ reduced down-time
+ reduced inventory
+ better data for management
  (more efficient use of time & funds)
+ indirect savings (feedback from PdM program results in better maintenance practice, and thus longer machine life)

Fig. 3. Savings possible with predictive maintenance.

The potential savings curve represents the savings available. Figure 2 lists a wide range of these savings. The savings curve starts at zero and eventually flattens, once perfect maintenance is achieved. It is important to note that the savings curve indicates only a potential. Actual savings may be considerably less, depending on how consistently and thoroughly the chosen maintenance program is carried out.

The net benefit curve is the critical consideration, as shown in Fig.4. This curve is the difference between the savings generated and the cost of the program which produced those savings. The important point to note is that there is a maximum in this curve. The objective is to find the program which represents this point of maximum net benefit for your plant.

Point of maximum benefit
There are no standard design procedures that you can use to define this point. However, the application of some industry experience, engineering judgment and common sense will result in a good estimate.

The peak in the curve varies for individual plants, but let's consider the example of XYZ plant with about 4000 readings. It would take one man about three weeks to take a set of readings manually. Extra time is then needed to analyze, compare, and store the data collected.

A good automated system would require less than a week for data collection, and no time to collate and analyze data for good machines. Use data for your own plant to make this comparison between manual and automated programs more meaningful. You will most likely find that for plants of significant size, and for plants where down-time is especially critical, an automated predictive maintenance system is the most cost effective.

Automated maintenance
Automated predictive maintenance programs vary, but they should all include the following elements:

Regular collection of good data: Base your predictive maintenance program on regular collection of vibration and significant process data. Small, spared equipment should eventually be included in the program. As a general guideline, data should be gathered and trends analyzed from each machine at least once a month.

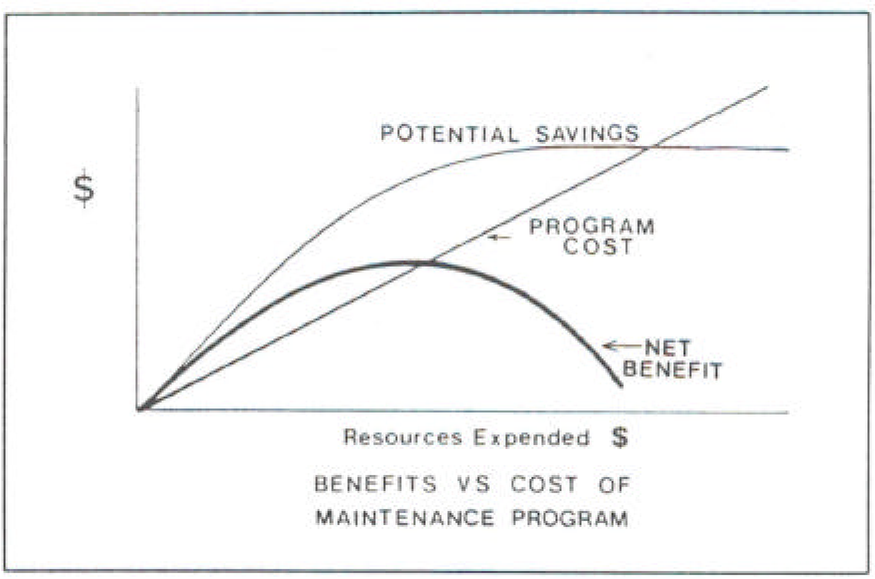

Fig. 4. Net benefit of maintenance programs.

ITEMS TO CONSIDER	PTS	A	B	C
1. Useability of Instrument Ergonomics Simplicity of Instrument	 25 25			
2. Cost of Pred. Maint. Prog. Initial cost of instrument Manpower Cost per Year Cost of Training	 10 20 15			
3. Flexibility of System all required vibn data bearing information process data inspector observations spectra Predictive Maintenance on Recip. Eqt. (0 to 50 pts.)	 5 5 5 5 5 ___			
4. DATA-BASE Quality User Friendliness Power of the DATA-BASE	 20 20			
5. DATA-BASE Reports Anomaly History, Trending Survey Information	 10 10 10			
6. DATA-BASE runs On “my” computer (0 to 25)	 ___			
7. Documentation Printed Screen Displayed Diagnostic Helps	 5 10 10			
TOTALS				

Fig. 5. Evaluation tool.

If the collection and analysis of vibration data is infrequent and/or inadequate, the savings generated will be too low, and the program will not be justifiable.

Trend analysis: Trending the data is valuable, but manual logging and t rending do not usually work out well. Use one of the intelligent predictive maintenance tools and let your computer take care of anomaly detection, record keeping and trend analysis.

Detection of anomalies: The most basic benefit of automated predictive maintenance (PdM) is the ability to detect problems at an early stage. Normally, you do not need to look at everyday data. The PdM program must identify those areas that have exceeded alarm levels or changed by some pre-determined amount without requiring the analysis of reams of data on good machines.

Use of a computer to manage data: One of the major problems associated with manual PdM programs is the overwhelming volume of data that has to be reduced to a manageable format and then analyzed. Well-designed computer programs make this a simple task.

Such programs can also provide survey information which permits continual evaluation of the maintenance program as well as the provision of proper feedback to the maintenance staff. Knowing that the quality of your work will be recognized is a powerful motivation.

Predictive maintenance design
Certain principles should be adhered to during the design procedure.

Use a broad-based design group: Include maintenance personnel from the user on up to the superintendent. Naturally, the rotating equipment specialist is a key member of the group. You will also want to include a representative of the operations group. An important member, but one who is often not included, is someone with a comptroller function, an individual whose basic concerns is the bottom line.

Identify objectives clearly: Keep in mind that the basic goal is to achieve the best return on investment for the entire plant, over the expected life of the plant. Nothing should take precedence over that goal. Members of your design group should state their objectives separately. Then the entire group should evaluate each objective against the main goal. If it fits, keep it. If it conflicts, discard it.

Use a standardized tool for evaluation: Evaluation is a difficult and time-consuming exercise, and should be approached with as much objectivity as possible. Figure 5 is a starting point toward a quantitative analysis of predictive maintenance systems. Under items to consider, we have included a list of factors you should take into account when evaluating alternative systems. Additionally, you may want to add others which have special concern for your mill.

The points column is the maximum possible credit any system could receive for that item, and it reflects the importance you attach to that item. We have included suggestions based on our experience and our contact with the industry, but the first task of your design group should be to look at the weighting and adjust it with the needs of your plant in mind. The remaining columns allow space to write down the results of your evaluations of each system. The importance of the chart is two-fold;

- you evaluate each system in the same way, according to your requirements.
- You can review and compare systems away from outside influences.

The evaluation
The items to consider are broken into seven groups.

- **Useability of instrument:** This item is first on the list because it is critical. We are dealing here with routine monitoring programs, and that implies day in, day out regular and repetitive work. Why not choose an instrument that makes the work easy?

Ergonomics, operator comfort, is the first aspect. If the person doing the data collection finds the instrument awkward and heavy, it will be more difficult for him to collect a lot of data in a short time. He may even begin to find other more important tasks, that he does not have to do the data collection.

This point is hard to appreciate without personal experience. Engineers and managers are especially likely to overlook its importance. If your chosen system is not used, the entire program fails, no matter how well planned.

Fig. 6. Wearing the unit improves comfort and safety.

The other and perhaps even more important part of useability is what we have termed the Complexity Factor. Industry experience is quite clear about a paradox in predictive maintenance programs: Those which rely on highly qualified personnel, complex equipment and sophisticated technology should be excellent but often fail. The situation arises because of the complexity factor, which includes the following aspects. Modern diagnostic equipment is difficult to use. It requires significant expertise, based on technical background, extensive training, and continual practice. Personnel with inadequate qualifications may be reluctant to use such equipment for fear of embarassment and failure.

Personnel who are qualified are usually enthusiastic at the start of a program and do a good job. But when they find that the great majority of the data collected is from machines in good health, requiring no analysis, they understandably become bored and lose interest. Their special skills are largely being wasted. They recognize that they are not really giving value for salary, and turn to other tasks.

In other words, it is not necessarily true that more is better. Sometimes more is counterproductive.

- **Cost of the program**: The most obvious and probably least expensive item in this area is the initial cost of the instrumentation required to do the job, but since this is a capital cost and other costs are expense items, it is considered separately.

The cost of personnel to keep the system working is more significant. This includes salaries, which of course vary with the expertise the person requires to do the work.

A hidden but significant cost is that of training your current personnel, and of training their replacements as necessary. A spectrum analyzer system, for example, is very costly in this area.

Any system which requires the ordinary operator to make good use of spectra at the machine site will require more expensive personnel and a higher ongoing investment in training. More time will be required for data collection per point because of the waiting time and analysis time at each point for which a spectrum is taken.

When you are evaluating the various options, consider the resources you have available. Does your plant have well-trained, knowledgeable, experienced people who have both the necessary time and are willing to do routine data collection? Would it be worthwhile to use a green hand for the routine work, and save your experienced people to work on problems you know are there?

After implementation of a predictive maintenance program, some 95% of machines inspected will be in good, normal operating condition. It is therefore usually a waste of resources to take vibration spectra on a routine basis. Skilled rotating machinery specialists should be used to follow up on the other 5%, rather than being used to gather data on good machines.

- **System flexibility:** Does the system record all the information you need? An optimum mix of data includes:

- overall vibration,
- bearing condition,
- process variables,
- inspector's observations,
- first-level diagnostic data.

Vibration alone is not enough, because you lose the ability to correlate it with other data, such as load or speed. Similarly, the inspector's observations can be vital to the whole picture.

If you have reciprocating equipment, predictive maintenance on it is important. The more equipment you have, the more weight you would assign to the item. You would also weight this item higher if you find it difficult to acquire, train, and retain reciprocating equipment specialists. If you do not use these specialists, allow zero points for this topic.

- **Data-base quality:** The data-base must provide excellent support. Even if the instrument is perfect, the associated data-base is an important consideration. It must be sophisticated and complete, but at the same time it must be simple to use. It must be designed for maintenance personnel rather than for computer experts. Otherwise, it won't be used, and a system that is not used tends to prevent purchase of a better one.

Data-base power is sometimes only apparent once you are well into the program and have almost no option of changing. For this reason, you will probably find it worthwhile to talk to people who have had their systems up and running for some time.

- **Data-base reports:** The data-base must provide an anomaly report so that on any given day you have only to deal with machines that have problems. It must also provide history and trending.

A report on machines overdue for inspection is useful as a check on operating practice. Are spare machines actually being alternated? Survey reports which help evaluate the overall maintenance program can be used to justify the program to upper management. They can also help improve maintenance practice by making specific feedback possible and by helping identify chronic problem areas.

- **Software host:** Which computer runs the software? If you already have a computer, or have other applications in mind, this item could be quite important. If not, you would probably give it zero points.

- **Documentation:** Program instructions and general information are usually presented in a printed manual which should be complete and informative. In addition, information can be presented on the screen, for easier access by users. Some systems provide help with problem diagnosis.

Conclusion

Predictive maintenance programs that improve maintenance practice can be a reality in every plant. It is time to apply cost/benefit evaluation techniques, in order to make these programs as cost effective as possible. Only in this way can predictive maintenance make the best contribution to the overall profitability of your plant.

Résumé: De nos jours, l'entretien prévisionnel relève d'un concept généralement admis dans l'industrie des pâtes et papiers. Les usines qui songent àimplanter un tel programme doivent d'abord et avant tout s'assurer que la méthode choisie est économiquement souhaitable. Notre article met en relief plusieurs méthodes possibles et s'efforce de formuler une méthodologie qui permette d'évaluer les implications économiques de chacune d'elles.

Abstract: Predictive maintenance is a concept that is generally accepted in the pulp and paper industry today. For those mills considering the implementation of such a program, a key consideration should be whether the method chosen will be cost effective. This paper briefly identifies several alternatives, and attempts to provide a method for evaluating the economics involved.

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