

Justifying Computer-based Predictive Maintenance

Using Expert Intelligence to Increase Analyst Utilization

Introduction to PdM

This paper describes, in brief, the issues involved in justifying a computer-based predictive maintenance (PdM) program. A general formula for cost-benefit analysis is proposed, which can be tailored to your particular process. There are many factors involved in deciding how to put together a PdM program. Even if another program is already in place, it is often difficult to quantify the benefits of implementing a computer-based system such as Azima's WATCHMAN Services, which utilize ExpertALERT, Expert Automated Diagnostic Software. The intention is to clarify the extent to which ExpertALERT can have your process running more efficiently.

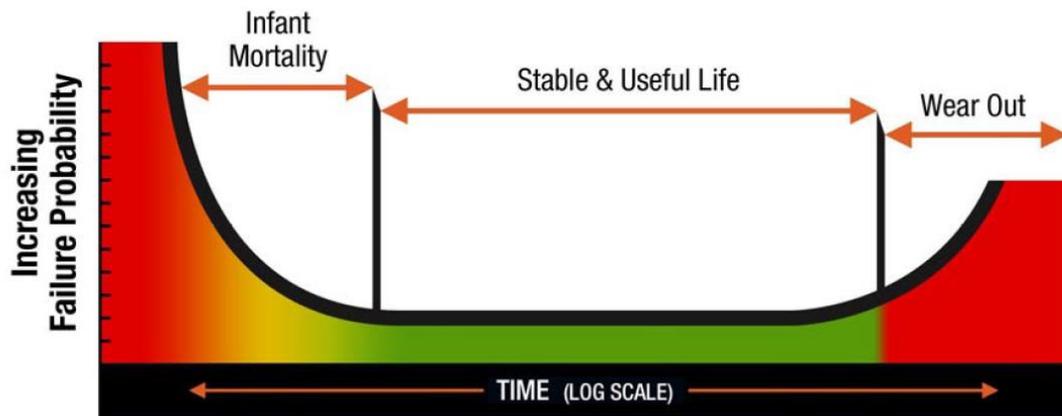
PREDICTIVE MAINTENANCE

The basic principle of predictive maintenance is to take such measurements that allow your organization to predict when plant machinery will break down. These measurements include machine vibration and plant operating data such as temperature, pressure and oil metal concentrations.

PREVENTATIVE MAINTENANCE

Preventative maintenance schedules regular machine/plant shutdowns, irrespective of whether repairs are required. There are many problems associated with this maintenance strategy including:

- Increased maintenance costs as parts are replaced when they are not necessarily required.
- Risk of infant mortality due, for example, to human error during dismantling work. The component life cycle chart shown here identifies that, by far, the greatest probability of assembly failure is at start-up.



BENEFITS OF PREDICTIVE MAINTENANCE

Predictive maintenance, on the other hand, determines when the machine REQUIRES repair. Plant machinery is therefore only repaired WHEN REQUIRED. The benefits of predictive maintenance can be separated into two main categories.

INCREASED SAFETY: PdM provides the reassurance of safe, continued plant operation. By reducing the likelihood of unexpected equipment breakdown, the safety of employees is improved. Although difficult to quantify, there is a definite economic benefit in improved employee and union relationships.

IMPROVED OPERATING EFFICIENCY: There are many areas in which a predictive maintenance program can increase the efficiency of your process. Please see chart below.

How an Effective Predictive Maintenance Strategy can Improve Plant Efficiency	
Reduction in Lost Production	<p>Predictive maintenance aims to identify problems in equipment so that necessary downtime can be scheduled. By identifying problems in their initial stages, the predictive maintenance system gives notice of impending failure, so downtime can be scheduled for the most convenient and inexpensive time.</p> <p>Predictive maintenance minimizes the probability of unexpected failures, which would result in lost production. This is always important, particularly so if your plant uses 'just in-time' manufacturing techniques, as the lost production and credibility to the customer may NEVER be regained.</p>
Reduced Cost of Maintenance	<p>As equipment is only repaired when needed (as opposed to routine disassembly), maintenance staff have more satisfying and worthwhile work and the costs of maintaining the machinery are reduced as resources (labor, equipment and parts) are only used when needed.</p>
Less Likelihood of Secondary Damage	<p>By identifying potential failures in advance, the severity of these failures can be substantially diminished by reducing or preventing secondary damage. For example, a failing bearing in a motor can be identified and replaced before the winding and shaft are also damaged.</p>
Reduced Inventory	<p>Predictive maintenance reduces inventory costs because, as substantial warning of impending failures is provided, parts can be ordered as required, rather than keeping a large backup inventory.</p>
Extending the Life of Plant Equipment	<p>Using a predictive maintenance program, machines are only dismantled when necessary, so the frequency of equipment disassembly is minimized, and thus the probability of 'infant mortality' is reduced.</p>
Improved Product Quality	<p>Predictive maintenance requires data to be taken from the plant. That process, coupled with the collection of additional plant performance data (performed by many predictive maintenance groups), means that the efficiency of plant equipment is scrutinized constantly. By increasing the efficiency of your process, the quality of your product will be improved. With an improved product, and a renewed confidence in product supply, customer relations will also be improved.</p>

DETERMINING THE BENEFITS / COSTS OF PREDICTIVE MAINTENANCE IN YOUR PLANT

BENEFITS	
Reduced Forced Outage Time	<p>Annual Benefits (\$ per unit per year), can be estimate as:</p> <div style="border: 1px solid black; padding: 10px; margin: 10px 0;"> <p style="text-align: center;">Benefit due to decrease in forced outage time</p> <p style="text-align: center;"> × </p> <p style="text-align: center;"> + </p> <p style="text-align: center;">Benefit due to some forced outage time becoming scheduled outage time</p> </div> <p>Benefit due to decrease in forced outage time is equal to: $c_f t_f f_1$</p> <p>Benefit due to some forced outage time becoming scheduled outage time is equal to: $c_s t_s + c_f t_f (1-f_1) - [c_s [t_s + f_2 (1 - f_1) t_f] + c_f [t_f (1 - f_1) (1 - f_2)]]$</p> <p>where:</p> <p>c_s = Cost of scheduled outage (\$ per unit hour) c_f = Cost of forced outage (\$ per unit hour) f_1 = Fraction of forced outage time which is eliminated - assume 0.2 (conservative) f_2 = Fraction of remaining outage time which becomes scheduled outage time - assume 0.2 (conservative) t_s = Current scheduled outage time (hours per unit per year) t_f = Current forced outage time (hours per unit per year)</p> <p>A conservative estimate for the probability of successful early detection is a minimum of 0.5</p>
Secondary Damage	<p>It is difficult to develop a general rule for the savings due to reduced secondary damage. An estimate of a factor of ten is suggested. That is, the repair bill will be ten times higher if a machine is allowed to fail, rather than repairing it before failure.</p>
Other Benefits	<p>The benefits of increased product quality, improved employee relationships due to increased safety and job satisfaction, reduced inventory and extended plant life can only be assessed in your plant.</p>
<p>Thus, the benefits of using ALERT to manage your predictive maintenance program can be readily estimated. ExpertALERT allows you to optimize on these savings.</p>	

COSTS											
Hardware	The equipment necessary will depend on your requirements, but should be in the range of \$20,000 to \$40,000, including instrumentation. Annual equipment cost in depreciation and interest on capital can be conservatively estimated of 30% of its capital cost. Maintenance cost can be estimated as 10%-15% of the capital cost.										
Software	The cost of the ALERT System ranges from \$8,000 - \$15,000 depending on the features required for your application. An additional benefit is that the cost of the ALERT System, as software, is completely tax deductible.										
Staff (Rough Estimates)	<p>Staffing requirements based on number of vibration test locations (points):</p> <table border="1" style="width: 100%; border-collapse: collapse;"> <thead> <tr> <th style="text-align: center;"># points measured & analyzed per month</th> <th style="text-align: center;">Staff required</th> </tr> </thead> <tbody> <tr> <td style="text-align: center;">0 – 50 points</td> <td style="text-align: center;">Readily done by maintenance engineer along with other work</td> </tr> <tr> <td style="text-align: center;">50 – 1500 points</td> <td style="text-align: center;">1 technician doing field work, sharing with 1 engineer</td> </tr> <tr> <td style="text-align: center;">1500 – 3000 points</td> <td style="text-align: center;">1 technician doing field work, 1 engineer to analyze, 1 to evaluate, depending on the degree of automated analysis equipment used.</td> </tr> <tr> <td style="text-align: center;">Over 3000 points</td> <td style="text-align: center;">More technicians for field measurements, again varying with automation, but keeping engineer staffing at 2.</td> </tr> </tbody> </table> <p>Thus, the more automation features available, the fewer people will be required to implement your predictive maintenance program. This highlights the need for ExpertALERT’s many automation features.</p>	# points measured & analyzed per month	Staff required	0 – 50 points	Readily done by maintenance engineer along with other work	50 – 1500 points	1 technician doing field work, sharing with 1 engineer	1500 – 3000 points	1 technician doing field work, 1 engineer to analyze, 1 to evaluate, depending on the degree of automated analysis equipment used.	Over 3000 points	More technicians for field measurements, again varying with automation, but keeping engineer staffing at 2.
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Analyst Utilization

Azima increases the analyst’s utilization through the use of automated technology. It is well understood that artificial intelligence and machine learning are not a substitute for the expert diagnostics of the human analyst, but with automation tools like ExpertALERT, the analyst becomes highly more efficient. Azima’s WATCHMAN programs allow for rapid deployment of new programs by leveraging the knowledge gained through automation, prioritizing the analysis requirements, and delivering consistent, reliable result to all key decision makers.

OUTLINE OF AZIMA PROGRAM

Connection

Azima programs are pre-configured to synchronize through the WATCHMAN Data Center. This connection allows for the seamless communication between data collection in the field, analysts and peer review, program contributors, and key decision makers.

Managing a master database in the WATCHMAN Data Center eliminates the capital expenses required for local servers as well as the IT infrastructure, security, and routine backups. It provides the ability for enterprise organizations to manage a centralized approach to their maintenance departments whilst delivering an understanding of risk to operation, readiness for production, understanding of compliance, and proactiveness to findings. All native to the Expert System.

Delivery

Azima are designed to be simple and intuitive requiring little training or understanding for the collection of high quality data which feeds into an intelligent automated diagnostic program for analysis. It is more advantageous to simplify the collection to put into the hands of technicians and operators, delivering the data to the analyst. Frequent turn-over of technical staff is no problem Azima programs.

Setup

Setup is accomplished in the ExpertALERT diagnostic software, which is included with your hosted program through a web application. A setup wizard will ask a series of questions to then create the machine, test locations, and vibration setups logical for complete, complex machinery analysis.

Azima Service Technician will schedule a walk through your plant, identify machines and establish ideal test parameters, as well as installing sensor mounting pads or mark locations for later installation. For enterprise organization, setup at subsequent plant can be rapidly deployed, leveraging all the knowledge and setup accomplished at the first site.

Synchronizing

Analysts can work at remote location and have outstanding communication with technicians and quality data for diagnostics. A centralized program with local analysts can greatly benefit by having the highest utilization rate of any other program. New machine setups, test operating conditions, and instructions are synchronized to the field through the WATCHMAN Sync Utility. Technicians in the field receive their survey of machines, complete with history, photos, and instructions and are ready to collect data. Once complete, the data is synchronized back to the cloud for analysis.

Analysts can trigger additional or complex text, relaying questions or instructions to the field. Data collectors can easily perform pre-defined advanced tests such as natural frequency measurements, phase and cross-channel and many others as well as add field notes, photo or audio notes to contribute to the data for analysis.

Teaching the Expert Intelligence

To build an automated diagnostic system, Azima uses Expert Intelligence, which use the health of real-machines and the experienced know-how of seasoned analysts. Azima's machine intelligence leverages the knowledge of healthy machines to perform comparisons and identify any deviations of normal. Every vibration peak that exceeds the defined baseline criteria is passed through a complex diagnostic rulebase, comprised of more than 6000 diagnostic rules and 1200 unique fault conditions.

The ExpertALERT software starts with its inherent knowledge built from millions of machine tests to provide a starting point for most analysts. Its machine grouping templates allow users to leverage multiple assets to rapidly build the expert baseline for comparison. A sophisticated program is intuitive and rapidly deployed to quickly build on your return on investment.

Collaboration

Vibration is not an exact science and for expensive, complex machines this is even more so. Relying on artificial, machine learning may be fine for simple fans, motors, and small pumps. But when your production or operation relies on the uptime of a machine component, you must have the integrity of software algorithms and rulebases coupled with the experienced know-how of seasoned professionals.

The automated expert system performs an advanced, first-pass machine diagnostic with a high degree of accuracy. These results establish a priority list for analysts to perform secondary analysis and confirm findings with more detailed understanding and plant actions. The benefit of this program allows analyst to be highly utilized, focusing their attention only on the assets that need further review.

Reporting

Maintenance programs are only valuable if results are delivered to all decision makers. Once data is reviewed, results are delivered through the WATCHMAN Reliability Portal. Additional emails and other alerts can be automated to deliver the right reports to the right people, at the severity level they desire.

Native to the Azima model is the ability to have additional contributors to the understanding of risk. In addition to multiple technologies, the WATCHMAN Portal also can understand financial impact of faults, identify common faults or worst machinery offenders, proactive response from fault to repair, and root cause finding for feedback to the analysts. Links to SCADA, Historian, CMMS systems are also possible.

Program Review

Azima's program managers ensure plant managers and executives understand spend and gain. Provided as routine assessments and in-depth annual comprehensive program review, Azima provides the executive sponsorship the information they need to maintain a successful program.

Operate at capacity™

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