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The Art of the Predictive Maintenance Report

by Howard W. Penrose, PhD, CMRP

In 1878, Frederick Taylor began his work in developing a process that he published in 1911, known as Scientific Management. This work, along with a century's worth of production work that started with John Hall of Harpers Ferry Armory in 1824, prompted Henry Ford's Highland Park manufacturing line in 1913. Through this period it was assumed that workers only worked for financial gain and would produce at whatever level in whatever position, as long as their income needs were met. In effect, management philosophy was to achieve machine-like standards of speed and reliability with money as the incentive. Also, during this time, 20% of the workforce was comprised of children aged 10 through 15 with a life expectancy of 46.3 years for men and 48.3 years for women. Additionally, with a large influx of immigrants at the time, unemployment remained at about 15%. If working conditions were dirty, dangerous or otherwise unsatisfactory, the worker did not have a choice as others were always waiting for their position. This fear of unemployment - combined with the fact that it was a time when there was no safety net like unemployment benefits, social security, welfare or OSHA - re-inforced the thought that money was the only incentive.

A series of studies performed by Western Electric in Cicero, Illinois, known as the Hawthorne Studies (1923 to 1933) identified how work groups provided mutual support and resistance concerning management to unreasonably increased output. These studies were implemented as a straightforward attempt to determine the relationship between the work environment and productivity. The studies identified that the work environment is not one of formal organization but is, instead, more of a social system. They were also able to determine that early managers were aware that most workers had a tendency to limit their personal efforts in order to maintain their membership in this informal social structure. With the exception of the individual 'rate busters,' the desire for communication, companionship and associations on the job was determined to be more important than the little bit of extra money that might be earned. These studies initiated the concept of Human Resources, which is meant to support and determine the requirements of this structure and how to increase morale amongst employees in order to increase production. Basically, it became important to determine the 'What's In It For Me' (WIIFM) of the employees as individuals and as a group.

Modern Reliability and Maintenance (R&M) training has been focusing on management with the same narrow view. Reports, budget requests, recommendations and other tasks are usually justified with such numbers as cost avoidance and cost savings. In reality, as was found in the Maintenance and Management Communication Study performed by SUCCESS by DESIGN in the Spring of 2006, these numbers have very little impact in the R&M decision-making process. Instead, it takes an understanding of the WIIFM of individual managers or groups of managers.

Business WIIFM

While it is all well and good that R&M personnel should expect management to understand the importance of the maintenance function, it is not always realistic. Most managers and executives have had little to no exposure to the realm of R&M, other than home and auto maintenance. Formal management training often leaves out the importance of the maintenance and reliability function with the only understanding of it as an expense column in the budget. Instead, the manager is focused outside the company, towards stockholders in publicly traded companies and the owners and customer pressures in all companies.

Figure 1 - Unplanned Failures Can Be Avoided Through Proper Reporting

The challenge is to determine the best ways to get management action on R&M related issues. It is important to understand that the financial portion of the recommendation is of relatively little importance, instead, the quality of presentation, how it is presented and the ability to present choices are more important. It is equally important to understand or recognize the existing goals of maintenance. For instance, if the company is focused on 'Lean Business,' or 'Lean Maintenance,' how will your recommendation help management accomplish this focus while minimizing the risks involved. In effect, you have to take the step beyond just presenting a finding or recommendation, but you also have to identify the WIIFM factor(s) and address it (or them). Will your recommendation help achieve the objectives that the decision maker has set for him/her-self?

Example

Management Perspective

Operations has a goal to produce 1,000 units of widgets in two shifts of five days (80 hours), which is a rate of 12.5 units per hour. The production line can produce 15 units per hour which equates to 1,200 widget capacity per 80 hour week. The cost for the production line is $650 per widget at full capacity and $800 per widget at 1,000 unit capacity. Both instances maintain a $10,000 per hour cost for the production line which is operating at 83% capacity. In the last fiscal year the sales cost for the factory has been $1,000 per widget, which results in a profit margin of $200 per widget, or 20%. Overtime will obviously increase the throughput costs. With the present environment, it is expected that labor, healthcare, materials and energy costs will increase the cost per hour of production to $11,000 per hour while new overseas competition is reducing the price to $950 per widget. This has resulted in a new fiscal year projection of $880 per widget and a potential profit margin of $70 per widget or 7.3%. The fiscal year report has caused shares in the company to drop significantly, reducing the ability to generate more capital investment. In order to counter this problem, management has tasked the sales force to increase sales in order to bring the production line to full capacity and has implemented a lean process in order to control costs while negotiating with labor through human relations to absorb some of the associated costs, such as changes to the health care benefit. If production can be increased up to 1,100 units per week (92% capacity) while maintaining costs at the $11,000 per hour level, the cost per unit will return to $800 per widget, resulting in a profit margin of 15.8%. If production cost can also be decreased to $10,500 per hour, then the cost per unit will drop to $764, resulting in a 19.6% profit margin. In this case, management has the task to reduce costs, prevent overtime and increase throughput by 9%, with the assumption that availability will be maintained at 80 hours per week. The operations manager has final say on maintenance access to the production line and knows that he has only 7 hours per week to work with for unexpected downtime and his incentive is that if he can maintain production at 1,100 units per week he will receive a bonus of 10% of his/her annual salary. If he/she falls below 1,100 widgets per week consistently either production will be moved to another location or he/she will be replaced.

R&M Perspective

A full infrared, vibration analysis and ultrasonics program has been implemented as part of the management objective to maintain equipment availability. Management has reviewed enough material and vendor presentations to know that such a program has had great results in other companies. During the first survey of equipment three findings are produced including: Air leaks to critical parts of the production line that have a combined impact of $5,000 per week ($250,000 per year) and will take 8 hours to repair; A noisy bearing on the main drive motor for the production line which will require six hours to repair ($66,000 cost avoidance if it fails during production); and, a hot connection on the B-phase secondary connection of the production transformer which would take five hours to repair but a total production downtime of ten hours if performed during the normal 80 hour work week. Standard greasing and other preventive maintenance tasks require four hours planned downtime per week at the same time the machinery is prepared for the week's work on the Monday morning startup.

Now, what happens, in the above example, when findings are reported to the operations

Figure 2 - Generator Removed From Mission-Critical Application Three Months After Fault Detected As Recommended

manager as follows:

- Repair Air Leaks, 8 hours, $250,000 per year
- Repair bearing, 6 hours, $66,000 cost avoidance
- Repair connection on transformer, 10 hours, $110,000

What appears to the operations manager is that the production line is still in operation and those components have not failed. If there is enough manpower, the work can be done during the Monday startup meaning that there are only 70 hours for production which leaves a capacity for 1,050 widgets with an associated cost of $800 and a resulting loss of 3.8% profit ($36/widget).

How do you think the operations manager would consider the maintenance recommendations given the above scenario? How could you adjust your recommendation presentation in such a way to convince management to make the improvements? What happens as the recommendations and findings begin to increase? What happens if you have limited maintenance manpower to perform the corrections? What is the WIIFM for the decision maker? For management? How can your program be used to the advantage of the goals for the company?

Once the WIIFM for the managers and corporation are determined, recommendations and presentations can be developed in such a way as to meet the requirements of management. So, what can be done with the above situation?

First, the objectives of the company must be identified. In this case, the objective is to return profitability back to the 20% realized in the past. Management has identified that an increase in throughput, resulting from sales, and a decrease in operating costs through lean management/maintenance and labor cost improvements, can meet this objective. As part of this, the application of planned maintenance was brought into play due to internal/external recommendations and publicity with little understanding of the needs of the program. Sales needs to meet the commitment of 1,100 units and the operations manager needs to maintain levels for his/her annual bonus.

First, you must consider the risks associated with not performing maintenance on each of the items identified. Which are safety/regulatory? Which are Production-Related? Which are related to expensive equipment? Which can be run to failure? Can they be prioritized? Can overtime be authorized and have a cost benefit?

Considerations for Recommendations

1. Make recommendations for which should be performed on overtime;
2. How important is each recommendation

for the corporate goal;
3. How can the recommendations be presented in such a way to show impact on profitability; and,
4. How can the recommendations be presented in such a way to ensure the operations manager meets his goal.

As time moves forward, additional issues will arise that will have to be addressed. This needs to be considered when developing the recommendations and incomplete recommendations will need to be assessed each time new findings are brought to light.

For instance, if the Saturday rate for overtime is $200 per hour for multiple maintenance personnel who can correct the issues, then a ten hour overtime shift on Saturday to take care of maintenance actions would cost $2,000 per week. Corrections to the compressed air system will yield $5,000 per week, which results in an immediate return on investment. In the meantime, the overtime recommendation results in the maintenance of the three hour buffer that existed in availability. The cost avoidance for all repairs can be measured as $426,000 per year, which seems impressive. However, given the company's objectives, the concept of maintaining production capacity and reducing production costs of each widget by $2.73 per widget in compressed air costs alone, will have more of an impact. This benefit can be directly measured in a relatively short time as an improvement. Therefore, that should be the focus of the report, then the soft findings of $176,000 and the benefit of avoiding lost production and meeting capacity needs should be presented in such a way to add support to the report.

Development of such a report, and its presentation, should be considered important along with the ability to prioritize recommendations. A common issue that causes a communication challenge with maintenance reports is that all of the problems are lumped into one. However, if recommendations are ordered based upon severity and impact on the WIIFM, then at least a few of them should be followed once it is presented.

Repair priority should be given in the following order:

1. Safety and Regulatory Impact
2. Production Impact and Severity of the Impact
3. Expensive Equipment to Repair or Replace

Each of these should be weighted by the severity of the defect detected. For instance, the connection on the transformer would be considered a potential safety and production impact with a relatively high risk of failure, so would be rated as a first priority. The drive motor bearing would have an impact on production with a medium risk of failure, so would be the second priority; and, the compressed air system may impact production, has a low risk of failure but has a high associated expense, so would be the last priority.

By combining a report, and presenting it, in such a way that you are identifying an impending failure, making thoughtful recommendations (ie: out of the box) that relate to the WIIFM of the company and decision-maker and prioritizing the recommendations, it is more likely that those recommendations will be followed.

Areas to Focus On

As the term 'cost avoidance' represents 'imaginary money,' it does not fit into any budget column. Playing with magic numbers in your recommendations will not normally obtain the results you want. Instead, the areas that management may consider could include the following, and additional, issues:

- Profitability
- Throughput
- On-time Delivery
- Just-In-Time Capability
- Bottleneck Reduction
- Improved Workforce Effectiveness
- Reduced Overtime
- Reduced Risk

It is also important to note that people are visual. A picture really is worth a thousand words. The more graphic your presentation the better. In addition, you will want to focus on the part of the graphic that emphasizes what you are trying to convey. For instance, if you are showing an FFT of a bearing problem, if you show the whole FFT, the peaks may be relatively small compared to the lower frequency (or other) peaks (Fig Figure 3). The result is a visual reduction in the severity of the problem. Therefore, focus in on just the peaks that are of concern and adjust the scale so that they seem large on the image that you put into the report (Figure 4). We often forget, management does not understand the technology that we are using. Remember, they are probably thinking, "The

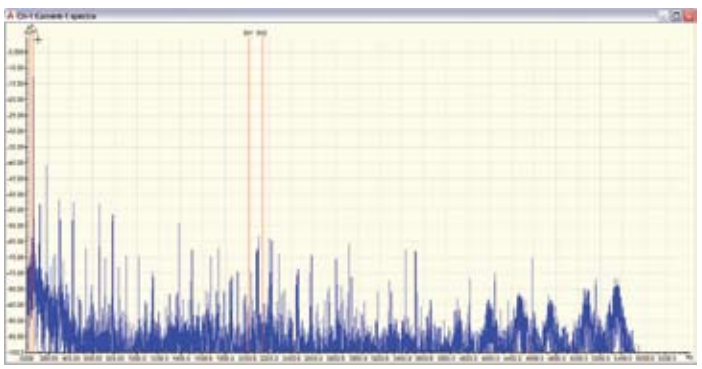

Figure 3 - A Full Spectra Can Be Confusing

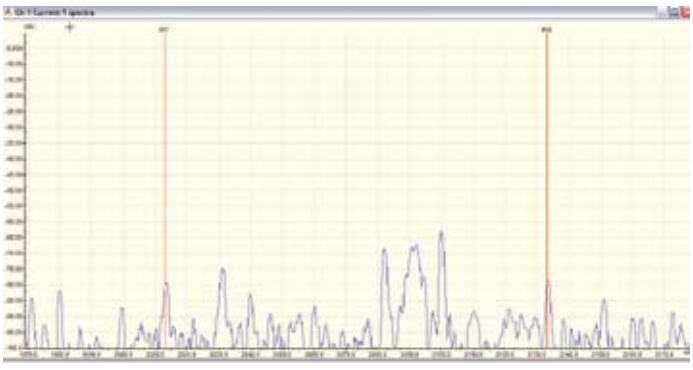

Figure 4 - A Closer View Can Remove Confusion While Conveying the Message

equipment is still running, so why should I be that concerned."

Outline of the Report

Most Condition Based Maintenance findings reports will have the following components:

1. List of what was in the route;
2. Statements of what was detected such as 'high temperature connection' and a value or high vibration and a value;
3. Graphics supporting statements; and,
4. Sometimes the cost avoidance.

A report that will have an impact will have the following components:

1. List of findings with priorities. You can still include the list of what was in the route, but place the findings at the top of the list in order of priority;
2. A description of what was detected and what it means;
3. Supporting graphics with emphasis on the problem;
4. Risk of impact on business if not addressed and a time limit. For instance: "There is a 50:50 chance that the windings will fail within two weeks and an 85% chance that they will fail within the next four weeks. When this motor fails, it will reduce production capacity by 20% on this line." Use definitive statements! You can add such things as throughput, on time delivery, etc.;
5. State the actions that need to be taken! For instance: "During shutdown next week, remove the motor and replace it with the spare. Send the motor in to the rewind shop for repair."; and,
6. Follow up with a reminder card or report (tickler) a few days after submitting your report.

Figure 5 shows an example of an effective report. It is important to remember that you usually will have only one chance to get the decision maker's attention. They will pick up the report, look at it, act and then put it down, not to pick it up again. So, SELL your recommendations!

Conclusion

In order to develop a successful condition-based maintenance report, modern R&M professionals will have to understand the WIIFM of the decision makers within their organization. In order to do this, the professional will have to have a deeper understanding of the business impact of the machines that they are responsible for. The basic design of the reports should de-emphasize such imaginary numbers as cost avoidance and, instead, focus on the impact of those areas that are most important to the organization and associated managers.

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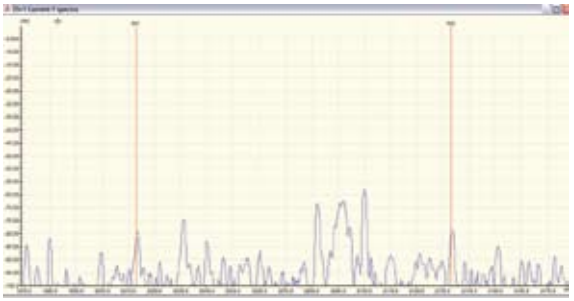
Name	#1 Fan Motor on Production Machine	Severity	1	Priority	1

Description	The #1 Fan Motor on the Production Machine has loose coils in the motor windings. This problem has led to failure of the electric motor and loss of 20% of the production machine operation, resulting in late product deliveries in the past. Additionally, contaminants are blocking the cooling system of the electric motor accelerating the failure. There is a 74% chance that the machine will fail in the next five weeks resulting in a 20% loss of production and late deliveries.



Coil Signature Identifying Loose Coils

Blocked Cooling Ports

Corrective Action	The motor needs to be removed during the planned outage in three weeks, or sooner, for rewind and a replacement motor is available to be installed. Total time to remove and install the spare, align and commission the motor is 14 hours. The condition of the other fan motors has identified that cooling port contamination is an issue and a maintenance procedure on cleaning the cooling ports needs to be developed and scheduled immediately. Repair of this motor and return to spare stocks normally takes 6 weeks in the local motor repair shop.
Date	July 27, 2006
Follow-Up	

Figure 5 - Sample of a Successful Report Format

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