PREDICTIVE MAINTENANCE TOOLS

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ABSTRACT
Predictive maintenance is a philosophy or attitude that, simply stated, uses the actual operating condition of plant equipment and systems to optimize total plant operation. In this paper are presented some aspects concerning tools used by Predictive Maintenance Management in an attempt to detect incipient or developing problems and to prevent catastrophic failure.

KEYWORDS: Predictive maintenance. Operating condition, Maintenance Management

1. INTRODUCTION
The main objective of the Integrity Management is maintaining the delivery stability by optimizing the use rate of the resources specific to the operation, inspection, and repair of the production systems.

Working Systems Security (WSS), comprising of the four specific components – security, availability, reliability and maintenance – represents a basic component of the system transient stages.

It may be emphasized (figure 1) that the Maintenance action role concerning the creeps warning and the evaluation risk, activity known as Integrity Management that supposes to coordinate the following functions:

- risk identification
- risk analysis concerning the performance impact
- costs
- activity quality management
- system risk exposure degree
- risk priorities ascertainment related to the exposure degree
- potential effect and the problems associated to the risk
- Condition Monitoring Management concerning the risk factors and the adoption of the suitable measures. /2, 5, 6, 7/

2. DEFINITIONS
Maintenance and repair of machinery in a petrochemical process plant can be defined as simply “defending machinery equipment against deterioration”.

There are several strategies used by maintenance when fighting failure, as it follows:

- No Maintenance and Run-to-Failure Management
- Breakdown or Demand Based (Corrective Maintenance)
- “Bad Actor” or Weak Spot Management – see the “Bottleneck Effect”
• Preventive Maintenance
• Predictive and Condition Monitoring
• Combinations of the above strategies

Figure 1: The WSS concept.

Is very important to mention that there is no pure strategies applied such as; all maintenance activities are a result of different strategies combination. This mainly depends on several variables such as the Maintenance Department Manager expertise, the business plan and its extent, Company’s financial potential, technical culture of the country where the Company is doing business, etc. /9, 10/

Machinery maintenance cannot be looked at in isolation; it will have to be governed by equipment failure experience, by effectiveness in failure analysis and troubleshooting, and by built-in reliability.

The No Maintenance concept was “the first form of maintenance”, and it is based on the old saying “if ain’t broke, don’t fixed it.” The only intervention from the management takes place only if an equipment actually fails, and then everything comes down to Corrective Maintenance. The logic of Run-to-Failure Management is simple and straightforward: “when a machine breaks down, fix it.” A plant using Run-To-Failure Management does not spend any money on maintenance until a machine or system fails to operate. This is a reactive management technique that waits for machine or equipment failure before any maintenance action is taken.

The net result of the Run-to-Failure Management is easy to anticipate: paying premiums for expedited delivery, therefore substantially increasing the costs of repair parts and downtime required to correct machine failures. Analysis of maintenance costs indicates that a repair performed in the reactive or run-to-failure mode will average about three times higher than the same repair made within a scheduled or preventive mode.

Corrective Maintenance is a straightforward strategy; it can be considered as a “necessary evil”. The equipment is governed by physical laws, and does not matter how over engineered is
sometimes it simply brakes down without warning, or with just a little time before it happens. Then, there is nothing else to do, but fixed it as it requires. The *Corrective Maintenance* represents the assembly of necessary activities after the component failed or after the degradation of its function in a tempestuous way (location, defect diagnosis, assurance of human resources and necessary materials, re-putting into operation, tests, handing in the installation to the user). The costs related to the *Corrective Maintenance* involving parts and labor costs, including skilled labor provided by vendors.

**The “Bottleneck Effect”**. A machine totally depending on a single component, such as a bearing or gearbox, failure of which would create a prolonged, unscheduled stoppage affecting large areas of the plant is called bottleneck equipment.

*Preventive Maintenance* naturally evolved from these two concepts as an effort to prevent equipment failure. As a rule of the thumb, all preventive maintenance management programs are time-driven; therefore maintenance tasks are based on elapsed time or hours of operation. The *Preventive Maintenance* is based on the in real time monitoring of significant parameters for the degradation of component and planning the interventions.

The **Mean-Time-To-Failure (MTTF)** or bathtub curve (figure 2) indicates that a new machine has a high probability of failure because of installation problems during the first few weeks of operation. After this initial period, the probability of failure is relatively low for an extended period. After this normal machine life period, the probability of failure increases sharply with elapsed time. In preventive maintenance management, machine repairs or rebuilds are scheduled based on the MTTF statistic.

![Figure 2: Typical bathtub curve.](image)

3. **PREVENTIVE MAINTENANCE**

The actual implementation of *Preventive Maintenance* varies greatly. Some programs are extremely limited and consist of only lubrication and minor adjustments. Comprehensive preven-
Preventive maintenance programs schedule repairs, lubrication, adjustments, and machine rebuilds for all critical plant machinery. All preventive maintenance management programs assume that machines will degrade within a time frame typical of their particular classification. Such program is MAXIMO, which is Preventive Maintenance orientated; below it is shown for reference the main screen from MAXIMO, with all eight modules.

The Preventive Maintenance strategy is classic, revealing a more careful approach when dealing with equipment than the Corrective Maintenance, by going a step further than simple monitoring and intervening when the machine is breaking down or needs some sort of repair.

![MAXIMO Options Main Screen – Preventive Maintenance Module.](image)

Figure 3: MAXIMO Options Main Screen – Preventive Maintenance Module.

Maintenance should be managed like a business; therefore the necessity of understanding the economics of an effective business enterprise, particularly that of the system in place, whether it has a preventive, corrective or predictive approach to maintenance. Preventive Maintenance is an investment. Like anything in which we invest money and resources, we expect to receive benefits from preventive maintenance that are greater than Company’s investment. Making preventive investment trade-offs requires consideration of the time-value of money.

4. PREDICTIVE MAINTENANCE

Predictive maintenance is a philosophy or attitude that, simply stated, uses the actual operating condition of plant equipment and systems to optimise total plant operation. There are several tools used by Predictive Maintenance Management in an attempt to detect incipient or developing problems and to prevent catastrophic failure, such as:

- monitoring the vibration of rotating machinery
- monitoring the infrared image of electrical switchgear, motors, and other electrical equipment
• monitoring thermal imaging (thermography)
• lubricating oil analysis (tribology)
• process efficiency (process parameter monitoring)
• other non-destructive testing techniques
• visual inspection.

Figure 4: The relationship between cost and amount of Preventive Maintenance.

SYSTEM 1 from Bently-Nevada is a Predictive Maintenance based program, and the main features are reminded below:

• The System 1 software relies on the accurate and timely handling and retrieval of data from machinery to manage, store, recall, compare, and display raw data and information on demand.
• System 1 is a powerful troubleshooting tool;
• System 1 is a dynamic product that is constantly adding interfaces and communications to other Bently-Nevada industry products; the application comes very handy since pre-defined templates are readily available for different machine trains, machines, and point types, but the Customer can also create its own custom templates.
• The System 1 CMMS Bridges supplies the 'Bridge' between the System 1 platform and the CMMS. A Computerized Maintenance Management System (CMMS) provides automated plant maintenance processes that enable the increase of plant efficiency and the reduction of maintenance costs. In general, CMMS includes functions, such as work order generation, equipment tracking, equipment history, labor scheduling, spare parts inventories, and other features. /3, 4/
Figure 5: The structure of System 1.

Figure 6: System 1 screenshot.
Figure 7: Typical cost of a Preventive Maintenance strategy.

Figure 8: Typical cost of Condition Monitoring installation and operation.

The financial justification will become fairly precise if the facilities to collect and analyse performance data accurately and consistently are readily available; the engineering and manufacturing departments are integrated under a precise standard value-costing system; and the maintenance engineering function is given the status of a profit centre. In conclusion, it is possible
to say that the financial justification for installation of any item of Condition Monitoring equipment should be based on a firm business plan, where investment cost is offset by quantified financial benefits. As a consideration, the cost of any current maintenance position is vague and unpredictable. This is true even if enough data are available to estimate past expenditure and allocate this precisely to a particular plant item.

5. CONCLUSIONS

Reliability engineering and predictive maintenance have two major objectives: preventing catastrophic failures of critical plant production systems and avoiding deviations from acceptable performance levels that result in personal injury, environmental impact, capacity loss, or poor product quality. Unfortunately, these events will occur no matter how effective the reliability program. Therefore, a viable program also must include a process for fully understanding and correcting the root causes that lead to events having an impact on plant performance. The goal is to accurately define deviations from acceptable performance levels, isolate the root causes of equipment failures, and develop cost-effective corrective actions that prevent recurrence. However, perhaps the most difficult part of troubleshooting analysis is separating facts from fiction. /14/

Coping with practical maintenance issues have been significantly expanded and analyzed during years of experience; lately, the Maintenance programs supports the view that RCM (Reliability Centered Maintenance) is perhaps the best way to develop a maintenance improvement program. Predictive Maintenance as strategy plays the pivotal role in this scenario.

To improve an efficient Predictive Maintenance program supposes:
- establishing the degradation status of components in installation
- creating the data base specific to the predictive repair program
- optimizing the exploitation technological process
- recording the functional parameters of the installation, in normal regime and in transitory regimes
- establishing the informational circuit to assure the normal conditions to develop the predictive maintenance program

Maintenance properly carried on, will not only smooth up the operations, but will also bring a significant contribution to Company’s revenue, by cutting down costs and minimizing the impact of breakdowns and shutdowns on the production. It has been emphasized that the type of maintenance in use is as important as the maintenance itself. New technologies readily available nowadays have brought the control of the plant at our fingertips; online condition monitoring and data recording systems are an important add-on to the maintenance and troubleshooting activities. However, the most complex and modern management approach to maintenance is Predictive Maintenance, and this is the major topic of this exercise. /15/

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