The Role of Information Technology in Plant Reliability

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Information technologies (IT), in the context of this paper, include all computer systems and networks, plant automation systems such as distributed control systems and programmable logic controllers, design drawing databases, procedures databases, and diagnostic monitoring systems. The role of information technology is critical for maintenance optimization because it relies on the ability of the plant personnel to bring all data together in a coherent fashion for optimum analysis and decision-making.

Advanced IT provides enhanced communication among plant workers and outside experts and allows the sharing of information, knowledge, experience and wisdom. Advanced communication supports the team approach to problem solving even though large distances may separate team members.

This paper examines how IT impacts maintenance decision- making to strike a balance between cost and reliability. The key to understanding where reliability can be implemented requires an knowledge of the current situation and identifying practical actions necessary for improvement. Another key aspect of maintenance optimization is uniformity in decision-making; necessary so that a single, optimum response is triggered for a particular system or set of symptoms. This uniformity can only occur when information technologies are used efficiently for condition monitoring, reliability analysis, and prognostic evaluation of data.

Companies investing in advanced information systems look at existing work practices to understand how these activities will be impacted by IT utilization. While some changes are obvious, others are more subtle. With increased computer capability and information availability, new, more efficient ways of grouping data for analysis become important. Examination of all data may not be practical, or even necessary in every situation. Data storage and retrieval will become major issues, requiring special resources. Data access is a key consideration in many organizations. In order to decide how data will be stored and accessed, we need to examine how the data will be used and establish a hierarchy for the various condition analysis parameters. Advanced data warehousing techniques and integration systems need to be developed based on how the information is used.

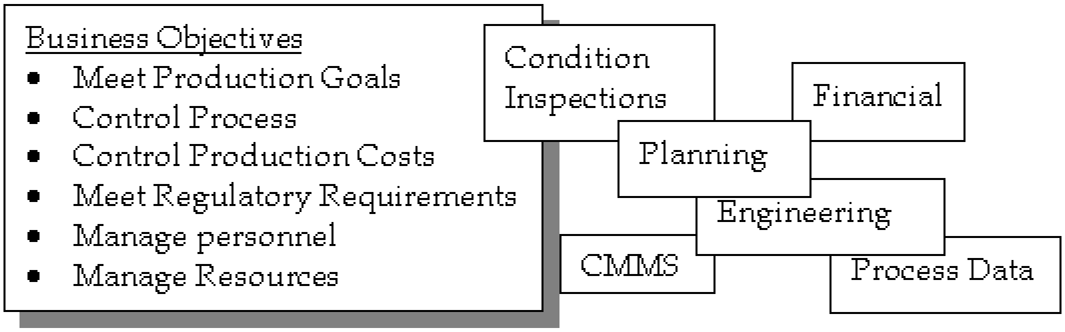
Emphasis needs to be put on results, not activities. The automation of analysis with expert rule-based systems and neural networks can prescreen data prior to decision-making. Software programs, called "intelligent agents," sort through the huge volume of data so workers will not get bogged down. This paper also looks at the future and examines how the industrial workplace will change in this era of advanced communication and IT usage.

Introduction

Industrial plants are under more pressure than ever to produce reliably and predictably. Predictability is an indicator of management's ability to control production, and one reason to improve the reliability of production equipment and focus on early prediction of equipment failure. Unpredictability affects company performance because equipment failures directly affect production costs. Ultimately, the ability to control these costs relies upon accurate data that is properly interpreted and acted upon.

Linking business objectives to information systems helps plants understand and improve equipment reliability. The link is not defined by how much data is collected and stored, but in how effectively employees use the data to make reliability decisions. Many companies have found that the barrier is in accessing the data that has been collected, and combining it with data collected from other parts of the organization.

Figure 1 - Business objectives

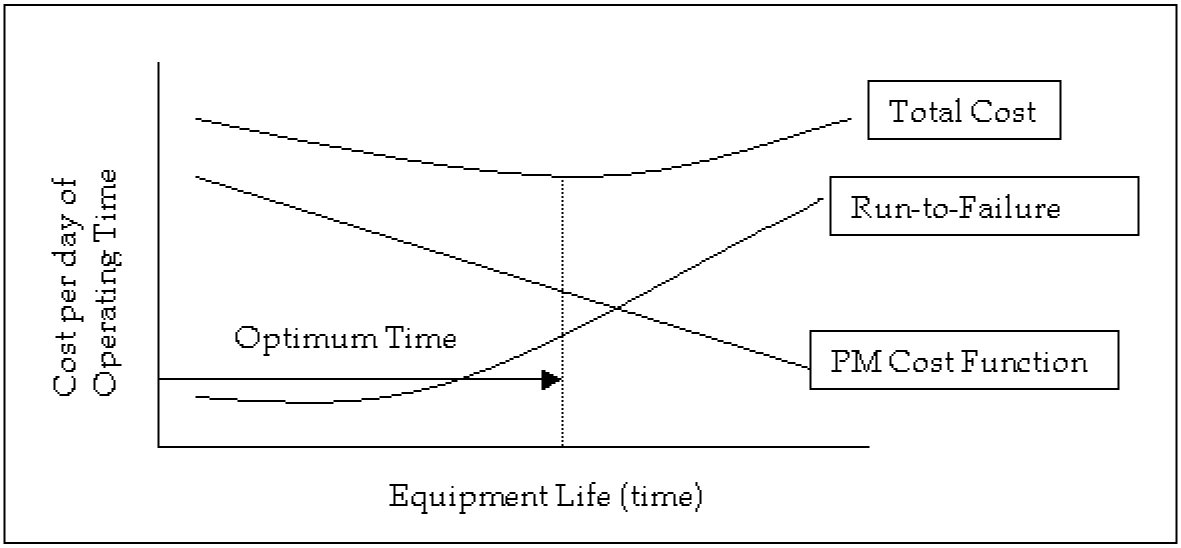


Improvements in worker productivity by improved information technology are centered on change. In a plant environment, new information technologies not only change the way people work (activities), but how they interact (communicate), and how they make decisions. Unfortunately, change does not come easily. New technology systems need to enable workers to become more efficient by streamlining current business practices. If the new technology system does not accomplish this, then it will not lead to an improvement and will ultimately go unused.

Improved information technology systems lead the way to maximum productivity and maximum equipment uptime. Productivity improvements come from making tasks simpler, with a higher level of automation. Uptime improvements come from a deeper understanding of the causes and impact of unreliability. Secondary benefits include improved working environment, better communication and higher worker effectiveness. Many companies today are trying to establish a team environment for more effective information sharing and problem solving. This "team" approach enhances personnel skills through increased technology usage. Individuals tend to shy away from advanced technologies and automation because of either lack of training or lack of understanding of results. Team members are often separated by distance or time, frequently working in different locations or are on different shifts. The team approach requires the use of advanced communication technologies integrated with information systems for remote problem solving.

The applications of advanced communication methods and systems cause both changes in the way workers solve problems and conduct business. Experts no longer need to be on the site to add valuable input to the resolution of problems, which allows teams of experts to work together on problems to find the best solutions. Studies have shown repeatedly that teams make the best decisions.

Figure 2 - Maintenance optimization cost function



Maintenance Optimization

Maintenance optimization is an evaluation process that examines current functions, tasks, and activities to achieve the proper investment balance between reactive, preventive, predictive, and proactive maintenance activities. This can only be achieved through a fundamental understanding of the predominant failure modes of the equipment. By understanding the failure mode and looking at the probability of failure for a particular sub-component, the best judgement can be made regarding the appropriate long-term and short-term corrective actions.

In some cases, a preventive maintenance approach is inappropriate for equipment where the design life of the parts involved in the failure mode is less than the expected minimum maintenance cycle. In this case, a change in the design specifications is often necessary to achieve reliability improvements. Other cases that show a PM strategy as inappropriate include failures caused by inadequate or improper repair procedures. These failures show up as "infant mortality" or "early wear-out" problems. Diagnostic technologies (vibration, thermography, or performance tests) can play a role in identifying symptoms associated with problems before a machine is put back into service. However, unless this information is readily available to the workers performing repairs, these kinds of problems are rarely identified before re-commissioning.

By maximizing individual worker effectiveness, the value of each worker's contribution to the overall plant reliability is increased. This improves the work environment because each worker has a greater share of the success of the company. The term "optimization" implies a single point or goal of maximum plant production capacity at minimum cost. The goal of maintenance optimization would be to achieve the highest level of reliability for the least investment in parts and labor. By leveraging against the investment in information technology, management begins to realize these benefits.

Maintenance optimization helps to strike a balance between cost and reliability. Looking at cost per day of a "run to failure" strategy, shows low costs early in the life of the equipment but increasing costs as reliability decreases. By overlaying the costs of an associated PM to address the failure mode, initial costs are high, but costs per unit time decrease as time progresses. This optimization occurs at a point where the total cost function (sum of the two cost functions) is at a minimum. The time at which the minimum occurs is the optimum time to perform maintenance.

Role of Information Technology

Current technology allows the integration of information into a single system for decision-making. Advanced IT makes maintenance optimization possible by making the data available for determining the proper time to perform maintenance. Today's computer technology allows data from multiple sources to be viewed from a single MS-Windows application, such as Internet Explorer. This gives workers the capability to apply decision-making criteria uniformly based on a common data set and a standard set of procedures and prioritization system. Maintenance optimization requires that a single, optimum response be generated for a given set of circumstances, independent of personnel involved.

Variations in decision-making are caused by individuals' aversion to risk. Risk is defined here as the probability of failure as perceived by the person responsible for analyzing and authorizing corrective actions. The degree of risk that a person accepts varies from person- to-person based upon:

- Previous experience with this type of problem
- The amount of information available regarding the equipment in distress
- The confidence in the accuracy of each data source.

In order to achieve an optimum response to a given set of circumstances, workers must have previously defined these circumstances, along with the appropriate response. In addition, the details of the response must be readily accessible to the workers once the conditions have been met. Diagnostic information, such as vibration analysis, helps to identify the risk in a trouble situation. Vibration is combined with reliability data to help workers evaluate risk and make the best decision. However, vibration alone does not provide a complete picture.

Existing Operation and Maintenance Practices

Existing practices are often ineffective at identifying and correcting equipment reliability problems. The reason for this goes back to the lack of emphasis on data collection. Existing information systems do not provide sufficient analysis capability, or even provide sufficient access to data necessary to understand the equipment reliability. In order to begin to take reliability issues into account when making maintenance decisions, the daily workflow needs to be redesigned. Operators, maintenance supervisors or engineers should consult reliability information before and after repairs are conducted.

An optimized approach for maintenance includes the review of diagnostic infor-nation once repairs are complete. In most cases this is not done because of a lack of emphasis on maintenance issues. Among the reasons for this are:

- Lack of tools - Equipment that does not have permanently installed instrumentation needs to have manual data collection. This presents a barrier to regular data collection because dedicated workers are often needed to install temporary instrumentation to collect the data. Operators are reluctant to call upon these resources unless conditions are extreme.

- Lack of procedures - adherence to standard data collection procedures ensures that post overhaul tests are conducted. Standard procedures also give rise to a higher degree of belief in the results.

- Lack of communication - critical communication between workers is the key to understanding reliability problems. Barriers to effective communication are as simple as time or distance, or as complex as differences in understanding or belief systems.

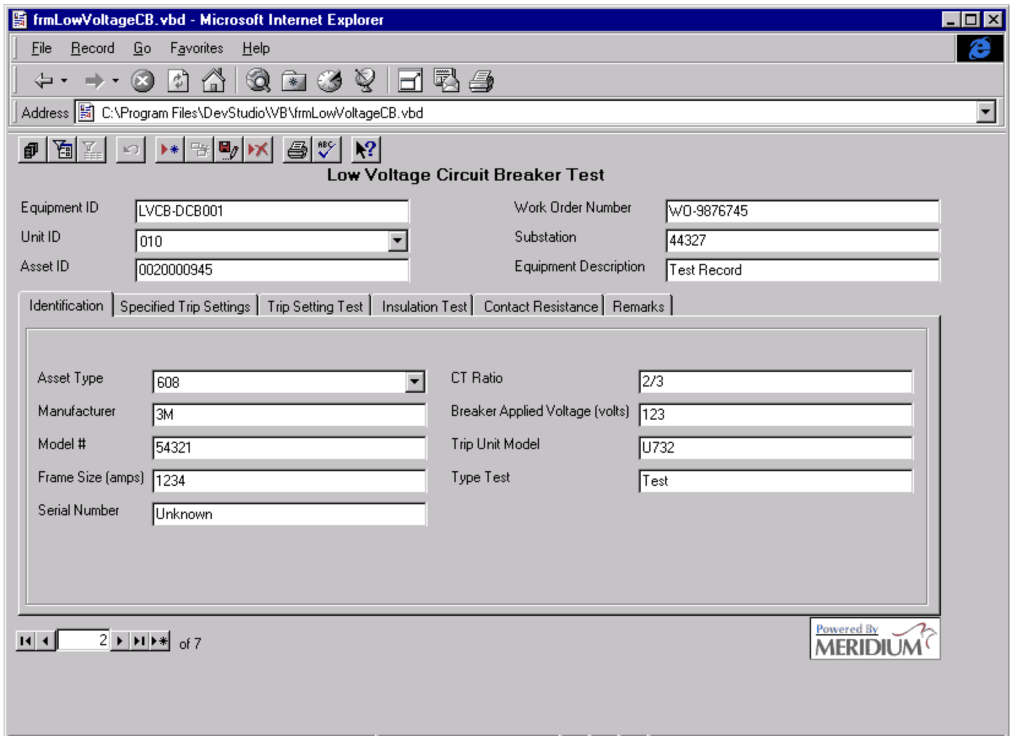
Understanding the link between maintenance activities, costs and reliability is critical for reaching the goal of optimized maintenance.

Value-based Asset Management

Strategies that maximize on-line production time such as extending time between major outages, shortening outage duration and avoiding periods of unexpected downtime are critical to operating in a competitive environment. One such strategy is value-based asset management. In order to optimize maintenance, the company needs to move from a "cost-based" approach to asset management to a "value-based" approach.

The key difference between the two approaches is that the value- based approach involves strategic decision-making that takes the long term effect of repairs into account when making replace, repair, overhaul, retrofit or refurbish decisions. The cost-based approach relies on available budget ("Can we afford it?") for maintenance decision-making that often ignores long-term reliability considerations. Cost-based decisions are based on experience; value- based decisions are based on experience and information.

Figure 3 - Equipment history brief viewed through a web browser



Address C:\Program Files\DevStudio\VB\frmLowVoltageCB.vbd

Low Voltage Circuit Breaker Test

Equipment ID	LVCB-DCB001	Work Order Number	WO-9876745
Unit ID	010	Substation	44327
Asset ID	0020000945	Equipment Description	Test Record

Asset Type	608	CT Ratio	2/3
Manufacturer	3M	Breaker Applied Voltage (volts)	123
Model #	54321	Trip Unit Model	U732
Frame Size (amps)	1234	Type Test	Test
Serial Number	Unknown		

2 of 7

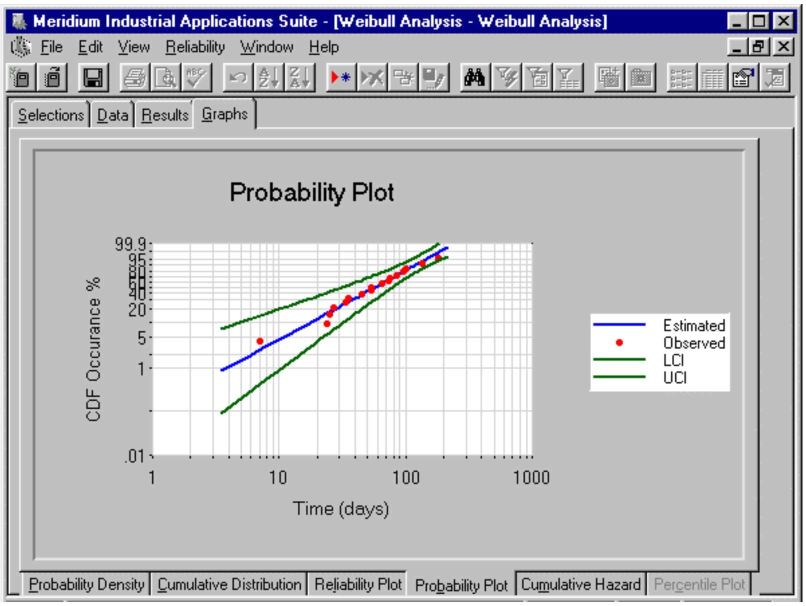
A value-based information system is necessary to bring together maintenance, operations and performance information. The fundamental feature of a value-based asset management system is that it de-couples the installed asset from the function that the asset performs. Once the performance of the asset is objectively viewed, then workers make comparisons with other like equipment or use published data to identify systematic or repetitive problems.

In order to make these decisions effectively; managers and engineers require access to more and more data. Along with this need for information comes a new emphasis on reliability, driven by competition for on-line production time. Equipment unreliability often causes production restrictions or frequent start-ups and shutdowns. Improved reliability means less time in a transition state that causes temperature variations and can ultimately effect reliability. While these effects are not directly related, the secondary effects of disturbances in operation cause a reduction in overall capacity. Conversely, by closely monitoring reliability problems at the component level, workers improve component reliability by spotting problems early.

Reliability Analysis - The Cornerstone of Optimized Maintenance

Advanced information technology makes regular reliability -analysis possible by connecting the asset management system to the computerized maintenance management system. By understanding how a piece of equipment behaves from a reliability viewpoint, equipment of different types and from different manufactures can be effectively compared. Variations in reliability related to design, installation quality and operation are easily identified and corrected in current and future installations. Statistical methods also allow an understanding of not only why equipment has failed, but also help to determine the failure mode.

Figure 4 - Weibull analysis chart



Statistical Reliability Methods

A complete set of statistical reliability tools is provided in the Meridium Industrial Applications Suite (MIAS). Working from within the Meridium Registry, a user simply queries the equipment database for equipment of a specific type, failure date and failure mode. Once this query is complete, the user applies a variety of statistical methods to the dataset, including Weibull, Normal, Lognormal, Growth and Statistical Process Control.

Weibull Analysis allows the user to model a distribution that gives the user important statistical information about the population of data contained within the datasets generated from queries. Quantities such as Mean Time Between Failure (MTBF), Failure Rate and Failure Mode are calculated within the software and stored as documents related back to the asset entity family. The results of a Weibull calculation are two parameters that characterize the slope and characteristic life of the population, respectively. Slope of the Weibull line gives the failure mode (infant mortality, wear-in or wear- out) where characteristic life values can be compared with published values for the components under study.

Normal and Lognormal Analysis, also provided in the Meridium Industrial Application Suite, provide an analysis of the dataset based on the assumption of normal and lognormal distributions. Population averages (mean) and standard deviation are calculated against the data set under study. Lognormal analysis is useful when analyzing failures associated with stress or vibration. This is sometimes the case for data values that span many orders of magnitude.

Growth analysis tracks improvements in MTBF as equipment reliability increases. Growth is also used in cases where the failure mode is unknown or MTBF is changing over time. Growth analysis conducted on a set of failure data is also used to predict the time until next future failure.

Statistical Process Control (SPC) takes trend data and applies statistical analysis methodology. Control limits are established based on the values in the population. The SPC module allows users to configure control charts for tracking diagnostic data or process parameters for the identification of equipment problems. SPC is especially well suited for analyzing trends of vibration data because the limits are based on the data. Control chart data is also subjected to non-randomness rules that can help to eliminate spurious readings from shifts in data caused by changing conditions within the machine under study.

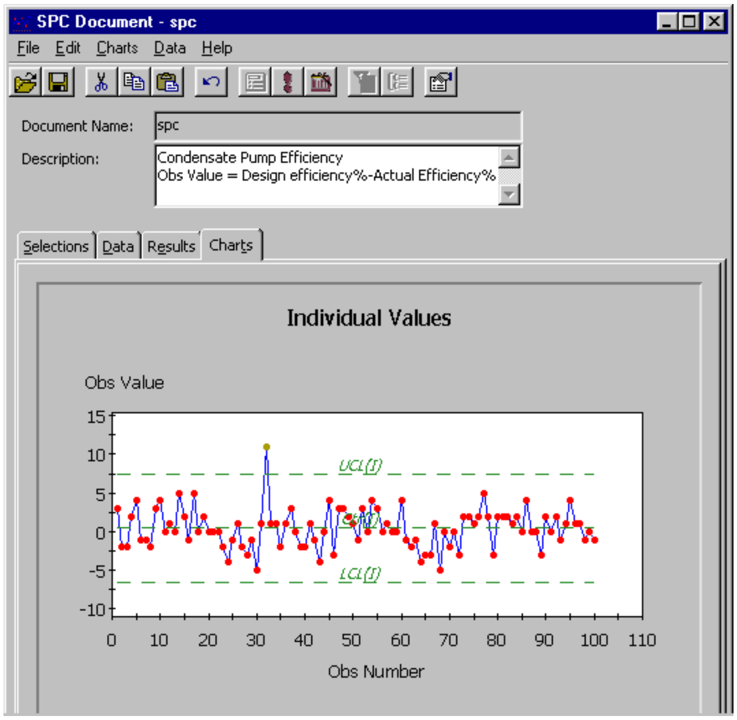
Uses of Reliability Analysis for Maintenance Optimization

Reliability analysis conducted on the equipment failure data results in calculated values that are used to characterize plant equipment reliability. These values are used in many ways to improve and optimize maintenance:

Mean Time Between Failures (MTBF) - MTBF Analysis gives users information about the typical life of the machinery in the population which is compared with manufacturer's expected values, other plants or even benchmark values from other companies. Reliability allows users to model changes in MTBF through the calculation of growth. Growth modeling also allows for the prediction of future failure, thus allowing users to set an interval for foure prevention and intervention.

Weibull Analysis - Weibull parameters give clues as to the type of failure (wear-in, wear-out, end-of-life, random failures) and also give indication of mixed mode populations so that analysts can isolate different causes of failure. By isolating the individual causes, individual solutions can be implemented.

Figure 5 - SPC chart



Document Name: spc

Description: Condensate Pump Efficiency
Obs Value = Design efficiency%-Actual Efficiency%

Root Cause Analysis - Reliability analysis of individual failure modes gives evidence to support the identification of root cause. Parts that have distinctive "wear out" failure modes have a different root cause than parts that exhibit infant mortality. As the root causes of failure are identified using reliability methods and as problems are corrected, the value of MTBF increases over time.

Identification of Vibration Related Failures - Failures caused by excessive vibration are identified through the use of lognormal distribution analysis. Lognormal analysis is a good fit for stress induced failures where the fault mechanism increases as the severity of vibration increases.

Identification of Machine Design Problems - Queries of failure modes by equipment types lead to the identification of commonly failed components among a population of similar equipment.

Identification of System Design Problems - Sometimes the wrong piece of equipment is used in the design of plant system and frequent failures of this equipment occur as a result. Failures of similar systems can be subjected to the same analysis procedures that are conducted at the asset level. Problem systems are identified by low values for MTBF and compared with other similar systems.

Identification of Equipment Material Problems - In some cases, the reliability analysis points to a deficiency in materials or in material selection. These problems often behave in an "early wear- out" failure mode, which is easily identified with a Weibull analysis.

Identification of Construction Problems - Problems sometimes occur during a start-up (after a repair period, turnaround or outage) and are often related to the repair activities. These problems occur as a result of inadequate or improper construction techniques and material failures. An example of this type of problem is an improperly poured foundation that prevents proper operation of a machine or system. These problems sometimes show up in the Weibull analysis as "infant mortality" failures, with low values for MTBF.

Identification of Unsatisfactory Maintenance Procedures - Like construction problems, inadequate or unsatisfactory maintenance procedures are identified and separated by comparing similar components between systems maintained by different crews. The level of training, adherence to standard procedure and attention to detail all play a role in the quality of repairs provided by the maintenance crew.

Identification of Improper Operating Procedures - Wide temperature swings and inadequate level control leads to reduced equipment life. Failures caused by inadequate operating procedures manifest themselves as premature "wear-out" modes easily identified through a Weibull Analysis.

Inadequate Preventive Maintenance Activities - Maintenance preventable failures are identified through sorting of work order backlogs and analyzing of spare parts usage. While usage of spare parts does not ensure their correct installation, inadequate PM activities shows up in a reliability analysis as uncharacteristically low values for MTBF for equipment of this type, as compared with manufacturer's or industry standards.

Inadequate Inspection Routines - unexpected equipment failures cause serious environmental and safety issues. Ruptured pressure vessels, leakage and fugitive emissions caused by cracks, weld failures and seal failures cause components to fail unexpectedly. Understanding the reliability behavior of equipment prone to these kinds of faults allows users to schedule inspections at appropriate intervals.

PM Optimization - Weibull analysis is used to estimate the optimum time for preventive maintenance procedures based upon a ratio of cost functions associated with planned repairs and unplanned failures. Future failure probability can also be estimated from the reliability data.

By combining design, construction, engineering, operation, maintenance and inspection data into a single asset management system and applying statistical analysis tools to failure data, problems that relate to technical as well as procedural issues are addressed. The reliability of individual plant components is only improved once current levels of reliability are identified and tracked. A computer- based asset management system makes this task manageable.

Expert Systems

By correlating diagnostic results to failure modes within the asset management system, we relate each failure mode to its corresponding asset. Medical professionals call this approach to diagnostic analysis "pathology." The concept of pathology implies that for a given set of symptoms, one disease is identified. In terms of equipment diagnostics, if all of the data necessary to identify a fault is available, this fault identification should be repeatable for the same set of symptoms found in other machines of a similar type.

This kind of data analysis results in a set of rules that can ultimately lead to the development of expert systems.

Information technology provides the opportunity to automate the diagnosis of problems through the identification of individual symptoms and the encapsulation of prior experience, thereby leading to an optimum solution. Simple rule based expert systems have been found to be very useful in situations where the existing knowledge base is extensive and a high level of automation is applied to the database. Expert systems have been used for vibration analysis, in which both the symptoms and analysis pathology are well known. In this case, measured values are compared with values stored within rules and are triggered automatically within the expert system.

Rule-based expert systems are not successful when the database is incomplete or when the pathology is not well known. In situations like this, a different approach is necessary for the application of expert systems. Neural networks are an appropriate solution when the symptoms or pathology is unknown. Neural networks use signals combined in parallel to "learn" the behavior of the equipment, and work much in the same way as the human brain. Abnormal patterns are "recognized" by the neural network system by previous experience.

At start-up, the neural network is given a set of "normal conditions." When the system parameters (vibration, temperature, pressure, etc.) are upset, the user needs to identify the cause. When future upsets occur, the neural network software recognizes the situation and notifies the user. Neural networks are generally more flexible than rule-based systems but take longer to become effective at recognizing fault conditions because each set of abnormal parameters must be experienced by the neural network.

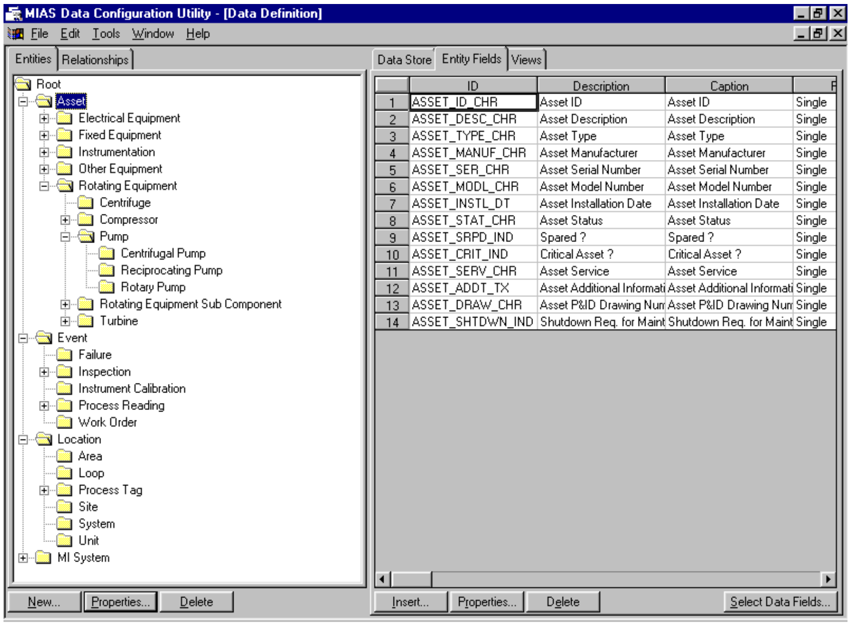
The future of expert systems lies in the automated education of neural networks through the use of extensive information. This is another key area in the future use of information technology. Implementers must begin to collect and organize information in such a way to educate others, including other computer systems. Today, many organizations are still trying to understand and document these "cause and effect" relationships through root cause analysis activities. The data collection systems need to be put in place that supports the future analysis automation.

IT Requirements for Data Storage and Retrieval

How will data be stored, accessed and used in the future? "Industrial strength" databases are needed to accurately store the necessary information. Data storage and retrieval systems must be designed and implemented now so that future data requirement needs are met. Reference 3 indicates that in order to adequately store data for advanced analysis, the information needs to be broken down into Entities, Subtypes, Supertypes, Attributes and Relationships.

An entity is a thing of significance which an organization wishes to hold (which is to say, collect, maintain and use) information. Subtypes and supertypes are a way to relate entities in a hierarchical format. For example, a family called "pumps" would have a subtype called "centrifugal pumps." One or more attributes describe the details of an entity or subtype. Examples of attributes are design data, specifications, and operating limits. Relationships define the ways in which other entities or subtypes are related to one another, which also defines the nature of the relationship. Relationships are "one-to-one" or "one-to-many." An example of a relationship is an asset, such as a heat exchanger, can have one or many inspections over the course of its life.

Figure 6 - Meridium Data Configuration Utility



	ID	Description	Caption	F
1	ASSET_ID_CHR	Asset ID	Asset ID	Single
2	ASSET_DESC_CHR	Asset Description	Asset Description	Single
3	ASSET_TYPE_CHR	Asset Type	Asset Type	Single
4	ASSET_MANUF_CHR	Asset Manufacturer	Asset Manufacturer	Single
5	ASSET_SER_CHR	Asset Serial Number	Asset Serial Number	Single
6	ASSET_MODL_CHR	Asset Model Number	Asset Model Number	Single
7	ASSET_INSTL_DT	Asset Installation Date	Asset Installation Date	Single
8	ASSET_STAT_CHR	Asset Status	Asset Status	Single
9	ASSET_SRPD_IND	Spared ?	Spared ?	Single
10	ASSET_CRIT_IND	Critical Asset ?	Critical Asset ?	Single
11	ASSET_SERV_CHR	Asset Service	Asset Service	Single
12	ASSET_ADDT_TX	Asset Additional Informati	Asset Additional Informati	Single
13	ASSET_DRAW_CHR	Asset P&ID Drawing Nun	Asset P&ID Drawing Nun	Single
14	ASSET_SHTDWN_IND	Shutdown Req. for Maint	Shutdown Req. for Maint	Single

Why is it important to store data in this fashion? Reliability Analysis depends on the relationship of failure data to individual assets. To conduct good failure analysis, a user needs dates and times of the failure, failure causes and effects and the actions or condition that caused the failure. Evidence gathered from the failure also needs to be stored with the asset along with events leading up to failure. Process data sets including normal conditions, abnormal conditions and causes are also useful in identifying the cause and effect of failures. Inspection data sets, including condition information such as vibration and temperature, add to the experience of the people responsible for the maintenance of the assets. Once data is separated in this fashion, failure prediction becomes possible. The way data is stored is important to its future use. This begins by separating asset information from location information and appropriately assigning event information.

Conclusions

Data integrity is an important consideration when making decisions about the current and long-term solutions for storage of information important to the business. "Industrial strength" data storage and access makes reliability analysis attainable and allows for the possibility of future expert system applications.

Emphasis needs to be put on results, not activities. Optimization implies that users should endeavor to understand how much information is necessary and only collect enough information to define the problems that call for effective solutions. With access to all of this data, users need to avoid the potential for "analysis paralysis" in which decision-making becomes difficult (or impossible) simply because too much data is available and we fail to make the proper links to cause and effect. Care must be taken to collect only the data necessary for a good solution.

As maintenance optimization progresses, implementers need to set up performance measurements that are sensitive to the implemented changes. If the goal is to improve reliability through the application of statistical analysis, then improvements in the reliability of individual assets need to be tracked. This only becomes possible if the information technology used allows for the regular inspection and analysis of this data.

Detailed data modeling is an important aspect of the future of information technology as it applies to plant reliability. Advanced data modeling techniques employ the latest in hierarchical database design methods to capture, relate and store information about installed and new assets.

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