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PLANT ENGINEERING & MAINTENANCE

Chair's Message

—DR. MEHERWAN P. BOYCE PE,
The Boyce Consultancy Group, LLC, Houston, USA

Welcome to the 2004 Plant Engineering & Maintenance Division Newsletter. I would like to wish all of our members and their families a very happy and prosperous New Year. As I said in my last letter that we have over 18,000 members, who are interested in our division, with over 4,000 members who consider this division to serve their primary area of interest. There are over 80 areas of interest varying from the food and process industries to the petro-chemical, electric power and engineering services. PEMD is a very major division

We have four technical committees under their dynamic chairs have been active this past year and we look for them to be active next year, and supplement them with at least two new committees.

Please contact the chairs of the committee and join them in ensuring that we have an active program for the year 2004. As members of the Plant Engineering and Maintenance Division our activities cover the traditional manufacturing, processes and maintenance, so we have a wide area of interest that we can bring to these committees.

In the post 9/11 era we have to also be constantly vigilante to protect our plants from those who desire to create havoc. I propose that we form a new Technical Committee on plant security that would address this area, and which would help develop new techniques and instrumentation to guard our infrastructure. I call on one of you to volunteer as chair of this committee and to build a viable committee that will be active in many conferences.

We would like to welcome you to send articles for our newsletter and for posting on our web site. The division wants to be active in serving your needs, thus we need your active participation.

In 2004 PEMD is going to actively take part in four major conferences. We are going to hold a general meeting of all our members at the Power Engineering Conference in Baltimore-MD on Wednesday March 31st, 2004. I hope all of you will try to make it a point to attend, and help us rejuvenate our division.

The division is proud to be the home of the Frederick P. Smarro Award. This award is presented to an engineer who has made significant contributions to the discipline and practice of plant maintenance and/or engineering.

The executive committee would like to bring back the division's flag ship conference The Plant Engineering and Maintenance Conference. To do this our members have to become very active so that the division can justify this expenditure.

To be successful at these and other conferences we need your help in volunteering as a speaker, a panel member, or become a member of our existing technical committees.

Please contact me, or any member of your executive committee, and volunteer to advance our division and your professional development. I strongly believe that if this division is to succeed we need the very active participation of our members.

INSIDE

Total Performance Condition Monitoring of Major Petrochemical Facilities

—DR. MEHERWAN P. BOYCE PE.

Introduction

The traditional concept of maintenance in the petro-chemical industry has been undergoing a major change to ensure that equipment not only has the best availability but also is operating at its maximum efficiency. There is a consistent trend in the Petrochemical Industry throughout the world to improve maintenance strategy from fix-as-fail to total performance based planned maintenance. In practice, this calls for on-line monitoring and condition management of all major equipment in the plant. To reach the Utopian goal of just in time maintenance with minor disruption in the operation of the plant requires a very close understanding of the thermodynamic and mechanical aspects of plant equipment.

The introduction of the total maintenance condition monitoring system means the use of composite condition monitoring systems which combine both mechanical and performance based analysis. Numerous case studies have shown that many turbomachinery operational problems can only be diagnosed and resolved by correlating the representative performance parameters with mechanical parameters.

Major petrochemical complexes contain various types of large machinery. Examples include many types of machinery, in particular gas and steam turbines, pumps and compressors, and their effect on heat exchangers, distillation towers, and other major plant equipment. Thus the logical trend in condition monitoring is to multi –machine train monitoring. To accomplish this goal an extensive database which contains data from all machine trains along with many composite multi-machine analysis algorithms are implemented in a systematic and modular form in a central system.

Implementation of advanced performance degradation models, necessitate the inclusion of advanced instrumentation and sensors such as pyrometers for monitoring hot section components, dynamic pressure transducers for detection of surge and other flow instabilities such as combustion especially in the new low NOx combustors. To fully round out a condition monitoring system the use of expert systems in determining fault and life cycle of various components is a necessity.

The benefits of total performance based planned maintenance not only ensure the best and lowest cost maintenance program but also that the plant is operated at its most efficient point. An important supplementary effect is that the plant will be operating consistently within its environmental constraints.

The new purchasing mantra for chemical processing plants is "Life Cycle Cost" and to properly ensure that this is achieved a "Total Performance Condition Monitoring" strategy is unsurpassed.

Total Condition Monitoring System

A Total Condition Monitoring System must be designed to provide the operators and rotating equipment engineers with clear insight into machinery performance problems:

- Enhance predictive maintenance capability by diagnostic tools.
- Plant operation with minimum degradation based on optimal washing of the train.
- Integrated condition monitoring utilizing *field proven hardware and software.*
- Provide voltage free contacts at the monitors for machine safeguarding.
- Data link to and from the plant D-CS system so as to upgrade performance curves in the D-CS system which control plant processes.

A Total Condition Monitoring System for a major Petro-Chemical installation requires a fully integrated system with an extensive database to ensure that it can achieve the following goals:

- High Machinery Availability
- Maintaining peak efficiency and limiting performance degradation of machine trains
- Extending time between inspections and overhauls
- Optimizing the cycle configuration
- Estimating Availability
- Evaluating scenarios by means of "What If" Analysis
- Estimating maintenance requirements and life of hot section components
- Fault identification by Expert System analysis.

A Condition Monitoring System designed to meet these needs must comprise of hardware and software designed by engineers with experience in machinery and energy system design, operation and maintenance. Each system needs to be carefully tailored to individual plant and machinery requirements. The systems must obtain real time data from the Plant DCS and if required from the

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gas and steam turbine control systems. Dynamic vibration data is taken in from the existing vibration analysis system into a Data acquisition system. The system can comprise of several high performance networked computers depending on plant size and layout. The data must be presented using a graphic User Interface (GUI) and include the following:

1. Aerothermal Analysis:
This pertains to a detailed thermodynamic analysis of the full power plant and individual components. Models are created of individual components including the gas turbine, steam turbine heat exchangers, and distillation towers. Both the algorithmic and statistical approaches are used. Data is presented in a variety of performance maps, bar charts, summary charts, and baseline plots.

2. Combustion Analysis:
This includes the use of pyrometers to detect metal temperatures of both stationary and rotating components such as turbine blades. The use of dynamic pressure transducers to detect flame instabilities in the combustor especially in low NOx applications

3. Vibration Analysis:
This includes an on-line analysis of the vibration signals, FFT spectral analysis, transient analysis, and diagnostics. A wide variety of displays are available including orbits, cascades, Bode and Nyquist Plots, and transient plots.

4. Mechanical Analysis:
This includes detailed analysis of the bearing temperatures, lube, and seal oil systems and other mechanical subsystems.

5. Diagnosis:
This includes several levels of machinery diagnosis assistance available via expert systems. These systems must integrate both mechanical and aerothermal diagnostics.

6. Trending and Prognosis:
This includes sophisticated trending and prognostic software. These programs must clearly provide users to clearly understand underlying causes of operating problems.

7. "What-If" Analysis: This program should allow the user to do various studies of plant operating scenarios to ascertain the expected performance level of the plant due to environmental and other operational conditions.

Monitoring Software

The monitoring software for every system will be different. However, all software is there to achieve one goal that is it must gather data, ensure that it is correct, and then analyze and diagnose the data. Presentations must be in a convenient form and should be easily understood by plant operational personnel. All priorities must be to the data collection process. This process must not in any manner be hampered since it is the corner stone of the whole system.

A convenient **framework** within which to categorize the software could be as follows:

1. Graphic User Interface (GUI):
This consists of screens which would enable the operator to easily interrogate the system and to visually see where the instruments are installed and their values at any point of time. By carefully designed screens the operator will be able to view at a glance the relative positions of all values thus fully understanding the operation of the machinery.

2. Alarm/System Logs:
To fully understand a machine we have to have various types of alarms. The following are some of the suggested types of alarms:

a) Instrument Alarms: These alarms are based on the instrumentation range.

b) Value Range Alarm: These alarms are based on operating values of individual points both measured and calculated points. These alarms should be variable in that they would change with operating conditions.

c) Rate of Change Alarm: These alarms must be based on any rapid change in values in a given time range. This type of alarm is very useful to detect bearing problems, surge problems, and other instabilities.

d) Prognostic Alarms: These alarms must be based on trends and the prognostics based on those trends. It is advisable not to have prognostics, which project in time more than the time of data that is trended.

3. Performance Maps:
These are performance maps based on design or initial tests (base lines) of the various machinery parameters. These maps, for example present how Power output varies with ambient conditions, or with properties of the fuel, or the condition of the filtration system; or how close to the surge line a compressor is operating. On these maps the present value is displayed, thus allowing the operator to determine the degradation in performance occurring in the units.

Analysis Programs – These include Aerothermal and Mechanical Analysis programs, with Diagnostics and Optimization programs.

Aero-Thermal Analysis: Typical aerothermal performance calculations involve evaluation of component unit power, polytropic and adiabatic head, pressure ratio, temperature ratio, polytropic and adiabatic efficiencies, temperature profiles and a host of other machine specific conditions under steady state as well as during transients—start ups and shut downs. This program must be tailored to individual machinery and to the instrumentation available. Data must be corrected to a base condition, so that it can be compared and trended. The base condition can vary from ISO ambient conditions, to design conditions of a compressor or pump if those conditions are very different from ISO ambient conditions. To analyze off design operation it is necessary to transpose values from the operating points back to the design point for comparison of unit degradation.

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Mechanical Analysis: This program must be tailored to the mechanical properties of the machine train under consideration. It should include bearing analysis, seal analysis, lubrication analysis, rotor dynamics and vibration analysis. This includes the evaluation and correlation of bearing metal temperatures, shaft orbits, vibration velocity, spectrum snapshots, waterfall plots, stress analysis, and material properties.

Diagnostic Analysis: This program can be part of an expert system or consist of an operational matrix, which can point to various problems. The program must include comparison of both performance and mechanical health parameters to a machine specific fault matrix to identify if a fault exists. Expert analysis modules can in many cases aid to faster fault identification but are usually more difficult to integrate into the system.

Optimization Analysis: Optimization programs take into account many variables, such as, deterioration rate, overhaul costs, interest, and utilization rates. These programs may also be dependent on more than one machine train if the process is interrelated between various trains.

Life Cycle Analysis: The determination of the effect of the material, the temperature excursions, the number of start-ups and shut-downs, the type of fuel all relate to the life of hot section components.

Historical Data Management: This includes the data acquisition and storage capabilities. Present day prices of storage mediums have been dropping rapidly, and systems with 14-16 gigabyte hard disks are available. These disks could store a minimum of two years of one-minute data for most plants. One-minute data is adequate for most steady state operation, while start-ups and shutdowns or other non-steady state operation should be monitored and stored at an interval of one second. To achieve these time rates, data for steady state operation, can be obtained from most plant wide D-CS systems and for unsteady state conditions data can be obtained from control systems.

Implementation of a Condition Monitoring System

The implementation of a condition monitoring system in a major Petro-Chemical plant requires a great deal of fore thought. A major petrochemical plant will have a number of varied, large rotating equipment. This will consist usually of various types of prime movers such as large Electrical Motors, Gas Turbines, Steam Turbines, Hot Gas Expanders, and Diesel or Gas Reciprocating Engines. These prime movers will be driving large Compressors and Pumps. The following are some of the major steps, which need to be taken to ensure a successful system installation:

The first decision is to decide on what equipment should be monitored on line and what systems should be monitored off-line. This requires an assessment of the equipment in terms of both first cost and operating costs, redundancy, reliability, efficiency, and criticality.

Obtain all pertinent data of the equipment to be monitored. This would include details of the mechanical design and the performance design. Some of this information may be difficult to obtain from the manufacturer and will have to be calculated from data being obtained in the field or after installation during commissioning tests in a new installation. Obtaining baseline data is critical in the installation of any condition monitoring system. In most systems it is the rate of change of parameters that are being trended not the absolute values of these points. It is also important to decide what type of alarms will be attached to the various points. Rate of change alarms must be for bearing metal temperatures especially for thrust bearings where temperature changes are critical. Prognostic alarms should be applied to critical points. Alarms randomly applied tend to slow down the system and do not provide added protection.

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PEMD Meeting Announcement

ASME's Plant Engineering & Maintenance Division (PEMD) will be holding an open session Membership Meeting on

Wednesday, March 31, 4:15 pm, in Room 336
at the ASME Power Conference

In conjunction with the Electric Power Conference to be held in Baltimore-MD, on

March 30 thru April 1, 2004,

Please join the PEMD Executive Committee to meet PEMD Colleagues and learn how to become involved and voice your suggestions and opinions.

For ASME Power: http://www.asmeconferences.org/power04/

Call For Response –Revisited

WALLY WALEJESKI, General Manager -Diagnostic Technologies & Associates, Inc.

In PEMD's last newsletter, I had asked our membership to think of issues that PEMD could latch onto and pursue as focus items for the Division and/or its Technical Committees. Some of you replied and I thank you for your interest and comments. I am sure many others had some ideas and possible comments but felt unsure of responding.

PEMD is anxious in its efforts to identify a clear focus for its attention. Benefits to, and participation of, its membership has been and remains our primary objectives but the Executive Committee has struggled as to the best means to achieve these objectives. Difficulties on determining that focus may come from participation logistics, to so many other critical issues already being pursued, impact from many other organization's activities, to even our present lack of a longer range Division vision. These are not just excuses or reasons, but a tall hill to overcome. Also, ASME's re-organization activities may have an impact on some division's future. PEMD appears to be on stable ground in this area.

Most of those who responded to my first article expressed their availability in participating and/or supporting potential technical Committee activities. A few offered some ideas for pursuance, such as developing an industry reliability standard, becoming a subject matter organizations' coordinator, and participating or leading various technical sessions at related conferences. The Executive Committee has reviewed these suggestions but has yet to decide on embracing and running with some of them. Hopefully, we will decide soon on that critical mission(s). Your involvement and responses would certainly help.

I and others continue to believe PEMD should be engaged in a focused activity. PEMD's leadership does want and looks forward to your feedback and input. Again, let us know what you think.

Wally Walejeski
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The following are some of the basic data that would be necessary in setting up a system:

1. Type of gasses and fluids used in the various processes.
2. The Equation of State and other thermodynamic relationship that govern these gases and fluids.
3. Type of fuel used in the prime movers. If the fuel analysis is available including the fuel composition and the heating values of the fuel.
4. Materials used in various hot sections such as combustor liners, turbine nozzles, and blades. This includes stress and strain properties as well as Larson-miller parameters.
5. Performance maps of various critical parameters such as power and heat consumption as a function of ambient conditions, pressure drop in filters, and the effect of back pressure. Compressor surge, efficiency, and head maps.
6. Determine the instrumentation, which exists, and their actual location. Location of the instrumentation from the inlet or exit of the machinery is important so that proper and effective compensation may be provided for the various measured parameters. In some cases additional instrumentation will be needed. Experience indicates that older plants require ten to twenty percent more instrumentation depending upon the age of the plant.
7. Once the data points have been decided limits and alarm must be set. This is a long and challenging task as the limits on many points are not given in the operation manuals. In some cases the criticality of the equipment may necessitate that the alarm threshold on certain points be lowered to give early warning of any deterioration of the system. It should be noted that since this is a condition monitoring system early alarm warnings are in most cases desirable.
8. Types of reports and summary charts should be planned to optimize the data and to present it in the most useful manner to the plant operations, and maintenance personnel.
9. The types of D-CS and the control systems available in the plant. The protocol of these systems and their relationships to the condition monitoring system. The slave or master relationship is important in setting up the protocols.
10. Diagnostics for the system requires to note any unusual characteristics of the machinery, especially in older plants, which have a history of operation inspections and overhauls.
11. Costs of operations such as fuel costs, labor costs, down time costs, overhaul hours, interest rates are necessary in computing parameters such as time of major inspections, off–line cleaning, and overhauls.

Best Maintenance Practices

—EXCERPTED FROM AN ARTICLE BY RICKY SMITH,
Executive Director of Maintenance Strategies for Life Cycle Engineering

Best Practices". These two words have achieved a meaning of their own within the past decade. The words represent benchmarking standards for whatever area they are applied to. Nothing is better or exceeds a "Best Practice". It is the highest point towards which we measure from the lowest point. The words are most often applied to the **quality of management**. There exists today enormous databases of *opinions* (author's definition) from executives in successful companies and institutions regarding what constitutes the best business practices, the best management styles, the best corporate philosophies. Unfortunately, in some people's minds, the words "Best Practices" conjure up some obscure, always-changing and rarely achievable goal upon which they must focus with only the faintest hope of ever attaining.

Welcome back to reality. "Best Maintenance Practices" are benchmarking standards, but these are real, specific, achievable and ***proven*** standards for maintenance management that have made many maintenance departments more efficient, that have reduced facility and plant maintenance and operating costs, that have improved reliability, and that have increased morale.

If everyone at your facility is satisfied with the existing maintenance program, why then, should you be interested in "Best Maintenance Practices"? Most maintenance departments in North America today operate at between 10% and 40% efficiency. Nearly 70% of facility equipment failures can be considered self-induced. These statistics can't, and shouldn't, be acceptable - not to upper management and certainly not to maintenance managers. These facts alone should generate some amount of interest in Best Maintenance Practices. Where does your maintenance department stand in relation to these figures? Do you measure and track maintenance efficiency? Do you accumulate, analyze and categorize data on equipment failures? Do you track maintenance costs for unplanned repairs or overtime? If you do none of these things, then you probably have no idea if you are the same as, better, or worse than these averages.

Before we define the standards for Best Maintenance Practices, it may be a good idea to make sure that we all have in mind the same idea of what maintenance means:

Maintenance:

(a) to keep in its existing state;

(b) preserve; continue in good operating condition; protect.

"Proactive Maintenance is the Mission"

Surprisingly, there are a substantial number of people who do not know the meaning of ***maintenance***. At least the way they practice maintenance would indicate this. In practice, the prevalent interpretation of maintenance is to "fix it when it breaks". This is a good definition for repair, but not maintenance. This style of maintenance is ***Reactive***. As stated above, the mission is ***Proactive*** Maintenance. Here is another definition worth remembering -

Discipline:

(a) self-control or orderly conduct

(b) acceptance of or submission to authority and control; orderliness; order; control; self-control; subordination to rules of conduct, system, method.

The Standards for Best Maintenance Practices

- 100% of maintenance person's time is covered by a work order.
- 90% of Work Orders are generated by Preventive Maintenance inspections.
- 30% of all labor hours are from Preventive Maintenance.
- 90% of planned / scheduled work compliance.
- 100% reliability is reached 100% of the time.
- OEE over 85%
- Spare parts stock-outs are rare (less than one per month).
- Overtime is less than 2% of total maintenance time.

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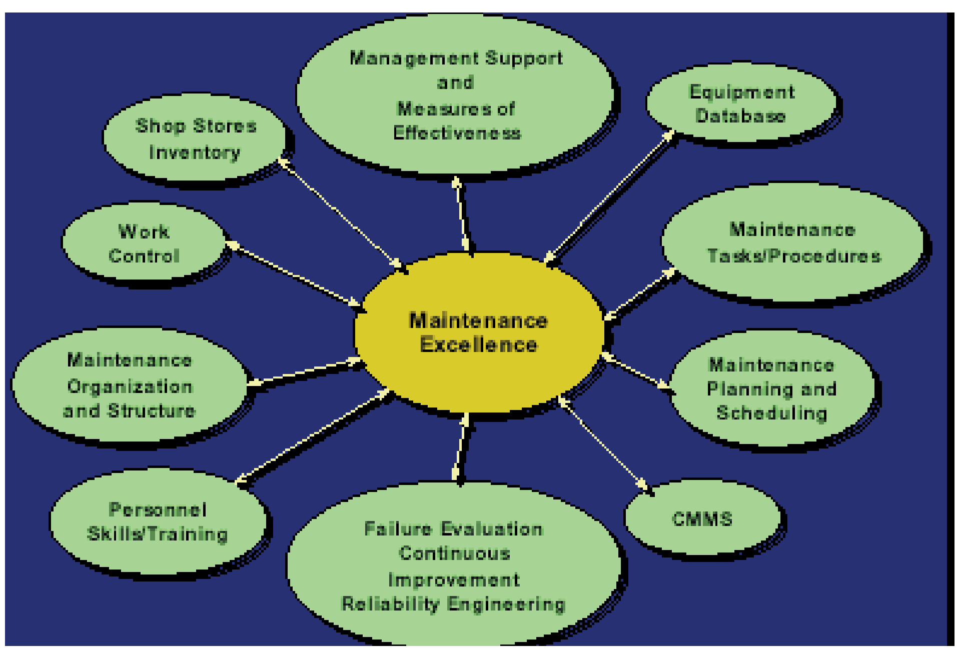

Figure 1: Integrated Planned Maintenance System

Best Maintenance Practices

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- Maintenance budget is within +/- 2% per piece of equipment.

Anyone may claim to be a maintenance expert but the conditions within a facility/plant generally cannot often validate that this is true. In order to change the organization's basic beliefs, the reasons why an organization does not reach out to achieve these standards in the maintenance of their equipment must be identified. Two of the more common reasons that a facility does not follow best maintenance practices are:

Maintenance is totally reactive and does not follow the definition of maintenance, which is to protect, preserve, and prevent from decline (reactive plant culture).

The maintenance workforce lacks either the discipline to follow best maintenance practices, or management has not defined rules of conduct for best maintenance practices.

The potential cost savings of implementing Best Maintenance Practices can often be beyond the understanding or comprehension of management. Many managers are in a state of denial regarding the impact of maintenance. As a result, they do not believe that maintenance practices directly reflect on an organization's bottom line or profitability. More enlightened facilities have demonstrated that, by reducing the self-induced failures, they can increase equipment reliability by as much as 20%. Other managers accept lower reliability standards from maintenance efforts because they either do not understand the problem or they choose to ignore this issue. A good manager must be willing to admit to a maintenance problem and actively pursue a solution. How can you actively pursue a solution? -

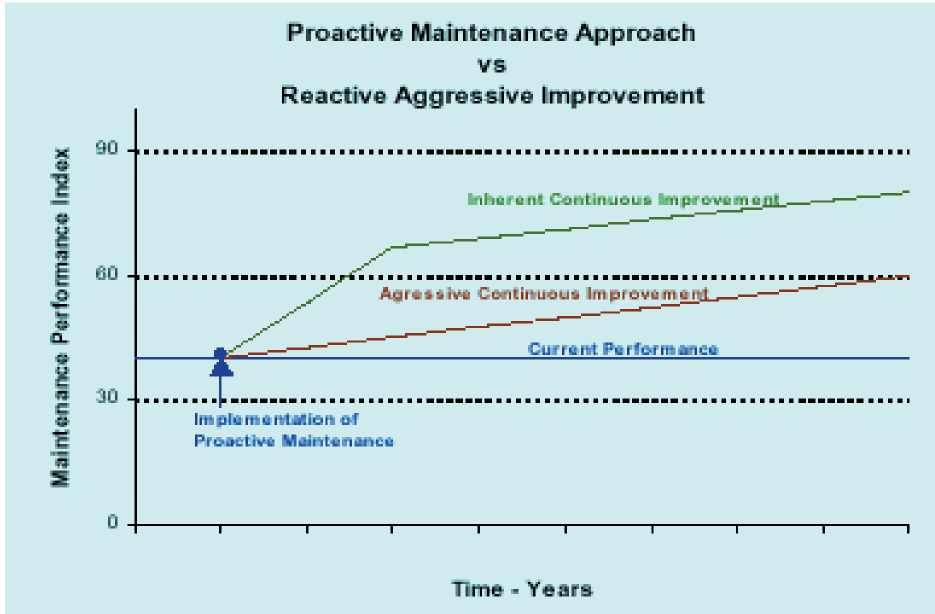

Figure 2: Maintenance Effectiveness Improvement

- Be Proactive, Disciplined and Accountable
- Manage to Maximize Available Resources
- Manage based on Information:
  - CMMS
  - Production/Operation Reports
  - Feedback from Work Reports

The major emphasis for actively pursuing solutions for maintenance ineffectiveness should be on proactive thinking. Adopting a proactive approach to maintenance will improve maintenance effectiveness dramatically and more rapidly than instituting an aggressive program of maintenance effectiveness improvement within the confines of the organizational and cultural environment of an existing, predominantly reactive maintenance program.

About the Author:

Mr. Smith is the Executive Director of Maintenance Strategies for Life Cycle Engineering. Mr. Smith is the co-author of *The Maintenance Engineering Handbook, the Plant Engineering Handbook* and *Hydraulic Fundamentals.* His contact information is :

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