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Key Elements to Achieving World Class Reliability and Maintenance

October 22, 2008

Agenda

- **Introduction**
- **Pitfalls of Traditional Maintenance Programs**
- **Aspects of World Class Maintenance Programs**
- **Risk-based Maintenance (RBM)**
- **Understanding and Utilizing RBM Methodology as a Key Element in:**
  - Routine Maintenance Programs
  - Reliability Maintenance Programs
- **Utilizing RBM in the Continuous Improvement Process**

Introduction

- **Dave Morgan – Senior Consultant with Baker & O'Brien**
- **B.S. Chemical Engineering – Lamar University; Beaumont, Texas**
- **Twenty-eight years experience in the petrochemicals and refining industry**
- **Plant Operations – 20 years**
  - Process and Maintenance Engineering
  - Maintenance and Turnaround Manager
- **Consulting – 8 years**
  - Primary focus - Reliability, Maintenance, and Turnaround Optimization
  - Experience in over 20 countries including:
    - Southeast Asia
    - North and South America
    - Middle East
    - Europe

Fundamentals to Success

- **Fundamental to any successful maintenance organization is the ability to:**
  - Focus efforts in the area of highest return
  - Optimize utilization of limited employee resources and budgets
  - Assure decisions and programs are in alignment with organizations' goals and objectives
  - Utilize a process to monitor progress and continuously improve performance
- **The foundation for world class performance is understanding and managing risk associated with failures – RBM**
- **Utilization of Risk-based Decision Making (RBDM) can then be applied to develop world class:**
  - Routine Maintenance Programs
  - Reliability Maintenance Programs

Typical Pitfalls to Successful Maintenance Programs

- **View maintenance as a cost center versus a technical resource for improvement.**
  - Improving maintenance costs is important.
  - Improvement in operations can often bring higher returns.
- **Decisions are experience-based and can be inconsistent between employees.**
- **Inability to improve reliability by addressing failures, not failure mechanisms.**
- **Instead of understanding the impact to the overall system performance, it can be equipment focused.**
- **Using resources inefficiently:**
  - Performing unnecessary task or performing task too often
  - Unplanned reactive maintenance
- **Creating failures by performing unneeded maintenance task.**

Characteristics of World Class Programs

- **Apply strategies and techniques to optimize maintenance programs and utilization of resources.**
- **Selection of tasks which are systematically derived based on understanding:**
  - Consequence of a failure
  - Probability of occurrence
- **Maintenance tasks are system focused, concentrating on failures that can prohibit a process from performing its task.**
- **Advanced technologies are used as tools to support maintenance programs and strategies.**
- **Continual improvement is pursued.**
- **All plant organizations and personnel are involved.**

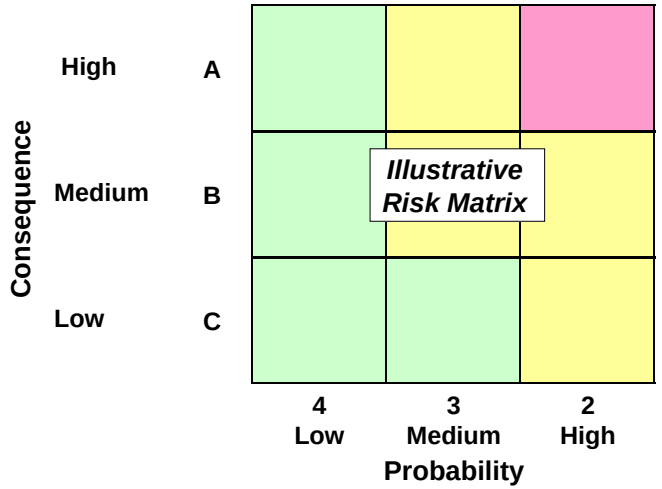
Risk Based Maintenance

- **Risk management is the foundation for an effective and consistent maintenance and reliability program.**
- **Risk-based methodology is utilized by most major organizations and consistent with U.S. industry regulations and professional organization guidelines, such as:**
  - OSHA 1910.119 - Process Safety Management, Guidelines for Risk-Based Process Safety
  - API RP 580 – Risk-based Inspection
  - ASME and AIChE have publications concerning risk assessment and analysis.
- **RBM is fundamental for:**
  - Routine maintenance and turnaround work selection
  - Prioritizing and scheduling work requests
  - Developing preventative (PM) and predictive (PdM) maintenance programs
  - Reliability improvement initiatives
  - Identifying critical equipment and critical spare parts

Risk = Consequence x Probability

- **RBDM is not about taking risk, but how to recognize, understand, and manage risk.**
- **Risk Management consists of:**
  - Developing a process to consistently determine what we should do and when we should do it
  - Understanding that we cannot afford, or have the resources, to do everything
  - Managing risk associated with work we are not doing at this time or at all

- **Risk is the function of consequence and probability, which must be considered separately**



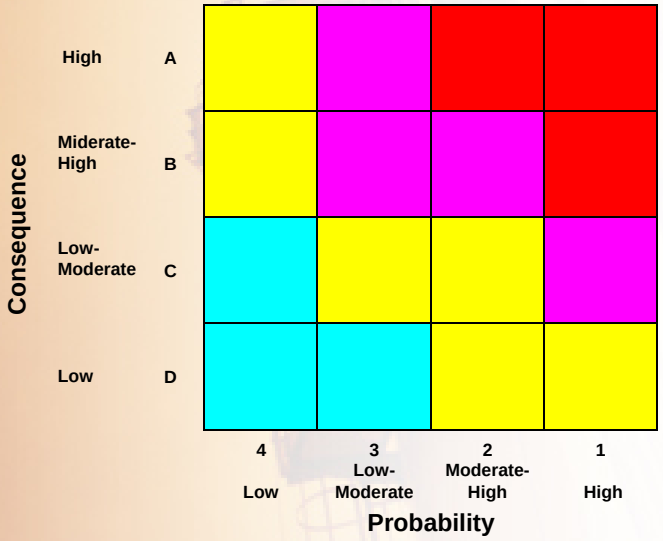
RISK = Consequence x Probability

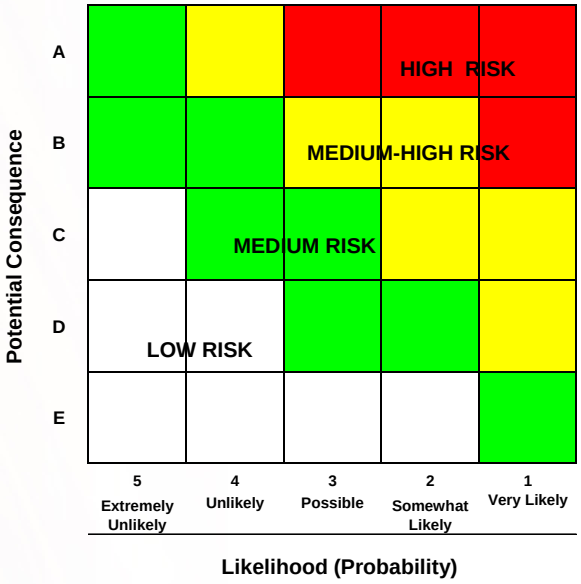
Applying Risk Based Decision Making

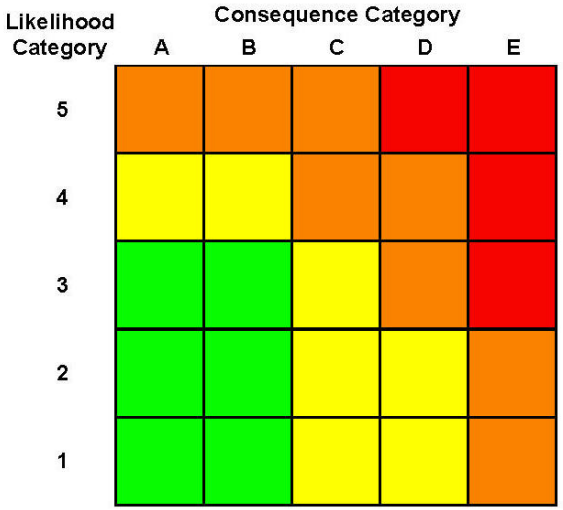
- **Utilization of a risk matrix can be a fundamental RBDM tool to:**
  - Provide a visual guide to support discussion and thought process
  - Add consistency between departments, shifts, and personnel
  - Support a decision-making process that is in line with the company's overall goal and objectives
- **A Risk Matrix is a chart of incident consequences versus the frequency of a failure.**
- **Consequences can be adjusted to meet individual companies' goals and objectives by considering:**
  - Health, safety, and environmental issues
  - Profitability and availability
  - Quality and customer satisfaction

Risk Matrices in Practice

- Risk matrix can vary in size or shading.
- Required dimensions are dependent on need to adequately differentiate between risk levels.
- Due to limited maintenance options, generally 3 to 6 levels are sufficient.







RBM Requires Broad Input and Participation

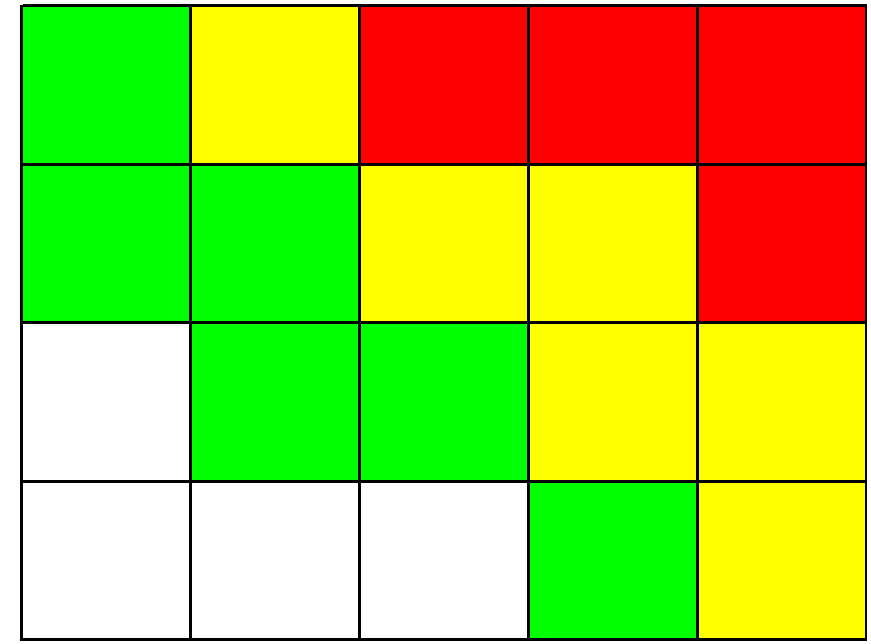
- **To assess the risk associated with a failure we must understand:**
  - What can go wrong (failure mode/mechanism)
  - How likely will it occur (failure frequency and probability)
  - What are the impacts (system consequence of the failure)
- **RBM programs, therefore, require participation and input from several plant organizations to work effectively, including:**
  - Maintenance: Equipment history, probability of failure, and repair durations
  - Inspection: Inspection records, failure mechanisms, and estimated remaining life
  - Operations: Impact to operations and mitigations to minimize effect
- **RBM can provide:**
  - Consistent decision making across the site by clearly defining and agreeing to the basis for making a decision
  - Reduced individual exposure by providing a process for personnel to follow
  - Improved effectiveness by focusing efforts on most important concerns
  - Improved efficiency by eliminating unneeded work and reducing emergency requests

RBDM Process

- **In basic terms, the thought process utilized for RBDM is:**
  - Understanding the true consequence associated with a failure
    - Start-up spare pump
    - Small, contained leak
    - Shut down entire plant or slow down a unit for 12 hours
  - Evaluating the probability of this consequence happening during a described time frame:
    - Probability is a best estimate based on available data.
    - Time frame can be a month, over a weekend, or between Turnaround cycles.
  - If the risk is too high, then a mitigation needs to taken to reduce the risk.
  - If the risk is low, then the work or action can be eliminated or reduced.
  - Time frame to take action can also be reconsidered to reduce risk.
- **This process can be optimized to support maintenance and reliability programs such as:**
  - Routine maintenance work selection, planning. and scheduling
  - Turnaround preparation
  - Materials management

Example Risk Matrix

Potential Consequence Health/ Safety/ Environment, Business Impact	
Fatality, serious impact to public Major uncontained environmental incident, with offsite impact Explosion or major fire with impact on neighboring community Total plant shutdown >10 days ($30)	**A**
Injury with restricted duty, lost time injury Release reportable to Federal Authorities Large fire requiring external support Total plant shutdown, major unit shutdown <15 days ($3M) Event with "high" impact on customers	**B**
First Aid Fire requiring internal Fire Brigade support Release reportable to Local Authorities/Corporate Major unit shutdown <15 days (US$300,000) Some impact on final customers	**C**
Near miss, first aid incident Small fire extinguished by operators Small contained toxic leak <reportable quantities Unit production rate reduction (US$30,000)	**D**



5 **Extremely Unlikely**	**4** **Unlikely**	**3** **Possible**	**2** **Somewhat Likely**	**1** **Very Likely**
< 0.1%	0.1% - 1%	1% - 10%	10% - 80%	80% - 100%

Likelihood (Probability):
(Assessment time frame)

HIGH RISK -- Work always justified
MEDIUM RISK -- Work usually justified
LOW RISK -- Work normally not justified. Is mitigation possible?
LOWEST RISK -- Work not justified

Routine Maintenance Programs

- **Routine maintenance programs consist of work selection, prioritization, planning, and scheduling.**
- **Fundamental to any successful routine maintenance program is:**
  - Determining what work must be performed.
  - Prioritizing the approved work requests to address the ones that pose the highest risk or provide greatest return.
  - Planning and scheduling work execution to utilize the limited resources and personnel in the most cost effective and efficient manner.
- **RBDM methodology can be the cornerstone for this process by:**
  - Thinking in terms of risk, instead of only in consequences.
  - Selecting work in line with the overall objectives and policies.
  - Determining priority based on risk to personnel and operations.
  - Reducing the amount and urgency of work.
  - Performing as much work as possible in a planned fashion.

Improved Work Selection

- **Risk based work selection will:**
  - Minimize most expensive work – “break-ins.”
  - Reduce overtime and emergency work.
  - Improve labor costs by allowing planners enough time to plan and schedule work in an efficient manner.
  - Improve safety by expanding the timeframe allowed to review job requirements and for operations to prepare equipment.
- **Risk-based work selection will also improve the effectiveness of reliability improvement programs by:**
  - Allowing engineers time to investigate failures through better scheduling.
  - Supporting reliability teams; allowing personnel time to focus on those initiatives instead of addressing unneeded emergency work request.
  - Scheduling preventative maintenance activities based on the risks of failing to perform work.
- **Improved reliability will enhance the efficiency of work execution process by :**
  - Eliminating need to perform work in the first place.
  - Reducing break-in or emergency work.
  - Allowing more time to properly plan and execute work.

Reliability Maintenance Programs

- **Reliability improvement programs can be categorized into two areas:**
  - Proactive - Equipment care programs
  - Reactive - Defect elimination programs
- **Techniques such as TPM®, TQM®, were developed to:**
  - Perform detailed analysis of equipment and systems
  - Develop routine maintenance tasks that would improve equipment performance
- **These are excellent practices and principles, but can be time consuming and provide minimal return in some areas,**
- **Companies can spend countless hours conducting analysis of systems that have:**
  - Little opportunity for improvement.
  - Failures, whose consequences have little impact to plant operations or safety.
  - Existing practical equipment care programs that can easily be utilized.
- **Reliability practices have shifted to risk-based approach to:**
  - Identify critical machinery based on consequence of failure to the system.
  - Optimize asset care programs based on equipment criticality analysis.
  - Prioritize equipment failures based on risk, focusing efforts in areas with the highest impact and return.

Proactive Reliability Maintenance

- **Proactive reliability maintenance or asset care programs is the practice of addressing minor equipment defects with routine corrective tasks.**
- **The purpose of these tasks is to avoid more costly work as the minor defect progresses to a major equipment failure.**
- **Asset care programs can belong to one of three categories:**
  - PM - Scheduled preventative maintenance to reduce the likelihood of failure or inhibit failure mechanisms.
  - PdM - A maintenance response that will be scheduled based on reaching some predetermined condition of the equipment or process parameter being monitored.
  - Prescheduled Maintenance - Response based on some interval - either time, operating hours, or fixed calendar date.
- **In any world class asset care program, you will find two things:**
  - A disciplined analysis process (exact methodology is not so important).
  - And an RBDM process

Optimized Asset Care Programs

- **Best approach is to use RBDM methodologies to optimize the asset care programs.**
- **RBDM will assure that the reliability work performed has the most value to the business by:**
  - Determining criticality of the equipment (optimizes which pieces of equipment require more detailed PM and PdM).
  - Evaluating the failure modes and associated risk (optimize the a degree of PM to be performed on an individual piece of equipment).
  - Optimizing cost and utilization of resources, while still addressing high risk areas.
- **PM and PdM programs are therefore developed to meet business needs and deliver required availability and integrity.**
- **Risk-based asset care programs are supported by TPM® and TQM®, but optimized to utilize these principles in areas of highest risk and biggest return.**

Reactive Reliability Maintenance

- **Even with effective asset care programs, there will be unplanned equipment failures.**
- **Therefore, reactive reliability maintenance or a defect elimination program is needed to address unacceptable equipment failures.**
- **Concerns regarding reliability improvement initiatives include:**
  - Too many issues being addressed at once, with few results or completed mitigations.
  - Priorities based on personal opinion or most visual failure.
  - Efforts being spent to make equipment repairs instead of making system improvements.
- **RBM is key to developing an effective reliability improvement program by evaluating failures to:**
  - Determine if failure is acceptable (run until failure) or if improvements need to be developed.
  - Prioritize failures to focus efforts of limited personnel and resources in areas of biggest return.

Foundation for Continuous Improvement

- **Risk-based reliability improvement programs can be the foundation for a continuous improvement process, which should include:**
  - Process for collecting and collating equipment history data for analysis (computerized maintenance management system [CMMS]).
  - Utilizing risk-based methodology to identify and prioritize concerns.
  - Selecting problems for investigation based on severity of consequence and likelihood of occurrence (risk analysis).
  - Developing a "bad actor" list to focus efforts on top ten items. (It is better to start with less and finish more.)
- **Once a "bad actor" list is established, individual assignments or teams should be formed to investigate failures and develop improvement initiatives.**
- **Teams for investigations can take several forms, including:**
  - Incident investigation teams for large or catastrophic failures.
  - Departmental engineers or craftsman assigned to evaluate monthly key performance indicators (KPIs) or department bad actors list.
  - Ad-hoc multi-department teams to address complex failures.

Continuous Improvement Process

- **Systems must be in place to assure that once the root cause is determined:**
  - Resources are available to develop and implement corrective actions.
  - Management supports initiatives and assures mitigations are implemented.
  - Performance monitoring exists to evaluate effectiveness of corrective action.
  - Mitigation can be applied elsewhere to eliminate systemic problems.
- **As items are eliminated from the "bad actor" list, resources are assigned to address the next high priority concern.**
- **Many problem resolutions fail after the root cause failure analysis (RCFA) process is performed; corrective actions are never developed or implemented.**
- **Due to lack of results, RCFA is underutilized, and the plant returns to reactive maintenance.**
- **Investigation completion and corrective action implementation require structure, discipline, and management support.**

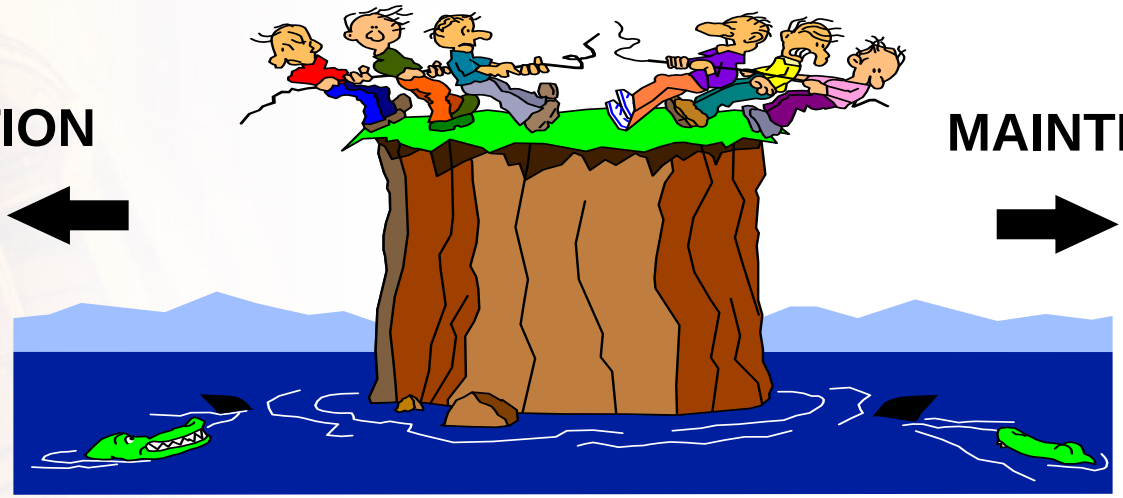
Key Element to World Class Maintenance

- **The "key element" to developing and implementing world-class routine maintenance and reliability programs is to understand and utilize RBDM principles.**
- **Effective utilization of this methodology will:**
  - Allow you to focus on areas that pose the highest risk to your facility.
  - Assure consist decision making in line with company goals and objectives.
  - Provide highest return for efforts.
- **Risk-based methodologies can be applied to:**
  - Turnaround preparation, execution, and optimization.
  - Materials management.
  - Capital project evaluation and development.
  - Risk analysis for capital projects and incident investigation.

Getting Started

We must work together to assure success.

PRODUCTION **MAINTENANCE**



- **Audit existing maintenance work practices to:**
  - Evaluate utilization of Risk-based Methodologies.
  - Compare against Industry Best Practices.
  - Identify gaps or areas for improvement.
- **Develop strategy for improvement.**
- **Work together to close gaps and institute new programs.**

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QUESTIONS

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Backup Slides

Acronyms

- AIChE = American Institute of Chemical Engineers
- API = American Petroleum Institute
- ASME = American Society of Mechanical Engineers
- CMMS = Computerized Maintenance Management System
- OSHA = Occupational Safety and Health Administration
- PdM = Predictive Maintenance
- PM = Preventative Maintenance
- RBDM = Risk-based Decision Making
- RBM = Risk-based Maintenance
- RCFA = Root Cause Failure Analysis
- RP = Recommended Practice
- TPM = Total Productive Maintenance
- TQM = Total Quality Management
- U.S. = United States

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Our consultants are engineers, many with advanced business or engineering degrees, and have advised the world's largest international oil companies on both commercial and technical issues. Additional information about the firm, including a list of representative assignments and consultant resumes, is provided on our website at *www.bakerobrien.com*.

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