Practical SEMS Mechanical Integrity (MI) Program Implementation

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U.S. 877/532-0806 ♦ www.RMPCorp.com

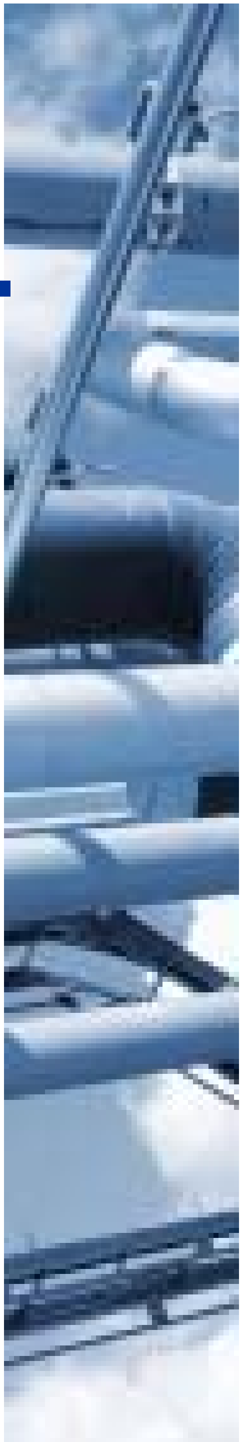
Download Presentation & Handout – www.SEMS1.com/BSEE.Mar15.htm

What is
Mechanical Integrity (MI)?

What is MI?

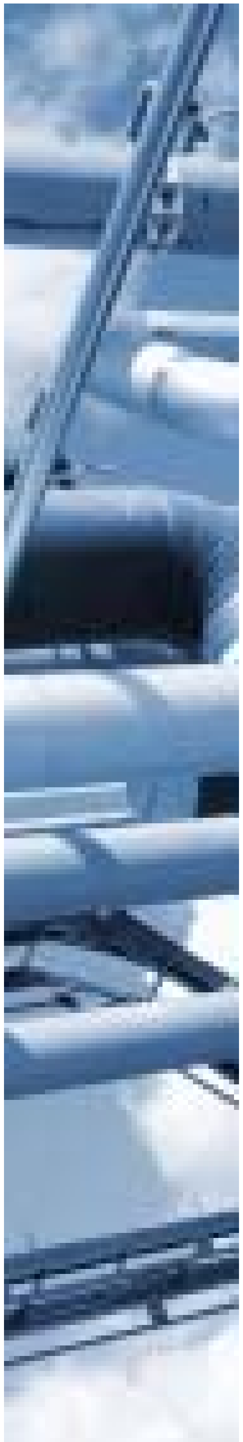
- Key Premise (from CMA Process Safety Code of Management Practices) – "Process equipment that is properly designed, fabricated, installed and operated should provide reliable service – if it is adequately inspected, tested and maintained over the life of the facility."
- MI Definition – Maintaining the design function of structures and equipment
- MI is required by SEMS, RMP, PSM, & State ARP.
- A less-rigorous requirement for simpler RMP and State ARP Programs is called Preventive Maintenance (PM).

What is MI?



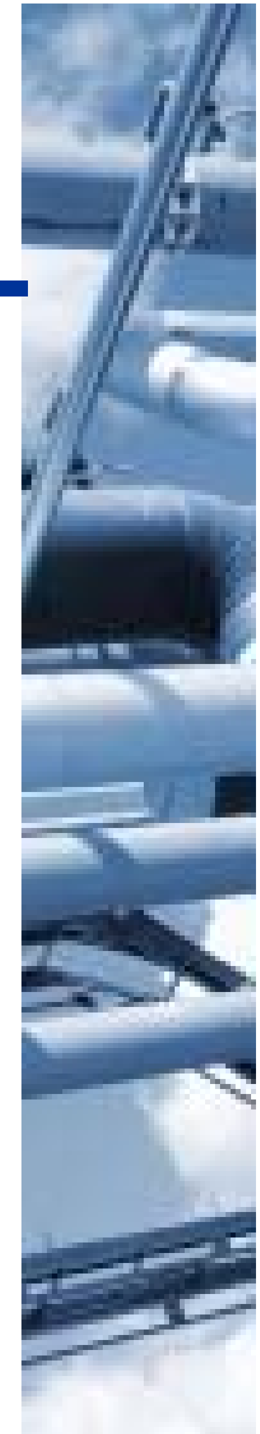
- Preventive Maintenance is a key component of Mechanical Integrity … also Inspection, Testing, & Repair.
- MI can apply to any type of the device or structure; however, for regulated facilities; MI may apply to:
  - Tanks, Pressure Vessels, and Piping
  - BOP and Pressure Relief Systems
  - Emergency Shutdown Systems
  - Rotating Equipment
  - Controls (including monitoring devices & sensors, alarms, & interlocks) (e.g., Gas Detector function & calibration)
  - Any Device That Might be Listed as a Safeguard in a Hazards Analysis
- MI can be used for reliability; however, the focus of PSM, RMP, & SEMS is safety & environmental.

Significant Events Involving Mechanical Integrity Failure



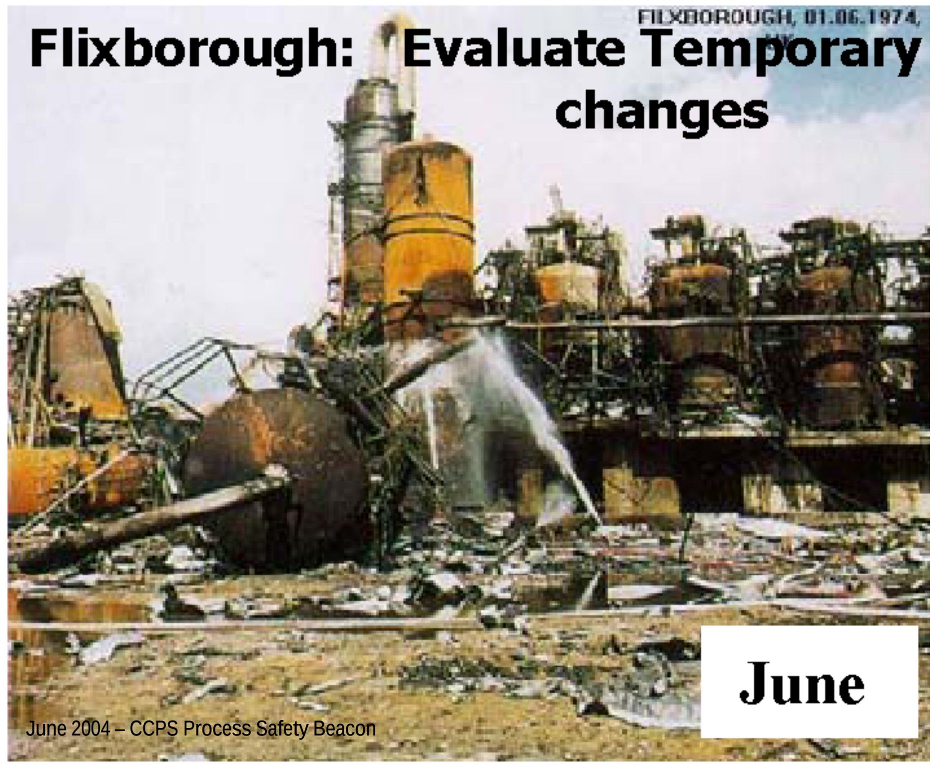
Significant Events Involving MI Failure

- Many of the events that precipitated the formulation of Safety Management System regulations were rooted in a failure of Mechanical Integrity practices.
- These same events provide a platform for helping explain the importance of Mechanical Integrity to Industry.



Examples of Significant Events Flixborough - 1974

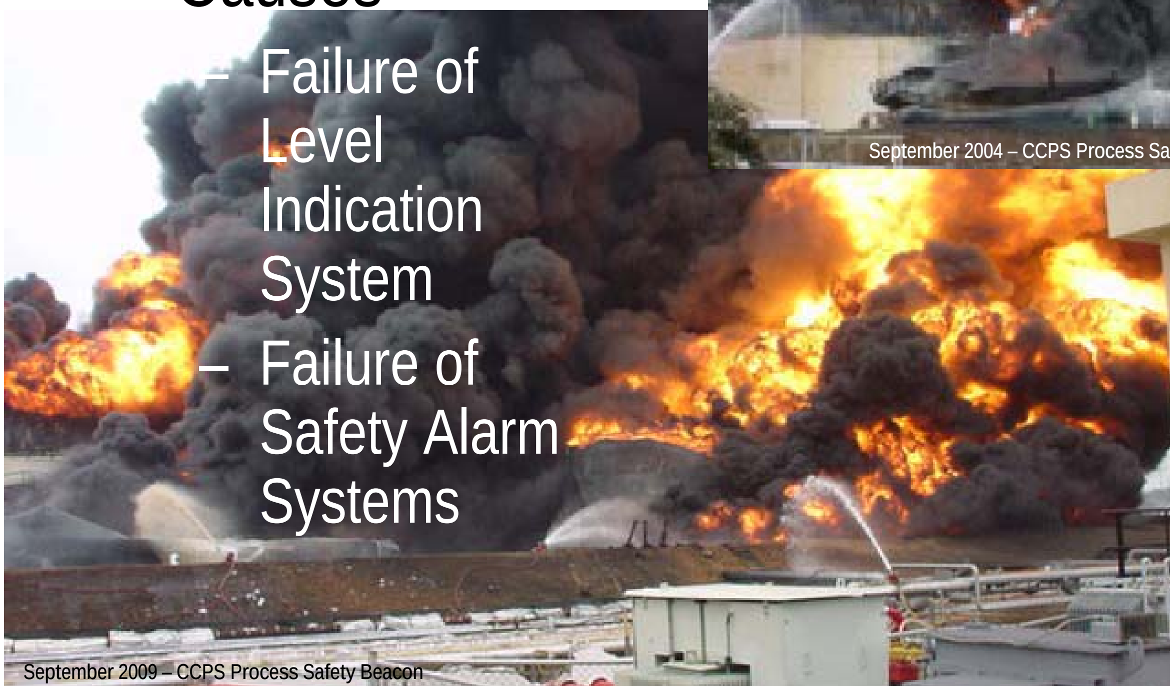
- Cyclohexane vapor cloud generated
  - Cracked reactor vessel
  - Temporary bypass fabricated in plant
  - Bypass failed
  - Significant explosion
  - 28 fatalities & 36 injuries



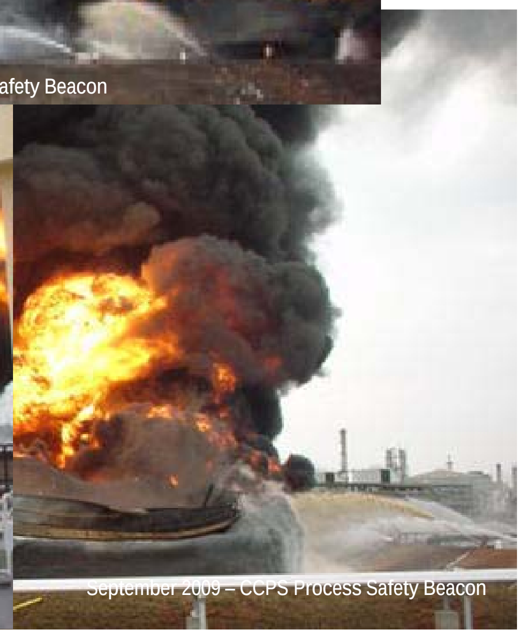
Examples of Significant Events
Flammable Liquid Tank

- Typical Flammable Liquid Tank Overflow Causes
  - Failure of Level Indication System
  - Failure of Safety Alarm Systems

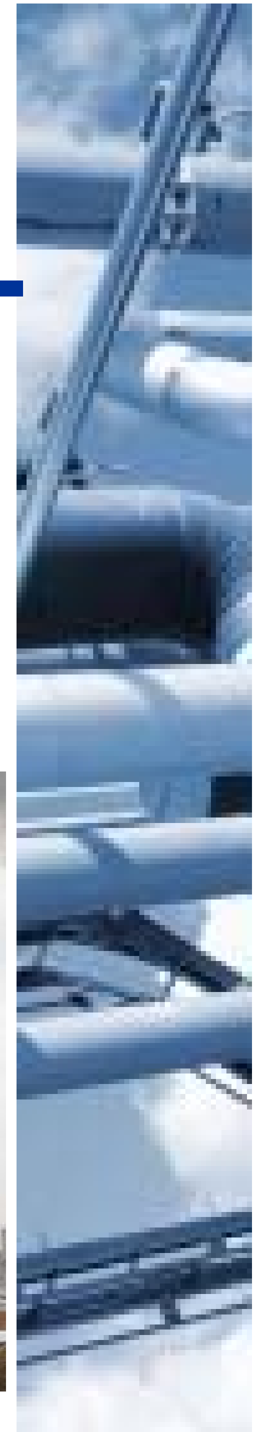
September 2004 – CCPS Process Safety Beacon



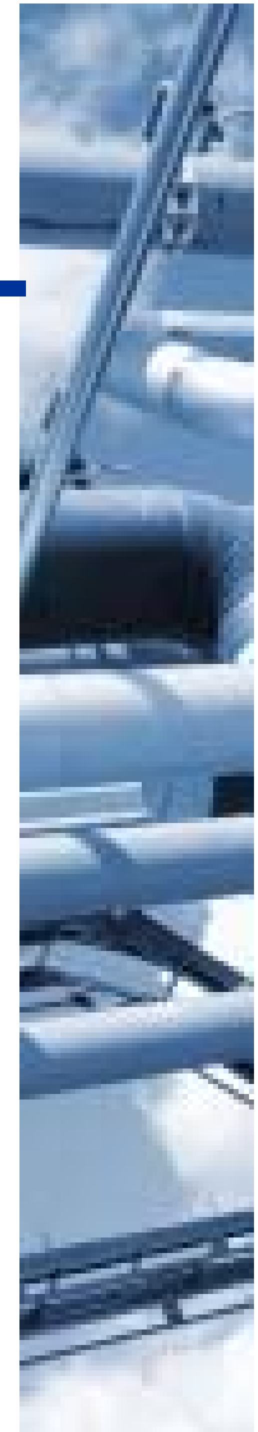
September 2009 – CCPS Process Safety Beacon



September 2009 – CCPS Process Safety Beacon



Examples of Significant Events Texas City - 2005



- During startup of ISOM Unit, overflow of Distillation Tower and Blowdown Drum
  - Valve left closed on liquid to drain from bottom of tower (procedural step omitted)
  - Failure of high and high-high liquid level alarm
    - No documented test methods
  - Level transmitter indicated that liquid level was falling at ~9 feet (actual level – 158 feet)
  - Overflow of flammables ignited by idling truck resulting in 15 deaths and 180 injuries
  - Siting Issues

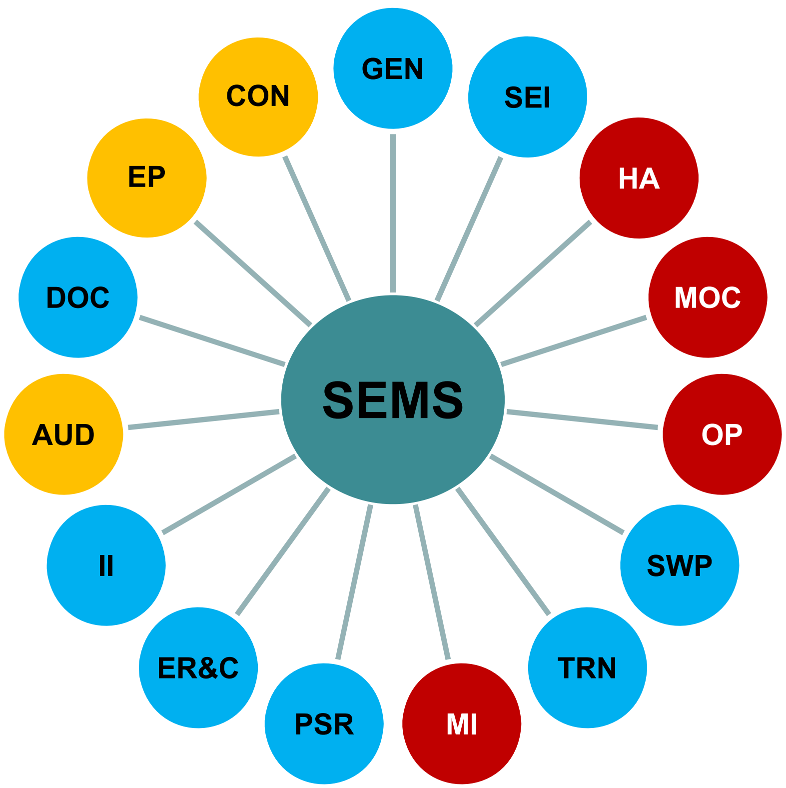
Examples of Significant Events Deepwater Horizon - 2010

- Well Blowout & Failure of BOP to Activate - From BP Deepwater Horizon Accident Investigation Report, 08Sep10
  - "The BOP maintenance records were not accurately reported in the maintenance management system."
  - "The condition of critical components in the yellow and blue pods and the use of a non-OEM part … suggest the lack of a robust maintenance management system for the Deepwater Horizon BOP."
  - The failure of the BOP to actuate when needed was one of the possible contributing factors to the overall consequences of the event.
  - 11 fatalities, 17 injuries, >4 million bbl of oil released

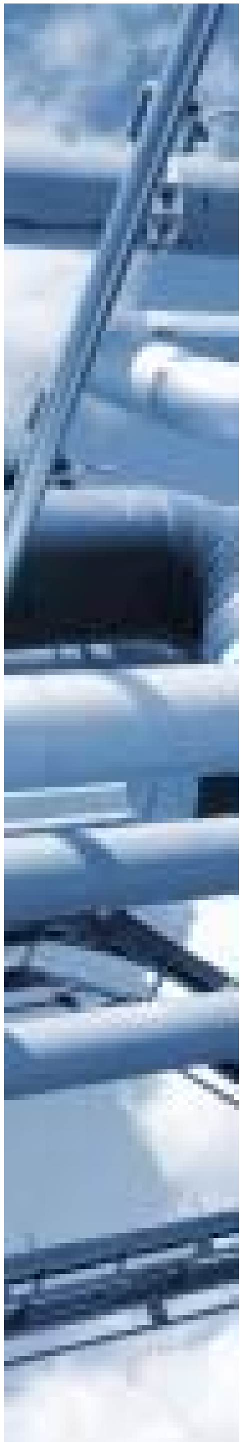

September 2009 – CCPS Process Safety Beacon

MI Regulatory Requirements

SEMS Elements

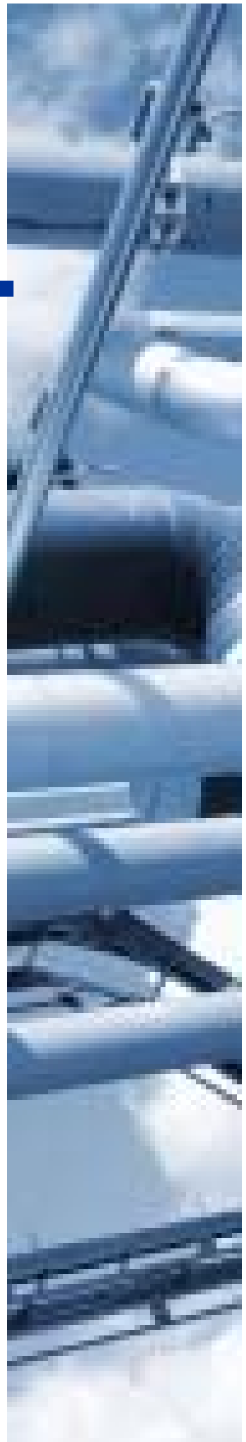


- General Provisions
- Safety & Environmental Information
- Hazards Analysis
- Management of Change
- Operating Procedures
- Safe Work Practices
- Training
- Mechanical Integrity
- Pre-Startup Review
- Emergency Response & Control
- Investigation of Incidents
- Audit of SEMS Elements
- Records & Documentation
- Employee Participation
- Contractor Safety



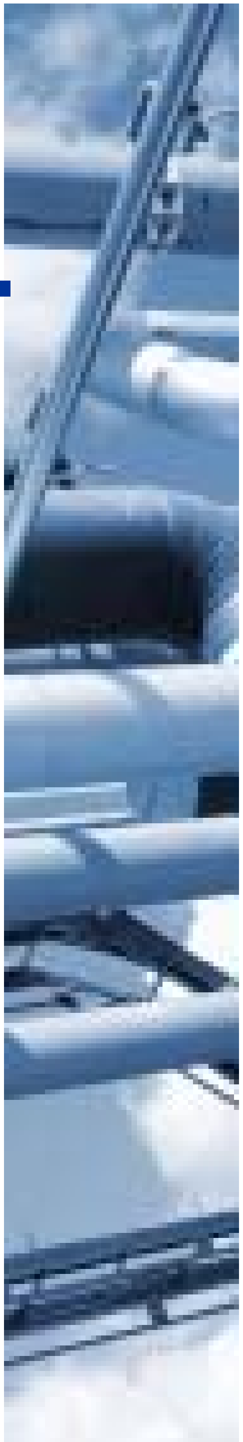
MI Regulatory Requirements

- Mechanical Integrity – 30 CFR Section 250.1916 – Requirements:
  - Establish and implement written procedures to maintain integrity of equipment
  - Training of maintenance & inspection personnel
  - Inspection and tests shall be performed on process equipment
  - Frequency of inspections and tests
    - Manufacturer’s recommendations
    - Good engineering practices



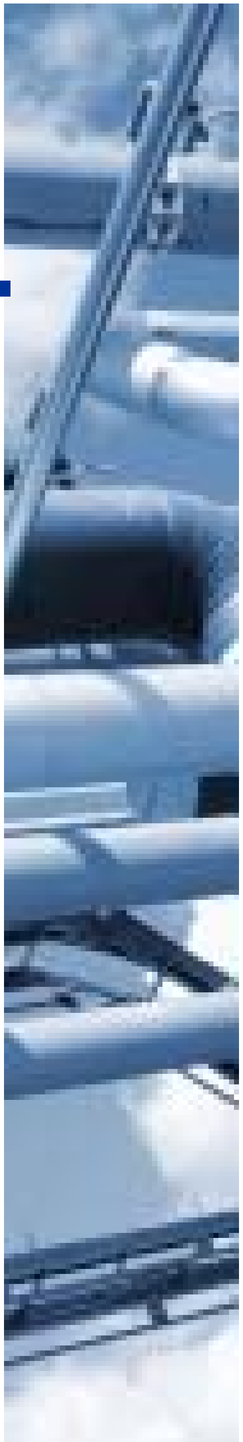
MI Regulatory Requirements

- Mechanical Integrity – 30 CFR Section 250.1916 – Requirements:
  - Documentation
  - Correct deficiencies outside acceptable limits
  - Quality Assurance
    - Ensure fabricated equipment is suitable for process applications
    - Perform checks and inspections to ensure proper installation and consistency with design specifications and manufacturer's instructions
    - Ensure that maintenance materials, spare parts and equipment are suitable for the process applications for which they are used
- SEMS is a "performance-based" regulatory requirement!



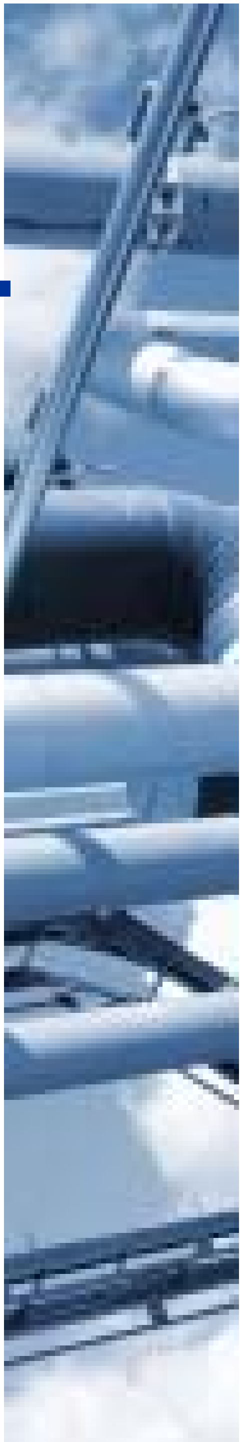
MI Regulatory Requirements

- Recognized/Generally-Accepted Industry Standard Governing Documents:
  - API 510 / ASME VIII – Pressure Vessels
  - API 653 / API 650 – Storage Tanks
  - API Specification 5L – Specification for Line Pipe
  - API 520 / 572 / NFPA 30 – Relief & Vent Systems
  - API 14A – Specifications for Subsurface Safety Valve Equipment
  - API 14B – Design, Installation, Repair and Operation of Subsurface Safety Valve Systems
  - API 14H – Installation, Maintenance, and Repair of Surface Safety Valve Systems and Underwater Safety Valves Offshore
  - API 16C – Choke and Kill System
  - API 16D – Control Systems for Drilling Well Control Equipment and Control Systems for Diverter Equipment
  - API 16Q - Design, Selection, Operation and Maintenance of Marine Drilling Riser Systems



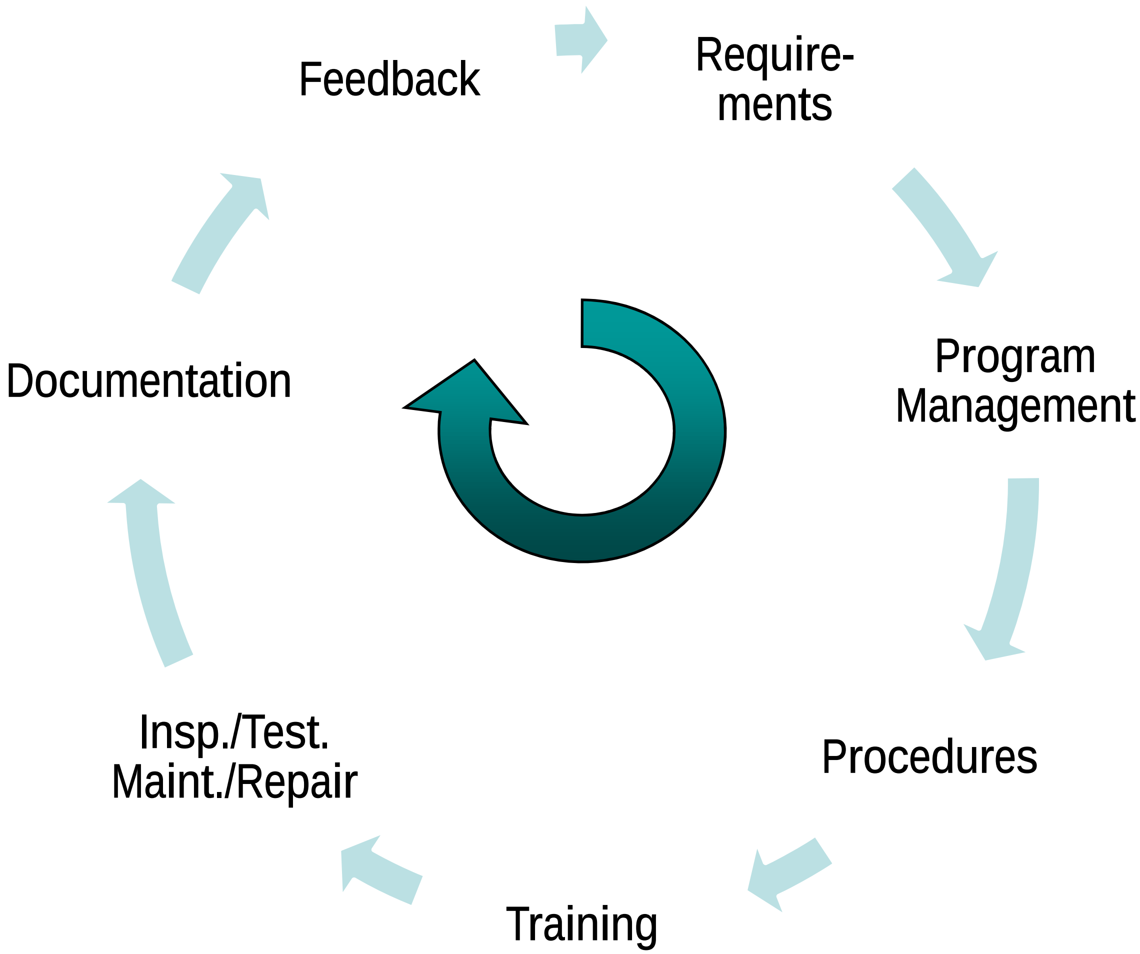
MI Program Elements & Program Formulation

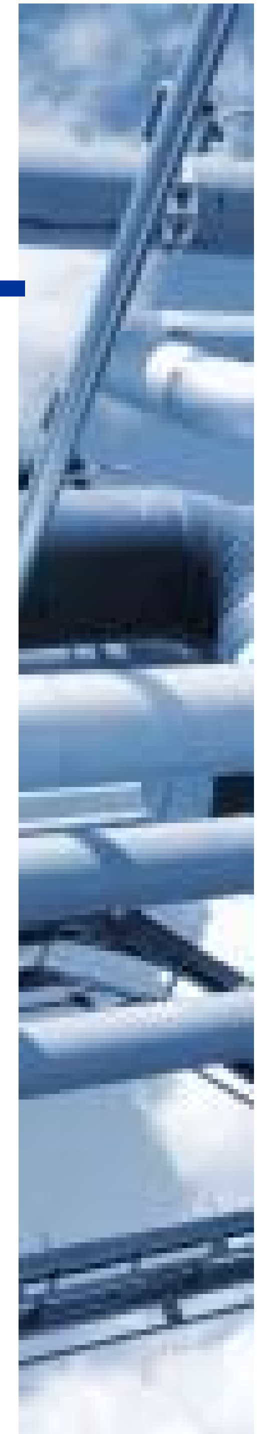
MI Program Key Responsibilities



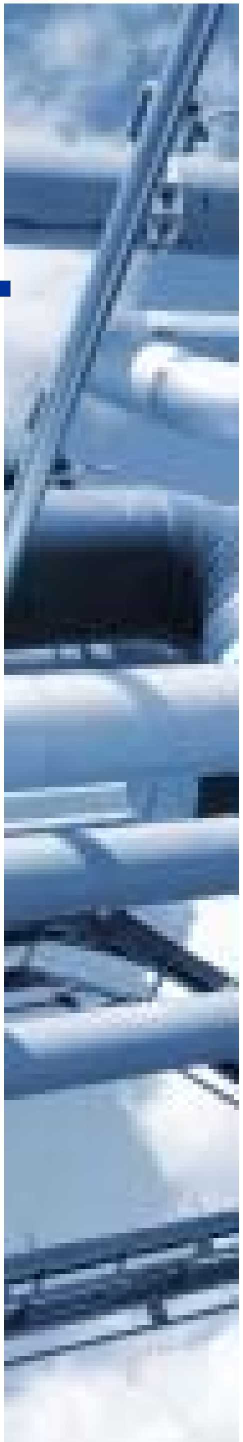
- Ensure that there is an established and implemented written procedure to maintain on-going integrity of process equipment.
- Ensure that each Employee or Contractor involved in maintaining the on-going integrity of process equipment is given an overview of that process and its hazards. Ensure that the Employee can perform the job task in a safe manner.
- Perform regular inspection and tests of equipment and perform the required maintenance work. Maintain inspection, testing, and maintenance records.

MI Program Elements





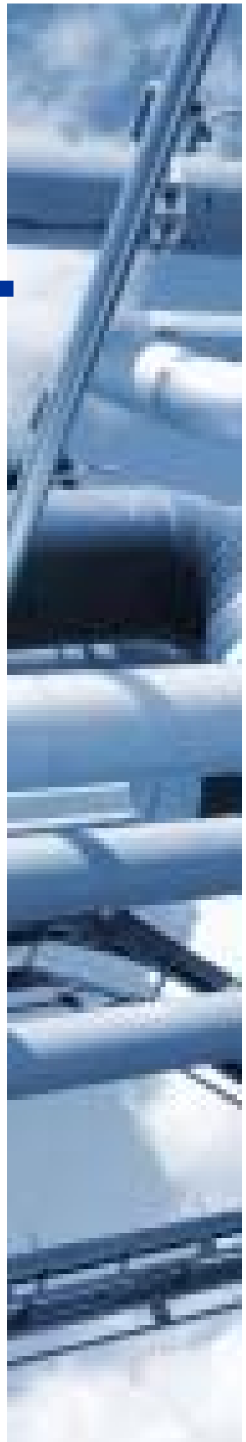
MI Program Elements



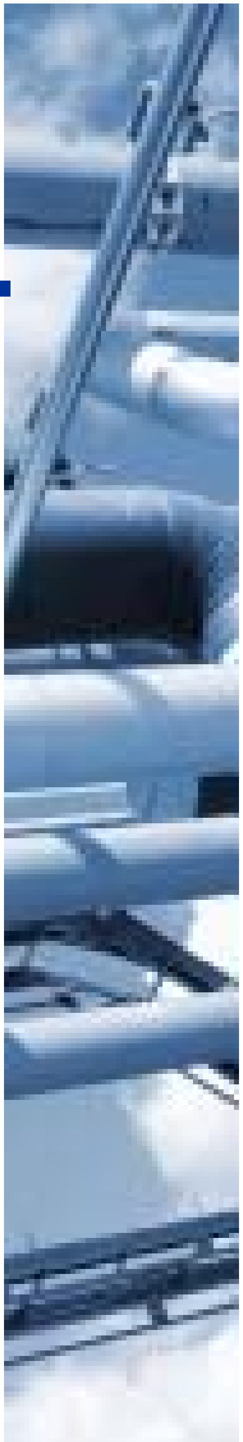
- Key MI Program Elements:
  - Definition of Requirements & Priority (Facility/System/Equipment)
  - Management of Program
  - Procedures
  - Training
  - Inspection/Testing/Maintenance/Repair
  - Documentation (e.g., daily/weekly/monthly checklists)
  - Feedback Mechanism

MI Program Elements

- Example Equipment to be Included in the Program:
  - Pressure vessels and storage tanks
  - Piping systems (including piping components such as valves)
  - BOP, relief and vent, systems and devices
  - Emergency shutdown systems
  - Controls (including monitoring devices & sensors, alarms, and interlocks) (e.g., Gas Detector Function & Calibration)
  - Pumps (and other rotating equipment)



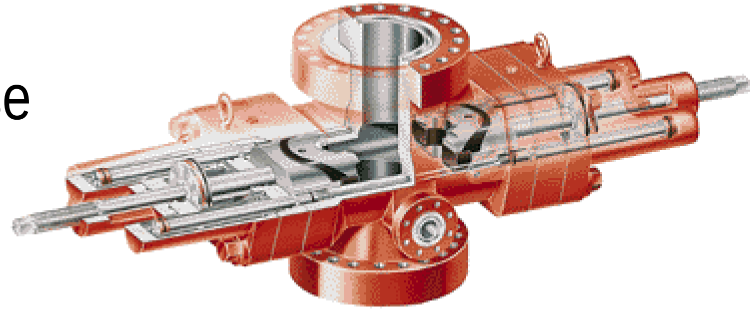
MI Program Formulation



- Testing/Maintenance Activities/Frequencies – Start with industry best practices and adjust based on field observation
- Equipment manuals and suggested maintenance tasks/frequencies
- Hazards Analysis/LOPA Safeguards and Causes can identify critical safety devices
  - added system of checks and balance to ensure critical safety devices PM/testing were addressed and work orders are completed.

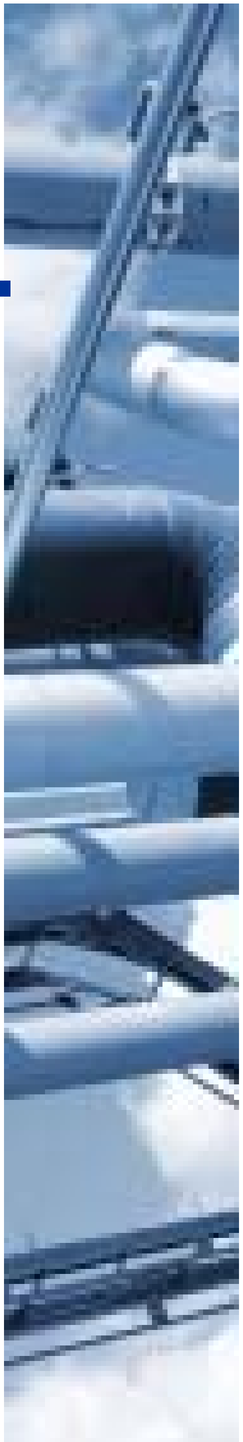
MI Program Formulation - BOP

- Example of Manufacturer Recommended Maintenance
  - ➢ Packer should be inspected weekly, after pressure test, between wells, after shipping, and in the event of a packer leak.
  - ➢ Top ID lip seal should be replaced at each between-well servicing.
  - ➢ Every two years, or as required by the appropriate regulatory agency, completely disassemble the BOP.
  - ➢ Using 1500 psi operating system pressure, open/close BOP 20 times.



U Blowout Preventer

- Correlate to API 16C, 16D, & 16Q



MI Program Formulation - SSV

CAMERON WILLIS

XI. Periodic Maintenance

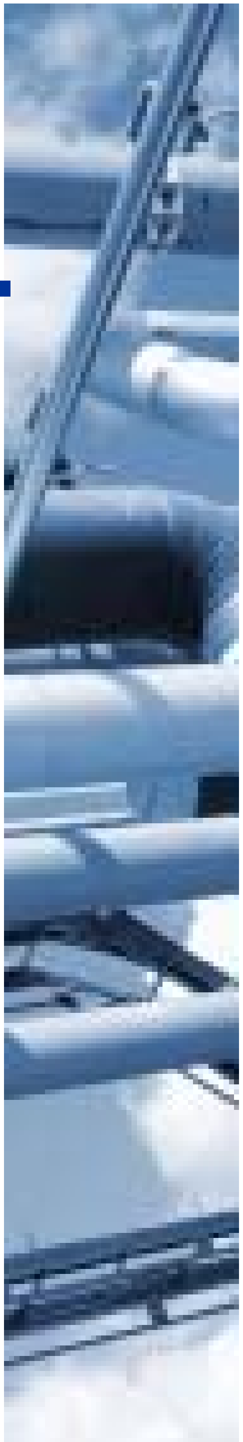
The following maintenance schedule is recommended for normal operations:

When actuator seals are replaced.	Inspect pistons, actuator head, actuator cap and top shaft.
Twice a month.	Close and open SSV. Operation should be smooth and consistent in both directions.
Every month.	Inspect safety head and control line fitting for leaks. Remove any debris from fitting.
Every 6 months.	Visually inspect for external damage such as dents, scratches, etc. If scratched or chipped, touch up with paint to prevent rust. If dented, disassemble and inspect actuator to ensure the damage does not affect the actuator's performance.
At least every 12 months or when leakage occurs.	Replace seals.
Every five years or when leakage occurs.	Replace diaphragm, seals, and Polypak.
As required following rupture or damage.	Replace rupture disc.
As required.	Clean debris from vent or breather holes.

Note: In order to maintain the traceability requirements, all certified replacement parts must be documented and referenced in writing to each individual SSV Actuator by its serial number.

NO EXCEPTIONS

Use the API 6A-Appendix L SSV Failure Report form for reporting failures.



MI Program Formulation - SSV

API 14 B – Design, Installation, Repair and Operation of Subsurface Safety Valve Systems

E.1 Procedure for testing installed surface-controlled subsurface safety valves — Standard depth

E.1.1 Record the control pressure.

E.1.2 Isolate the control system from the well to be tested.

E.1.3 Shut the well in at the wellhead.

E.1.4 Wait a minimum of 5 min. Check the control line for loss of pressure, which may indicate a leak in the system.

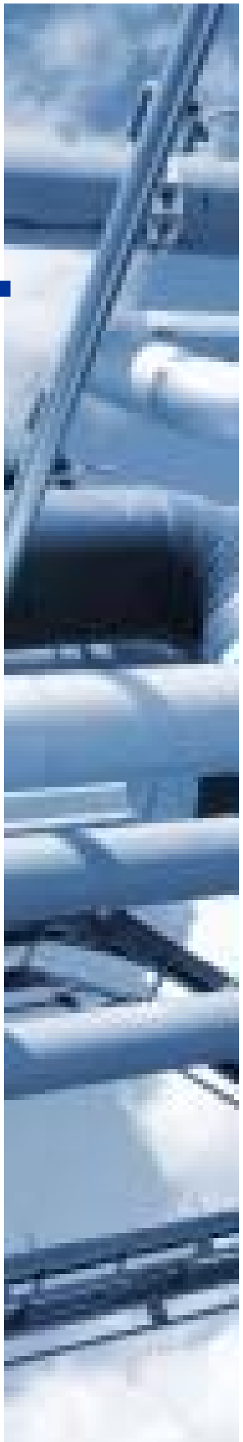
E.1.5 Bleed the control line pressure to zero to shut in the SCSSV. Close the control line system and observe for pressure buildup, which may indicate a faulty SCSSV system.

E.1.6 Bleed the pressure off the wellhead to the lowest practical pressure and then shut in the well at the wing or flow-line valve. When possible, bleed flow-line header pressure down to or below wellhead pressure and observe the flow-line and wellhead for a change in pressure, which would indicate a faulty surface valve. Any leaks through the wing or flow-line valve shall be repaired before proceeding with the test.

E.1.7 Conduct leakage test and document results. For gas wells, flow rates can be computed from pressure build-up by the following formulae.

$$q = 17\ 07\left(\Delta \frac{p}{Z}\right)\left(\frac{1}{t}\right)\left(\frac{V}{T}\right) \qquad \text{(SI units)}$$

$$q = 2\ 122\left(\Delta \frac{p}{Z}\right)\left(\frac{1}{t}\right)\left(\frac{V}{T}\right) \qquad \text{(USC units)}$$



MI Program Formulation - SSV

API 14 H – Installation, Maintenance, and Repair of Surface Safety Valve Systems and Underwater Safety Valves Offshore

6.3.2 Testing

Recommendations for testing SSVs/USVs following onsite repairs are stated below. Testing may be limited according to onsite repairs performed.

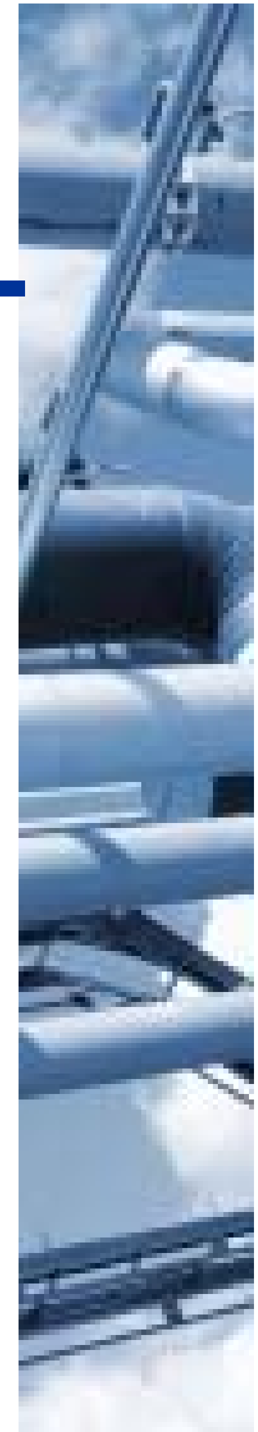
6.3.2.1 *Onsite repairs where the SSV/USV actuator pressure containing seals are broken or disturbed*. The SSV/USV actuator should be tested for leakage using the SSV/USV actuator media. Test pressure should be normal field operating supply pressure. No leakage is allowed.

6.3.2.2 *Onsite repairs that might affect the alignment of the gate (plug) and seats*. The SSV/USV valve should be opened and checked visually or, if possible, with a drift mandrel for proper alignment.

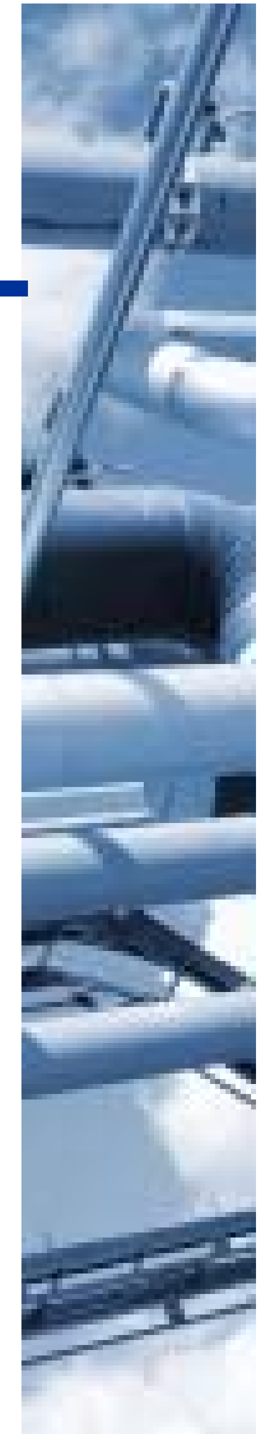
6.3.2.3 *Onsite repairs that might affect operation of the SSV/USV*. The complete assembly should be tested for operational integrity; cycle the assembly fully open and fully closed three times with the SSV/USV valve body at ambient pressure or at wellhead shut-in tubing pressure (SITP) with no flow. (If equipment through the first downstream block valve will not withstand full wellhead SITP, conduct this test at the working pressure of the downstream equipment.)

6.3.2.4 *Onsite repairs that require breaking or disturbing a pressure containing seal in the SSV/USV valve*. The SSV/USV valve seals should be tested for leakage with the SSV/USV in a fully or partially open position and with the SSV/USV valve body exposed to maximum wellhead SITP. Test duration should be a minimum of 5 minutes with no leakage. (If equipment through the down-stream block valve will not withstand full wellhead SITP, conduct this test at the working pressure of the downstream equipment.)

6.3.2.5 *Onsite repairs that might affect the SSV/USV valve seat seal*. The SSV/USV valve seat should be tested according to 6.1 or 6.2 following the test prescribed in 6.3.2.4 above.



MI Program Formulation - Modifications



- Premature failures should be evaluated or investigated as part of the incident investigation/near-miss procedures. This will help modify the PM frequencies to account for specific environmental factors such as sand erosion or corrosion.
- Isolation valves in particular need to be evaluated during periodic inspections to protect against premature failure.

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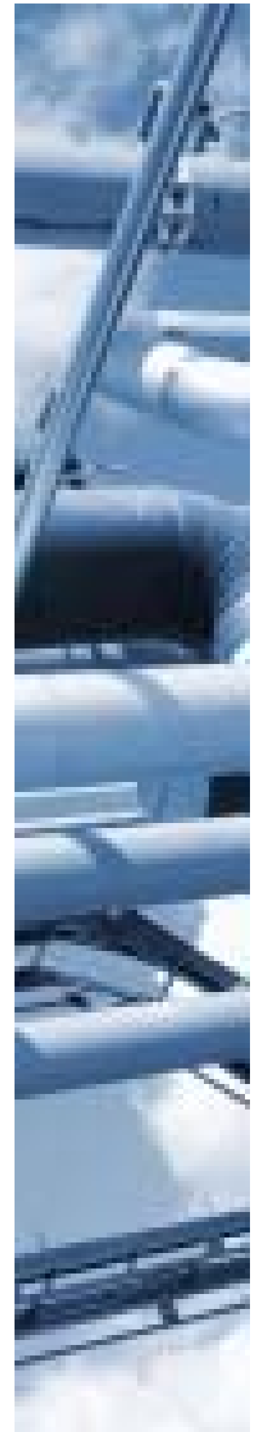
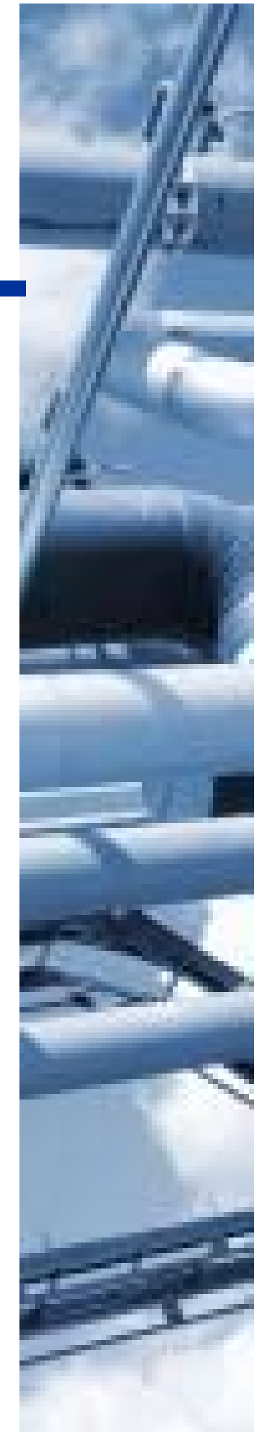
MI Program Monitoring, Auditing, & Common Deficiencies

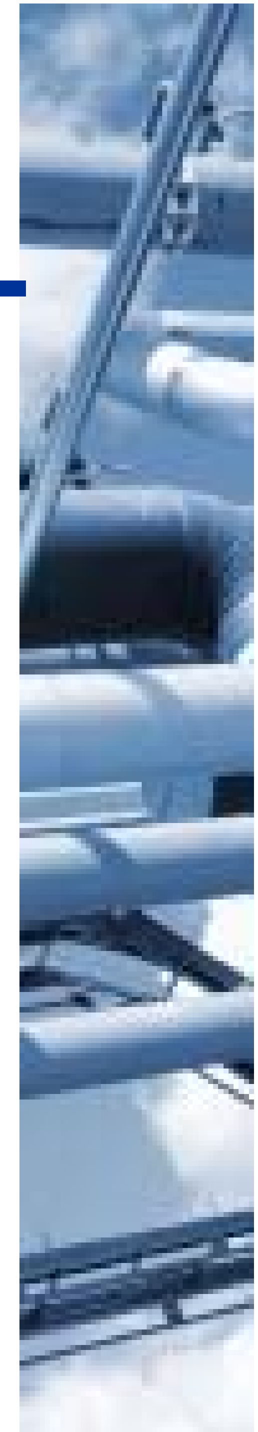


MI Program Monitoring Elements

- Key Elements of An Effective/Efficient MI Process
  - Adequate Definition of Coverage
  - Accurate Determination of Requirements for:
    - Procedures
    - Training
    - Inspection
    - Maintenance
    - Quality Assurance
  - Efficient Scheduling of Resources
  - Effective Reporting System
  - Performance and Quality Audits
  - Experienced, Professional Project Management and Staff



MI Program Monitoring Elements



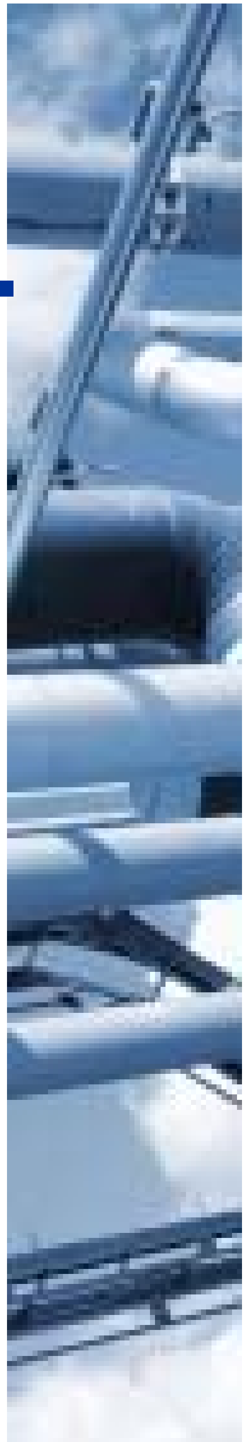
- Typical Documentation
  - Written Procedures For:
    - System Identification
    - Inspection Methodology
    - Training Requirements
    - Maintenance Response
    - Reporting
  - System/Equipment Information Packages That Provide:
    - System Identification / Basis For Inspection Needs
    - Supporting Documents / Drawings

MI Program Audit Approach

- Mechanical Integrity Program Auditing Challenges
  - Breadth of Program for Larger Facilities
- MI Audit Objectives
  - Definition of Requirements & Priority (Facility/System/Equipment)
  - Management of Program
  - Procedures
  - Training
  - Inspection/Testing/Maintenance/Repair
  - Documentation (e.g., daily/weekly/monthly checklists)
  - Feedback Mechanism
  - Interface Between Field Locations and Central Offices
- Key Objective is to Gauge MI Program Effectiveness

MI Program Audit Approach

- Audit Focus
  - Identify a Key Component (e.g., HA Safeguard).
  - Review All Inspection/Testing/Maintenance requirements associated with that equipment.
  - Review 5 Years of records to verify that all MI elements were performed.
- Audit Techniques
  - Use of Audit Protocol
  - Documentation Review
  - Interview
  - Audit Documentation

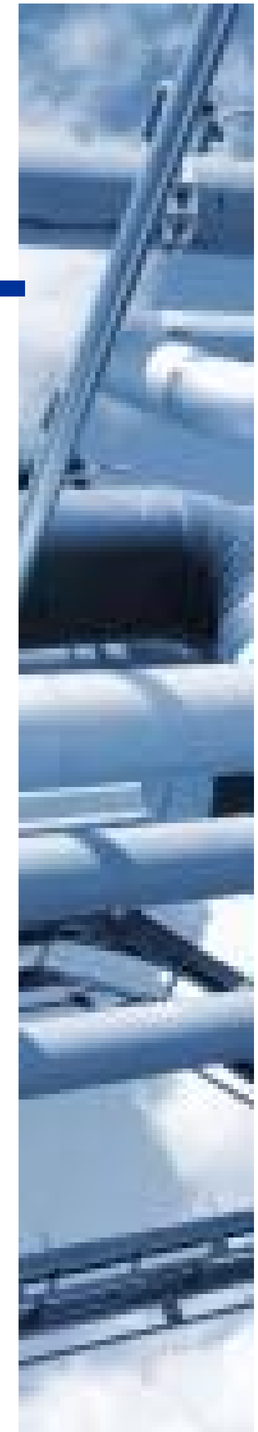


MI Program Audit Approach

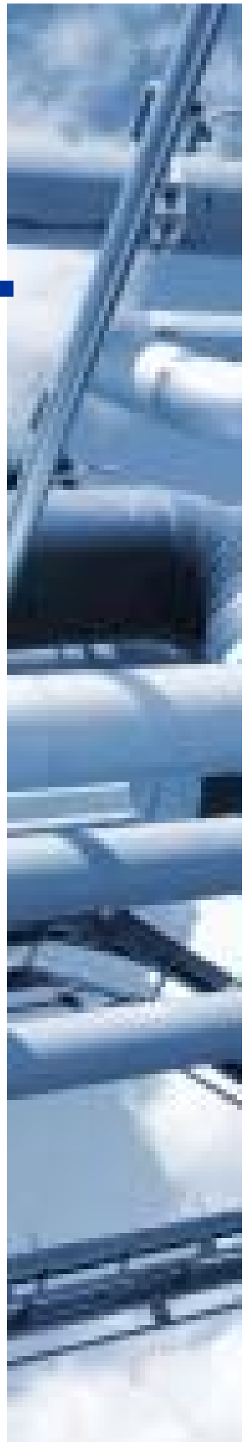
- Site Walkdown to Verify that Safety Equipment has been Tested and Appears Fit-For-Service

Common Deficiencies

- Written procedures related to the ongoing integrity of the process not available, not complete, or not implemented
- Inspections/maintenance not occurring or inspection/maintenance frequency not consistent with industry standards or best practices
- Equipment deficiencies not corrected in a safe or timely manner
- Facility relies on a Contractor and does not have a written preventive maintenance schedule that it is committed to
- MI activity NOT DOCUMENTED!!



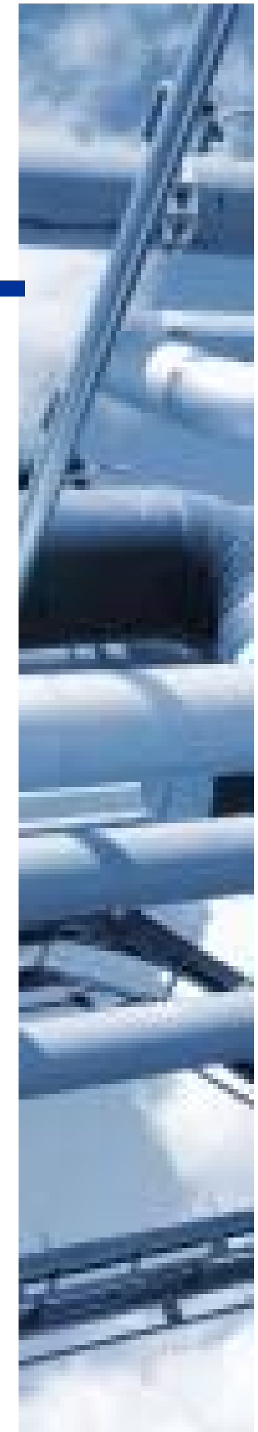
Agency Insights from Audits of SEMP Implementation



Most Critical MI Elements:

- Testing and PM of Safety Instrumented Systems (all items on SAFE Chart)
- Testing and PM of Emergency Support Systems ESS
  - LEL gas detections system
  - Thermal, flame, & smoke fire detection systems
  - Fire loop detection and suppression activation
  - Spill containment features and systems
  - Emergency Shutdown ESD
  - SSSV's

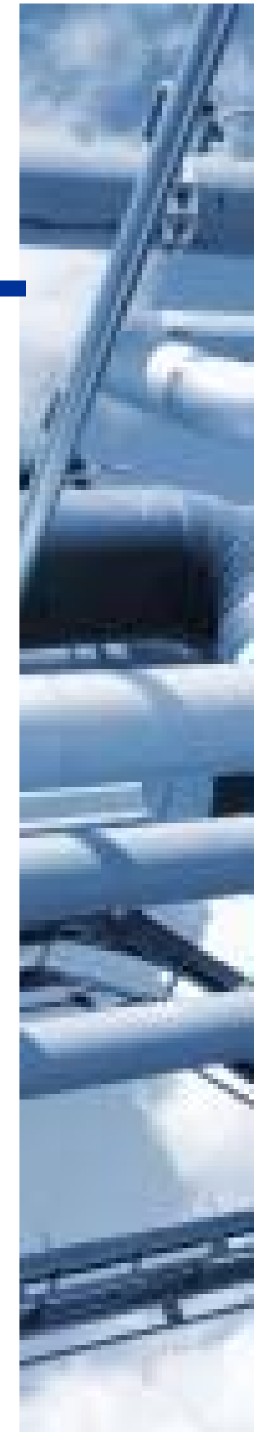
Agency Insights from Audits of SEMP Implementation



Most Critical MI Elements (continued):

- Testing and PM of Other Support Systems
  - Lifesaving & escape or abandonment systems and equipment
  - Fixed firefighting system – firemain, pump, deluge, and stations
  - Auxiliary or emergency power
  - Pressure relief devices and system including flare.
  - Control air system

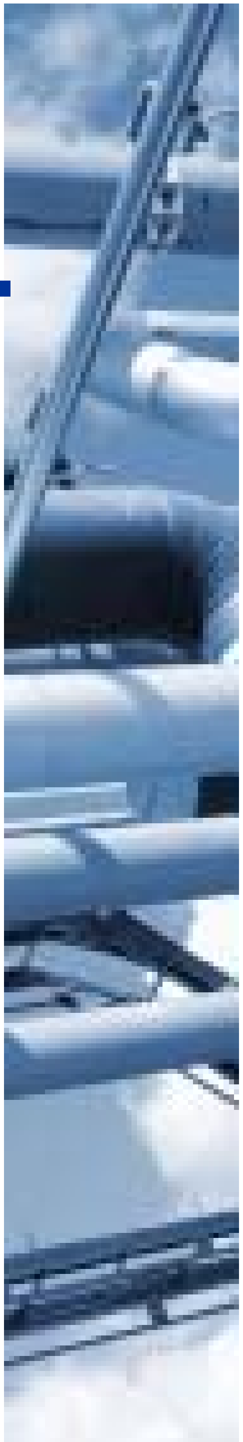
Agency Insights from Audits of SEMP Implementation



Most Critical MI Elements (continued):

- Tank and Pressure Vessel integrity
- Piping Integrity and corrosion monitoring program
- Electrical system integrity and PM
- Integrity of steel structure including decks, ladders, catwalks, & railings & coatings
- Long maintenance backlogs
- Use of safety walkdowns to ID hazards and fitness for service problems

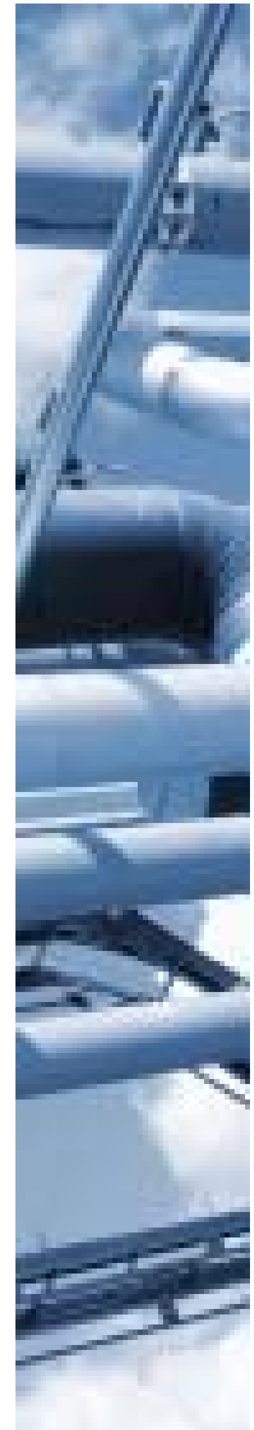
Agency Insights from Audits of SEMP Implementation



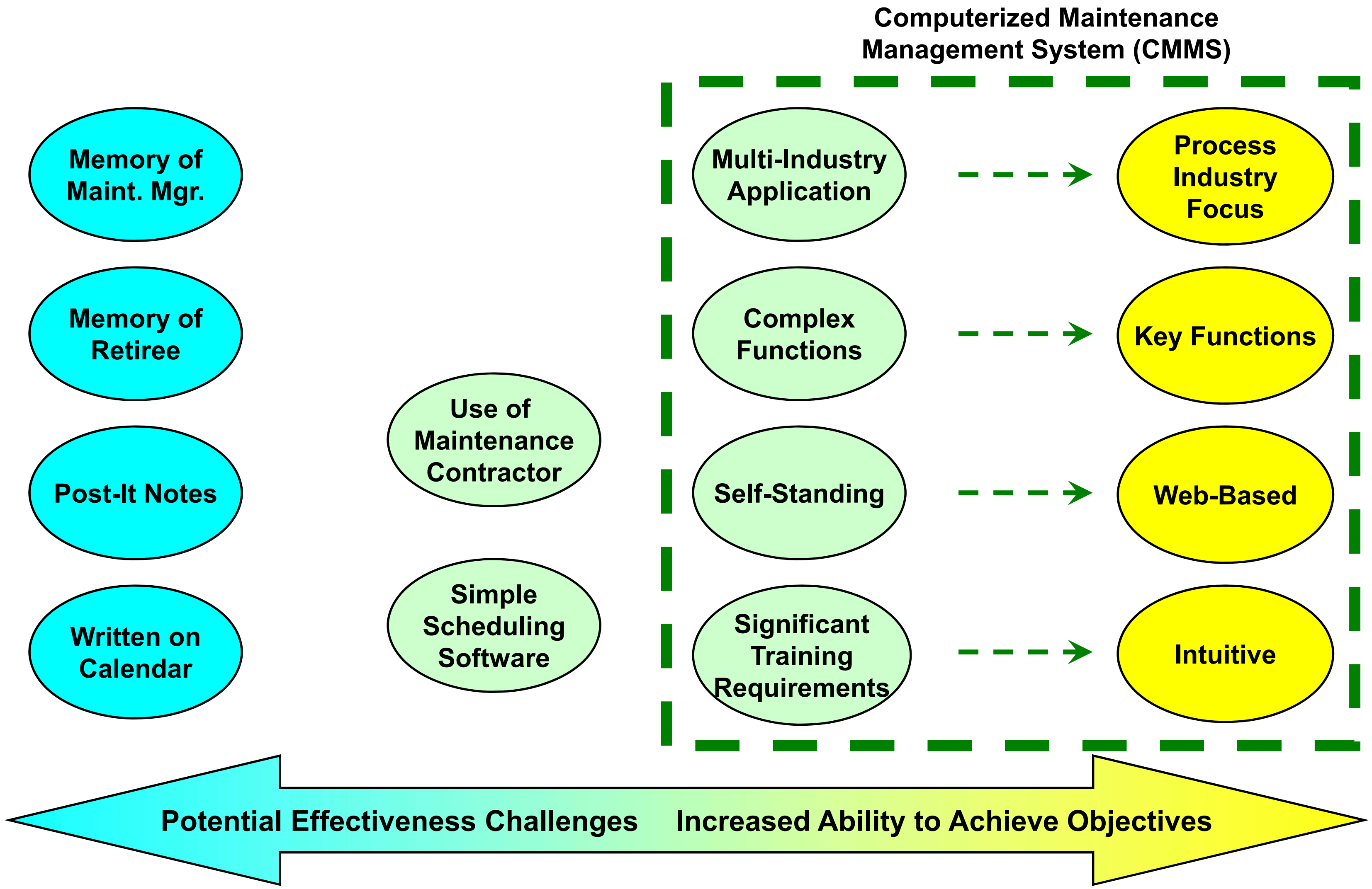
Documentation Tips: The CMMS helps build & tie together MI Programs.

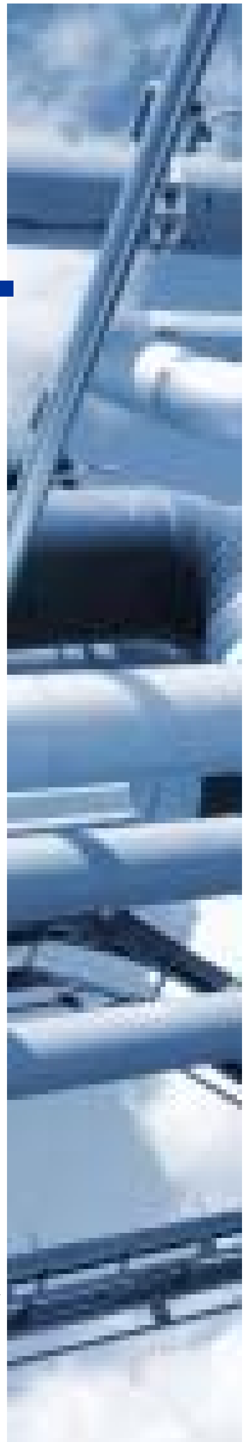
- Use existing programs and methods by agency or field, but centralize maintenance scheduling with CMMS to capture concurrent activity.
- Monitor worklist backlog. Required test inspections need to get done on required schedule. Repair items should have a max limit for completion.
- CMMS should eventually give a true prediction of all maintenance and repairs that must occur at a major shutdown.
- The equipment and systems that have routine PM scheduled by CMMS should also have procedures developed and may be the basis for critical spare parts lists.
- Maintenance responsibilities, detailed information, records, and other management tools are retained by specialists.

MI Implementation



MI Implementation Spectrum



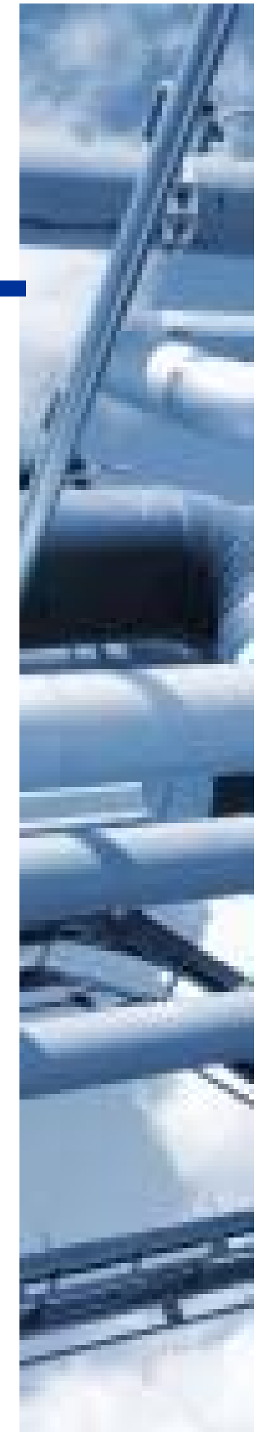


MI Implementation Spectrum

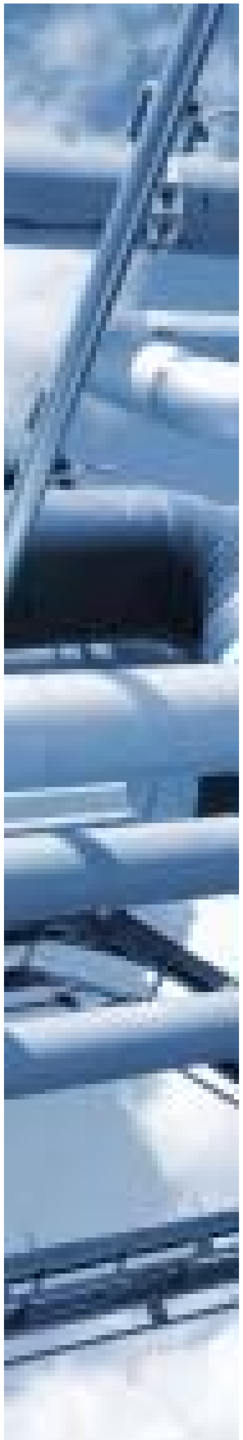
- Wide Varieties of Approaches to Implement MI Exist
  - Post-It Notes on Calendar
  - Computerized Maintenance Management System (CMMS)
  - Maintenance Contractor
- Key Functions and Tracked Data
  - Manufacturer-Recommended Testing Frequency
  - Manufacturer-Recommended Inspection Frequency
  - Manufacturer-Recommended Preventive Maintenance (PM) Frequency
  - Log of Testing/Inspection/PM
  - Observations from Testing/Inspection/PM
  - Procedures for Performing the Required Action

MI Implementation Spectrum

- Key Functions and Tracked Data (continued)
  - Safety Precautions
  - Parts Needed/Used
  - Schedule and Assignment for Next Testing/Inspection/PM
  - Reminder System
  - Work Order Generation
  - Modifications to Testing/Inspection/PM Frequencies/Activities
  - Planning
  - Key Performance Indicators (i.e., WO life, actual frequency, etc.)
  - Spare Parts Management

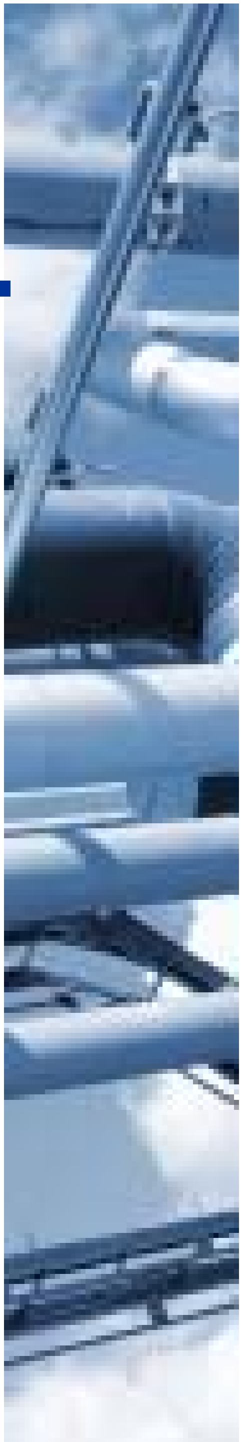


Tips, Conclusions, & Organizing an Effective SEMS Program



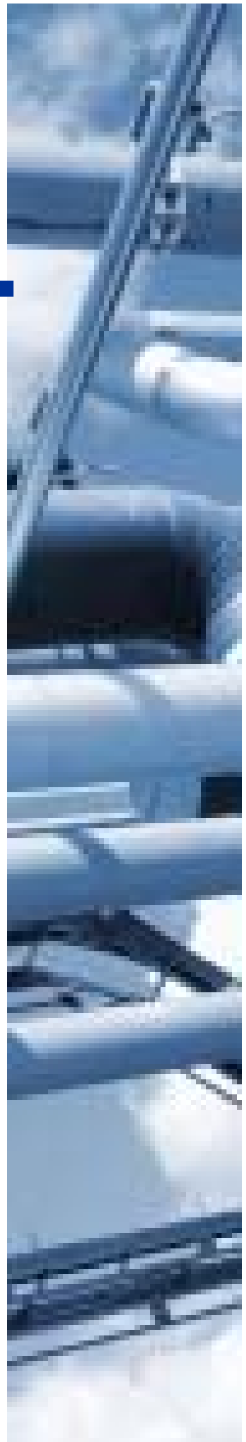
MI - Tips & Best Practices

- Mechanical Integrity - Tips & Observed Best Practices
  - Organization & Internal Accountability
  - Availability of Equipment Specifications
  - Clear Definition of Requirements
  - Use of Software for Tracking, Generation of Work Orders, Documentation, & Records Retention



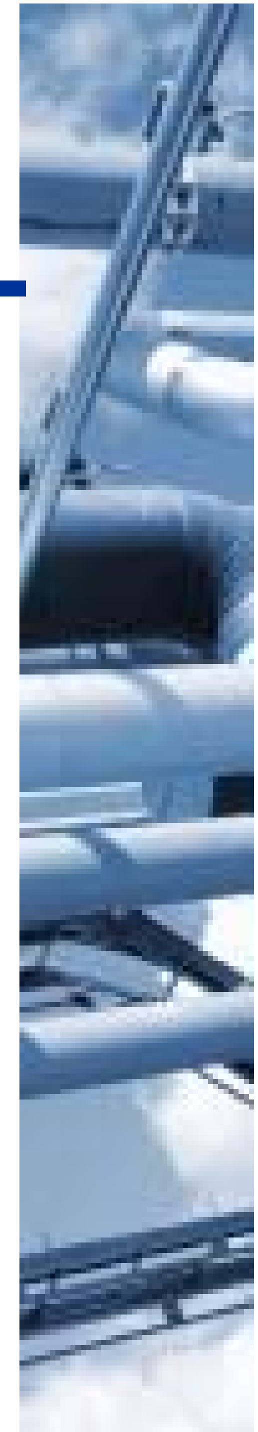
MI - Tips & Best Practices

- Mechanical Integrity - Tips & Observed Best Practices (continued)
  - Fix-at-Failure Maintenance Strategy may not be acceptable
  - Must have a Preventive Maintenance Program based on manufacturer recommendations or best engineering practices
    - If a Contractor is used, you still must develop a written schedule of what he is replacing, overhauling, cleaning, etc., and on what frequency.



Summary

- MI is an important issue for managing the health & safety of personnel, the public, and the environment. Hence, a high quality, formal MI Program is a key element for any Safety Management System.
- MI is a known "challenge" for the process industries, and an important audit element.
- MI Program deficiencies are one of the most frequently issued SMS Citations.
- As well as its safety importance, balanced application of MI is good for business.



Questions?

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