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Why Is Mechanical Integrity So Tough?

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Introduction

The Mechanical Integrity (MI) element of OSHA's Process Safety Management (PSM) Standard [29 CFR 1910.119(j)] has been a difficult element for many facilities to implement. The results of PSM audits by OSHA have consistently demonstrated that MI is a PSM element receiving a large number of citations at most facilities. In some cases, it has been the last PSM element to be fully addressed. This is not to say that inspection, testing, and preventive maintenance programs do not exist at PSM-covered facilities, nor that the maintenance programs at these facilities are "breakdown-only" programs. Preventive and predictive maintenance programs have existed in the chemical/process industry for many years. What have been lacking in some cases are complete integrated MI management system programs that address all of the sub-elements of MI, as it is defined in the PSM Standard. There are several reasons for this situation:

- The MI element of the PSM regulations is written in very broad, performance-based language – even more so than the remainder of the PSM Standard. Interpretation of these broadly stated MI requirements and the matching of these requirements to actual facility policies, practices, and procedures can be a difficult process.
- There is still a distinct impression by some that MI means only preventive maintenance and therefore MI is assigned solely to the Maintenance Department/Group. Actually, because MI includes a wide variety of tasks and activities, the responsibilities for MI activities are spread widely across the facility and many of these personnel may not realize that their job includes an activity that is a regulated part of the MI program.
- MI activities cover the entire life cycle of the covered equipment, not just the ongoing maintenance activities, and therefore many requirements of the MI element may not be completely implemented.
- Currently, there is no overall industry-published, consensus guidance on establishing and implementing a MI program (Note: AIChE/CCPS plans to help rectify this situation by publishing a comprehensive guidelines book on MI in 2005).

This article will explore these issues, including the interpretation issues that confound many sites, the responsibilities of various site personnel for executing MI activities, and typical weaknesses in MI programs. It is hoped that the information contained herein will clarify these points and thereby help sites to improve their MI programs.

Interpretation of the MI Element of the PSM Standard

Applicability. The PSM Standard states in 29 CFR 1910 .119(j)(1) that the MI element applies to the following process equipment:

- Pressure vessels and storage tanks;
- Piping systems (including piping components such as valves);
- Relief and vent systems and devices;
- Emergency shutdown systems;
- Controls (including monitoring devices and sensors, alarms, and interlocks) and,
- Pumps.

OSHA's wording of the Standard may have caused some confusion since it appears to be an incomplete list of equipment. Most of the equipment types listed above are self-explanatory, however, several clarifications are necessary;

- Pressure vessels that are not registered vessels and are operated at less than 15 psig should also be included in the MI program if they contain PSM-covered materials.
- Heat exchangers are either pressure vessels or components in a piping system, and therefore should be included in the MI program if they cool or heat PSM-covered materials.
- Piping system components includes any mechanical device that is installed in-line in the piping system and is exposed to the PSM-covered materials inside the piping, e.g., filters, strainers, flanges, gasket materials, valves of all kinds, mechanical portions of instrumentation, etc.
- Relief and vents systems and devices includes all components that are used to control pressure, e.g., relief valves, rupture disks, conservation vents, vent systems, vacuum breakers, flares, etc.
- Controls would also include mechanical systems or devices that are intended to terminate or control exothermic reactions, pressure transients, or other types of process safety scenarios, or to mitigate the results of such a scenario, e.g., a water curtain, quench systems, etc. Controls might also include local instrumentation that is intended to be read by operators so that they can then take appropriate manual or remote-manual actions to terminate or control abnormal conditions. The 2004 version of ISA Standard S84.01 recognizes manual actions as valid components of safety instrumented functions.
- Pumps include all rotating machinery containing or exposed to PSM-covered materials, e.g., pumps, compressors, fans, blowers, agitators, etc. It would also include non-rotating machinery that is used to move PSM-covered fluids such as an eductor.

However, there are also other equipment types that are clearly important to process safety that should be carefully considered for inclusion in the MI program. The PSM Standard does not explicitly require that these types of equipment be included in the MI program. However, if they are not included in the MI program (either formally or informally) the risk of process safety scenarios involving PSM-covered equipment may be higher because the MI concepts described below will not be completely applied to types of equipment that are important to process safety and are key safeguards in reducing the severity and/or likelihood of process safety scenarios. Examples include:

- Employee alarm systems.
- Structural and civil systems (including foundations, anchor bolts, supports, pipe hangers, pipe bridges, etc.) that support the weight or movement of equipment otherwise included in the MI program.
- Key utility or service systems or components for equipment included in the PSM program, including, electrical power, air, steam, nitrogen/inerting, cooling water, refrigeration/chilling systems, explosion suppression systems, quench systems, etc., where the utility failure could contribute to a process safety scenario or safeguards against such a scenario.
- Fire protection equipment.
- Fixed and portable area monitors that would detect releases of toxic or flammable materials.
- Secondary containments for tanks and vessels containing PSM-covered materials.
- Ventilation systems in buildings that have been designated as safe havens or assembly points during emergency evacuations.
- Test, measuring and evaluation equipment (electrical, electronic, or mechanical) used to perform inspection, testing, and other preventive maintenance tasks on equipment in the MI program. The proper functioning of test equipment ensures the accurate performance of ITPM activities where this equipment is used.
- Transportation containers used to transport PSM-covered materials via air, water, rail, or ground, when a container is used as a temporary storage tank/vessel and is connected directly to a PSM-covered process, whether the container is owned by the site or others.
- Loading dock equipment, e.g., loading arms, hoses, etc. where PSM –covered materials are being transferred.

It is important to note that the PSM regulations do not explicitly call for these equipment types to be included many are listed above because of written and verbal interpretations of MI by OSHA. Therefore, a site probably cannot be cited under the PSM Standard for not including them (note that OSHA can, and sometimes does invoke the General Duty Clause for these types of issues that are not explicitly stated in the regulations).

An important issue related to this additional equipment is related to utility systems. Whether included formally or informally in the MI program, the ongoing maintenance of some of these systems is critical to process safety. There is a line of thought that states that if appropriate safeguards are provided, then the utility system need not be included in the MI program. For example, if the loss of cooling water can cause a runaway reaction, and if emergency shutdown systems (e.g., temperature and pressure interlocks and trips) are provided, then the inclusion of cooling water system in the MI program is not warranted. This philosophy says that it is acceptable to challenge the safety instrumented functions and that the systems that the SIFs are protecting are not as important as the SIFs themselves. This philosophy should be applied with care.

Beyond determining what equipment should be included in the MI program, what does it mean that MI is applicable to these types of equipment?

- What it doesn't mean is that inspection, testing, and preventive maintenance (ITPM) tasks are mandatory.
- Nor does it mean that ITPM is the only activity that must be planned and executed - being included in the MI program means that the equipment is subject to the other five other sub-elements of MI, as described below.

Written Procedures.

The PSM Standard states in 29 CFR 1910 .119(j)(2) that "The employer shall establish and implement written procedures to maintain the on-going integrity of process equipment." This means that the preventive and corrective maintenance tasks that are performed on covered equipment must be written down. What isn't defined is:

- What format should be used for these procedures? They can be separate documents, embedded in work orders, attached to work orders, or be part of a separate manual.
- Can original equipment manufacturer (OEM) manuals suffice? In general this seems to be acceptable. However, these procedures should be as up-to-date and complete as the OEM has generated for that type and model of equipment. This would also elevate the OEM manuals to the same controlled document status as other, internally generated site procedures.
- How detailed should the procedures be? How much of a maintenance technician's training can be relied upon without generating highly detailed procedures? In general, simple tasks, such as lubrication, do not require detailed explanation in the maintenance procedures, however, the level of detail must be consistent with the complexity of the tasks to be performed and the level of skill of the maintenance work force.
- How often, if any, should the maintenance procedures be reviewed and updated? Should they be certified periodically like the SOPs? Formal certification on an annual basis is generally not warranted for maintenance procedures, however, some sort of periodic review and update is prudent. The provisions of typical ISO or other document control systems are usually sufficient.
- Should the maintenance procedures contain safety and health information and precautions? This information should be included or referenced in the work order or procedure. If using maintenance procedures from OEM manuals, site specific safety and health information should be added to the work order.
- Should the maintenance procedures be formally approved? The provisions of the document control system for any controlled procedure onsite should be followed.

Training

The PSM Standard states in 29 CFR 1910 .119(j)(3)that "The employer shall train each employee involved in maintaining the on-going integrity of process equipment in an overview of that process and its hazards and in the procedures applicable to the employee's job tasks to assure that the employee can perform the job tasks in a safe manner."

The process and hazard overview training is relatively straight forward – it does not mean PSM or MI overview training, but the same type of initial overview training given to the process operators before they begin to actually practice operations in the field. This training does not need to be highly detailed, nor does it have to be recurring.

The requirement that training be provided in "the procedures applicable to the employee's job tasks" causes the most confusion. This broad regulatory statement infers the following:

- Training in the safe work practices that the maintenance technicians will require to perform their work.
- Training (and in some cases certified qualifications) in the general craft and specialty skills that will be required to perform their work. However, this does not mean that a company or site has to establish a formal apprentice program.
- A special subset of general craft skills includes specialty skills that require certification of the skill by an outside agency. These include:
  - Welders
  - API pressure vessel, tank, and piping inspectors
  - Non-destructive testing (NDT) technicians
  - Vibration monitoring technicians
  - Thermography technicians

Craft and specialty skills can be obtained from an internal training program, from outside sources (e.g., military, union training programs, etc.), or assigned to properly qualified contractors. Several states have instituted apprentice programs that lead to certification as a maintenance technician. These are cooperative programs established by the sate labor department and the industries that need the skilled personnel. The personnel trained in these programs are generally hired as employees and then enrolled in the state training program. Note that welding on the process equipment itself, including pipe fabrication, and the structural equipment that supports the weight or movement of the PSM-covered process equipment require certified welders (certification every six months using outside services or by inspecting and documenting production welds). Other welding onsite might not require such certifications. e.g., welding on railings and ladders.

<u>Inspection and Testing.</u>
The PSM Standard states 29 CFR 1910 .119(j)(4):

- Inspections and tests shall be performed on process equipment.
- Inspection and testing procedures shall follow recognized and generally accepted good engineering practices.
- The frequency of inspections and tests of process equipment shall be consistent with applicable manufacturers' recommendations and good engineering practices, and more frequently if determined to be necessary by prior operating experience.
- The employer shall document each inspection and test that has been performed on process equipment. The documentation shall identify the date of the inspection or test, the name of the person who performed the inspection or test, the serial number or other identifier of the equipment on which the inspection or test was performed, a

description of the inspection or test performed, and the results of the inspection or test.

What are the governing recognized and generally accepted good engineering practices (RAGAGEP)? The three most common forms of RAGAGEPS are:

- Federal, state, or local law or regulation
- ITPM recommendations made by the original equipment manufacturer (OEM).
- Consensus codes, standards, and other guidance published by industry trade and professional organizations, such as American Society of Mechanical Engineers (ASME), American Petroleum Institute (API), National Fire Protection Association (NFPA), International Institute of Ammonia Refrigeration (IIAR), etc. These are the most common and recognized form of RAGAGEPs.

However, RAGAGEPs may come from other sources:

- Do written company policies and procedures constitute RAGAGEPs? In general they do because OSHA also treats company procedures as compliance requirements.
- Does guidance published by insurance companies represent a RAGAGEP? Sometimes insurance companies publish consensus guidance, or by common and frequent usage it becomes consensus guidance. For example, many Factory Mutual standards have become consensus fire protection guidance.
- Does plant-specific equipment history represent a RAGAGEP? For some type of equipment there no other sources of information or guidance for planning ITPM tasks and their frequencies other than the operating history of the equipment itself. Hence, it becomes a RAGAGEP of sorts, or at least a source of data.

There is frequent confusion regarding the selection of the frequency of ITPM tasks, particularly when the RAGAGEPs do not specify a frequency. This is a common situation for rotating equipment and instrument/electrical (I/E) equipment.

- Can the frequency of the ITPM tasks be less than the manufacturer's recommendations? Although the PSM Standard does not explicitly address this situation, common practice indicates that this is allowable, as long as there is documented evidence of previously ITPM results that justify extension of ITPM frequencies, and that the MOC or equivalent program onsite is used to review and approve such changes.
- Is overdue ITPM a compliance issue? Yes, because if the RAGAGEP specifies a frequency and that frequency has been exceeded, then the RAGAGEP is not being followed. Also, a published ITPM schedule represents a company/site procedure and not performing the maintenance on time constitutes not following the procedure.

Deficiencies

The PSM Standard states in 29 CFR 1910 .119(j)(5)that the employer shall correct deficiencies in equipment that are outside acceptable limits (defined by the process safety information in paragraph (d) of this section) before further use or in a safe and timely manner when necessary means are taken to assure safe operation.

MI deficiencies (i.e., equipment operating outside acceptable limits) can occur from a number of sources:

- Out-of-specification ITPM results: The PSI element states that the relevant RAGAGEPs are to be followed and documented. For example, those RAGAGEPs include the API-510 and API-570, These codes specify formulas to be used to calculate the minimum wall thickness of the vessels and piping. If ITPM results indicate that these thicknesses have been reached, then such results are deficiencies.
- Equipment operating beyond the safe upper or lower operating limits, as specified in either the RAGAGEPs, operating procedures, or design documentation. A MI-covered pump that is operating below the head vs. flow specifications in the pump curve would be a MI deficiency if the pump provides a critical service.
- Loss of containment of any PSM-covered material, e.g., a leak from a pump seal.
- Bypassed or removed safety features.

Are overdue ITPM tasks considered deficiencies? Although the frequencies are determined from RAGAGEPs, overdue ITPM tasks are not generally considered a MI deficiency, although they can be treated in the same manner if desired.

MI deficiencies must be permanently corrected immediately or the equipment can be operated with the deficiency in place for some temporary period of time. This time period should be reasonable given the nature of the deficiency and the time needed to plan and execute the permanent repair. Temporary safety measures (e.g., reduced throughput, reduced pressures or temperatures, lower relief valve setpoints, more frequent ITPM, etc.) must be implemented if they are warranted. Sometimes, an evaluation of the deficiency will show that such temporary safety measures are not needed, i.e., the equipment can be operated safely until it can be shutdown for permanent repair as is. If temporary safety measures are warranted, the site management of change procedure will be needed to implement them. The evaluation of the deficiency, its seriousness, and the need for temporary safety measures must be performed on a case-by-case for each potential deficiency, and this process should be thoroughly documented in each case.

Quality Assurance

The PSM Standard states 29 CFR 1910 .119(j)(6) that:

- In the construction of new plants and equipment, the employer shall assure that equipment as it is fabricated is suitable for the process application for which they will be used.
- Appropriate checks and inspections shall be performed to assure that equipment is installed properly and consistent with design specifications and the manufacturer's instructions.
- The employer shall assure that maintenance materials, spare parts and equipment are suitable for the process application for which they will be used.

Quality assurance (QA) in this context does not refer at all to product quality or ISO-related quality concepts. In this context, QA refers to the process of ensuring that the PSM-covered equipment is designed, purchased, fabricated, installed, and commissioned properly, and that these processes are controlled and documented. Most of this activity involves engineered projects. Although the PSM Standard does not explicitly require procedures for these activities, to successfully control them there should be procedures that govern the technical and administrative aspects of engineered projects, regardless of project size, scope, or cost. For example, the site should have pipe specification to govern the design of piping in PSM-covered processes, or approve the use of a contractor's specification.

There should also be proper controls over the ordering, receipt, storage, and disbursement of spare parts and material for PSM-covered processes to ensure that the right part is used in the right application. In the context of MI, spare parts management has nothing to do with the economic management of the storeroom or warehouse.

Responsibilities

Given the above interpretation of what a MI program should contain, the responsibilities for planning and executing the necessary activities are broadly distributed throughout the site and they cover the life cycle of equipment.

- ITPM (determination of ITPM tasks and their frequencies, planning, scheduling, execution, and documentation) – usually the responsibility of the Maintenance Department/Group, however, at many medium-to-large facilities, these activities are split among an Inspection Group, Rotating Machinery Group, and Instrument/Electrical Group. Contractors are often involved in this work.
- Repairs/corrective maintenance – usually managed by the same groups as ITPM work, and contractors are often involved in the execution of this work as well.
- Training & qualification of maintenance technicians (design of training qualification, determination of final qualification criteria, conduct of training, and documentation of training and qualification process) – usually a split responsibility between Safety/Training Group (safe work practice and other EHS-related training), and the shop/group where the ITPM/repair work is performed.
- Written procedures (creation of procedures, filing/maintenance of OEM manuals) – usually the shop/group where the work is performed. If the site is ISO certified, a document control group is also involved because the documents in question are generally controlled documents.
- Engineered projects (organization, execution, and documentation of projects) – usually the responsibility of the Engineering Group, except that Maintenance is sometimes involved in installation activities for smaller/simpler projects. Contractors are often heavily involved in these activities.
- Spare parts management (ordering, receipt, storage, disbursement, and documentation of spare parts) – the storeroom or warehouse is the responsibility of either Maintenance or Purchasing.
- MI Deficiency Management (reporting and evaluation of deficiencies, and execution of temporary and permanent corrective measures) – usually the responsibility of Maintenance, however, the entire process of managing deficiencies involves many personnel onsite (e.g., person(s) who manage management of change program).

The total scope of responsibilities for performing MI activities spans nearly every major group and discipline onsite. Some of the persons in these groups may not be aware that their job responsibilities involve fulfilling MI requirements. This is mostly an awareness problem, and a lack of understanding of persons involved in the PSM program as to what activities are required to maintain a functional program. For the MI program to function properly, it is imperative that all of the activities that constitute the MI program be defined and then the responsibilities for these activities be carefully assigned and communicated.

Typical MI Program Weaknesses

The following section describes common findings discovered in examining MI programs during PSM audits and other MI program development work. Where the finding is not an explicit requirement of the PSM Standard, but would help alleviate compliance-related findings and institutionalize policies, practices, and procedures, this has been described.

Applicability

- Many times a consolidated list of equipment included in the MI program does not exist, or exists in multiple types of records maintained by different people. Although it is not an explicit requirement of the PSM Standard to create a single list or register of MI-covered equipment, this would help alleviate the awareness problem where diverse groups across the site do not know that the equipment they are responsible for maintaining is part of the MI program and hence subject to all elements of the MI program, not just ITPM activities.
- Although the formal inclusion of many of the equipment types described above in the MI program is not mandatory, these equipment types are clearly important to process safety (e.g., fire protection) and require the same activities as the process equipment that must be included in the MI program. Many MI programs ignore these other equipment types resulting in many ITPM tasks being planned and performed and deficiencies also not being managed properly.

Written Procedures

- The collection of OEM manuals, home-grown procedures, embedded work order task instructions that constitute the written maintenance procedures are often not complete.
- There is often little maintenance of the OEM manuals that are part of the body procedures. Many are not even catalogued or indexed so that an inventory of them can be maintained. Although there is no need to convert these vendor documents into site controlled documents (if there is such a system onsite), some management of these documents is necessary to ensure that the site has all that are available and that they are maintained properly.
- Often there are no approved welding procedures onsite for welding on process equipment performed by site employees or contractors.

Training Of Maintenance Technicians

- There is often little or no definition of the practical craft skills training that is required to create a “journeyman” maintenance technician, that is, a technician that is trusted to perform ITPM and repair maintenance activities independently. These skills are usually obtained during on-the-job training, but there is no approved list of what skills must be practically demonstrated before the technician is considered fully qualified.

- Sometimes the process overview training for maintenance technicians that is required by the PSM Standard has not been performed.
- The qualifications of site employees that perform welding on process equipment has often expired or is completely undocumented.
- Site personnel performing vibration monitoring of rotating equipment are often not Level 1 or Level 2 vibration technicians. The Vibration Institute has established these qualifications and thus this constitutes a RAGAGEP, although OSHA has not explicitly issued any written guidance on this subject.
- Site personnel performing thermography are often not Level 1 or Level 2 thermography technicians, although this is rare, since this work is often performed by contractors who have the proper certifications.

<u>Inspection, Testing, & Preventive Maintenance</u>

- It is very common to find many overdue ITPM tasks - some overdue by years.
- There is usually no documentation of the selection of the ITPM tasks and their frequencies. Although this is not an explicit requirement of the PSM Standard, it is very difficult to change these tasks or their frequencies without knowing the rationale for choosing the original ones. When the seasoned maintenance foremen and similar personnel who made the initial selections based on their experience retire or resign, this knowledge is lost.
- There are many ITPM tasks required by various RAGAGEPs that are not being performed. Examples:
  - The ITPM tasks required by API-570 for process piping are not always being performed. In particular the periodic external inspections must be performed by qualified API-570 piping inspectors and not operations or other site personnel.
  - The ITPM tasks on electrical distribution equipment required by the maintenance section of the National Electric Code (NFPA-70B) are often ignored. There is an extensive list of these tasks, including thermography, that is applicable to electrical distribution equipment.
  - NFPA-25 contains a relatively large list of tasks that must be performed on water-based fire protection systems. Many of these are often missed. There is a common belief that if the insurance company is not interested in the task being performed then it must be unnecessary.

<u>Deficiency Management</u>

- It is typical for ITPM records to contain evidence of deficiencies. In some cases these deficiencies have been documented for several years without any temporary or permanent corrective action, or often even any recognition that the situation constitutes a MI deficiency. Examples:
  - ITPM piping/vessel thickness measurement readings often contain evidence that the readings are at or near retirement thickness or that the next thickness measurement has been accelerated and that time has passed. Sometimes this situation is created by the flawed use of the software chosen to calculate

remaining life and the date for the next measurement, in which case the real deficiency is in the calculations, not in the equipment itself. However, the ITPM records contain these deficiencies with no evidence of investigation or correction.
  - Unqualified weld repairs on registered pressure vessels and the vessel is still being used as a pressure vessel without a fitness-for-service (FFS) evaluation being performed. A FFS evaluation is a formal engineering, testing, and inspection process defined in API-579 when the pedigree of a pressure vessel has been lost or compromised. Note that if the state where the site is located regulates unfired pressure vessels, the use of a FFS to restore the pedigree of a vessel must be acceptable to the jurisdiction in question.
  - Fire protection ITPM records often document problems discovered during annual flow tests on the fire pumps (pump capacity not as specified by the pump curve), of problems associated with deluge or sprinkler system nozzles or flow patterns, with no documentation of corrective follow-up actions.
  - Thermography records on electrical distribution equipment (where these tests have been performed) often contain documented hot spots that have not been repaired.
  - Bypasses of safety features exist beyond the time specified in the procedure governing such bypasses.
  - Sites generally do not have a deficiency procedure to define and streamline the MI deficiency management process. There is no explicit requirement to have such a procedure, but without one, there is a much greater likelihood that deficiencies might not be promptly resolved when they occur.

Quality Assurance

- Spare parts management does not create a process that ensures that right parts are being used in the right applications. In particular, shelf lives of spare parts and materials are often not tracked. There are usually only a few components stocked in spare parts for a chemical/process facility, but some bearings, calibration gas, chemical hoses, and sealants/adhesives may have shelf lives.
- Some sites have not begun the process of implementing ISA Standard S84.01 (original 1996 version revised in 2004). This relatively new standard that governs the entire life cycle of safety instrumented systems (i.e., emergency shutdown systems) at chemical/process facilities now constitutes a RAGAGEP, and OSHA has recognized (in writing) that this standard is a RAGAGEP for ESDs. Note that this is also a Process Safety Information (PSI) issue. The PSI element of the PSM Standard, which stipulate that the RAGAGEPs be followed for the design of PSM-covered equipment. ISA Standard S84.01 also contains provisions that impact the ITPM of ESDs.

Overall Conclusions

- The performance-based regulatory language of the MI element of the PSM Standard is so broad that it is difficult for some to interpret and translate into functional policies, practices, and procedures.

- Responsibilities are generally very diffuse and many site personnel who have responsibility under MI do not realize this.
- As a result, systemic weaknesses have been found in many MI programs, particularly in the areas of ITPM program design and execution, training and qualification of maintenance technicians, and deficiency management.

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