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INTRODUCTION

For decades, mechanical integrity (MI) activities have been a part of industry's efforts to prevent incidents and maintain productivity. Industry initiatives, company initiatives, and regulations in various countries have helped (1) define MI program requirements and (2) accelerate implementation of MI programs. MI is already ingrained in the culture of many process plants, as well as in other related industries. Some MI activities are essential for these facilities to maintain economic viability.

Since 1992, a major incentive for the chemical process industries (CPI) in the United States to implement MI programs has been the Occupational Safety and Health Administration's (OSHA's) process safety management (PSM) regulation (29 *Code of Federal Regulations* [CFR] 1910.119) (Reference 1-1). This was followed by the Environmental Protection Agency's (EPA's) risk management program (RMP) rule (40 CFR 68) (Reference 1-2). These performance-based regulations each contain an MI element that defines the minimum requirements of a program through six subelements that address:

- Application (equipment to include)
- Written procedures
- Training
- Inspection and testing
- Equipment deficiencies
- Quality assurance (QA)

The specific requirements are not prescriptively stated in these regulations, but the subelements represent time-proven practices for an effective MI program. The details of each subelement are left to the discretion of the facility to develop and implement. All PSM- and RMP-covered U.S. facilities in operation since the regulations were issued should have completed at least three compliance audits. Many of these audits reveal that companies continue to have significant opportunities to improve their MI programs. In response, the Center for Chemical Process Safety (CCPS) Technical Steering Committee launched a project to

develop a guidance book to address the development, implementation, management, and continuous improvement of MI programs.

This guidelines book was written for CPI companies; however, the majority of the information presented applies to other industries as well. Although this book was written in the United States, a conscious effort has been made to keep the book applicable to facilities worldwide. This book recommends efficient approaches for establishing a successful MI program, while taking into consideration that facilities with small staffs and fewer resources must also develop MI programs. The practices described in this book are intended to help facilities create or improve MI programs.

1.1 WHAT IS MECHANICAL INTEGRITY?

For the purposes of this book, MI is the programmatic implementation of activities necessary to ensure that important equipment will be suitable for its intended application throughout the life of an operation. MI programs vary according to industry, regulatory requirements, geography, and plant culture. However, some characteristics are common to all good MI programs. For example, a successful MI program:

- Includes activities to ensure that equipment is designed, fabricated, procured, installed, operated, and maintained in a manner appropriate for its intended application
- Clearly designates equipment included in the program based on defined criteria
- Prioritizes equipment to help optimally allocate resources (e.g., personnel, money, storage space)
- Helps a plant staff perform planned maintenance and reduce the need for unplanned maintenance
- Helps a plant staff recognize when equipment deficiencies occur and includes controls to help ensure that equipment deficiencies do not lead to serious accidents
- Incorporates recognized and generally accepted good engineering practices (RAGAGEPs)
- Helps ensure that personnel assigned to inspect, test, maintain, procure, fabricate, install, decommission, and recommission process equipment are appropriately trained and have access to appropriate procedures for these activities
- Maintains service documentation and other records to enable consistent performance of MI activities and to provide accurate equipment information to other users, including other process safety and risk management elements

This book provides advice for developing an MI program with all of these characteristics.

1.2 RELATIONSHIP TO OTHER PROGRAMS

A practical MI program will fit within a facility's existing process safety and RMPs as well as other improvement initiatives (e.g., reliability, quality). Personnel charged with developing and administering the MI program can optimize the process by taking advantage of existing programs and by knowing which people and groups of people are responsible for related activities. Table 1-1 illustrates potential interfaces with other facility programs.

1.3 EXPECTATIONS FOR THE MI PROGRAM

To present sound guidance for developing and/or improving MI programs, this guidelines book evaluated lessons learned by the CPI. This is not a "cookbook"; however, many ways to approach the implementation of an MI program exist. MI programs must be effective in preventing incidents and should be an efficient component of a facility's process safety, environmental, risk, and reliability management system(s). Where appropriate, this book presents strengths and weaknesses of different approaches. Company management will need to recognize which approaches best suit their facility and company needs.

One beneficial practice is to establish program objectives early in the MI program development process. Companies should consider the implications of setting objectives for their programs. Reasonable expectations of MI programs include:

- Improved equipment reliability
- Reduction in equipment failures that lead to safety and environmental incidents
- Improved product consistency
- Improved maintenance consistency and efficiency
- Reduction of unplanned maintenance time and costs
- Reduced operating costs
- Improved spare parts management
- Improved contractor performance
- Compliance with government regulations

However, each of these objectives may have associated costs (e.g., more detailed procedures, a larger warehouse, improved computer systems); therefore, companies should consider prioritizing their objectives.

One MI program development approach that is not advocated in this book is to focus on compliance with regulations. The motivation for this approach is usually financial. Unfortunately, using this philosophy often puts a facility at a disadvantage because the requirements for compliance are often vague and subject to misinterpretation. Furthermore, requirements are subject to change (via legislated modifications or new interpretations of existing legislation). In addition, a compliance-only program may miss out on many of the benefits of a more

TABLE 1-1
Potential MI Interfaces with Other Programs

Program	*Potential MI Interface*
Equipment Reliability	• Reliability program activities (e.g., vibration monitoring, equipment quality control [QC]) contribute to MI • An MI program can be the foundation of a plant's reliability program
Occupational Safety	• Occupational safety programs help ensure the safe performance of MI activities • Occupational safety personnel may help maintain the integrity of emergency response equipment
Environmental Control	• Environmental initiatives (e.g., monitoring for fugitive emissions, investigating chemical releases) contribute to MI
Employee Participation	• Employees from various departments should have input into the MI program
Process Safety Information	• Design codes and standards influence MI activities such as equipment design, inspection, and repair • MI QA activities help document that equipment is appropriate for its intended use • MI activities may help establish or dictate a change to safe upper and lower operating limits
Process Hazard Analysis (PHA)	• PHAs can help define the equipment scope for the MI program • PHAs can help prioritize MI activities • MI history can help PHA teams determine the adequacy of safeguards
Operating Procedures	• Operating procedures may cover MI-related activities, such as equipment surveillance as part of operator rounds, reporting operating anomalies, recording historical equipment operating data, and preparing equipment for maintenance
Operator Training	• MI training in an overview of the process and its hazards should be consistent with the content of the operator training program
Contractors	• Inspection and maintenance tasks under the MI program may dictate skills required of contractors • Because contractors often perform MI activities, the contractor selection process should consider both contractor safety performance and the quality of the contractor's work
Prestartup Safety Review (PSSR)	• The MI QA practice to ensure that equipment is fabricated and installed according to design may be fully or partially addressed during a PSSR
Hot Work Permit (and other safe work practices)	• Safe work practices are relied upon to perform MI activities
Management of Change (MOC)	• MOC should apply to MI activities and documents (e.g., changes to task frequencies, procedures) • The MOC program should ensure that MI issues (e.g., corrosion rates and mechanisms) are considered when evaluating process changes • Establish hazard review teams that include process and MI personnel • The MOC program may be upgraded to help manage equipment deficiencies • Practices for replacing equipment "in kind" should be reviewed to ensure that MI records are not compromised (e.g., inspection records and schedules are updated)
Incident Investigation	• MI records may be needed by investigation teams • Investigation recommendations may impact MI activities
Emergency Planning and Response	• Emergency response equipment should be included in the MI program
Compliance Audits	• The MI program will be audited — audit results can help improve the MI program
Trade Secrets	• Trade secrets needed for MI activities cannot be withheld

holistic approach, such as reduced risks for employees, the neighboring community, and the facility. A more holistic approach can help to:

- Present the MI program as a company priority, rather than just something the company is forced to do; this approach helps to ensure compliance because personnel are less likely to take shortcuts
- Create synergies with equipment and process reliability initiatives that could improve results and/or lower cost
- Address actual risks to employees, community, and the business

Therefore, the more holistic approach helps to ensure compliance with governing regulations and, ultimately, often turns out to be less expensive than the minimum compliance effort would have been.

1.4 THE EFFECT OF RAGAGEPs

RAGAGEPs are important resources for an MI program. Many process safety reference documents and guidance documents rely on RAGAGEPs for a wide range of equipment and practices. For example:

- CCPS, "Design codes represent ... minimum requirements"; *Guidelines for Engineering Design for Process Safety* (Reference 1-3).
- CCPS, "The more widely accepted design practices are contained in various national and industry standards"; *Guidelines for Implementing Process Safety Management Systems* (Reference 1-4).
- American Chemistry Council (ACC), "Each member company shall have an ongoing process safety program that includes ... facility design, construction, and maintenance using sound engineering practices consistent with recognized codes and standards"; *Resource Guide for the Process Safety Code of Management Practices for Facilities*, Responsible Care® Process Safety Code (Reference 1-5).

In addition, regulations require the use of RAGAGEPs:

- EPA and OSHA, "Inspection and testing procedures shall follow recognized and generally accepted good engineering practices"; EPA 40 CFR 68 and OSHA 29 CFR 1910.119.
- EPA and OSHA, "The employer (owner or operator) shall document that equipment complies with recognized and generally accepted good engineering practices"; EPA 40 CFR 68 and OSHA 29 CFR 1910.119.

What are RAGAGEPs? Simply stated, RAGAGEPs are documents that provide guidance on engineering, operating, or maintenance activities based on an established code, standard, published technical report, or recommended practice (RP) (or a document of a similar name) (Reference 1-6). They outline in detail a generally approved way to perform a specific engineering, inspection, or

maintenance activity, such as fabricating a pressure vessel, inspecting a storage tank, or servicing a relief valve. Many of these documents were developed after obtaining broad industry and expert public technical input, and many were accepted by consensus of industry and technical organizations. Therefore, RAGAGEPs provide a valuable starting point for an MI program.

In some cases, a country, state, or locality may mandate the use of a RAGAGEP. In addition, many companies internalize standards provided by the manufacturer or licensor of a process (these often are based on RAGAGEPs). Some companies have developed internal standards based on company and industry operating experience. To effectively use RAGAGEPs, facility management must determine which practices are available and then assess the applicability of each practice to their facility. Regardless of the consensus reached to publish a RAGAGEP, most standards were not written for a facility's specific equipment, specific chemical application, specific locale, or specific operations culture. Facilities with successful MI programs are establishing their own data records to help determine (or to validate) the ongoing applicability and use of each standard.

Several chapters of this book address the applicability and use of RAGAGEPs in more detail. Descriptions of these practices, and approaches for using them (e.g., to determine an inspection interval or technique), are included, but the actual RAGAGEPs are not repeated in this book. New and revised codes, standards, and recommended practices continue to evolve; therefore, companies should have management systems in place to keep up with the new standards and with changes to existing standards.

1.5 STRUCTURE OF THIS GUIDELINES BOOK

This guidelines book is intended for anyone interested in developing a new MI program or enhancing an existing program. The book was written in the United States, but few references are made to jurisdictional regulations. Note, however, that following the approaches described in the book should help any organization that is trying to comply with rules or regulatory requirements related to MI. Similarly, the codes and standards referenced are generally from the United States, but other code references are also provided. Also note that most of the information within the book is consistent with codes and regulations, but it is not extracted directly from those codes or regulations. The suggested approaches are applicable everywhere.

This guidelines book begins with chapters that help set the groundwork for the MI program. Chapter 2 discusses roles and responsibilities for company personnel and examines the ongoing activities that management undertakes to help ensure MI program success. Chapter 3 reviews considerations a facility may have when defining the equipment to include in its program.

Chapter 4 discusses inspection, testing, and preventive maintenance (ITPM). Some peer reviewers of this text suggested that preventive maintenance (PM) does not belong in an MI program. Many traditional PM programs were established to

address routine nonintegrity-related tasks. However, in this book "preventive maintenance" refers to those activities performed to prevent the failure of equipment within the MI program that are not inspections or tests (e.g., lubrication of rotating equipment).

Chapter 5 covers personnel training and Chapter 6 addresses the procedures needed for MI. A life-cycle approach to QA is presented in Chapter 7. Chapter 8 covers equipment deficiency recognition and resolution. Chapter 9 is dedicated to the equipment-specific aspects for the management systems covered in Chapters 4 through 8. Chapter 10 reviews common issues encountered with MI program implementation. The remaining two chapters contain supplemental information related to MI programs. Chapter 11 provides overviews of risk-based tools that can be used to help make decisions related to MI activities. Chapter 12 offers advice for continual assessment and improvement of an MI program. Many MI activities are concentrated in four areas:

1. New equipment (design, fabrication, and installation)
2. Inspection and testing
3. Preventive maintenance
4. Repair

As illustrated in Table 1-2, Chapters 4 through 8 describe management systems for addressing these four areas. Chapter 9 is dedicated to the equipment-specific aspects for these areas. Activity tables in Chapter 9 and on the CD accompanying this book are presented in a format similar to Table 1-2.

TABLE 1-2
Chapters Addressing Management Systems for MI Activities

Attributes	*New Equipment*	*Inspection and Testing*	*Preventive Maintenance*	*Repair*
Task Definition, Purpose, and Documentation Requirements	Chapter 7 (QA)	Chapter 4 (ITPM)	Chapter 4 (ITPM)	Chapter 8 (Deficiency Resolution)
Acceptance Criteria	Chapter 7 (QA)	Chapter 4 (ITPM) and Chapter 8 (Deficiency Resolution)	Not applicable	Chapter 7 (QA)
Technical Basis	Chapter 7 (QA)	Chapter 4 (ITPM)	Chapter 4 (ITPM)	Chapter 7 (QA)
Procedures	Chapter 6 (MI Procedures)			
Personnel Qualifications	Chapter 5 (MI Training)			

1.6 REFERENCES

1-1 Occupational Safety and Health Administration, *Process Safety Management of Highly Hazardous Chemicals*, 29 CFR Part 1910, Section 119, Washington, DC, 1992.

1-2 Environmental Protection Agency, *Accidental Release Prevention Requirements: Risk Management Programs*, Clean Air Act, Section 112 (r)(7), Washington, DC, 1996.

1-3 American Institute of Chemical Engineers, *Guidelines for Engineering Design for Process Safety*, Center for Chemical Process Safety, New York, NY, 1993.

1-4 American Institute of Chemical Engineers, *Guidelines for Implementing Process Safety Management Systems*, Center for Chemical Process Safety, New York, NY, 1994.

1-5 American Chemistry Council, *Resource Guide for the Process Safety Code of Management Practices*, Washington, DC, 1990.

1-6 Decker, L. and R. Montgomery, *Defining and Maintaining a RAGAGEP Program*, presented at Process Plant Safety Symposium, Houston, TX, December 1998.