Elements for the Establishment of a Fixed Equipment Mechanical Integrity Program

API PUB 592

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Special Notes (To be added by the API Editors prior to publication)

Foreword (To be revised/updated per API Editorial)

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Suggested revisions are invited and should be submitted to the Standards Department, API, 200 Massachusetts Avenue, NW, Suite 1100, Washington, DC 20001, standards@api.org.

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1 Scope

1.1 General

Mechanical integrity (MI) is a key pillar in safe operation of any process facility. The term mechanical integrity (or asset integrity) applies broadly to all equipment types including rotating equipment, fixed equipment, mitigation equipment (LEL, deluge, gas detector, suppression), and instrumentation/controls. Inspection, testing, and preventive maintenance tasks for each equipment type are crucial for safe operation and reliability of a process facility.

1.2 Purpose

The purpose of this document is to provide guidance on the application of the MI program to the different types of fixed equipment. Other process equipment, such as rotating equipment and instrumentation/controls, are not covered in this document. Determination of MI applicability may involve interpretation of regulations and case-by-case decision making, depending on the complexity of the equipment. The contents of this document are intended to assist in determination of:

- What type of equipment should be included in the MI program?
- What in-service inspection codes & standards are typically applied for each type of equipment?

1.3 Limitations

PUB 592 should not be construed as being related only to API documents. The principles outlined are intended to be used by owner-operators for fixed equipment in their facilities regardless of the Construction Code, Inspection Code, Standard, or other prevailing requirements. This document should not be used as a substitute for a complete Mechanical Integrity Program as defined by OSHA[1] 1910.119 but only as a compendium of principles and common industry practices by which such a program is established.

2 Normative References

The following referenced documents are indispensable for the application of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

U.S. OSHA 1910.119(j)

EPA 40 CFR 68.73

The structure and contents of these references are the basis for the guidelines shown in Sections 4 through 8 of this document provide a framework for a fixed equipment mechanical integrity program.

[1] U.S. Department of Labor, Occupational Safety and Health Administration, 200 Constitution Avenue, NW, Washington, DC 20210, www.osha.gov.

3 Terms, Definitions, Acronyms, and Abbreviations

3.1 Terms and Definitions

For the purposes of this document, the following terms and definitions apply.

3.1.1
aboveground storage tank
A vertical, cylindrical structure built above ground level and designed to hold a liquid or gas, but other shapes are also used.

3.1.2
applicable construction code
The code, code section, or other recognized and generally accepted engineering standard or practice to which the equipment was built or that is deemed by the owner-operator or the engineer to be most appropriate for the situation.

3.1.3
atmospheric pressure
When referring to (vertical) tanks, the term "atmospheric pressure" usually means tanks designed to API 650, although API 620 uses the term atmospheric pressure to describe tanks designed to withstand an internal pressure not exceeding the weight of the roof plates.

NOTE 1 API 650 also provides rules to design tanks for "higher internal pressure" up to 2.5 lb./in.2 (18 kPa).

NOTE 2 API 653 uses the generic meaning for atmospheric pressure to describe tanks designed to withstand an internal pressure up to, but not exceeding 2.5 lb./in^2 (18 kPa) gauge.

3.1.4
boiler
Fired or unfired equipment that generates steam.

3.1.5
corrosion allowance
Additional material thickness available to allow for metal loss during the service life of the component.

NOTE Corrosion allowance is not used in design strength calculations.

3.1.6
critical check valve
Check valves in piping systems that have been identified as vital to process safety.

NOTE Critical check valves are those that need to operate reliably in order to avoid the potential for hazardous events or substantial consequences should reverse flow occur.

3.1.7
deficiency
A condition that falls short or exceeds a pre-established threshold and/or no longer complies with the applicable codes or standards or will no longer be in compliance during the next service interval or operating period.

NOTE 1 *Equipment Deficiencies* are physical damage, imperfections, or indications that exceed the acceptable limits, or fail to meet equipment specifications and may require actions to repair or remediate.

NOTE 2 *Program Deficiencies* are those pertaining to the mechanical integrity program (e.g., delinquent inspection activities, missing inspector qualification, missing inspection procedures).

3.1.8
design metal temperature
DMT
The tube metal or skin temperature used for design.

3.1.9
design pressure
The pressure, together with the design temperature, used to determine the minimum permissible thickness or physical characteristic of each vessel component as determined by the vessel design rules.

3.1.10
design temperature
The temperature, together with the design pressure, used for the design of the equipment per the applicable construction code.

3.1.11
facility
Any location containing equipment and/or components to be addressed under this document.

3.1.12
firetube boiler
fired tube boiler
A shell and tube heat exchanger in which steam is generated on the shell side by heat transferred from hot gas flowing through the tubes.

3.1.13
fireproofing
A systematic process, including materials and the application of materials that provide a degree of fire resistance for protected substrates and assemblies.

3.1.14
furnace
Fired equipment that provides heat to process streams to create a molecular change.

3.1.15
fired heater
Equipment that uses indirect heat transfer from combustion to heat process streams.

3.1.16
In service
Designates a piece of equipment that has been placed in operation as opposed to new construction prior to being placed in service or retired vessels.

NOTE 1 A piece of equipment not in operation because of a process outage is still considered in-service.

NOTE 2 Does not include equipment that is still under construction or in transport to the site prior to being placed in service or equipment that has been retired from service.

NOTE 3 It does include equipment that is temporarily out of service but still in place in an operating site.

NOTE 4 A stage in the service life of a vessel between installation and being removed from service.

3.1.17
jurisdiction
A legally constituted government administration that may adopt rules relating to equipment.

3.1.18
level bridle
The piping assembly associated with a level gauge attached to a vessel.

3.1.19
maximum allowable working pressure
MAWP
The maximum gauge pressure permitted at the top of a pressure vessel in its operating position for a designated temperature.

NOTE 1 This pressure is based on calculations using the minimum (or average pitted) thickness for all critical vessel elements, (exclusive of thickness designated for corrosion) and adjusted for applicable static head pressure and non-pressure loads (e.g., wind, earthquake, etc.).

NOTE 2 The MAWP may refer to either the original design or a rerated MAWP obtained through a FFS assessment.

3.1.20
owner-operator
The legal entity having control of and/or responsibility for the operation and maintenance of existing equipment.

3.1.21
pipe
A pressure-tight cylinder used to convey, distribute, mix, separate, discharge, meter, control or snub fluid flows, or to transmit a fluid pressure and that is ordinarily designated “pipe” in applicable material specifications.

NOTE See exceptions in 4.3.

3.1.22
piping circuit
A subsection of piping systems that includes piping and components that are exposed to a process environment of similar corrosivity and expected damage mechanisms and is of similar design conditions and construction material whereby the expected type and rate of damage can reasonably be expected to be the same.

NOTE 1 Complex process units or piping systems are divided into piping circuits to manage the necessary inspections, data analysis, and record keeping.

NOTE 2 When establishing the boundary of a particular piping circuit, it may be sized to provide a practical package for record keeping and performing field inspection.

3.1.23
piping system
An assembly of interconnected pipe that typically is subject to the same (or nearly the same) process fluid composition and/or design conditions.

NOTE Piping systems also include pipe-supporting elements (e.g., springs, hangers, guides, etc.) but do not include support structures, such as structural frames, vertical and horizontal beams and foundations.

3.1.24
tubing
tube
See Note 1 in **3.1.18, pipe**

3.2 Acronyms and Abbreviations

For the purposes of this document, the following acronyms and abbreviations apply.

AWS	American Welding Society
ASME	American Society of Mechanical Engineers
ASNT	American Society for Non-destructive Testing
CMMS	Computerized Maintenance Management System
CWI	Certified Welding Inspector (AWS)
DOT	U.S. Department of Transportation
FE	Fixed Equipment
IDMS	Inspection Data Management System
ISO	International Organization for Standardization
ITPM	Inspection, Testing, and Preventive Maintenance
LEL	Lower Explosive Limit
MI	Mechanical Integrity
MOC	Management of Change
NB, NBBI	National Board, National Board of Boiler and Pressure Vessel Inspectors
NBIC	National Board Inspection Code
NDE	Non-destructive Examinations
OEM	Original Equipment Manufacturer
OSHA	Occupational Safety & Health Administration (U.S.)
PSI	Process Safety Information
RP	Recommended Practice

4 Fixed Equipment in an MI Program

4.1 Unfired Pressure Vessels

The term "pressure vessel" is generally used to cover a variety of process equipment types that are subject to internal (or external) pressure. Although the term covers equipment commonly known as pressure vessels (e.g., towers, air-cooled heat exchangers, shell-and-tube heat exchangers, bullet tanks), it can also cover equipment types which are less commonly used, such as brazed aluminum heat exchangers, pipe-in-pipe exchangers, spiral exchangers, and plate-frame heat exchangers.

When determining the applicability of MI to a pressure vessel, the owner-operator or inspector should consider several factors including:

a) the equipment construction code,

b) hazards of the process,

c) risk of loss of containment, and

d) potential secondary consequences in case of equipment failure.

4.1.1 Coded Pressure Vessels

The most commonly used construction code for pressure vessels is the ASME[2] Boiler & Pressure Vessel Code, Section VIII (often referred to simply as "Section VIII"), but equipment built to other construction codes may also meet the applicability of a pressure vessel. Other construction codes include but are not limited to API 661 for air-cooled heat exchangers, Tubular Exchanger Manufacturers Association (TEMA[3]) document(s) for shell and tube heat exchangers, and company-specific internal design standards (sometimes referred to as "non-code").

Some equipment which are typically considered as piping components, such as small strainers, filters, instrument bridles, accumulators, and sample collection cylinders may be considered as pressure vessels based on factors including design, size, and function.

API 510 is a Code that describes the in-service inspection, rating, repair, and alteration requirements and recommendations for pressure vessels. API 572 is a Recommended Practice (RP) document which supplements API 510 by providing specific guidance on inspection and testing of pressure vessels. Owner-operators may choose to follow API 510 for unfired pressure vessels that are not explicitly included in the API 510 scope, or they may choose another inspection code to evaluate asset integrity.

NOTE See Section 2, Annex C, and Bibliography for description of all Codes and Standards cited in this document. Annex A shows an example web diagram of common fixed equipment MI codes, standards, and other guidance documents.

4.1.2 Guidance for Code Exempted Pressure Vessels

API 510, Annex A lists a number of criteria by which a pressure vessel may be exempted from the requirements of API 510. Even some pressure vessels that are constructed in accordance with Section VIII

[2] American Society of Mechanical Engineers, Two Park Avenue, New York, New York 10016-5990, www.asme.org.
[3] Tubular Exchanger Manufacturers Association, 25 N Broadway, Tarrytown, NY 10531, www.tema.org.

may meet the exemption criteria of API 510 Annex A. Although the pressure vessels that meet these criteria can be exempted from the specific requirements of API 510, owner-operators should still consider including the exempted equipment in the facility's general MI program based on the associated potential risk. The MI program should clearly specify the items that are exempted and why.

When considering exempting a pressure vessel from the MI program, the owner-operator should take caution in justifying the exemption and be aware of common mistakes. For example, a common mistake is assuming pressure vessels that are not built to a known construction code (e.g., ASME Section VIII Div.1) are automatically exempted from the inspection code (e.g., API 510); exemption in one does not necessarily mean exemption in the other. The risk, and subsequent consequences, associated with loss of containment of the contents of the pressure vessel should be considered when justifying an exemption.

Examples of equipment types that often meet the exemption criteria of API 510 Annex A may include vertically suspended pump cans, underground sumps containing process fluids, atmospheric flare knockout tank, and sample cylinders. However, these equipment types should still be included in the facility's mechanical integrity program.

The owner-operator may choose to adopt the inspection practices of API 510 or API 570 for exempted pressure vessels, as applicable to the equipment configuration. Another common practice is for the owner-operator to develop appropriate inspection practices to verify the integrity of those pressure vessels.

4.2 Storage Tanks

4.2.1 Aboveground Storage Tanks

The term "aboveground storage tank" generally refers to tanks that are vertical, cylindrical, and uniformly supported at the bottom.

The commonly used construction codes for these types of storage tanks include API 620, API 650, and API 12 series (each operating under the pressure prescribed in the specific standards). In addition to the storage tank itself, secondary containment systems such as dikes, curbs, and sumps may be considered for inclusion in the MI program for storage tanks.

API 653 describes the inspection, repair, alteration, and reconstruction requirements for storage tanks constructed to API 650 and its predecessor API 12C, while API 575 provides inspection practices for aboveground and low-pressure storage tanks. The scope of API 653 states that it may be applied "to any steel tank constructed in accordance with a tank specification". Applicable parts of API 653 are also commonly adjusted as necessary and used for tanks constructed to API 620. API 12R1 describes the installation, operation, maintenance, inspection, and repair of tanks in production service. API 12R1 applies primarily to tanks fabricated to API 12-series specifications for onshore production services, although it may be applied to other tanks and services at the discretion of the owner-operator.

The inspection standards and codes listed above do not specifically address secondary containment systems such as dikes, curbs, and sumps. Where not already covered by some other means (e.g., SPCC, Spill Prevention Controls and Countermeasures), secondary containment may be considered for inclusion in the MI program for storage tanks.

4.2.2 Other Storage Tanks

For aboveground storage tanks not constructed to API 620, API 650, or API 12-series specifications, other inspection and repair standards may be more appropriate. Examples of such tanks include UL142 tanks, spheroids, and fiberglass tanks. Inspection codes to consider for storage tank inspection include (Steel Tank Institute) STI SP001, API 12P, or (Fiberglass Tank & Vessel) FT&V 2007-01 for fiberglass tanks.

NOTE For purposes of this document, other storage tanks may also include horizontal cylinders or spherical structures designed to contain liquid or gas, and/or rectangular structures that contain liquid.

4.2.3 ISO Storage Containers and other Transportable Storage Totes

Transportable storage equipment such as ISO[4] storage containers or other storage totes regulated by DOT[5] are often included as part of the supplier's MI program. In cases where the transportable storage equipment is considered a permanent structure of the operating facility, the owner-operator should include the equipment as part of the facility MI program.

Railcars (as soon as disconnected from the mode of transportation or inside the fence) become the responsibility of the owner-operator. In this case, the railcars are no longer governed by DOT and should be included in the owner-operator's MI program.

4.3 Piping & Pipelines

Various construction codes are commonly used in piping design and construction, depending on their service application. Some of the most used construction codes are ASME B31.1, ASME B31.3, ASME B31.4, and ASME B31.8.

API 570 describes the in-service inspection, rating, repair, and alteration requirements for piping systems, while API 574 covers inspection practices for piping system components.

For transportation pipelines, the U.S. Department of Transportation has promulgated regulations for pipelines and hazardous materials, including Title 49 CFR Parts 192, 193 and 195.

4.3.1 Piping – General Information

Piping in an operating facility setting is generally divided into piping systems and/or circuits to efficiently manage inspection and testing activities. The term "piping system" not only includes piping, but also the associated components that are essential to the function and purpose of the pipe, such as fittings, flanges, valves, eductors, in-line strainers, and supporting elements. Flex hoses and flexible joints are also considered a part of a piping system when used in the MI covered process. Piping and components that are included as a part of a skid package (e.g., pre-assembled compressor package) are treated the same as other process piping.

The term "tubing" can imply different meanings depending on its context, and often causes confusion when considering applicability of MI. When used in context of pressure service, tubing used for bridle connections or as an alternate to small bore piping is considered piping and should follow the appropriate inspection and testing practices. When used in context of impulse tubing, heat tracing, seal flush lines, or instrumentation lines, tubing is not considered as piping. In this context, tubing also does not include heat transfer coils in fired heaters or heat exchanger tubes (see 4.5).

Piping that is physically open to atmosphere, and poses no structural risk is generally included as a part of its adjacent, or parent equipment for MI inspections. For example, outlet piping of a pressure relief device

[4] International Organization for Stadardization, ISO Central Secretariat, Chemin de Blandonnet 8, CP 401, 1214 Vernier (Geneva), Switzerland, www.iso.org.
[5] U.S. Department of Transportation, 1200 New Jersey Avenue, SE, Washington, DC 20590, www.transportation.gov.

that discharges to atmosphere may be included in the inspection of the pressure-relieving device or the pressure vessel to which it is connected.

Piping components that should be considered for additional vigilance include (among others), dead legs, injection points, and vibrating sections of small-bore piping.

4.3.2 Critical Check Valves

The reliable functionality of critical check valves plays a role in mitigating the potential for hazardous events. Critical check valves are normally identified during a Process Hazard Analysis (PHA) or a separate risk evaluation. API 570 and API 574 provide guidance on the inspection and testing of critical check valves.

4.3.3 Pipelines – General Information

Pipelines are piping systems through which liquid and gas are transported across a long distance (e.g., cross-country, facility-to-facility). Pipeline systems include pipes, valves, fittings, flanges (including bolting and gaskets), pressure and flow regulators, pulsation dampeners, relief valves, appurtenances attached to pipe, pump units, metering facilities, pressure-regulating stations, pressure-limiting stations, pressure relief stations, and fabricated assemblies. Refinery and chemical plant owner-operators should consider the mechanical integrity of pipelines “inside the fence” (non-DOT, custody transfer) and agree with the pipeline operator on who will take the lead in managing mechanical integrity.

API 1160 and ASME B31.8S provide systematic, comprehensive, and integrated approaches to managing the safety and integrity of Hazardous Liquid and Gas pipeline systems, respectively. Both documents provide a way to improve the safety of pipeline systems and to allocate operator resources to:

- identify and analyze actual and potential precursor events that can result in pipeline incidents,
- examine the likelihood and potential severity of pipeline incidents,
- provide a comprehensive and integrated method for examining and comparing the spectrum of risks and risk reduction activities available,
- provide a structured, easily-communicated way for selecting and implementing risk reduction activities,
- establish and track system performance with the goal of improving that performance.

API standards and recommended practices that are commonly used by pipeline owner-operators for integrity programs include API 1163, API 1173, and API 1188. Refer to Annex A for further examples of documents that provide design, inspection, and corrosion guidance for pipeline assets.

4.4 Pressure Relief Devices

Pressure Relief Device is a general term used to describe the devices that physically activate to provide protection against an overpressure scenario, including pressure safety valves, rupture disks, conservation vents, and weighted hatches.

API 520, Parts I and II, API 521, ~~API 525,~~ and API 527 describe sizing, selection, installation, purchase specifications, and seat tightness for pressure relieving devices and valves.

API 576 describes the inspection, testing, and repair requirements for pressure relief devices, with additional information covered by API 510 and API 570. API 2000 addresses pressure/vacuum vents. Further information can also be found in the National Board Inspection Code NB-23[6], Part 4.

Thermal relief devices and rotating equipment internal relief devices are generally small integral parts of the rotating equipment assembly. Depending on their design, these devices may require inspection and testing that is different from the requirements of API 510 and API 576. When determining the inspection and testing requirements, the owner-operator should consult the manufacturer of the device for recommendations to find the appropriate testing requirements.

4.5 Fired Equipment

In this document fired equipment refers to equipment utilizing combustion to heat the process such as fired heaters, boilers, or furnaces.

API 560 describes design and construction requirements for fired heaters. API 530 provides guidance on determining the tube thickness of fired equipment.

API 573 provides inspection and testing guidance for fired boilers and fired heaters, including tubes, hangers, and burners, etc.

For equipment such as reboilers or bath heaters, which may not be covered by the typical, fired heater configurations in API 573 and API 560, the owner-operator should determine the most appropriate inspection practices (e.g., API 510, API 570) as API 573 may not be the most applicable inspection code for certain fired equipment. Further guidance for fired equipment may be found in the National Board Inspection Code, NB-23.

Although included in the facility MI program, boilers are inspected and certified, where applicable, by the requirements of the boilers' jurisdiction.

4.6 Critical Utility Systems

Process equipment in utility systems such as steam, lube oil, and cooling water may be included in the MI programs despite the nature of the fluid being categorized as Class 4 as defined by API 570. Maintaining the integrity of certain utility systems may be critical to process safety. Some utility systems are designed to play a key role in safeguarding against potential safety risks. Before excluding utility systems, the owner-operator should consult the process hazards analysis (PHA), and consider the risk associated with failure of the utility systems.

4.7 Equipment that Combines Fixed Equipment (FE) and Other Equipment Types

Certain equipment or equipment components may be assumed to fall under the responsibility of other departments within owner-operator organizations. These types of equipment are referred to by many in the industry as "grey zone" equipment. Examples include filters, seal pots, level bridles, cathodic protection, thermowells, process hoses, sample cylinders, the pressurized can of API VS6/VS7 pumps, and cooling towers. Failure of these types of equipment could lead to unintended FE MI-related issues. Owner-

[6] The National Board of Boiler and Pressure Vessel Inspectors, 1055 Crupper Avenue, Columbus, Ohio 43229, www.nationalboard.org.

operators should evaluate the applicability of the grey zone equipment in their MI program and determine the appropriate inspection and testing practices.

4.8 Other Fixed or Periphery Equipment

The following subsections provide general guidance and information on inspection and testing for FE types that are not covered by API.

4.8.1 Assets Owned by Third-Party

A facility may have process equipment and systems that are owned by another company (e.g., air compressor, coolers, hoses). This can cause confusion on whether the responsibility for inspection and testing falls under the host facility, or the equipment owner company. While the equipment owner is generally responsible for conducting the testing and inspection of the equipment, the host facility should ensure that the inspection and testing are being conducted and appropriate documentation is available.

Often, the host facility and the equipment owner establish a work process or an agreement on how the equipment will be maintained and inspected, and who is responsible for performing and documenting the inspection. The host facility may choose to include these types of equipment in their MI program as though they were owned by the host facility. If the equipment owner is solely responsible for inspection and documentation, the host facility should have access to review the results of the inspection of equipment located at the host facility.

4.8.2 Fire Protection Equipment

Another important asset type for consideration are those assets and systems in place to mitigate or to act as the final means to address chemical releases, fires and other adverse events. This may include flame arresters, suppression systems, fixed and portable fire protection equipment, and sprinkler and deluge systems, among others.

Fire protection equipment is generally managed outside of a FE MI program and driven by the requirements of other standards (such as National Fire Protections, NFPA[7]). Equipment such as these are normally inspected and tested by personnel other than inspectors (e.g., safety personnel, fire chief). The owner-operator should, however, ensure that the inspection and testing is being conducted and documented.

4.8.3 Marine Docks and Other Transportation Assets

Owner-operators of waterfront facilities, including the piping, hoses, and loading arms located in the marine transfer area, may be subject to specific inspection and testing regimes at a certain prescribed frequency by the local jurisdiction.

As an alternative compliance practice, regulators may consider piping inspection practices in accordance with API 570 as acceptable and providing an equivalent level of safety and protection against potential failures. Owner-operators should maintain an effective and demonstrable record of their piping inspection compliance with minimum requirements established by API 570.

[7] The National Fire Protection Association, 1 Batterymarch Park, Quincy, MA 02169, U.S., www.nfpa.org.

4.8.4 Structural Components

The consideration for including structural components in the MI program may be critical. They can include, but are not limited to:

a) regions where the environment presents higher susceptibility for damage and corrosion (e.g., atmospheric corrosion, or impact by hurricane),

b) the age of the facility,

c) environmental condition in operating context, e.g., drift from cooling towers,

d) fireproofing,

e) post-seismic event,

f) condition of ladders, stairs, platforms, grating, and guywires,

g) cooling tower structures,

h) stacks, chimneys,

i) columns and beams supporting piping and pressure vessels, and

j) secondary containment dikes.

4.8.5 Electric Process Heaters

There are many processes and units in a plant that incorporate equipment that electrically generate heat to exchange with process fluids and increase their temperature. Electric process heaters are typically light-duty and heavily engineered. They have diverse applications, design objectives, and configuration but in general terms, with the exception of the electrical components and heating elements, they may experience the typical damage mechanisms of fired equipment (see 4.5).

Electric process heaters are typically designed to ASME BPVC, and as such the inspection requirements from API-510 are applicable. Since this equipment may also experience typical fired equipment damage mechanisms, many elements from API-573 can also be used as a guidance to create inspection plans.

4.8.6 Refractory

Special attention should be provided to refractory systems as they constitute a critical element of the overall integrity of heating equipment. API 573 Section 13.4 provides good guidance on the main threats to refractory systems as well as minimum requirements to generate inspection and maintenance plans.

4.9 Equipment Decommissioning and Re-Use

Owner-operators that consider re-use of equipment as part of their operational policies should establish decommissioning and recommissioning procedures to manage and minimize degradation. A decommissioning procedure should consider depressurization, removal of any process/service materials and thorough cleaning, additional measures for equipment preservation, and ongoing inspections and preventive maintenance activities that should be performed. Entire units that are mothballed for intermittent use (e.g., seasonally operated equipment) should have procedures to ensure that liquids are drained, systems are purged, and other measures are taken to preserve equipment integrity.

All design and inspection documentation should be retained and kept organized in the document control system. If the equipment is going to be transported and placed in a yard, it should be properly labeled and tagged.

Recommissioning involves fitness for service review, inspections and other equipment checks to verify that the reused equipment is suitable for the new service.

4.10 Acquiring and Recommissioning Used Equipment

When acquiring used equipment to be installed for temporary or continuous operation, the owner-operator should consider developing specific procedures to ensure that they are provided with design documentation, previous service information, inspection data, failures and/or previous repairs. These procedures may include the same considerations for recommissioning procedure listed in 4.9 for equipment reuse.

5 Written Guidance

5.1 General

An owner-operator organization is responsible for developing, documenting, implementing, executing, and assessing written procedures to maintain the mechanical integrity over the life cycle of process equipment. Written procedures are key to an effective MI management system and can be thought of as a framework of four (4) levels of documentation (see Figure 5.1, below):

1. policies, processes and systems;
2. programs;
3. practices and guidelines; and
4. detailed procedures.

The owner-operator should consider what procedures are needed to support the MI program requirements. These written procedures are influenced by regulations and standards applicable to the industry and the types of assets used by the owner-operator. The written procedures should have consistent definitions and terminology to clarify guidance and instructions. The terminology should provide differentiation between required and optional processes or activities.

Having a structured framework of written procedures provides a means for every level of the organization to plan, direct, and execute MI activities in a clear and consistent manner. The written procedures should provide a standardized approach to the implementation of the company's risk management strategy such that it may be applied consistently across the operations of the company and have flexibility for different sources and types of risk. Written procedures also provide a means of measurement and assessment of performance and a foundation for continuous improvement.

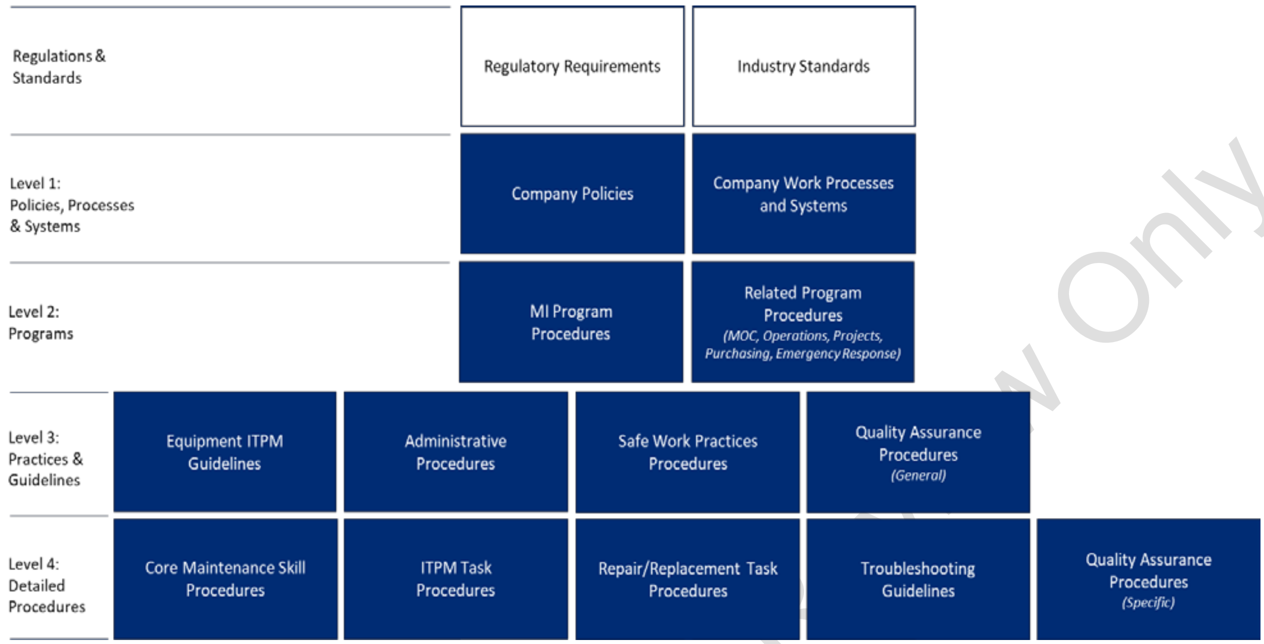


FIGURE 5.1 Example of a Company Written Document Framework

5.2 Policies, Processes and Systems

Documents for Policies, Processes and Systems are the owner-operator's broad guidelines and policies, business work processes, and systems, that describe how an owner-operator organization fulfills the business and regulatory requirements of a MI program. In larger organizations, system level documents are sometimes called corporate or level 1 documents. Examples of system level documents might include:

- Company organizational structure including roles, responsibilities, and expectations for all employees involved in MI activities.
- Expectations for contractors, subcontractors, and suppliers for providing services, assets, materials, etc.
- Guidance regarding how the various departments within the company should execute their work, how work should flow from department to department, and communication within and between departments and external agencies.
- Management, structure, implementation, maintenance and upgrade policies for enterprise system enablers which support the MI activities. These enablers may include a computerized maintenance management system (CMMS), inspection data management system (IDMS), or procurement/accounting system, among others.
- Owner-operator defined risk management policy; process safety management policy; safety, health, environmental, and security policy, sustainability policy, etc.
- The overall MI program.

5.3 Programs

Program documents fit under the umbrella of policies, processes and systems and provide additional levels of detail. In larger organizations, programs are sometimes called cross-site or level 2 documents. Examples of program level documents might include:

- More detailed MI programs for fixed equipment, rotating equipment, electrical equipment, and process controls and interlocks.
- Other programs which interface with the MI program to ensure acceptable performance and execution are sustainable. These programs include management of change (MOC), process safety information (PSI), operating procedures, project management, procurement programs, emergency response, condition monitoring and inspection programs.
- Operational programs to monitor and control process parameters may be critical to the facility's MI program. For processes where Integrity Operating Windows (IOWs) have been established, the programs to monitor process parameters can be interfaced with the MI programs. Refer to Section 15 and API 584 and for more information on IOWs.

5.4 Procedures

Practices and guidelines provide further breakdown and additional detail under the umbrella of programs. They are sometimes called site specific or level 3 documents. Examples of practices and guidelines documents might include among others:

5.4.1 Inspection, Testing, and Preventive Maintenance (ITPM) Guidelines

ITPM guidelines capture the owner-operator's strategy for inspection, testing, and predictive and preventive maintenance activities for the various types of FE to identify failure modes and damage mechanisms that may impact the equipment's mechanical integrity. See Section 7.

5.4.2 Administrative Procedures

Administrative procedures may include documents describing how work related to the equipment included in the MI program is planned, prioritized and scheduled, and documented. Types of administrative procedures may include:

a) User operation of CMMS and IDMS systems
b) Maintenance work process – managing work orders, planning and scheduling work
c) Maintaining equipment files
d) Reporting and coding equipment failures

5.4.3 Safe Work Practices

Examples of safe work practices necessary for the protection of personnel while performing ITPM, repairs, and other activities related to the equipment included in the MI program include:

a) Personal Protection Equipment (PPE) requirements
b) Lock Out / Tag Out (LOTO)
c) Hot work permits
d) Confined space entry
e) Line break procedure

5.4.4 General Quality Assurance Procedures

General quality assurance procedures relating to FE MI focus on assuring the materials of construction, craft skills, and executed work during the fabrication, installation, construction, and maintenance of equipment meets the MI design and performance requirements. Examples of general quality assurance procedures include:

a) Selecting and auditing suppliers and contractors
b) Project engineering technical and administrative procedures
c) Equipment construction and installation standards
d) Equipment repair and replacement procedures

5.4.5 Special Emphasis Program Procedures

Owner-operators may develop special emphasis programs that focuses on specific inspection activities within their MI program that require an elevated level of priority. The need for Special Emphasis Programs may be determined by the owner-operator focusing on areas where higher risk, or deficiencies have been identified. The Special Emphasis Programs may establish inspection methodologies, requirements, and execution strategies. Examples of Special Emphasis Programs include:

a) Buried Piping Inspection
b) Corrosion Under Insulation and Fireproofing
c) Positive Material Identification
d) Deadleg Inspection

5.6 Detailed Work Instructions

Level 4 documents are detailed procedures which address task specific activities. These procedures are intended to provide guidance on the sequences of steps, execution parameters, and acceptance criteria for personnel performing MI activities such that they are performed safely, repeatedly, and to meet the minimum requirements for the program. The detailed procedures may be grouped into five (5) categories:

5.6.1 Core Maintenance Skill Procedures

Examples of core maintenance skill procedures include:

a) Welding procedure specifications (WPS)
b) Inspection technique procedures
c) Mechanical joint torque procedures
d) Flange make up procedures

5.6.2 ITPM Task Procedures

Examples of ITPM task procedures include:

a) Heat exchanger bundle cleaning
b) Visual inspections for pressure vessels – external and internal
c) Atmospheric storage tank visual inspection and surveillance
d) Relief valve inspection and pop testing
e) Chemical cleaning of piping and exchangers

5.6.3 Repair/Replacement Task Procedures

Examples of repair/replacement task procedures include:

a) Welding repairs for piping, pressure vessels, or atmospheric storage tanks
b) Relief valve rebuild and replacement
c) Heat exchanger tube plugging

5.6.4 Troubleshooting Guidelines

Examples of troubleshooting guideline procedures include:

a) Equipment failure root cause flow chart
b) Corrosion control documents (CCDs)
c) Manufacturer's recommended maintenance guide

5.6.5 Specific Quality Assurance Procedures

Types of specific quality assurance procedures may include:

a) Purchasing of equipment and materials
b) Warehouse materials management including receiving, stocking, kitting, issuing of materials and spare parts
c) Positive material identification (PMI)
d) Welding procedure qualification record (PQR)

6 Training and Qualifications

There are many common roles and responsibilities involved in implementing and executing a mechanical integrity program. For more information, see Section 10. Some of these personnel (both owner-operator employees and contractors) should be trained and qualified as appropriate to the role they fulfil. These personnel are needed throughout the life cycle of the equipment.

6.1 Certifications

Certain mechanical integrity activities, such as inspection, non-destructive testing, welding, and repairs are required to be performed by a person who is certified by the appropriate certifying body (e.g., AWS[8]). The requirements are typically specified in the codes and standards that the activity conforms to such as API, ASME, and NBIC.

6.2 Experience

In roles where industry qualifications or certifications are required, the owner-operator should look for and develop the practical experience of personnel and not assume competency when qualifications are obtained simply by testing. A training program or other methods for building competency are useful for keeping personnel aware of changes in their discipline and current in their skills. Some qualifications and certifications require continuing professional development (CPD) credits and documentation.

When contract personnel are engaged in mechanical integrity activities, some owner-operators have found it beneficial to conduct their own testing of skills, particularly for NDE, irrespective of the industry qualifications of contractors.

[8] American Welding Society, 8669 NW 36 St. #130, Miami, FL 33166, www.aws.org.

6.3 Local Process and Safety Training

In addition to qualifications for their role, personnel should be trained in the units where they work so as to understand the processes, damage mechanisms, and resulting hazards. This training should be refreshed periodically.

A program for keeping a safe workplace, staying focused on maintaining a sense of vulnerability, and staying fresh on emergency procedures is also recommended. As conditions change, personnel should be updated to help with risk mitigation.

6.4 Documentation

The owner-operator should document the qualifications for company personnel. They are also responsible for ensuring that contract companies maintain such documentation for their employees and make it available when requested.

7 Inspection and Testing

Inspection and testing of fixed equipment are used to evaluate the physical condition of the equipment throughout its lifecycle. Because process conditions may cause equipment degradation, the owner-operator should maintain a system for scheduling and completing the necessary inspections, tests, and preventive maintenance (ITPM) activities to maintain the mechanical integrity of the assets. The following subsections describe the components of an ITPM program and the factors that should be considered during development.

NOTE This section refers to the inspection and testing of equipment once it has been put into service. Refer to 9.4 for guidance on Quality Assurance inspection and testing during and immediately after new fabrication, repairs, or alterations.

7.1 ITPM Tasks

Appropriate tasks for ITPM activities vary depending on the equipment type, operating conditions, damage mechanisms, and any applicable jurisdictional or regulatory requirements. Generally, the tasks included in an MI program are:

- Visual Inspections
- Non-destructive examinations
- Tests (e.g., hydrotests, leak tests)
- Preventative Maintenance (e.g., coating application or repair, insulation repair)

The equipment type usually determines which codes or standards are followed when creating ITPM plans for assets. 7.2 provides guidance on where to find common industry codes and standards that may be relevant when creating an inspection plan.

7.2 ITPM Methodology and Frequency

The frequency of an inspection or test will vary depending on the equipment being inspected and the suspected damage mechanisms. The owner-operator is responsible for determining the inspection frequency for each asset. The frequency should consider those factors as outlined in the applicable standards.

To determine the frequency of a given activity on an ITPM plan, the owner-operator must first determine which methodology will be employed by the MI program. The following three inspection program methodologies are the most common and ordered from least to most complex:

- Time-Based
- Condition-Based
- Risk-Based

Depending on the complexity of the facility, the maturity of the facility's MI program, and the consequence of failure, different methodologies provide different benefits and require varying levels of resources to implement and execute. Some facilities apply different methodologies for different asset types. For example, the owner-operator may apply a risk-based methodology for pressure vessels and a time-based methodology for piping. Once a methodology is selected, the inspection frequencies can be determined.

The frequency of an inspection or test will vary depending on the equipment being inspected and the suspected damage mechanisms. The owner-operator is responsible for determining the inspection frequency for each asset. The frequency should consider those factors as outlined in the applicable standards. Applicable jurisdictional requirements should be considered because they are often more stringent than the inspection code. If an owner-operator chooses to implement a risk-based inspection program, the frequency is calculated by the program as permitted by the governing code, standard, or jurisdiction.

When an inspection will not be completed prior to the date determined by the inspection plan, an owner-operator should have a documented deferral process. Refer to 8.1.3 for more information about deferrals. Inspection standards, such as API 510 and API 570, provide requirements for their respective equipment types.

In cases where a deferral is needed, but the applicable inspection standard does not provide requirements or guidelines, the owner-operator may choose to adopt the recommendation deferral process as written in API 510 or API 570, or develop a new deferral process for the organization. This deferral process should document:

- Reason and justification for deferral
- Approving person
- Specified due date after deferral

7.3 Inspection Documentation (Inspection / Test Report Templates)

Documentation of all completed inspections is critical to managing the MI of equipment. The historical record providing details and findings of an inspection is referred to as an inspection report, while the permanent and progressive record of all inspections performed on an asset is referred to as the inspection record. The format and level of detail included with each inspection report may vary depending on the type of inspection performed, the criticality of the asset, and the specific requirements of the applicable code. Generally, each report may include:

- Equipment or Asset Number
- Date of inspection
- Date of next planned inspection
- Type and extent of inspection performed
- Description of the inspection or examination performed
- Name of inspector and inspection company performing the inspection
- Detailed results from the inspection
- Acceptance criteria as applicable
- Copy of test report(s) as applicable

In most facilities, the inspection documentation is recorded and maintained in an electronic database known as the Inspection Data Management System (IDMS). Numerous IDMS software solutions exist, and given the digital nature of an IDMS, it enables a facility to store the inspection records of an asset throughout the service life of that asset. Many IDMS programs calculate corrosion rates, asset remaining life, and next inspection dates based on calculated corrosion rates.

In addition to the report for each inspection performed, the owner-operator should maintain the inspection record for each asset. Generally, the inspection record may include:

- Construction and design information, including construction certification forms
- Inspection history that includes the details and data from each inspection/test performed
- Repair, alteration, and rerating information (as applicable)
- Fitness-for-Service assessment documentation

The equipment type, complexity, and governing codes will determine the necessary details that are maintained in the inspection record.

8 Deficiency

In the context of mechanical integrity, the term "deficiency" can be categorized into two sub-topics: equipment deficiency and program deficiency. The management processes for these two types of deficiencies can be substantially different.

- *Equipment Deficiencies* are physical damage, imperfections, or indications that exceed the acceptable limits, or fail to meet equipment specifications. They may require actions to repair or remediate. Discussed in 8.1.
- *Program Deficiencies* are those pertaining to the mechanical integrity program. Examples of program deficiencies are delinquent inspection activities, missing inspector qualification (e.g., CWI), and missing inspection procedures; see 8.2.

8.1 Equipment Deficiency Management Process

Owner-operators should develop and implement a management process to track and resolve equipment deficiencies and the respective repair or remediation recommendations. The management process should include definition of acceptable limits for different deficiency types, roles and responsibilities, prioritization guidelines, and appropriate documentation requirements.

Deficiencies and their associated recommendations can be effectively documented and tracked using a CMMS or IDMS. The use of such tracking software is beneficial so that each repair recommendation is appropriately documented and tracked to closure and for preventing the individual recommendation from being overlooked. The number of coming due and overdue associated recommendations can be effective key performance indicators (KPIs) to aid the owner-operator in managing the recommendations.

Applicable codes and standards (e.g., API 510, API 570, NB-23, and ASME PCC-2) may provide specific requirements on how repair recommendations are managed.

8.1.1 Identifying Equipment Deficiencies

Equipment deficiencies may be identified during ITPM tasks, engineering studies (e.g., process hazard analyses, relief design bases, equipment engineering calculations), incident investigations, quality control activities, and operator rounds. When imperfections or indications are discovered, further analysis may be required by personnel with technical expertise prior to elevating it as a deficiency (i.e., exceeding the acceptable limits) and determining the extent of its associated recommendation. While other imperfections may require immediate remediation such as a shutdown or a pipe clamp, in some cases, further analysis may reveal that a repair is not required or that a reevaluation is required at a later time.

Deficiencies can be both subjective (i.e., based on qualitative judgment) and objective (i.e., based on quantitative acceptable limits). The acceptable limits may be established by owner-operator guidelines or by applicable codes, standards, or jurisdiction, whichever is more stringent. In many cases, the deficiencies that are qualitative may lead to deficiencies that are quantitative over time.

Table 1 - Example Deficiency types

Subjective (Qualitative)	Objective (Quantitative)
-External coating failure -Extent of insulation damage -Vibration level on piping	-Thickness loss -Leakage -Deformation / Bulging -Cracking

8.1.2 Following Up on Equipment Deficiencies

A prioritization process for deficiencies can be beneficial in effectively managing the associated recommendations and their completion. The prioritization process may consider factors such as the consequence, probability, and risk of failure, type of deficiency, time required for repair, opportunity for repair, operating history, jurisdictional requirements, and technical judgment.

Generally, the required time (i.e., due date) to remediate a deficiency can vary widely depending on the deficiency type, severity, and other factors. In most cases, repair timing should consider technical or scientific determination of when the equipment will no longer be fit for service. Determining the required time to remediate a deficiency should also consider jurisdictional requirements, such as environmental regulations, which may impact how soon a deficiency must be corrected.

The associated recommendation in remedying a deficiency can be physical repair (e.g., weld repair, coating), further inspection to fully assess the extent of the deficiency, or engineering analysis/modifications (e.g., rerating, fitness-for-service). For example, API 579-1/ASME FFS-1 provides methods for determining the fitness for service for equipment.

When temporary repairs such as pipe clamps and composite wraps are installed, each location should be assigned an expiration date, maintained, and replaced in accordance with the applicable code prior to the expiration date. Although the temporary repair may permit equipment with a deficiency to operate for a defined extended period of time, it should be considered and treated as a deficiency until the permanent repair is made. If the repair is considered as a permanent repair, then it should be clearly documented as such.

When the deficiency identified was not anticipated (e.g., degradation found correlating to a damage mechanism that was not identified as credible), the inspector or engineer should reassess and update the necessary documents (e.g., Corrosion Control Document, damage mechanism review, inspection plans) in order to effectively anticipate the type of damage in the subsequent inspections.

8.1.3 Equipment Deficiency Recommendation Deferrals

Deferring recommendations should be part of the equipment deficiency management process. The elements of the process are similar to ITPM deferrals described in 7.3.

8.1.4 Equipment Deficiency Documentation of Closure

Each recommendation and its completion or closure action should be appropriately documented. Recommendation where further analysis reveals that a repair per its original recommendation is not required should be documented with the justification. The completion or closure action can be documented in CMMS, IDMS, or directly on the inspection report. However, a consistent documentation approach is beneficial in recommendations management and during audits.

Updates to equipment documentation, such as equipment drawings, inspection sketches, and IDMS data may be needed as result of the repair recommendation. Updates to the equipment inspection plan (e.g., coverage, type of inspection, interval) should be considered where appropriate.

When analysis by personnel with technical expertise finds a recommendation is determined to not be required, the closure should be justified in a written manner (i.e., closing the work order with justification, or a note made directly on the inspection report). A potential issue is that the lower priority recommendations are either ignored or dismissed without documenting the reason for dismissing the repair recommendation.

8.2 Program Deficiency Management Process

Owner-operators should develop and implement a management process to identify, track, and resolve program deficiencies and their associated recommendations. Program deficiencies are systematic issues that compromise the effectiveness or the compliance within the MI program.

Examples of potential MI program deficiencies are:

- Overdue inspections
- Inadequate documentation
- Insufficient inspection and testing
- Inadequate training and qualifications
- Incomplete or outdated process safety information
- Poor preventive maintenance planning
- Ineffective corrosion management
- Inadequate management of change (MOC) procedures
- Lack of performance indicators
- Inadequate incident investigation and follow-up
- Ineffective communication and coordination
- Missed equipment in MI program

8.2.1 Identifying Program Deficiencies

A systematic approach, involving periodic audits, assessments, and surveys can be beneficial in identifying program deficiencies. The effectiveness of these activities may vary depending on the level of expertise of the assessor, and employee participation. The practices described in this document can be subjects for self-assessment. Comparing the MI program to industry practices and performance guidelines (e.g., API Process Safety Site Assessment Program) can identify areas where the program may be lacking or could be improved. See Section 17.

9 Quality Assurance

9.1 General

Quality assurance is a key element of a MI program and proactively focuses on preventing defects by establishing requirements in the approaches, methods, techniques, and processes in all phases of the fixed equipment lifecycle. These requirements are typically outlined in a variety of procedures and work practices which are focused on one or more of the lifecycle phases. This section outlines examples of quality assurance methods for FE.

Quality control is a process which focuses on ensuring the approaches, methods, techniques, and processes are being correctly followed and in identifying defects.

Quality assurance and quality control work together to provide equipment which is suitable for the intended operation.

9.2 QA for Design and Fabrication of New Equipment (prior to installation)

To ensure mechanical integrity, all newly fabricated equipment should be inspected to the appropriate design and construction code. See ASME PTB-2 for an example listing of these codes.

The inspection requirements should be followed and documented in accordance with the applicable code. Appropriate inspection should provide the information necessary to determine that the equipment is safe to operate. The user can refer to API 588 for source inspection guidance.

For shop fabricated equipment, a hold point may be established prior to a release for shipment to ensure that the equipment has been fabricated to the design requirements, all the required QA documentation is available, and the equipment is adequately prepared for transport to the facility.

9.3 QA for Receiving, Storage and Retrieval

Quality Assurance procedures and work instructions should be in place for receiving equipment at a facility, proper storage, and accurate retrieval for construction and installation.

For receipt of equipment and materials at a facility, procedures for acceptance can vary from a comparison of the items with the purchase order to a full inspection to verify materials and any damage in transport. The owner-operator should understand all pathways for which equipment and materials may enter a facility.

Quality Assurance procedures may also include storage requirements of the received equipment and materials to prevent possible contamination and damage prior to construction and installation. Examples include placing materials in assigned locations and under specific conditions (e.g., welding consumables being kept dry), isolation from other materials to avoid contamination, or maintaining an inert atmosphere purge on equipment in storage.

Retrieval of equipment and materials from storage may also have specific quality assurance procedure requirements to ensure the correct materials are pulled for the construction and installation work. Proper handling requirements may also be specified.

9.4 QA for Construction and Installation

Installation and construction activities for fixed equipment are typically performed by contract personnel and in some cases in-house crafts.

Quality assurance requirements should be included in the contractor selection process as well as the ongoing contractor performance throughout the construction and installation activities.

Procedures and work instructions are often used to specify construction and installation requirements, hold points, and acceptance criteria. The use of checklists, weld maps, and installation drawings are a few examples.

Equipment should be inspected by an inspector, or authorized inspector, as defined by the applicable code or standard, at the time of installation. The purpose of this inspection is to verify the equipment is clean and safe for operation, that no unacceptable damage occurred during transportation to the installation site, and to initiate facility inspection records for the equipment. This inspection also provides an opportunity to collect desired base line information and to obtain the initial thickness readings at designated condition monitoring locations (CMLs).

Verification that the installed materials are correct and meet the design requirements is often performed towards the end of the construction and installation phase. A punchout, or walkdown of the equipment will typically verify that the installation matches the design requirements and that the proper materials were installed.

Typically, an integrity test of the equipment is performed at the end of the construction and installation activities. The integrity test may consist of a hydrotest, pneumatic test, or other acceptable testing method.

Any discrepancies identified during the construction and installation phase should be reviewed, corrected, and documented to meet the appropriate code requirements. For some repairs, it may be possible that an engineering assessment is required to ensure the equipment is fit for service.

Finally, all quality assurance documentation should be retained as part of the equipment records. Often this information is included as part of the Pre-Startup-Safety-Review (PSSR) program requirements.

9.5 QA for In-Service Inspections, Repairs, Alterations, and Rerating

Similar to the construction and installation of equipment, quality assurance requirements should be included in the contractor selection process. Additional qualifications may include validation and calibration of the inspector's NDE equipment and technician qualifications using a known sample with defects.

Repairs and alterations to equipment should be performed in accordance with the applicable principles of the code to which the equipment was built or the applicable construction or repair code and the equipment specific repair plan prepared by the inspector or engineer. The equipment repair should follow a fully documented quality assurance program. See ASME PTB-2, for examples of in-service equipment codes and standards.

Repairs and alteration work should follow an authorization and approval process as designated by the applicable code or standard. Repair or alteration design work should be completed by an engineer experienced in the design of the equipment. An inspection and test plan for the repair or alteration should be developed in accordance with the applicable code or standard to address the specific asset.

9.6 QA for Temporary Installations and Repairs

Frequently, an installation or repair is designated as "temporary," and it is not subject to the requirements of a permanent repair or installation. Owner-operators should consider implementing a policy to regulate temporary installations and repairs to ensure that they do not lead to catastrophic consequences.

Such a policy may be integrated into the owner-operator's MOC policy to help ensure that QA issues are properly addressed by determining whether:

- Modifications to operational conditions are necessary for the duration of the installation or repair.
- Operational procedures need updates.
- Potentially impacted personnel should be informed of the changes.

Temporary installations and repairs should be assigned an expiration date, and measures should be in place to ensure that the installation and/or repair is removed, upgraded, or revisited prior to the expiration date.

9.7 QA for Spare Parts

Considerations for spare parts management include identifying spare parts and minimum quantities to stock for equipment and developing procedures and training for purchasing and receiving replacement parts, and for approving substitute parts in place of original equipment manufacturer (OEM) parts.

9.8 QA for Contractor Supplied Equipment

Quality Assurance for contractor supplied equipment can either be covered by the owner-operator QA procedures or as a requirement to the contractor QA program. In either instance, the owner-operator should ensure that all contractors understand requirements and should consider auditing the contractor's practices.

10 Roles & Responsibilities Associated with MI

The following are examples of the responsibilities of various departments, including operations, maintenance, engineering, process safety, and other departments, involved with the mechanical integrity program.

Leadership responsibilities are applicable to the appropriate roles throughout the organization and departments, including site leadership, department managers, supervisors, and other similar roles, who are responsible for assignment of resources needed to execute the mechanical integrity program.

Table 2 – Mechanical Integrity Roles and Responsibilities

Role	Responsibility
Leadership	• Assign personnel and resources to assure compliance with the MI program. • Assure qualified personnel are performing MI activities, including ITPM tasks and repairs. • Communicate MI program expectations. • Ensure reporting programs are in place for asset health condition and status of MI program. • Review and approve changes in inspection schedules and modifications to normal operations as required. • Tracking and taking action on KPIs.
Process Safety	• Implement practices and procedures to verify that all covered equipment are accounted for in the MI program. • Assure that plant procedures follow regulatory requirements and advise document owners when changes in regulations require modifications in plant practices and procedures. • Manage closure of all identified deviations.
Engineering	• Provide subject matter expertise regarding current industry practices to support MI program requirements across all phases of the asset life cycle.

	• Advise leadership regarding changes for inspection schedules and modifications to normal operations. • Maintain asset information in equipment records.
Operations	• Operate the facility within design operating parameters. • Identify deviations and provide support through closure of the deviation. • Manage business unit operations in order to conduct required ITPM activities according to schedule.
Maintenance/ Inspection	• Plan, schedule, and conduct ITPM tasks, equipment repairs and modifications in accordance with current industry practices. • Maintain ITPM data and results in IDMS and/or CMMS. • Identify deviations and provide support through closure of the deviation. • Make available reports indicating status of mechanical integrity PMs.
Contractor	• Provide qualified personnel to: • Fabricate, construct, install equipment for new installations. Perform MI activities including ITPM tasks and repairs.

11 Process Safety Information

General

Process Safety Information (PSI) is a broad element of a process safety management (PSM) program that covers various aspects of a facility's processing technologies and its equipment. In context of FE MI, PSI typically refers to the design documents, drawings, and other forms of asset information that indicates the intent and specifications of the equipment.

Process Safety Information can be grouped into three categories:

- Information pertaining to the hazards of the chemicals in the process (e.g., Safety Data Sheets)
- Information pertaining to the technology of the process (e.g., process chemistry)
- Information pertaining to equipment of the process (e.g., design codes, material of construction)

This document focuses on the information pertaining to FE of the process. PSI for FE is a key piece of information in determining its inspection tasks, inspection methodologies, frequency, and repair plans.

Table 3 shows examples of documents that are typically considered as PSI for different FE types.

Table 3 – Typical PSI for Fixed Equipment

Equipment Type	Typical PSI can include:
Pressure Vessels (Coded)	• Design Code • Design Calculations • U-1A, U-2A, U-4A – See NBBIC www.nationalboard.org • Stamped Nameplate • Design / As-Built Drawings • Repair Package
Pressure Vessels	• Design Code

(Non-coded)	• Design Calculations • Nameplate • Design / As-Built Drawings • OEM Manual • Repair Package
Piping	• Pipe Specification • Positive Material Verification • Welding Data
Aboveground Storage Tanks	• Design Calculations • Nameplate • Design / As-Built Drawings
Pressure Relieving Devices	• Design Basis • Nameplate • Specification Sheet • Certificate of Conformance • OEM Manual
Fired Heaters	• Design Code • Design Calculations • Nameplate • Design / As-Built Drawings • OEM Manual • Repair Package

11.2 PSI Management Program

Establishing a program to obtain, organize, and maintain the PSI for fixed equipment is a crucial element in building a robust MI program.

The key components in managing PSI for FE may include:

a) Steps to confirm PSI is retained when installing new or replaced assets
When installing new or replaced assets, the owner-operator's quality control process should include verification of pertinent PSI for the asset. PSM programs such as Management of Change (MOC) or Pre-Startup Safety Review (PSSR) can be effective measures to formalize verification of the documents as long as the checklists include specific steps pertaining to document verification.

Establishing a document handoff process with the inspection group can be beneficial. When other inter-disciplinary departments are leading such equipment installation, replacement, and alterations, the document handoff process can establish the types of documentation to be handed off, document format, and the timing of handoff.

b) Steps to confirm PSI is updated when changes are made to the assets
When modifications are made to an asset's design, its PSI should be updated to reflect the latest state of the asset. A modification can mean a repair, an alteration, derating/rerating, or other activities that could alter the asset's integrity.

c) Steps to organize the documents

Standardizing the file structure in which PSI is stored for FE is beneficial in making PSI accessible to not only the inspection group, but to operations, engineering, and management as well. Generally, compartmentalizing documents per unit and per asset can be an effective way to configure the file structure. Digitizing old documents by scanning and storing the documents electronically is a good practice.

d) Steps to identify PSI gaps for existing assets
A proactive audit of PSI against the facility's asset list can be an effective way to identify the PSI gaps for existing assets. Such gaps are considered program Deficiencies as described in Section 8.

Owner-operators may come across cases where the pertinent equipment PSI cannot be found. When these PSI gaps are identified, steps should be taken to retroactively obtain the documentation. Examples of such steps are:

- Gather all other information available for the equipment, including pictures of nameplates and stamping. This may provide clues on how to proceed on next steps.
- Contact The National Board of Boiler and Pressure Vessel Inspectors (NBBI), if the nameplate has a national board number. If the equipment was registered with NBBI, owner-operators can request the manufacturer's data reports through the website.
- Contact the original manufacturer with serial number.
- Verify legacy files, job books, and hard-copy documents at the facility.
- When the original documentation cannot be obtained, consider performing a retroactive engineering analysis per the construction code to verify and document the equipment design.

12 Repair Organizations

12.1 Qualified Repair Organizations

Qualified Repair Organizations are separate and distinct from fabricators and manufacturers. Fabricators and manufacturers construct new equipment compliant with applicable codes and standards. To do so, they must obtain specific certifications from various industry standards organizations such as ASME or API to authorize their work. Repair Organizations perform post construction activities on equipment, and they similarly obtain specific certifications from various industry standards organizations to authorize repair work.

A qualified repair organization is essential for those involved in repairing or altering, pressure vessels and boilers. It supports compliance with safety standards, legal requirements, and industry best practices. Specifically:

- **Legal Compliance:** In many jurisdictions, repair or alteration is subject to strict regulations. Various codes and standards are widely recognized and adopted in the industry. Becoming a qualified Repair Organization demonstrates compliance with these codes.
- **Safety:** Industry standards are designed to ensure the safe operation of these devices, and a qualified Repair Organization is expected to adhere to these standards during repairs and maintenance.

- **Quality Assurance:** Industry standards organizations set rigorous quality control and inspection requirements for organizations holding certification(s). These requirements help ensure that repairs and alterations are done to the highest criteria, reducing the risk of equipment failures and accidents.

- **Insurance Requirements:** Insurance companies may require that repairs to FE be performed by certified Repair Organizations to mitigate their own risks.

- **Technical Conformity:** Having a qualified Repair Organization perform repairs ensures that the repaired components remain compliant with the original design and can be seamlessly integrated into existing systems.

- **Documentation:** Qualified Repair Organizations are required to maintain thorough records of repairs and alterations, which can be crucial for regulatory compliance and liability protection.

12.2 Repair Stamps

Fabricators and manufacturers who are certified are authorized to ‘stamp’ equipment as compliant with codes and standards. Repair Organizations similarly obtain specific certifications from various industry standards organizations and are authorized to stamp their work. While individuals hold code certifications, this does not constitute a qualified Repair Organization. Individuals do not have the authorization to ‘stamp’ equipment.

As an example, the NBBI offers several different types of repair stamps, each designated for specific types of pressure equipment and services. The primary NBBI repair stamps applicable to the process industries include:

- **R Stamp** (Repairs and Alterations): One of the most common repair stamps, the R Stamp is used for organizations involved in the repair and alteration of pressure vessels. This stamp covers a wide range of pressure equipment, including boilers, heat exchangers, and storage tanks. The NBBI R Stamp is applied to the repaired pressure vessel, typically near the original ASME code stamp. It signifies that the repair has been performed by an NB-certified organization and is compliant with code requirements.

- **VR Stamp** (Valve Repair): The VR Stamp is used for organizations specializing in the repair, alteration, and testing of pressure relief valves, safety valves, and relief valves. It ensures that these critical safety devices are maintained and tested to industry standards.

- **HV R Stamp** (Heating Boilers - Repairs and Alterations): This is a subset of the HV Stamp (boilers) and is specifically for organizations performing repairs and alterations on heating boilers.

Codes and regulations may evolve over time, and new stamps or changes to existing stamps may have been introduced. It's essential to refer to the most current standards organizations or a qualified authority for the most up-to-date information regarding repair stamps and their requirements.

12.3 Repair Data Reports (Forms):

Several records and documents are typically employed during repairs execution to ensure compliance with codes and standards. Examples of key records associated with a code repair include:

- **R-1 Report**: A Repair/Alteration Report used to document repairs and alterations to pressure vessels and boilers. It includes details of the repair process, materials used, and inspection results.

- **R-2 Report**: Similar to the R-1 report but used for pressure vessels that are repaired in multiple sections or locations.

12.4 Repair Inspection Reports and Records

- Detailed inspection reports documenting the condition of the equipment before and after the repair.
- Records of non-destructive testing (NDT) procedures and results.
- Records of visual inspections, including photographs, if necessary.
- Welding procedure specifications (WPS) and welding procedure qualification records (PQR) when welding is involved in the repair.

12.4.1 Repair Material Certifications:

- Records of materials used in the repair, including certificates of compliance for new materials and traceability of materials used in weld repairs.

12.4.2 Repair Welding Records:

- Welder qualifications and certifications.
- Welding procedure specifications (WPS) used for the repair.
- Welding maps showing the location and details of welds.

12.4.3 Repair Pressure Test Records:

- Records of hydrostatic or pneumatic pressure tests performed after the repair to verify the integrity of the vessel.

12.4.4 Documentation of Repairs:

- Detailed documentation of the repair process, including repair procedures, techniques, and any deviations from the original code requirements.

12.4.5 Manufacturer's Repair Data Plate:

- If applicable, the manufacturer's data plate on the equipment may need to be updated to reflect the repair and any changes made during the repair.

12.4.6 QA/Quality Control Documentation for Repairs:

- Records of quality control measures, including inspections, checks, and verifications performed during the repair process.
- Inspection Test Plan (ITP), which outlines the conditions being corrected, methods for repair and NDE to be applied.

12.4.7 Regulatory Approvals for Repairs:

Documentation of approvals from regulatory authorities may be required by local or national regulations.

These records and stamps are critical for demonstrating that the repair has been carried out in accordance with appropriate codes and standards, ensuring the safety and integrity of the pressure equipment. Proper documentation and adherence to code and/or standard guidelines are essential to comply with legal and safety requirements.

13 Pre-Startup Safety Review (PSSR)

13.1 General

The Pre-Startup Safety Review (PSSR), sometimes referred to as the Operations Readiness Review, is a broad element of a PSM program that covers various aspects of a facility's processing technologies and its equipment. In context of FE MI, PSSR is an opportunity to identify and verify MI program requirements for FE have been accomplished for the newly installed, repaired, or re-rated equipment prior to process operations.

13.2 Description

The PSSR is a QA review to verify that the equipment, as installed, repaired, re-commissioned, or re-used in a different process, meets the design requirements for the intended service, has the necessary documentation captured in appropriate systems of record, and all affected procedures and training have been developed and/or updated. Any discrepancies are documented in a punch list and prioritized with respect to what needs to be completed prior to startup, and what may be completed post startup, with assigned responsibilities and timing.

13.3 Checklist

The PSSR checklist is typically site specific and facilitates acceptance of the necessary changes by the authorized personnel from each of the departments affected by the change.

Refer to Annex B for an example PSSR Worksheet with questions pertaining to FE MI.

13.4 Documentation

PSSR documentation for FE includes updating the asset file with the new information and archiving obsolete information. Documentation may also include updating operations, maintenance, and emergency response procedures; process inventory lists; CMMS and IDMS databases; relief valve programs; DCS screens; and other site requirements.

14 Management of Change

14.1 General

Management of Change is a broad element of a PSM program that covers various aspects of a facility's processing technologies and its equipment. In context of FE MI, the OSHA PSM-driven process requires owner-operators to review and approve all significant changes to PSM-driven processes and equipment as well as update PSI information prior to implementation. Ineffective or inconsistent MOC processes can invalidate previous hazard and risk assessments or compromise protective layers.

14.2 Creating a MOC process

A process for creating, documenting, tracking and training on MOCs should be documented. This provides guidance to personnel responsible for executing portions of a MOC and ensures proper documentation update.

14.3 When to initiate a MOC

A MOC process should be initiated anytime changes in process chemicals, technology, equipment or facilities are proposed. Examples of applicable changes could include:

- adding, removing, or modifying an equipment or piping component
- changes to process conditions or composition
- changes to operating procedures
- any change that requires an update to process safety information

14.1 MOC Review and Approval

The regulations and procedures for MOC are not covered in detail in this document, but in general, MOC review/approval should be conducted using a multi-discipline team with representatives from appropriate disciplines based on the scope of work. MI personnel should be involved in the initial review/approval of changes to ensure the proposed change does not have unintended negative consequences related to equipment MI and/or remaining life. An example of such negative consequences would be an increase in throughput resulting in a flow induced vibration in a heat exchanger, drastically reducing tube bundle life.

14.5 Updating MOC Associated Documentation and Closure

The MOC process requires that equipment files are updated when changes are made to the equipment to ensure the equipment files reflect the equipment as currently installed in the field. This is important for a number of reasons including:

- ensuring spare parts ordered are appropriate
- equipment replacements match what is in the field
- MI inspection records are based on accurate equipment information

See Section 11.

It is important to have a closure system that ensures records and elements of the MI program are updated as part of the MOC such that the MOC cannot be closed without positive confirmation the updates have occurred.

15 Integrity Operating Windows

15.1 General

Integrity Operating Windows (IOWs) can be used to strengthen the MI program for a process facility. They allow operational monitoring programs to directly interface with the MI program and identify when process operation is negatively affecting the integrity of FE. Correctly establishing IOWs and operating within those limits can maintain the integrity of FE. The contents of this section are intended to summarize IOWs. Refer to API 584 for more information.

Establishing IOWs does not eliminate all credible damage mechanisms for process equipment. When IOWs are established correctly, degradation should be predictable and able to be reliably monitored through an inspection program.

It is important to understand that operating parameters established as safe upper and lower limits (per OSHA PSM 1910.119(d)(2)(i)(D)), often referred to as Safe Operating Limits (SOL), may differ from the operating parameters of IOWs. The purpose of establishing IOW limits is to identify where materials begin to experience accelerated degradation, whereas the safe upper and lower limits may only consider safety scenarios such as overpressure.

15.2 Establishing Integrity Operating Windows

The main elements to establishing IOWs are:

- Defining process and design conditions
- Identifying damage mechanisms
- Setting limits for process variables

Thoroughly defining process conditions (e.g. pressure, temperature, pH, and fluid velocity) and understanding design conditions (e.g., mechanical design, material of construction, heat treatments, etc.) is key to correctly identifying applicable damage mechanisms.

Based on these factors, credible damage mechanisms are identified for each piece of equipment and all known process conditions. Reference API 571 for common damage mechanisms in the refining industry. If equipment experiences multiple process conditions during facility operation, including facility start-up and shut down, intermittent or irregular service, and other known abnormal operation, then IOWs can be established for each set of conditions. API 970 details a work process that can be used to identify damage mechanisms through corrosion control documents (CCD).

Typically, equipment with similar process and design conditions are grouped together to establish an IOW basis for multiple assets. If an individual piece of equipment experiences unique operation compared to the rest of the unit, then it may have its own set of operating limits.

A limit should be set for a process variable if passing that trigger will result in a significant change to degradation rate or damage mechanisms. Limits may need to be set conservatively depending on the risk of exceeding that limit. This risk can also affect the criticality of the IOW as explained in API 584. API 584 also provides guidance on how to risk rank IOWs.

15.3 Management of IOWs

Establishing IOWs for a process facility should include identifying an individual as the IOW owner and manager. Typically, this is a unit representative such as the Process Engineer. IOWs are more effective when integrated with existing operational monitoring programs, but additional monitoring may be needed to measure variables and ensure they do not exceed allowable limits. To properly integrate IOWs and operational monitoring, there should be effective communication between the Unit Process Engineer, Corrosion Specialist, and Inspector. This communication allows action to be taken when operation is outside the limits established by the IOWs.

In the event that a limit is exceeded, the Corrosion Specialist and Inspector should be informed. The Corrosion Specialist should evaluate the potential impact from the event on the equipment. If the potential impact is significant, then additional inspection may be necessary to determine the condition of the equipment.

IOWs should be updated when a change to mechanical design or operating conditions occurs in a process facility. This includes not only replacement of equipment or changes to operating conditions, but also changing a feed stock material, velocity, etc. See Section 14 for more details on using MOC to document these changes.

16 Key Performance Indicators

16.1 General

Implementing FE MI key performance indicators (KPIs) can bring numerous benefits to owner-operators. These benefits include:

- providing clarity and focus by defining specific objectives and measurable targets, aligning the efforts of individuals and teams toward shared goals.
- enabling effective performance monitoring and evaluation, allowing owner-operators to track progress, identify areas of improvement, and make data-driven decisions.
- promoting accountability and fostering a culture of continuous improvement.

API 754, identifies leading and lagging process safety KPIs, including some FE MI indicators. Examples of FE KPIs are:

- Number of overdue inspections defined as per applicable codes and standards.
- Loss of containment due to FE failure. This can be further classified by damage mechanism.
- Number of locations below minimum thickness found during onstream condition monitoring.
- Number of Fitness for Service Assessments. This can be further classified into Level1, Level 2 and Level 3 completed.
- Number of temporary repairs.
- Number of times equipment has exceeded its IOWs (Integrated Operating Window).

16.2 Challenges Associated with KPIs

Key challenges for KPIs include:

- If the strategic goal(s) and key objective(s) are not clear or are misaligned, KPIs tend to focus on outcomes only or may be meaningless.
- Too much reliance on one type of KPI may offer a very imbalanced and incomplete view of the whole health of a program.
- Every organization is different; thus, every organization will have different strategic goals and different KPIs. KPIs deemed important by industry may not be applicable to an organization's specific operation.
- Identifying both leading and lagging indicators is an in-depth process that should require stakeholder engagement from various parties such as, equipment specialists, inspectors, corrosion specialists, and management.
- The ability to accurately measure and report on the identified measures may be difficult or impossible given internal reporting system limitations.

A healthy process for sustaining the identification, implementation, and active use of KPIs involves all associated personnel regularly revisiting and revising the measures. This fine-tuning process takes time and diligence by all parties, which in turn promotes the sustainability and stability of the program.

16.3 Mistakes Associated with KPIs

One important thing to remember about a KPI is that it is not an end in itself. Another way of saying this is that each KPI should be tied into the organization's overall strategic goals, but the KPIs are not the goal themselves. With that in mind, several mistakes could occur during the creation/use of a KPI, for example:

- Defining too many KPIs.

- Reporting too much detail behind the KPIs.
- If it takes too long to consolidate all the data, then a KPI report may become outdated, and will tend to describe past performance rather than give insights into future performance.
- Using KPIs as a method to pass the “blame” for missed targets and milestones.

16.4 Reporting

KPIs should monitor the sustainability and stability of a program as well as facilitate learning and improvement. Communication (reporting) is critical to their acceptance and value. The format for reporting will be dependent upon the target audience. However, reporting should have a philosophy of openness and transparency in communication that helps in demonstrating the effectiveness of the KPI(s) of meeting the strategic goal(s).

17 Program Assessments and Audits

General

The term audit as used in this document references the compliance validation performed by a regulating body. Owner-operator MI programs may also have established assessment processes (self-audit) that are performed on a regular interval to identify opportunities for program improvement. For the purposes of this document, audits and assessments together will be called reviews. In either case, the program should be reviewed against two categories:

- The owner-operator’s written MI documents
- Applicable industry codes and standards.

While a MI audit may focus on many disciplines, this document is focused on FE scope.

17.1.1 FE MI Scope

Facility MI reviews should be performed using a documented protocol to allow for repeatability and consistency. MI reviews should cover significant areas that impact overall FE reliability as well as specific program priorities of individual owner-operators. The protocol scope categories typically include:

1. Basic Programs
   Basic programs include elements that measure compliance to jurisdictional rules, inspection codes and in-house policies. This may include inspection programs for pressure vessels, piping, PRDs, tanks, and steam generators, and others.

2. Special Emphasis Programs
   Special Emphasis Programs include those elements that generally have inspection strategies different than basic programs. See 5.4.5 for more information. Special emphasis programs may include damage mechanism specific programs such as wet H_2S, CUI, HTHA, and sulfidation, as well as specific equipment items such as critical check valves, flares, and heat exchanger bundles.

3. Data Management and KPI Reporting
   Data management includes the processes for obtaining, recording, and evaluating inspection data, monitoring of IOWs), and execution of MI-related action items. This section may also include documentation of results and the inspection recommendation process. KPI effectiveness and reporting is an important element in this category.

4. Other Topics

   Areas that are important to the FE reliability efforts that do not fit well into the other categories are often captured in a separate category. Examples may be equipment repair practices, QA/QC, and material verification programs.

17.1.2 Frequency

Review frequency is defined by the owner-operator, based on facility risk profile and/or previous audit performance. The period between reviews should be long enough to allow for implementation of improvement efforts (see 17.4).

17.1.3 Reporting/Recommendation

Each program deficiency discovered during an assessment or audit should be provided with a recommendation to effectively mitigate the deficiency. A recommendation provides most value when it is worded such that it is actionable and practical. The recommendations can be formally tracked based on the type of review performed and following the policy of the owner-operator. Typically, the final recommendations are reviewed and agreed upon among the auditor and management.

17.2 Assessments

17.2.1 Assessment Team Members

An audit team is a multidisciplinary group and should consist of people experienced in:

- the relevant operating processes
- work practices
- inspection
- NDE
- engineering principles
- codes and standards

17.2.2 Assessment Process

An effective assessment process may consist of the following components:

17.2.2.1 Written Guidance Review

A review of applicable written guidance pertaining to FE MI is an essential step to ensure it aligns with at least the minimum regulatory requirements. Examples of written guidance include MI policies, programs, inspection procedures, ITPM plans, and special emphasis programs.

17.2.2.2 Data Review and Verification

The assessor should select a representative sample size of MI data to be reviewed. The MI data may include inspection schedule (e.g., IDMS, CMMS), inspection reports, inspector certification documents, repair packages, PSI for assets, etc. When a program deficiency is discovered, it is typical to expand the sample to confirm and understand if the deficiency is systemic throughout the program.

17.3 Audits

Periodic self-auditing by those directly involved with the facility FE MI program should be supplemented by external audits performed by an audit team external to the facility. These may include stamp holder audit, NBIC audit, jurisdictional boiler audit, and state pressure vessel audit.

17.3.1 Audit Team Members

An audit team is a multidisciplinary group like an assessment. It also typically consists of employees from other facilities, the corporate office, and/or 3rd party organizations.

17.3.2 Audit Process

The value of an audit can be maximized by thoroughness of the audit, quality of representative samples reviewed, and outside perspective from experts in MI topics. Effective audits consist of not only documentation review but also interactions with the site personnel to understand the state of the facility's mechanical integrity program as it stands at the time of the audit.

In addition to the categories listed for assessment, audits should consider:

17.3.2.1 Field Walkthrough

Performing a field walkthrough prior to beginning document review can be beneficial in identifying representative samples to request, as well as developing interview questions for the site personnel. A field walkthrough can include process areas, storage warehouse, and welding shop to give the auditor an opportunity to observe field conditions and quickly identify the general topics to focus on throughout the audit (e.g., poor insulation condition in field leading to a focus on CUI, poor storage condition in warehouse leading to a focus on material verification program, abandoned-in-place equipment leading to a focus on proper inspection exemptions).

17.3.2.2 Interviews with facility personnel

Interviews with the site personnel are a key component in understanding the state of the facility's MI program, how the MI activities are managed, and their awareness on particular focus topics of FE MI. An interview does not always mean a series of audit protocol questions asked by the auditor but can be performed by discussing the overall program or reviewing inspection documents/data together.

17.3.2.3 Site Organization and Leadership

Site organization includes staffing levels and training/certifications/technical ability of the FE group. Other site departments such as operations and maintenance are included in the site organization. Site leadership engagement and support for the FE MI program is a key element for this category.

17.4 Continual Improvement

The results from an MI review may identify gaps within a facility's FE MI program and may have recommendations to close the identified gaps. Owner-operators should prioritize the list of gaps and develop an implementation plan for each item. The facility owns the implementation plan (not the auditor or assessor) and should assign necessary resources and due dates to address the gaps.

To gain the most benefit from the review and drive continual improvement, it is important to:

- track these implementation items in a system of record until completion. Approval of the completed action(s) should follow the company's workflow process. Beware of the tendency to "close with a promise". Instead, the completed action should be approved by management.
- verify that the actions were effective.

If corrective actions are not completed or don't have the desired effect, the issues may not be addressed.

18 Safe Work Practices

18.1 General

Mechanical integrity ITPM activities and repairs require work within operating facilities where the equipment may or may not be in operation. Safe work practices have been developed to help protect personnel, prevent damage to equipment, and prevent environmental releases while performing work in these facilities.

18.2 Safe Work

The preparation of the work plan, communication with the operations team, execution of the work, and follow-up once the field work is complete are typical of phases of the work. The following are examples of how safe work practices may be incorporated with MI work.

18.2.1 Preparation

Planning the MI work helps to ensure the work is performed safely and efficiently. The work plan should, at a minimum, identify the necessary procedures, work permits, and personnel protection equipment required for the job. The work plan should follow the facility's work practices and procedures for the type of work to be performed. Additional procedures may be required if the work being performed is not covered under the site's existing procedures. Examples of common safe work practices for MI work include (but are not limited to)

- General work permit
- Hot work
- Lock-Out / Tag-Out
- Confined space
- On / Near Live Energy
- Fall protection
- Rope Access
- Radiation
- Hazardous insulation
- Respiratory protection
- Breathing air
- Barricades for work

When using contractors to perform the work, the contractor's safe work practices and safety performance should be part of the selection process.

18.2.2 Communication

Key items to inform the operations team include communications regarding:

- the type of work to be performed
- the area and/or equipment within the plant where the work will be done
- the number of personnel performing the work
- the expected start and duration of the work
- when the work is complete

Communication on safety issues from operations to those performing the work is also extremely important. These include (but are not limited to) information regarding:

- emergency evacuation

- location of safety showers/eye-wash stations
- other work being performed in the area
- and other potential risks in the work area

18.2.3 Execution

While executing the work in the field, the following are a few examples of safe work practices:

- Housekeeping
- Awareness of others working nearby/above/below
- Awareness of surrounding equipment
- Stop - If work extends beyond the scope or area of work

18.2.4 Follow up

When the work in the field is complete, the facility's procedures for closing out the work permits and leaving the facility should be followed.

19 Inspection Data Management Systems

19.1 General

Inspection Data Management Systems (IDMS) play a crucial role in modern industries by efficiently organizing, analyzing, and leveraging inspection and integrity data. These systems are designed to support the overall inspection process, ensure compliance, and enable data-driven decision-making.

The organization and categorization of data are fundamental features of IDMS. These systems are designed with structured databases and software architecture that allow for systematic storage and retrieval of inspection data. This organized structure not only facilitates day-to-day activities but also serves as a valuable resource for historical analysis, trend identification, and predictive maintenance strategies. Moreover, IDMS facilitate data analysis and reporting. The ability to generate detailed reports and analytics from inspection data empowers decision-makers to identify patterns, evaluate asset health, and make informed choices regarding maintenance, repair, or replacement.

19.2 Benefits

IDMS comes from the need to centralize and organize inspection data effectively. Traditional methods of inspection data tracking often involves scattered data sources, leading to inefficiencies and challenges in data retrieval and data analysis. IDMS provides a single source for storing inspection data and simplifies the overall complexity of inspection data analysis by providing integrated data analysis tools.

19.2.1 Management of Large Volumes of Data

Managing and organizing large volumes of data can be complex, costly and time consuming. Owner/Operators are continuously collecting large volumes of data points, often without management systems mature enough to fully leverage this data. To overcome this challenge, a robust data management system is crucial. These systems need to be able to handle the complex relationships between different types of data or data sets and need to provide users with the ability to quickly and easily find and reproduce the desired information.

Another challenge of working with large volumes of data is the need for clear protocols for data labeling, entry and verification. To ensure that good data can be leveraged, it is important to have clear procedures in place for all aspects of the data collection protocols, including training and supervision of the personnel involved in the collection, the use of standardized measurement instruments, and the procedures for verifying the accuracy of the data. This can help to ensure that the data is properly collected and incorporated into the data management system.

19.2.2 Data Integration

If done properly, integrated data management can tell the full story. This is because data can come from various incompatible sources, such as multiple types of NDE tools and online monitoring systems that have been collecting data for years with different levels of completeness and complexity. For integrating these distinct sources, a comprehensive computerized solution specialized in risk assessment, management of inspection and corrosion data management, and with powerful visualization capabilities is fundamental. Such a solution should not only be able to store data but it should also be able to analyze and generate actionable insights from the data that enables operators to execute more strategic and targeted inspections, risk mitigation and repair activities.

19.3 Roles and Responsibilities

IDMS involve diverse roles and responsibilities within an organization. Inspectors utilize the system to input real-time data, ensuring accurate and up-to-date information. Engineers and managers rely on IDMS for data analysis, trend identification, and making informed decisions about maintenance or asset replacement. Compliance managers benefit from the system's ability to track and demonstrate adherence to regulatory standards, reducing the risk of penalties.

19.4 Types of IDMS

There are various types of IDMS tailored to meet specific industry needs. Some systems focus on NDT data, while others integrate with enterprise systems to provide a comprehensive view of asset health. Additionally, cloud-based IDMS offer flexibility and accessibility, allowing stakeholders to access crucial information from anywhere.

19.5 Selecting an Inspection Data Management System

Choosing the right IDMS is a critical decision. Several considerations and steps should be taken into account to ensure the selected IDMS aligns with the organization’s specific needs and goals.

- Identify Specific Requirements: Begin by clearly defining the organization’s requirements and objectives for implementing an IDMS. Consider the types of inspections, the volume of data, and any industry-specific regulations.
- Assess Compatibility and Integration: Evaluate the compatibility and seamless integration of the IDMS with existing systems, such as CMMS and Enterprise Resource Planning (ERP).
- Scalability and Flexibility: Choose an IDMS that is scalable and adaptable to the organization’s future needs. As the business evolves, the IDMS should accommodate increased data volume, additional inspection types, and emerging technologies. Scalability ensures a long-term investment that grows with the organization.

- User-Friendly Interface: The IDMS should be accessible to inspectors, engineers, managers, and other stakeholders with varying levels of technical expertise. Therefore, an intuitive and user-friendly system promotes efficient data input, retrieval, and analysis, and is crucial for widespread adoption within the organization.
- Data Security: Security is paramount, especially when dealing with sensitive inspection data. Ensure that the IDMS implements robust data security measures, including encryption, access controls, and regular security audits. A secure system protects against unauthorized access and safeguards confidential information.
- Cost Analysis: Conduct a thorough cost-benefit analysis, considering the initial acquisition costs and ongoing maintenance, support, and potential scalability expenses. Understanding the total cost of ownership ensures that the IDMS aligns with the organization's budget constraints.

Selecting the right IDMS should be an effort that involves a comprehensive assessment of requirements, compatibility, scalability, user-friendliness, data security, and cost. Following these considerations support a well-informed decision that aligns with the organization's specific needs and goals.

20 Managing Codes & Standards Updates and Revisions

20.1 General

Codes and Standards are developed, published, and typically updated on a routine basis. To ensure that the owner-operator's MI program is in compliance with the current codes and standards, it is necessary to establish a standards management process including:

- Identifying the applicable codes and standards,
- Periodically reviewing the publishing organization's listing of those codes and standards,
- Modifying the owner-operators' practices, internal policies and procedures to ensure compliance with those codes and standards.

Individual codes and standards are frequently updated or re-authorized. The specific revision is referred to as the edition of the particular code. Some organizations, such as API, perform reviews and updates of standards on a fixed interval. Common intervals are 2 to 5 years. Codes and standards organizations often provide an index of their publications with editions on the organization's website.

Through the updates, the requirements and recommended practices within the documents are often revised. For example, a 'should' recommendation may become a 'shall' requirement in the next edition of the document.

20.2 Selection, Application, and Revisions

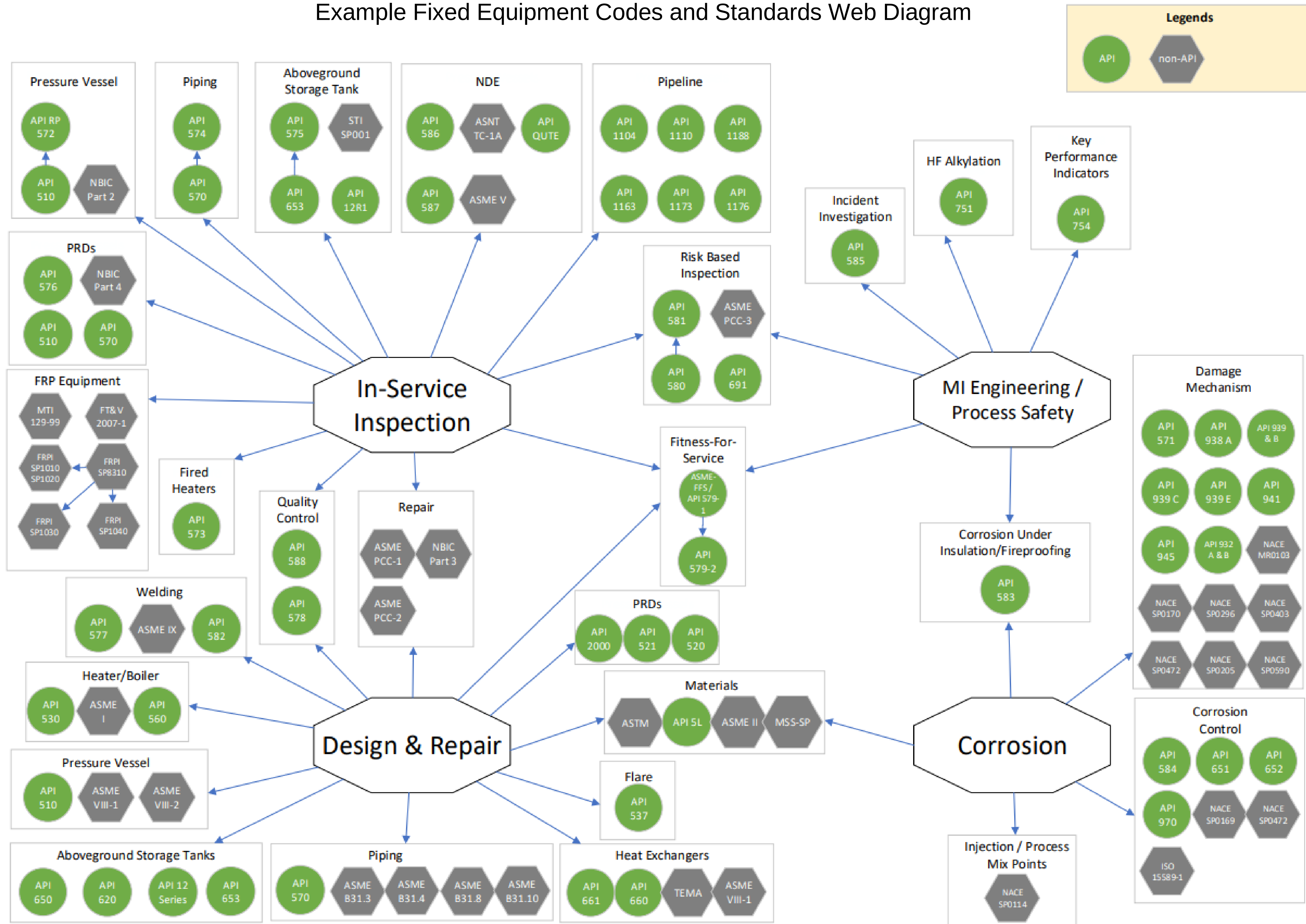
The selection of other codes and standards is dependent upon the jurisdictional requirements of the facility's location. In the United States, the jurisdictions having authority are often a combination of city, state and federal agencies. These agencies may elect to adopt specific codes and standards, making them mandatory for the facility and enforcing through permitting or compliance inspections.

A few, representative examples of technical bodies that publish such codes and standards are listed in Annex C.

Refer to Annex A for a web diagram that shows an example of how the specific relevant codes and standards published by these organizations can be integrated into a MI program.

Annex A
(informative)

Example Fixed Equipment Codes and Standards Web Diagram



Annex B
(informative)

Sample PSSR Worksheet

MOC # and Title:	PSSR Date:			
Item	**Complete**	**Not Complete (Assign)**	**N/A**	**Person Assigned**
Decommissioned equipment is blinded or physically disconnected				
Training or notification of affected operating / maintenance personnel has been completed				
The controlled PID has been updated to reflect changes				
All required regulatory documents have been updated and filed with the appropriate agencies				
Operations has been informed of any items that must be completed prior to equipment start-up				
Atmospheric vents/relief devices are routed to a safe location				
Installation is free of personnel hazards				
All LDAR/VOC tags in place and new fugitive components added to tracking				
All equipment has been installed per the MOC Package				
Appropriate equipment files have been updated				
Painting/coating/fireproofing is complete per specification				
Insulation installed per specification				
Correct gaskets and bolts installed per specification				
Flanges, bolts and screwed fittings are tightened and torqued				
Expansion joints installed to move per design requirements				
Piping/equipment has been pressure tested and properly drained or vented				
Cold service piping/equipment has been drained and dried				
Directional indicators on valves, steam traps, and rupture discs have been verified correct				
Pre-load settings on spring supports and hangers have been verified, and straps and shims removed				
Proper thrust blocks are in place for underground piping				
Cathodic protection has been installed on underground piping where required				
Steam or electric tracing has been installed per specification				
Temporary connections utilized during installation have been blinded or disconnected				
Equipment is properly bolted down/anchored per design specification				
Equipment internals are installed per design and temporary internal components and trash have been removed				
Eqiupment has been grounded or bonded				
A permanent name plate has been installed on the vessel and data been verified correct				
Structural steel and piping/equipment structural elements have been installed per drawings, specifications, and OSHA regulations and temporary supports removed				
Relief valves and rupture discs have been installed with proper setting & tagged correctly				
Rupture disks in combination with pressure-relief valves are vented and/or monitored to prevent or detect pressure buildup				

PSSR Attendee's Signature & Date:

Print Name	Signature	Role/Position	Date

Annex C
(informative)

Examples of Codes and Standards Technical Bodies

A few representative examples of technical bodies that publish codes, standards, and other documents that may be relevant to a fixed equipment mechanical integrity program are:

- **American Fuel & Petrochemical Manufacturers (AFPM)[9]** - a trade association representing high-tech American manufacturers of gasoline, diesel, jet fuel, other fuels and home heating oil, as well as the petrochemicals.
- **Association for Materials Protection and Performance (AMPP)[10]** - a professional association focused on the protection of assets and performance of materials. AMPP was created with the merger of NACE International and SSPC.
- **American National Standards Institute (ANSI)[11]** - a nonprofit organization that oversees the development of voluntary consensus standards for products, services, processes, systems, and personnel for a variety of equipment used within the process industries.
- **American Petroleum Institute (API)** - a trade organization which publishes a wide variety of codes for safety and performance in the oil, gas and chemical industry.
- **American Society of Civil Engineers (ASCE)[12]** - a professional body representing members of the civil engineering profession worldwide. It is the world's largest publisher of civil engineering content, and an authoritative source for codes and standards that protect the public.
- **American Society of Mechanical Engineers (ASME)** - a professional organization which publishes a wide variety of codes for pressure equipment used within the process industries.
- **American Society for Nondestructive Testing, Inc. (ASNT)** - a technical society for nondestructive testing (NDT) professionals. It publishes and maintains important standards and manages a central certification scheme for ASNT NDT Level I, II, or III professionals.
- **American Society for Testing and Materials (ASTM)[13]** - an international standards organization that develops and publishes voluntary consensus technical standards for a wide range of materials, products, systems, and services.
- **American Welding Society (AWS)** - a non-profit organization to advance the science, technology, and application of welding and allied joining and cutting processes, including brazing, soldering, and thermal spraying.
- **Center for Chemical Process Safety (CCPS)[14]** - a nonprofit organization within AIChE, that identifies and addresses process safety needs in the chemical, pharmaceutical, and petroleum industries.
- **National Association of Corrosion Engineers (NACE,** now **AMPP)** - a nonprofit organization that develops and publishes standards focusing on the prevention of corrosion, a major issue concerning many industries.

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[9] American Fuel and Petroleum Manufacturers, 1800 M St. NW, Ste 900, Washington DC 20036, www.afpm.org.

[10] AMPP (the Association for Materials Protection and Performance, formerly NACE International), 15835 Park Ten Place, Houston, TX 77084, www.ampp.org.

[11] American National Standards Institute, 1899 L Street, NW, Washington, DC 20036. www.ansi.org.

[12] American Society of Civil Engineers, 1801 Alexander Bell Drive, Reston, VA 20191, www.asce.org.

[13] American Society for Testing and Materials, ASTM International, 100 Bar Harbor Drive, PO Box C700, West Conshohocken, PA, 19428, www.astm.org.

[14] Center for Chemical Process Safety, Part of AIChE, 120 Wall Street, 23rd Floor, New York, NY, 10005, www.AIChE.org/ccps.

- **National Board of Boiler and Pressure Vessel Inspectors (NBBI)** - composed of Chief Boiler and Pressure Vessel Inspectors representing states, cities, and provinces enforcing pressure equipment safety laws and regulations.
- **The National Fire Protection Association (NFPA)** - covers a variety of conditions and occupancies. which are predominately for the safety of personnel.
- **The Uniform Building Code (UBC)[15]** - focuses primarily on occupied structure and are also focused on safety, rather than efficiency or effectiveness.

In addition to the technical bodies listed above, industry-specific associations may publish relevant codes and standards that are applicable to owner-operators. Examples include:

- **The Chlorine Institute (CI)[16]** - is a technical trade association of companies involved in the safe production, distribution and use of chlorine, sodium and potassium hydroxides and sodium hypochlorite, the distribution and use of hydrogen chloride and the distribution of vinyl chloride monomer.
- **International Institute of Ammonia Refrigeration (IIAR)[17]** - an organization that serves those who use industrial refrigeration technology and promotes the safe use of ammonia and other natural refrigerants through education, information, and standards.

There are several associations of specialty equipment and equipment manufacturers which establish standards which serve to improve the effectiveness and uniformity of their products and provide inspection guidance for the equipment. The more common organizations include:

- **American Gear Manufacturers Association (AGMA)[18]** - a trade group of gears, couplings and related power transmission components and equipment companies which has established standards on gearing, including terminology, nominal dimensions, tolerances, and tools for manufacturing and control.
- **Fiberglass Reinforced Plastics Institute (FRPI**)[19] - a nonprofit risk mitigation organization supporting publications for industry to help mitigate premature fiberglass chemical process equipment failure risks resulting in longer equipment life, reduced cost and hardship prevention.
- **Materials Technology Institute (MTI)[20]** - nonprofit technology development organization which focuses on developing new technology, transferring existing knowledge to day-to-day practice, and sponsors practical, generic, non-proprietary studies on the selection, design, fabrication, testing, inspection and performance of materials of construction used in the process industries.
- **Steel Tank Institute (STI)** / **Steel Plate Fabricators Association (SPFA)[21]** - a trade association representing the steel fabrication industry. STI develops, licenses and updates shop fabricated tank technologies.

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[15] Uniform Building Code or International Building Code, Published by the International Code Council, 200 Massachusetts Ave, Washington DC, 20001, codes.iccsafe.org.

[16] The Chlorine Institute, 1300 Wilson Blvd, Arlington, VA 22209, www.cholrineinstitute.org

[17] International Institute of All-Natural Refrigeration, 1001 N. Fairfax St. Suite 503, Alexandria, VA 22314, www.iilar.org

[18] American Gear Manufacturers Association, 1001 n. Fairfax Street, Ste 500, Alexandria, VA 22314, www.agma.org.

[19] Fiberglas Reinforced Plastics Institute, 210 Park Ave, #8, Worcester, MA 01609, www.frpi.org.

[20] Materials Technology Institute, 1001 Craig Rd, Ste 490,St. Louis, MO 63146, www.mti-global.com.

[21] Steel Tank Institute/Steel Plate Fabricators Association, 944 Donata Ct, Lake Zurich, IL 60047, www.stispfa.org.

- **Tubular Exchanger Manufacturers Association (TEMA)** - an association of fabricators of shell and tube type heat exchangers. TEMA maintains a set of construction standards for heat exchangers.

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[1] API Specification 12P, Specification for Fiberglass Reinforced Plastic Tanks

[2] API Standard 12R1, Installation, Operation, Maintenance, Inspection, and Repair of Tanks in Production Service

[3] API 510, Pressure Vessel Inspection Code: In-service Inspection, Rating, Repair, and Alteration

[4] API Standard 520, Sizing, Selection, and Installation of Pressure-Relieving Devices – Part I - Sizing and Selection; Part II – Installation

[5] API Standard 521, Pressure-Relieving and Depressuring Systems

[6] API Standard 527, Seat Tightness of Pressure Relief Valves

[7] API Standard 530, Calculation of Heater-Tube Thickness in Petroleum Refineries

[8] API Standard 560, Fired Heaters for General Refinery Service

[9] API 570, Piping Inspection Code: In-Service Inspection, Rating, Repair, and Alteration of Piping Systems

[10] API Recommended Practice 571, Damage Mechanisms Affecting Fixed Equipment in the Refining Industry

[11] API Recommended Practice 572, Inspection Practices for Pressure Vessels

[12] API Recommended Practice 573, Inspection of Fired Boilers and Heaters …

[13] API Recommended Practice 574, Inspection Practices for Piping System Components

[14] API Recommended Practice 575, Inspection Practices for Atmospheric and Low-Pressure Storage Tanks

[15] API Recommended Practice 576, Inspection of Pressure-Relieving Devices

[16] API Bulletin 590, SCIMI Term, Definition, and Acronym Standardization Work Process

[17] API Standard 579 / ASME FSS-1, Fitness for Service

[18] API Recommended Practice 584, Integrity Operating Windows

[19] API Recommended Practice 588, Recommended Practice for Source Inspection and Quality Surveillance of Fixed Equipment

[20] API Standard 620, Design and Construction of Large, Welded, Low-Pressure Storage Tanks

[21] API Standard 650, Welded Tanks for Oil Storage

[22] API Standard 653, Tank Inspection, Repair, Alteration, and Reconstruction

[23] API Standard 661, Petroleum, Petrochemical, and Natural Gas Industries—Air-Cooled Heat Exchangers for General Refinery Service

[24] API Recommended Practice 970, Corrosion Control Documents

[25] API Recommended Practice 1160, Managing System Integrity for Hazardous Liquid Pipelines

[26] API Standard 1163, In-line Inspection Systems Qualification

[27] API Recommended Practice 1173, Pipeline Safety Management System

[28] API Recommended Practice 1188, Hazardous Liquid Pipeline Facilities Integrity Management

[29] API Standard 2000, Venting Atmospheric and Low-pressure Storage Tanks

[30] ASME B31.1

[31] ASME B31.3

[32] ASME B31.4, Pipeline Transportation for Liquids and Slurries

[33] ASME B31.8, Gas Transmission and Distribution Piping Systems

[34] ASME Boiler and Pressure Vessel Code, Section VIII Div 1, Rules for Construction of Pressure Vessels

[35] ASME FFS-1 (API Standard 579/ASME FFS-1), Fitness for Service

[36] ASME PCC-1, Pressure Boundary Bolted Flange Joint Assembly

[37] ASME PCC-2, Repair of Pressure Equipment and Piping

[38] ASME PTB-2, Guide to Life Cycle Management Of Pressure Equipment Integrity

[39] ISO 15589-1, Cathodic Protection of Pipeline Systems

[40] OSHA 1910.119, Mechanical Integrity

[41] US DOT 49 CFR 192, Transportation of Natural And Other Gas By Pipeline: Minimum Federal Safety Standards

[42] US DOT 49 CFR 193, Liquified Natural Gas Facilities: Federal Safety Standards

[43] US DOT 49 CFR 195, Transportation Of Hazardous Liquids By Pipeline