**SUBJECT:** This guideline provides information on recognized and generally accepted engineering practices for test and inspection of chemical process equipment and related safety systems. This guideline should be used with manufacturers’ recommendations, Lilly standards, and site-specific process conditions and equipment history to set inspection and test methods and frequencies for equipment included in the mechanical integrity program.

**ORGANIZATION:**

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**PROCESS AREAS INVOLVED:** All Lilly high-risk processes and US-regulated processes

Note: References for all documents cited in this guide can be found in Section 16.

**1.0 INTRODUCTION, SCOPE, AND DEFINITIONS**

1.1 **Introduction** – This guideline lists generally accepted codes and standards used for testing and inspecting of process equipment and related safety systems that fall within the scope given in Section 1.2. Where applicable, specific requirements or recommendations of generally accepted codes and standards are referenced. Some recommendations have been included in cases where there are no generally accepted codes or standards for testing and inspecting process equipment or related safety systems. In these cases, the recommendations in this document should not supersede manufacturer recommendations or site practice based on equipment history.

If sites choose to not follow these codes or standards, or choose to use a longer time between tests than what is recommended, the site must clearly document its rationale for doing so and the rationale must be reviewed and approved by those who have authority to authorize management of change requests for the process.

1.2 **Scope** – This guideline applies to equipment that provides containment for hazardous chemicals or is designed to prevent or mitigate effects of the release of hazardous chemicals. U.S. sites operating processes regulated by OSHA’s Process Safety Management (PSM) or EPA’s Risk Management Program [also known as 112(r)] should use this guideline to determine test and inspection methods and frequencies for their mechanical integrity (MI) program. Sites should also use this guideline to determine test and inspection requirements for other processes, based on the requirements listed in the GIPSM document PS-9.1-REQ.

1.2 **Definitions**

|  |  |
| --- | --- |
| **American Petroleum Institute (API)** | Industry organization that publishes standards and recommended practices covering a wide range of design, operation, maintenance, and management practices that are widely used by the chemical process and refining industries. |
| **American Society for Nondestructive Testing (ASNT)** | Professional society that also publishes guidelines and certifies inspectors in nondestructive testing methods. |
| **American Society of Mechanical Engineers (ASME)** | Professional society that also publishes numerous codes and standards used by industry and in some cases adopted by States and other jurisdictions. In particular, the ASME publishes design codes for boilers, pressure vessels, and piping systems that are widely used in the process industry. |
| **ASME B31.3** | Design, fabrication, installation, and initial inspection code for chemical process and refinery piping systems. This code is useful in planning MI tests and inspections, but it does not directly address ongoing test and inspection requirements. |
| **Emergency Shutdown System (ESS)** | System designed to automatically (or via a very limited number of operator actions) shutdown a process or limit the potential for a loss event by shutting off flow of hazardous chemicals, electrical power, or similar systems. |
| **External Visual Inspection (EV)** | A rigorous inspection by a trained (and normally certified) inspector following a detailed procedure and documented in a prescribed manner. |
| **Failure Modes and Effects Analysis (FMEA)** | Systematic method for examining the effects of component failure on system performance. FMEAs typically identify safeguards and include recommendations related to prevention of unacceptable failure modes. |
| **Failure on Demand** | Measure of the probability that a system, control, or safeguard will not work when called upon. For example, the probability of failure on demand of an interlock with a nonredundant sensor, logic solver, and final control element is typically 1% (per ISA-S84.01). See also safety integrity level. |
| **Good Management Practice (GMP)** | U.S. Food and Drug Administration regulation that specifies management systems and practices that must be in place for manufacture of pharmaceuticals. GMP requirements for maintenance and calibration of process equipment often overlap with MI requirements. |
| **Hazardous Chemical** | Hazardous chemicals include any of the following:   1. Toxic chemicals listed in Appendix A to the OSHA Process Safety Management standard (29 CFR 1910.119) 2. Substances with a Lilly/NFPA flammability rating of 4 or 3 (flash point less than 100°F) 3. Chemicals listed in Table 1 and Table 3 to 40 CFR 68.130 of the EPA Risk Management Program rule [112(r)] 4. Other chemicals identified as hazardous by local site management (see GISPM document PS-1.2-PRD for additional information) |
| **Hazardous Waste** | Waste material meeting the definition given in 40 CFR 261. |
| **Instrument Society of America (ISA)** | Professional society concerned with instrumentation and controls. ISA publishes standards and recommended practices for a wide range of process instrumentation, including design, installation, operation, and maintenance of safety instrumented systems, combustible and toxic gas detectors, and electrical enclosures. |
| **Internal Visual Inspection (IV)** | Rigorous inspection methodology used to identify subtle indicators (that are difficult to detect) of potential or developing failures. Equipment problems are detected through either the use of test equipment (may include ultrasonic, vibration, thermography, oil analysis, or system test) or a rigorous inspection. The test results are analyzed to prove the capability of the system under test. |
| **Leak Detection and Repair (LDAR)** | Method of leak detection and repair using a vapor sensor to detect leaks near seals, gaskets, valves, and fittings. |
| **Leak Testing (Hydro Testing)** | Method of testing for leaking fittings or small cracks in pressure vessels and piping by raising the pressure in vessels above the design pressure using water, air, or an inert gas. See Section 345 of ASME B31.3 for test methods for pipe; see I-502.10 of the NBIC for test methods for pressure vessels. |
| **Mechanical Integrity (MI)** | A program to minimize the risk of equipment failure in modes that could lead to loss of containment of hazardous chemicals, fire, explosion, toxic chemical release, or other catastrophic accident. |
| **National Association of Corrosion Engineers (NACE)** | Professional society that also publishes numerous standards and recommended practices related to corrosion prevention and protection. |
| **National Board Inspection Code (NBIC)** | Manual of methods, frequencies, and technical information related to inspection and testing of boilers and pressure vessels published by the National Board of Boiler and Pressure Vessel Inspectors. The NBIC is often adopted by states as a legal requirement for operators of pressure vessels over a certain size and/or pressure rating. |
| **National Fire Protection Association (NFPA)** | Organization that publishes codes, standards, and recommended practices related to fire protection and electrical safety (i.e., the National Electric Code). These codes are typically referred to as “NFPA” and the related number of the code (e.g., NFPA 30 is the code for storage, handling, and processing of flammable and combustible liquids). |
| **nte** | Not to exceed, used in this document in conjunction with inspection intervals. |
| **Oil analysis** | Method of detecting wear in machinery moving parts (e.g., bushes bearings, bushings, and pistons) and deterioration of oil quality due to thermal degradation, pH change, or contaminants. |
|  |  |
| **Predictive Maintenance (PdM)** | Equipment testing used to evaluate the condition of a piece of equipment to determine if further maintenance activity is required. Examples include vibration analysis, oil analysis, and thermography. |
| **Preventive Maintenance (PM)** | Maintenance activity based on elapsed time since the last activity, hours in use, or other criteria. Examples include replacing lubricant, filters, or other wear components. |
| **Process Hazards Review (PHR)** | A structured review of process hazards based on deviation from design conditions performed by a team with detailed knowledge of the process. PHR teams typically use the hazard and operability (HAZOP) or what-if technique, often supplemented with checklists. |
| **Process Safety Management (PSM)** | An integrated set of management systems used to minimize the risk of a catastrophic accident involving hazardous chemicals. |
| **Process Safety Information (PSI)** | Information regarding process hazards, process technology, and process equipment as defined in PS-2.1-PRD and PS-2.1-SUP.001. |
| **Radiographic Testing (RT)** | A method of detecting subsurface defects in metal and welded joints. RT can also be used to measure thickness over a wider area than UT. |
| **Recommended Practice (RP)** | Typically an API publication that is based on accumulated knowledge and experience of a large number of personnel in the respective industry. RPs do not have the force of codes, standards, or regulation. However, they contain useful information that has been reviewed and validated by numerous experts. |
| **Root Cause Failure Analysis (RCFA)** | A structured approach to determining and fixing systemic weaknesses that support conditions that lead to contributing events or factors that ultimately result in a near-miss or loss event. |
| **Routine Inspection** | Inspection of process equipment using only the inspector’s senses (e.g., visual, touch, smell, hearing) and knowledge of how the equipment normally operates to detect equipment problems. This inspection is normally performed while the equipment is running by the area operations personnel. |
| **Safety Systems** | Systems to prevent or mitigate the effects of a catastrophic release of a hazardous chemical. See the GIPSM glossary in Section 2 of the GIPSM well for a full definition of safety systems. |
| **Self-Contained Breathing Apparatus (SCBA)** | Backpack-style portable air supply typically used by emergency responders. |
| **Safety Integrity Level (SIL)** | Measure of the expected or required probability of failure on demand for a safety instrumented systems such as an emergency shutdown. |
| **Ultrasonic Testing (UT)** | Method of measuring thickness of metal pipes, tanks, and vessels. UT can be used to identify corrosion or erosion in pipes, vessels, and tanks, but may be limited by temperature and concerns regarding electrical classification. UT measurements typically give average metal thickness over a very small area (normally <1 in2). Numerous measurements are required if UT is used in lieu of internal visual inspection. |
| **Vibration analysis** | Method of detecting loss of alignment, bearing wear, out of balance, and other mechanical flaws in rotating equipment prior to failure. |

2.0 PRESSURE VESSELS

2.1 **Scope** – Pressure vessels include all vessels that meet the definition given in Paragraph U-1 of Section VIII of the ASME Boiler and Pressure Vessel Code (ASME Code). In general, any vessel used to contain a fluid where the difference between internal and external pressure exceeds 15 psi is a pressure vessel. See the ASME Code for exceptions to these requirements for direct-fired vessels, vessels in water service, piping systems, vessels with an inside diameter less than 6”, and vessels designed for human occupancy.

States or other jurisdictions may require that pressure vessels be registered. For example, Indiana requires that any pressure vessel with a volume greater than 15 ft3 operating at a pressure greater than 15 psig or with a volume greater than 1.5 ft3 operating at a pressure greater than 300 psig be registered with the state. Requirements for other U.S. jurisdictions can be found in API Publication 910.

The requirements listed in this section apply to all pressure vessels that contain hazardous chemicals, regardless of any state requirements for vessel registration.

2.2 **Inspection and Test Requirements** – Pressure vessel inspection requirements are included in \*Part 2 of the National Boiler and Inspection Code (NBIC) and API 510. A local Authorized Inspector (see Section UG-91 of the ASME Code) shall determine which document applies at a given site and can provide additional guidance regarding state and local regulations. Inspection requirements are listed in Table 2.1.

|  |  |  |  |
| --- | --- | --- | --- |
| **Table 2.1 – Test and Inspection Methods and Frequencies for Pressure Vessels** | | | |
| **Service and Operating Conditions** | **Routine Inspection/ Inspection Interval** | **External Visual Inspection/ Inspection Interval** | **Internal Visual Inspection/ Inspection Interval** |
| Boilers and fired pressure vessels | Consult with Authorized Inspector for state or local jurisdiction | | |
| Unfired pressure vessels in hazardous chemical service (not qualified for exemptions listed below or in API 910, see Note 3) | Required, interval nte monthly | Required/nte \*the lesser of 5 years or the required interval for on-stream inspection (Section 6.4.1 of API 510)  See Note 2 | Required/nte \*10 years or at ½ of the remaining life (Section 6.5 of API 510)  See Notes 1 and 2 |

Notes:

1. The State of Indiana prescribes a test frequency of 5 years (or 3 years if systematic corrosion data are not available) for pressure vessels and steam generating equipment which is an integral part of a continuous processing unit.
2. Remaining life = (tactual – trequired)/ [established corrosion rate (in consistent units)]

tactual – actual thickness based on field measurement (normally via UT)

trequired – minimum allowable thickness of the limiting section of the vessel (see \*Section 4.4.7.2 of the NBIC)

1. Exceptions:
2. States may not require inspections of vessels that are <5 ft3 with a design pressure <250 psi,\* <3 ft3 with a design pressure <350 psi, or <1.5 ft3 with a design pressure <600 psi (see Section U-1(j) of the ASME Code for all of the criteria necessary to meet this exception).
3. \*Section 2.3.2b of the NBIC and Section 6.5.2 of API 510 allow for external inspection and thickness testing in lieu of internal inspection of vessels in non-corrosive service if certain conditions are met.
4. See \*Section 4.4.7.2d of the NBIC for guidance on inspection interval for vessels with a corrosion-resistant lining.

2.3 **Routine Inspection** – Routine visual inspection shall be conducted on all pressure vessels containing hazardous chemicals. These inspections shall be conducted by any trained employee or contractor, and shall focus on the following:

* Leaks or signs of previous leaks
* Broken, cracked, or distorted supports or footings
* Missing, loose, or “short” flange bolts
* Corrosion
* Damaged or missing insulation
* Other site-specific inspection criteria (based on process hazards or piping design)

Notes:

1. Procedures or checklists shall specify buildings, areas, or inspection routes, inspection criteria, and any special area-specific requirements.
2. Inspection intervals shall be included in the site MI inspection and testing plan. Routine inspection intervals shall not exceed once per month. Specific vessels may require higher inspection frequencies (e.g., hazardous waste tanks at U.S. sites shall be inspected daily per EPA hazardous waste regulatory requirements).
3. Documentation of routine vessel inspection may be by exception only if specifically stated in the site MI program document.

2.4 **External Visual Inspection** – EVs shall be conducted by a National Board Commissioned Inspector or an Owner-User Inspector (see \*Section 1 of the NBIC). Inspections shall conform to jurisdictional requirements and be based on \*Section 2 of the NBIC or Section \*5 of API 510. Inspections shall be documented per the requirements of Section \*5 of the NBIC or Section \*7.8 of API 510 using forms similar to those in \*Section 5.3 of the NBIC, Appendix C of API 510, or \*Annex C of API RP 572.

2.5 **Internal Visual Inspection** – IVs shall be conducted by a National Board Commissioned Inspector or an Owner-User Inspector (see \*Section 1 of the NBIC). Inspections shall conform to jurisdictional requirements and be based on \*Section 2 of the NBIC or Section 5 of API 510. Inspections shall be documented using the forms in \*Section 5.3 of the NBIC, Appendix C of API 510, or \*Annex C of API RP 572. If internal visual inspections are not done (see \*Section 2.3.2 of the NBIC \*and Section 6.5.2 of API 510 for restrictions on this practice), documentation shall include thickness readings in a form similar to appropriate inspection sheets given in Appendix C to API 510 or \*Annex C to API RP 572.

2.6 **Thickness Testing** – If thickness testing is needed or is selected in lieu of internal inspection (per Section \*2.3.2 of the NIBC \*and Section 6.5.2 of API 510), it shall be performed by ASNT-certified technicians using recognized and generally accepted techniques such as those described in \*Section 9.2of API RP 572.

2.7 **Additional Test Methods** – Several additional testing methods are described in Section \*9.5 of API RP 572, and Section 10 of API RP 574. In general, these methods are used to evaluate specific defects discovered during EV, IV, and (where applicable) thickness testing.

3.0 STORAGE TANKS

3.1 **Scope** – Storage tanks containing hazardous chemicals as defined in Section 1 will be included in the MI program. The test requirements in this section do not apply to:

* Storage tanks containing water, air, steam, condensate, non-hazardous aqueous solutions, ethylene glycol solutions in cooling service, or other Category D service materials as defined in the piping specifications (see also ASME Code for Chemical Plant and Petroleum Refining Piping, B31.3, \*Chapter 1, Section 300.2)
* Storage tanks with a design pressure >15 psi, regardless of operating conditions (see Section 1, Pressure Vessels)

3.2 **Inspection and Test Requirements** – Storage tank inspection requirements are included in Section 6 of API 653. Inspection requirements are listed in Table 3.1.

| **Table 3.1 – Inspection Methods and Frequencies for Storage Tanks** | | | | | |
| --- | --- | --- | --- | --- | --- |
| **Service and Operating Conditions** | **Routine Inspection/ Inspection Interval** | **External Visual Inspection/ Inspection Interval** | **Thickness Testing/ Test Interval** | **Internal Visual Inspection/ Inspection Interval** | **Cathodic Protection (if tank is equipped with a cathodic protection system)** |
| Storage tank containing hazardous chemicals (except for hazardous waste) | Required/ nte one month \*(Section 6.3.1 of API 653) | Required/ nte lower of ¼ of corrosion life or 5 yrs \*(Section 6.3.2.1 of API 653) | \*Required, interval is 5 to 15 years, depending on knowledge of corrosion rates and remaining corrosion life (Section 6.3.3 of API 653) | Required/ nte lower of ½ of corrosion life or 20 years (Section 6.4.2.2 of API 653; \*see note 2 regarding initial inspection) | See NACE Standard RP0193-01 for guidance |
| Storage tank containing hazardous waste | Required daily | Required/ nte lower of ¼ of corrosion life or 5 yrs \*(Section 6.3.2.1 of API 653) | \*Required, interval is 5 to 15 years, depending on knowledge of corrosion rates and remaining corrosion life (Section 6.3.3 of API 653) | \*Required/ nte lower of ½ of corrosion life or 20 years (Section 6.4.2.2 of API 653; see note 2 regarding initial inspection) |  |
| Storage tank not in hazardous chemical or hazardous waste service | No applicable codes or standards | | | | |

Notes:

1. Corrosion life = (tactual – tminimum)/ [established corrosion rate (in consistent units)]

tactual – actual thickness based on field measurement (normally via UT)

tminimum – minimum allowable thickness of the limiting section of the tank (often the bottom plate, see Table 4.4 of API 653 for minimum thickness data)

1. \*For a new tank the interval from initial service until the initial internal inspection shall not exceed 10 years unless a risk-based inspection (RBI) assessment per Section 6.4.2.4 of API 653, or a similar service assessment per Annex H of API 653 is performed, and a leak prevention, detection, or containment safeguard is employed. See Section 6.4.2.1 of API 653 for details.

3.3 **Routine Inspection** – Routine visual inspection shall be conducted on all storage tanks containing hazardous chemicals. These inspections shall be conducted by any trained employee or contractor, and shall focus on the following:

* Leaks or signs of previous leaks
* Broken, cracked, or distorted supports or foundations
* Missing, loose, or “short” flange bolts
* Corrosion, especially around the base of the tank
* Damaged or missing insulation
* Other site-specific inspection criteria

Notes:

1. Procedures or checklists shall specify buildings, areas, or inspection routes, inspection criteria, and any special area-specific requirements.
2. Inspection intervals shall be included in the site MI inspection and testing plan. Routine inspection intervals shall not exceed once per month. Specific tanks may require higher inspection frequencies (e.g., hazardous waste tanks at U.S. sites shall be inspected daily per EPA hazardous waste regulatory requirements).
3. Documentation of routine tank inspections may be by exception only if specifically stated in the site MI program document (exception: daily inspections of hazardous waste tanks must be fully documented).

3.4 **External Visual Inspection** – EVs shall be conducted by a Certified Inspector (see Sections \*6.10 and \*12.1.1.2, and Annex D of API 653). External visual inspections shall conform to Section \*6.3.2.1 of API 653. Inspections shall be documented per the requirements of Section 6.8 of API 653 using forms similar to those in \*Annex C.1.1 to C.1.6 of API 653.

3.5 **Internal Visual Inspection** – IVs shall be conducted by a Certified Inspector (see Section \*6.10 and \*12.1.1.2, and \*Annex D of API 653). Internal visual inspections shall conform to Section \*6.4 of API 653. Inspections shall be documented per the requirements of Section 6.8 of API 653 using forms similar to those in \*Annex C.2.1 to C.2.12 of API 653.

3.6 **Thickness Testing** – If the Certified Inspector determines that thickness testing is needed or it is selected in lieu of internal inspection (per Section 6.5 of API 653), it shall be performed by an ASNT-certified technician using recognized and generally accepted techniques such as those described in Section \*9.2 of API RP 572 at the interval specified in Section \*6.4.2 of API 653.

3.7 **Cathodic Protection Surveys** – If cathodic protection is used to protect the tank bottom, consult NACE standard \*RP0193-01 and \*Section 6.4.2.1 of API 653 for guidance on maintenance and inspection activities.

4.0 PIPING SYSTEMS

4.1 **Scope** – Piping systems containing hazardous chemicals as defined in Section 1 will be included in the MI program.

These test requirements do not apply to:

* Piping systems containing water, air, steam, condensate, non-hazardous aqueous solutions, ethylene glycol solutions in cooling service, or other Category D service as defined in the piping specifications (see also ASME Code for Pressure Piping, B31, \*Chapter 1, Section 300.2)
* Piping systems that are integral to rotating or reciprocating equipment (e.g., pumps or compressors)
* Internal piping for fired heaters and boilers, pressure vessels and heat exchangers
* Process, sanitary, or storm sewers

\*Note: Piping or tubing with an outside diameter of less than ½” nominal pipe size (NPS) (approx. 0.84”) is no longer excluded per API 570 and API RP 574.

Piping systems include piping, fittings, valves, flow instruments, filters, strainers, and other process equipment that is integral to the piping system.

4.2 **Inspection and Test Requirements** – Inspection and test requirements for process piping are generally based on API 570 and API RP 574. These should be used as a guideline since the chemical industry has no equivalent standard. The test and inspection frequencies in Table 4.1 below are based on Section 6 of API 570. Sites may deviate from the guidelines given in Table 4.1, but must document the technical basis for extending intervals or not doing specific tests or inspections.

| **Table 4.1 – Test and Inspection Methods and Frequencies for Piping Systems** | | | | |
| --- | --- | --- | --- | --- |
| **Risk Rating (see Section \*6.3.4 of API 570)** | **Routine Inspection** | **LDAR** | **External Visual Inspection** | **Thickness Testing** |
| API 570 Class 1 (\*services with the highest potential of resulting in an immediate emergency if a leak were to occur, e.g. H2S, anhydrous HCl, HF, flammables above their auto-ignition temperature, flammable gases liquefied under pressure) | Required nte monthly | See Section 4.4 | Required/nte \*lower of ½ of remaining life or 5 years (Table 2 in API 570)  (see notes and exceptions) | Required/nte \*lower of ½ of remaining life or 5 years (Table 2 in API 570)(see notes and exceptions) |
| API 570 Class 2 (\*services not included in other classes, e.g. flammable solvent below its flashpoint at normal process conditions, combustible material above its flashpoint at normal process conditions, natural gas, strong acids and caustics) | Required nte monthly | See Section 4.4 | Required/nte  \*lower of ½ of remaining life or 5 years (Section 6.3.3 of API 570)  (see notes and exceptions) | Required/nte \*lower of ½ of remaining life or 10 years (Section 6.3.3 of API 570)  (see notes and exceptions) |
| API 570 Class 3 (\*combustible material normally below its flashpoint at normal process conditions, flammable material located in non-occupied areas such as tank farms) | Required nte monthly | See Section 4.4 | Required/nte \*lower of ½ of remaining life or 10 years (Section 6.3.3 of API 570)  (see notes and exceptions) | Required/nte \*lower of ½ of remaining life or 10 years (Section 6.3.3 of API 570)  (see notes exceptions) |
| \*API 570 Class 4 (services that are nonflammable and nontoxic, e.g. steam and steam condensate, air, nitrogen, water, lube oil, seal oil, ASME B31.1 Category D services, plumbing and sewers) | \*Required nte monthly | \*See Section 4.4 | \*Optional (Section 6.3.4 of API 570)  (see exceptions) | \*Optional (Section 6.3.4 of API 570)  (see exceptions) |
| \*Injection Points | \*Required nte monthly | Not applicable | \*By Class as noted above (Table 2 in API 570) | \*Required/nte 3 years (Table 2 in API 570)  (see Exception 4) |

Notes:

1. The remaining life = (tactual – trequired)/ (established corrosion rate)

tactual – actual pipe thickness based on measurement for a given location or component

trequired – required pipe thickness at the same location or component at the same location or component before corrosion allowance and manufacturer’s tolerance are added based on design data or pipe specifications. If design data is not available, see Chapter II, Part 2 of ASME Code B31.3 for methods to determine minimum thickness for a given pressure and temperature service.

Established corrosion rate – rate of change (loss) in thickness based on measurements for similar process fluids, flow rate, and materials of construction at the site (or at another Lilly site operating the same process)

Consistent units shall be used for thickness and corrosion rate

1. \*Inspection of Class 4 piping is optional and usually based on reliability needs and business impacts as opposed to safety or environmental impact.

Exceptions:

1. The number of condition monitoring locations (\*CMLs, formerly known as thickness measurement locations or TMLs), should take into account the patterns of corrosion that would be expected and have been experienced in the process unit. See Section 5.6.3 of API 570 for detailed guidance.
2. Thickness testing is not required for lined pipe or services where published corrosion data is available that shows that there the corrosion rate is negligible (e.g., solvents in stainless steel pipe). However, for non-corrosive services where the presence of water or other common contaminants accelerates the corrosion rate, thickness testing is required. (E.g., dry chlorine is not corrosive to carbon steel, but it is very corrosive if water is present.)
3. Thickness measurements are not applicable to polymer or glass-lined pipe. However, weep holes shall not be plugged and shall be specifically included in routine testing. Documented internal visual inspections (or destructive testing when pipe is removed from service during modifications) are highly encouraged to establish local inspection and/or replacement frequency.
4. \*Inspection intervals for potentially corrosive injection/mix points can be established by a valid risk-based inspection analysis in accordance with API RP 580.
5. See Section \*10.10 of API 574, and \*NACE SP0169, for special guidance and requirements for underground piping.

4.3 **Routine Inspection** – Routine visual inspections shall be conducted by any trained employee or contractor on all piping systems included in the MI program. The scope of routine inspection shall include piping, piping components such as valves, fittings, in-line filters, and related equipment such as pumps. The inspection shall include, but is not limited to the following:

* Leaks or signs of previous leaks
* Seepage or leaks from weep holes (applies to lines pipe only)
* Missing, loose, or distorted pipe supports
* Missing, loose, or “short” flange bolts
* Excessive vibration
* Misalignment
* Corrosion
* Damaged or missing insulation
* Other site-specific inspection criteria (based on process hazards or piping design)

Notes:

1. Procedures or checklists shall specify buildings, areas, or inspection routes, inspection criteria, and any special area-specific requirements.
2. Inspection intervals shall be included in the site MI inspection and testing plan. Routine inspection intervals shall not exceed once per month. Specific processes may require higher inspection frequencies (e.g., hazardous waste lines at U.S. sites shall be inspected daily per EPA hazardous waste regulatory requirements).
3. Documentation of routine piping inspection may be by exception only if specifically stated in the site MI program document.

4.4 **Leak Detection and Repair (LDAR)** – LDAR activities shall be conducted as required by site-specific environmental permits and local regulations. The person doing the LDAR inspection can simultaneously do the routine inspection described in Section 4.3 (or EV inspection described in Section 4.5), but LDAR alone cannot be used in lieu of routine observation or EV inspection (e.g., LDAR may not detect missing or broken pipe supports).

4.5 **External Visual Inspection** – EVs shall be conducted on all piping systems included in the MI program at the frequencies given in Table 4.1. The inspections shall be performed in accordance with API 570 using methods given in API 570 and API RP 574. EV inspection shall include all of the applicable visual corrosion and cracking scenarios given in Section \*5.4 of API 570, including corrosion under insulation where applicable. These inspections shall be done by an authorized inspector per the requirements of Section \*4 of API 570. EV procedures shall include inspection of the following for pipe and piping components:

* Spot checking for corrosion under insulation
* Corrosion at soil to air interfaces
* Service-specific and localized corrosion (as applicable)
* Erosion and erosion/corrosion
* Environmental, fatigue, creep, and stress corrosion cracking
* Brittle fracture
* Freeze damage
* All routine inspection items listed in Section 4.3

Notes:

1. Procedures or checklists shall specify buildings, areas, or inspection routes, inspection criteria, and any special area-specific requirements.
2. EVs shall be documented using a checklist similar to the one in \*Annex A of API 574. Documentation of testing shall be maintained according to site MI program procedures.

4.6 **Thickness Testing** – Thickness testing shall be conducted on all piping systems included in the MI program at the frequencies given in Table 4.1, unless one of the exceptions listed below Table 4.1 applies. The inspections shall be performed in accordance with \*Section 5.5.3 of API 570 using the methodology given in \*Section 10.2 of API RP 574.

In most cases, UT or RT shall be used to measure pipe thickness, (See Section \*10.2 of API 574 for guidance on selection of the proper thickness testing method.) UT or RT testing shall be performed by an ASNT-certified inspector. Interpretation of UT or RT data shall be done by a qualified API 570 inspector in conjunction with the individual making the measurements or administering the thickness testing program.

Thickness test results shall be documented in a form specified in the site MI procedure or in a spreadsheet or database similar to Figure \*34 in API RP 574. Records shall be traceable to a specific test point that is identified on the piping in the field.

The format of the records should allow sites to quickly check for deficiencies (e.g., thickness below t required as defined in Section 4.2) and to estimate corrosion rate to adjust test frequency or future replacement requirements. Sites should keep piping inspection records for the period specified in their MI procedures, and should strongly consider keeping all thickness inspection data for the life of the piping system.

4.7 **Leak Testing (hydro testing)** – One common technique for testing new and modified piping systems is a leak test as described in Section 345 of ASME Code B31.3. In general, this test requires that the piping system be hydrostatically tested at 150% of rated pressure or pneumatically tested at 110% of rated pressure for at least 10 minutes and that all joints be visually examined for leaks. See Section 345 of ASME Code B31.3 for a complete list of test requirements prior to conducting a leak test for a new or modified piping system (see also Section A345, M345, or K345 for nonmetallic, high hazard, and high pressure systems, respectively). Note also that in most cases, ASME Code B31.3 requirements include EV or RT testing in addition to a leak test for new piping.

There is no requirement for hydro testing following repair or replacement of a piping component. However, maintenance practices or procedures should include steps to ensure that the repaired section will not leak under operating conditions as part of the repair activities.

4.8 **Additional Test Methods** – several additional testing methods are described in Section5 of API 570 and Section \*10 of API RP 574. In general, these methods are used to evaluate specific defects discovered during EV, IV (where applicable), and thickness testing.

5.0 RELIEF AND VENT DEVICES

5.1 **Scope** – Relief and vent devices include pressure relief valves (also called pressure safety valves), rupture disks, conservation vents, and flame arrestors.

5.2 **Inspection and Test Requirements** – Inspection and test methods, and frequencies for relief devices are given in API 510, the NBIC, API RP 576, Chlorine Institute Pamphlet 5, ANSI K61.1 (for anhydrous ammonia), and in manufacturer recommendations.

The frequency of tests and inspections is normally determined by operating experience in the specific service involved. Therefore, the intervals given in Table 5.1 should be considered as maximum intervals, and should be adjusted downward based on site history. Sites should carefully consider inspection data and “as found” relief pressures on pressure relief valves to validate test frequencies. Signs of blockage in inlet or outlet piping or failure of a pressure relief valve to open at its set pressure should result in a reduction of the test interval. Likewise, long-term test data indicating that relief systems are consistently fully operational “as found” could justify an extension in test interval. However, intervals should not exceed 10 years or industry association recommendations (e.g., Chlorine Institute or Compressed Gas Association recommendations).

5.3 **External Visual Inspection of Relief Valves and Rupture Disks (all applications)** – EVs of relief valves and rupture disks shall be conducted as part of the external visual inspection of the vessel. These inspections shall be conducted by any trained employee or contractor, and shall focus on the following:

* Ensure the correct relief device is installed by matching the tag number, set pressure, and relief rate to data in the CMMS (computerized maintenance management system) Check for blinds, closed valves, or obstructions in the inlet or outlet piping
* If there are valves in the lines, ensure that they are sealed or chained open
* Check for leaks, signs of previous leaks, or bypassing (e.g., is the outlet line not at ambient temperature?)
* Check for broken, crimped, or deformed inlet or outlet piping or tubing
* Check for damaged or missing relief piping supports
* Check for open valve body and vent stack drains
* Check for pressure relief valves are installed in a vertical position
* If a rupture disk is located upstream of a relief valve, ensure that there is a pressure gauge between the two devices and that the pressure is 0 psig
* Check other site-specific inspection criteria (based on process hazards or piping design)

Inspection procedures should include all manufacturer’s recommendations and be based on API RP 576. External visual inspection shall be performed annually on pressure relief valves in anhydrous ammonia service per Section 5.8.14 of ANSI K61.1.

| **Table 5.1 – Test and Inspection Methods and Frequencies for Relief and Vent Devices** | | | | |
| --- | --- | --- | --- | --- |
| **Service** | **External Visual Inspection** | **Internal Visual Inspection** | **Function Test** | **Clean, Refurbish, or Replace** |
| Spring-loaded relief valves in ammonia service | Required, 1 year (ANSI K61.1) | During refurbish-ment | During refurbish-ment | Required, 5 years (ANSI K61.1) |
| Spring-loaded relief valves in nonrefrigerated liquid chlorine service | Required, \*at regular intervals (Chlorine Institute Pamphlet 5) | Required, \*at regular intervals (Chlorine Institute Pamphlet 5) | Required, \*at regular intervals (Chlorine Institute Pamphlet 5) | As part of function test |
| Spring-loaded relief valves in other hazardous chemical service | Include with EV vessel inspection | Include with function test | Required, \*interval can be up to 5 years (§6.6.2.2 of API 510) | Valves can be replaced in lieu of function test |
| Spring-loaded relief valves for boilers | Include with EV boiler inspection | Include with function test | Required, \*1 year (§2.5.8 of NBIC Part 2) | Valves can be replaced in lieu of function test |
| Spring-loaded relief valves in “nonfouling” nonhazard-ous chemical service on a pressure vessel | Include with EV vessel inspection | Include with function test | Required, interval can be up to 10 years (\*§6.6.2.2 of API 510 and §6.4 of API RP 576) | Valves can be replaced in lieu of function test |
| Spring-loaded relief valves in “fouling” nonhazardous chemical service on a pressure vessel | Include with EV vessel inspection | Include with function test | Required, interval can be up to 5 years (\*§6.6.2.2 of API 510) | Valves can be replaced in lieu of function test |
| Rupture disks on pressure vessels in “fouling” service | Include with EV vessel inspection | Inspect or replace disks every 5 years (\*§6.6.2.2 of API 510) | N/A | Replacement is preferred to inspection |
| Rupture disks on pressure vessels in “nonfouling” service | Include with EV vessel inspection | Inspect or replace disks every 10 years (\*§6.6.2.2 of API 510) | N/A | Replacement is preferred to inspection |
| Flame arrestors |  | \*Recommended, 1 year or when process material is known to have entered the vent line |  | \*Recommended, 1 year or when process material is known to have entered the vent line |
| Conservation vents |  | \*Recommended, 1 year |  | \*If necessary |

5.3 **Internal Visual Inspection** – IV requirements vary depending on the device.

**Inlet and Outlet Piping** – Internal inspection of relief and vent devices should always include a visual inspection of the inlet and outlet piping for (1) deposits that could reduce the venting rate, (2) corrosion, (3) thinning, or (4) other signs of malfunction.

**Pressure Relief Valves** – Internal inspection of pressure relief valves should be done prior to performing valve decontamination procedures necessary for sending the valve out for testing. Valves should be checked for deposits that could reduce the venting rate or signs of foreign materials or corrosion around the seat area. See Section \*6.2.6 through 6.2.10 of API RP 576 for additional information.

**Rupture Disks** – Rupture disks should be checked for signs of leakage, fatigue, corrosion, or buildup of process chemicals on the disk surface. It is strongly recommended that rupture disks be replaced after visual inspection. See Section \*6.2.22of API RP 576 for additional information.

**Conservation Vents** – Conservation vents should be inspected, cleaned, and serviced per manufacturer’s recommendations and Section \*6.2.21 of API RP 576. The inspection interval listed in Table 5.1 is not based on a Code or Standard, and may be adjusted based on manufacturer recommendations.

**Flame Arrestors** – Design, installation, and maintenance requirements for flame arrestors are discussed in NFPA 69 and \*Section 6.2.21 of API RP 576. Flame arrestors should be inspected, cleaned, and serviced per manufacturer’s recommendations, with particular attention to the integrity of the arrestor media. The inspection interval listed in Table 5.1 is not based on a Code or Standard, and may be adjusted based on manufacturer recommendations.

5.4 **Function Test** – Function tests shall be performed on pressure relief valves per Section \*6 of API RP 576 by a repair organization meeting the requirements of Section \*4.2.3 of API 510. In general, specialized outside contractors shall perform this test. Function tests shall be documented using forms similar to those given in the \*Annex B of API RP 576. It is important that the reports be reviewed. If the “as found” relief pressure is within ± 2 psi for set pressures up to 70 psig or ± 3% of set pressure for pressures greater than 70 psig, the valve is considered serviceable. If the valve does not initially relieve at the set pressure but does relieve within tolerance the second time it is tested, it is likely that the disk was stuck to the valve seat. If this occurs (or if the valve will not open at all), reliability engineers should examine the failure as an MI deficiency and determine if more frequent testing or if different valve materials are necessary.

Pressure relief valves in anhydrous ammonia service shall be disassembled, inspected, repaired, and tested at least every five years or before the recertification date stamped on pressure relief valves per Section 5.8.16 of ANSI K61.1.

Pressure relief valves in chlorine service should be inspected, cleaned, and tested \*at regular intervals, in accordance with an established maintenance program, per Section 9.1 of Chlorine Institute Pamphlet 5. \*The frequency of these procedures is dependent on various factors, but the primary goal is safety.

There is a provision in \*Part 2, Section 2.5.7 of the NBIC and in Section 6.2.8 of API RP 576 of the NBIC for on-line testing of relief valves. This option should only be considered for systems containing air, water, glycol solutions, and inert gases (and only with the prior agreement of the Authorized Inspector for relief valves on pressure vessels).

5.5 **Refurbishment and Replacement** – Pressure relief valves, conservation vents, and flame arrestors should be refurbished every time they are removed from service for an internal visual test.

**Pressure Relief Valves –** In many cases, it is more cost effective to replace small pressure relief valves, in which case they do not need to be refurbished. However, a representative number of pressure relief valves from each service shall be function tested in the “as found” condition to verify that the valve selection and replacement frequency are appropriate.

**Conservation Vents** – As part of IV, conservation vents should be cleaned and manually forced open to verify that the seats are not stuck. \*Seals should be replaced and the valve should be serviced and lubricated in accordance with manufacturer’s recommendations.

**Flame Arrestors** – As part of IV, flame arrestors should be inspected for fouling or plugging, cleaned and serviced per manufacturer’s recommendations, with particular attention to the integrity of the arrestor media.

**Rupture Disks** – It is highly recommended that rupture disks be replaced rather than inspected and returned to service. Otherwise, it may be difficult to achieve a good seal between the disk and disk holder (or between the disk and flange, depending on the design) or small pinhole leaks may go undetected.

6.0 DIKES AND NEUTRALIZATION PITS

6.1 **Scope** – This section provides guidelines for test and inspection methods and frequencies for dikes, other secondary containment, and neutralization pits used in hazardous chemical or hazardous waste service.

6.2 **Inspection and Test Requirements** – There are no generally recognized codes or standards for inspection of dikes and neutralization pits. Sites should consider using the inspection and test guidelines in Table 6.1 to develop their MI program.

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| **Table 6.1 – Inspection Methods and Frequencies for Dikes and Neutralization Pits** | | |
| **Service and Operating Conditions** | **Routine Inspection/ Inspection Interval** | **Preventive and Predictive Maintenance/Test Interval** |
| Dikes for collection, secondary containment, or diversion of hazardous chemicals | Required/nte one month | Inspection method and frequency set at site’s discretion |
| Dikes for collection and secondary containment, of hazardous waste | Required/daily | Inspection method and frequency set at site’s discretion |
| Neutralization pits | Required/nte one month | Inspection method and frequency set at site’s discretion |

6.3 **Routine Inspection** – Routine visual inspection shall be conducted on all dikes and neutralization pits in hazardous chemical and hazardous waste service. These inspections shall be conducted by any trained employee or contractor, and shall focus on the following:

* Cracks or signs of loss of integrity
* Spalling or crumbling of concrete
* Failed or separated joint sealant
* Function test of any liquid level sensors or alarms (see also Section 10)
* \*Unsealed penetrations (e.g., new piping installed without sealing the penetration)
* \*Obstruction of sewers or sumps
* \*Debris in the sump pit
* \*Deterioration, loss of function, or incorrect positioning of drain valves for secondary containment areas.

Notes:

1. Procedures or checklists shall specify buildings, areas, or inspection routes, inspection criteria, and any special area-specific requirements.
2. Inspection intervals shall be included in the site MI inspection and testing plan. Routine inspection intervals shall not exceed once per month. Specific tanks may require higher inspection frequencies.
3. Documentation of routine dike inspections may be by exception only if specifically stated in the site MI program document.

7.0 PUMPS

7.1 **Scope** – This section provides guidelines for test and inspection methods and frequencies for pumps in hazardous chemical service.

Pumps that are part of systems to prevent a release of hazardous chemicals or mitigate the effects of a release (e.g., cooling water pumps and fire system pumps, respectively) will fall under the MI program. In most cases, these guidelines apply to pumps in nonhazardous chemical service that are part of a safety system (as listed in the PSI) as well. However, additional activities may also be required such as periodic starting and running of infrequently used equipment such as backup fire water pumps. Additional functional testing requirements may be found in Sections 13, 14, and 15 on fire protection equipment, emergency response equipment, and utilities, respectively.

7.2 **Inspection and Test Requirements** – There are no generally recognized codes or standards for inspection of pumps. Sites should use FMEA to evaluate failure modes and develop maintenance strategies for pumps. If FMEAs have not been performed, sites should consider using the inspection and test guidelines in Table 7.1 to develop their MI program.

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| **Table 7.1 – Inspection Methods and Frequencies for Pumps** | | |
| **Service and Operating Conditions** | **Routine Inspection/ Inspection Interval** | **Preventive and Predictive Maintenance Method** |
| Centrifugal pump in hazardous chemical service | Required/nte 90 days | Vibration, oil analysis, or other PdM technique |
| Positive displacement pump in hazardous chemical service | Required/nte 90 days | Vibration, oil analysis, or other PdM technique |
| Other pumps in hazardous chemical service | Required/nte 90 days | Vibration, oil analysis, or other PdM technique |
| Pump in nonhazardous service | Suggested but not required | Vibration, oil analysis, or other PdM techniques as applicable |

7.3 **Routine Inspection** – Routine visual inspections shall be conducted by any trained employee or contractor on all pumps included in the MI program. It is recommended that the routine pump inspections be included with piping inspections. The inspection shall include, but is not limited to the following:

* Leaks or signs of previous leaks
* Broken, cracked, or distorted pump base or foundation
* Missing, loose, or “short” flange bolts
* Corrosion
* Damaged or missing insulation
* Excessive vibration
* Other site-specific inspection criteria

Notes:

1. Procedures, checklists, or route lists shall specify buildings, areas, or inspection routes, inspection criteria, and any special area-specific requirements.
2. Inspection intervals shall be included in the site MI inspection and testing plan. Routine inspection intervals shall not exceed once per month. Specific pumps may require higher inspection frequencies (e.g., pumps in hazardous waste service at U.S. sites shall be inspected daily per EPA hazardous waste regulatory requirements).
3. Documentation of routine tank inspections may be by exception only if specifically stated in the site MI program document (exception: daily inspections of hazardous waste pumps must be fully documented).

7.4 **Inspections During Repair Activities** – Sites should ensure that pump repair procedures include an internal visual check of pump components whenever a pump is opened for maintenance. Procedures should ensure that maintenance personnel alert supervision or reliability engineering whenever they discover signs of corrosion, erosion, or other unexpected wear on pump casings, impellers, or other wetted parts.

7.5 **Preventive and Predictive Maintenance** – Sites shall perform preventive maintenance on pumps in hazardous chemical service in accordance with manufacturer recommendations, and FMEAs / RCFAs conducted as part of PAM implementation.

8.0 CENTRIFUGES

8.1 **Scope** – This section provides guidelines for test and inspection methods and frequencies for centrifuges in hazardous chemical service.

8.2 **Inspection and Test Requirements** – There are no generally recognized codes or standards for inspection of centrifuges. Sites should use FMEA to evaluate failure modes and develop maintenance strategies for centrifuges. If FMEAs have not been performed, sites should consider using the inspection and test guidelines in Table 8.1 to develop their MI program.

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| **Table 8.1 – Inspection Methods and Frequencies for Process Centrifuges** | | |
| **Service and Operating Conditions** | **Routine Inspection/ Inspection Interval** | **Preventive and Predictive Maintenance/Test Interval** |
| Centrifuges in hazardous chemical service | Required/nte 90 days | Vibration, oil analysis, or other PdM technique/nte once per quarter |
| Centrifuges in nonhazardous service | Not required | Vibration, oil analysis, or other PdM techniques as applicable (frequency based on equipment history) |

8.3 **Routine Inspection** – Routine visual inspection shall be conducted on all centrifuges in hazardous chemical service. These inspections shall be conducted by any trained employee or contractor, and shall focus on the following:

* Leaks or signs of previous leaks of process chemicals or hydraulic fluid
* Broken, cracked, or distorted base or foundation
* Missing or loose bolts
* Excessive vibration
* Other site-specific inspection criteria

Notes:

1. Procedures, checklists, or route lists shall specify buildings, areas, or inspection routes, inspection criteria, and any special area-specific requirements.
2. Inspection intervals shall be included in the site MI inspection and testing plan. Routine inspection intervals shall not exceed once per month.
3. Documentation of routine inspections may be by exception only if specifically stated in the site MI program.

8.4 **Inspections During Repair Activities** – Sites should ensure that centrifuge repair procedures include an internal visual check of internal components whenever a centrifuge is removed from service for maintenance. Procedures should ensure that maintenance personnel alert supervision or reliability engineering whenever they discover signs of corrosion, erosion, or other unexpected wear on housings, impellers, or other wetted parts.

8.5 **Preventive and Predictive Maintenance** – Sites shall perform preventive maintenance on centrifuges in hazardous chemical service in accordance with manufacturer recommendations. Sites shall determine appropriate predictive maintenance activities and apply them based on equipment history and manufacturer recommendations.

9.0 PROCESS BLOWERS AND FANS

9.1 **Scope** – This section provides guidelines for test and inspection methods and frequencies for process blowers and fans in hazardous chemical service. This section also applies to related process equipment such as compressors that are used to move process gases or vapors by increasing their pressure. It does not apply to compressors in air or inert gas service, ventilation systems, or interlocks and controls associated with process blowers and fans.

See the following sections for test and inspection methods for components of process blowers and alarms and similar non-process equipment:

* Guidelines for controls and alarms are given in Section 10
* Guidelines for interlocks and emergency shutdown systems are given in Section11
* Guidelines for ventilation systems (listed as safety systems in the PSI) are provided in Section 12
* Guidelines for air and other gas compressors that are part of control or safety systems (as listed in the PSI) are provided in Section 13

9.2 **Inspection and Test Requirements** – There are no generally recognized codes or standards for inspection and testing of process blowers and fans in hazardous chemical service in the chemical or pharmaceutical industries. Sites should use FMEA to evaluate failure modes and develop maintenance strategies for process blowers and fans. If FMEAs have not been performed, sites should consider using the inspection and test guidelines in Table 9.1 to develop their MI program.

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| **Table 9.1 – Inspection Methods and Frequencies for Process Blowers and Fans** | | |
| **Service and Operating Conditions** | **Routine Inspection/ Inspection Interval** | **Preventive and Predictive Maintenance/Test Interval** |
| Process blowers and fans in hazardous chemical service | Required/nte 90 days | Vibration, oil analysis, or other PdM technique/nte once per quarter |
| Process blowers and fans in nonhazardous service | Not required | Vibration, oil analysis, or other PdM techniques as applicable (frequency based on equipment history) |

9.3 **Routine Inspection** – Routine visual inspection shall be conducted on all blowers and fans in hazardous chemical service. These inspections shall be conducted by any trained employee or contractor, and shall focus on the following:

* Leaks, particularly if an appropriate vapor monitoring device is available
* Broken, cracked, or distorted ducting, housing, or mount
* Missing or loose bolts
* Excessive vibration
* Worn belts, couplings, or other drive parts
* Other site-specific inspection criteria

Notes:

1. Procedures, checklists, or route lists shall specify buildings, areas, or inspection routes, inspection criteria, and any special area-specific requirements.
2. Inspection intervals shall be included in the site MI inspection and testing plan. Routine inspection intervals shall not exceed once per month.
3. Documentation of routine inspections may be by exception only if specifically stated in the site MI program.

9.4 **Inspections During Repair Activities** – Sites should ensure that fan and blower repair procedures include an internal visual check of internal components whenever a process blower is removed from service for maintenance. Procedures should ensure that maintenance personnel alert supervision or reliability engineering whenever they discover signs of corrosion, erosion, or other unexpected wear on housings, fans, or other parts in contact with the process fluid.

9.5 **Preventive and Predictive Maintenance** – Sites shall perform preventive maintenance on process blowers and fans in hazardous chemical service in accordance with manufacturer recommendations. Sites shall determine appropriate predictive maintenance activities and apply them based on equipment history and manufacturer recommendations.

10.0 CONTROL SYSTEMS AND ALARMS

10.1 **Scope** – Controls and alarms are often used to (1) control process conditions to ensure product quality, maximize throughput, and maximize yield, (2) alert operators to situations that are out of predetermined operating ranges, (3) prevent or mitigate unsafe conditions, and (4) alarm personnel to the presence of toxic or flammable gases.

The scope of the MI program is limited to controls and alarms that prevent or mitigate process-related incidents. In most cases, these controls and alarms will (1) prevent loss of containment (both to the process area and to blowdown tanks), (2) mitigate the effects of loss of containment, or (3) detect and report hazards such as toxic or flammable vapors, smoke, or flame. The test and inspection requirements listed in this section only apply to controls and alarms that meet these criteria. Teams charged with conducting PHRs or FMEAs should determine which controls and alarms meet these criteria.

10.2 **Inspection and Test Requirements** – Limited information on test requirements for safety instrumented systems is given in Sections 9.7 and B.15 of ISA-S84.01-1996. Unlike piping systems and pressure vessels, there are no generally accepted engineering standards that directly prescribe test frequencies and methods for controls and alarms. Some guidance is provided in Table 10.1 and Section 10.4. However, the reliability of controls and alarms can vary widely. This information should only be used as a starting point in setting inspection and test requirements.

| **Table 10.1 – Test and Inspection Methods and Frequencies for Controls and Alarms** | | |
| --- | --- | --- |
| **System Design** | **Component Maintenance and Testing** | **Functional Test** |
| Simple control loops | Per manufacturer recommendations | Planned field observation or functional test per Section 10.4.1 |
| Advanced control loops | Per manufacturer recommendations | Full system test required, test interval based on system design per Section 10.4.2 |
| Simple alarms | Per manufacturer recommendations | Field observation or functional test per Section 10.4.3 |
| Alarms with multiple inputs and a custom logic solver | Per manufacturer recommendations | Full system test required, test interval based on system design per Section 10.4.4 |

\*Test frequencies should be based on manufacturer recommendations, equipment history, and recommendations from FMEA, RCFA, and PHR teams. Unless otherwise specified, controls and alarms should be tested as part of PMs and tests performed on the equipment to meet GMP requirements. If no GMP requirements or other recommendations exist regarding test frequency, test intervals should range from 3 months to 2 years. Sites should also consider testing safety systems at the start of each production campaign. Sites should specifically justify any test interval greater than 3 years for controls or alarms included in the MI program.

10.3 **Component Maintenance and Testing** – Controls and alarms typically include some sort of sensor or other activation mechanism and some sort of final control element or alarm device. These may be directly coupled together or may be linked through a control device. All components that are required for proper operation of each control or alarm should be identified and maintained per manufacturers recommendations.

**Sensors and Activation Devices** – In many cases, sensors or other activation devices will be calibrated or tested as part of the site’s GMP PM program. These calibrations will normally meet both GMP and MI requirements. If sensors or other activation devices are not part of the GMP PM program, the maintenance and calibration activities should be set based on manufacturer recommendations or on practices in place for maintenance of similar instruments under the GMP PM program.

**Final Control Elements** – In general, final control elements are either discrete devices (e.g., alarms that sound in a control room or full open/full closed valves) or analog devices (e.g., a flow control valve). For the purposes of MI testing, discrete devices only need to be function tested and the device must only be proven in its “safe” position (e.g., did the valve close fully?). Testing and pass/fail criteria will have to be developed for each analog control device depending on the impact that failure to accurately perform a function may have on the effectiveness of a loop.

**Logic Solvers** – Signals from sensors or other activation mechanisms may be analyzed in some form of logic solver such as a programmable logic controller that will send a signal to one or more final control elements. In this case, the logic solver and its components such as a battery backup system become part of the system and each component must be identified and tested according to manufacturer recommendations.

10.4 **Function Testing** – No generally accepted code applies to testing of controls and alarms installed before 1996. ISA S84.01-1996 may apply to design and testing of certain safety systems installed during or after 1996; \*ISA 84.01-2004 may apply to design and testing of certain safety systems installed after 2004. Requirements for other instrumented systems that serve a safety function include:

10.4.1 **Simple Control Loops** – Simple control loops have a single input and a single output with some combination of PID control. If these loops serve a day to day regulatory function (e.g., control flow of steam to a reactor), proper loop function can simply be verified by operational personnel.

10.4.2 **Advanced Control Loops** – Advanced control loops typically include cascade control, feed-forward control, fuzzy logic control, multivariate control, model predictive control, or a wide range of other control strategies. If loop function is required for process safety (based on the list of safety systems in the PSI), detailed test procedures will be required.

10.4.3 **Simple Alarms** – Simple alarms are based on comparing a single input to predetermined values for parameters such as high, low, deviation from setpoint, or rate of change of a process variable. If these alarms are listed in the PSI as safety systems, their function should be tested whenever the field instrument is calibrated. The test procedure should include steps to ensure that the controller or other alarming mechanism has the proper alarm setpoints and that related audible and visual alarms (e.g., on an alarm panel or computer screen) are activated and cleared as appropriate.

10.4.4 \***Conditionalized Alarms or Alarms with Multiple Inputs** – Alarms with multiple inputs typically involve if/then logic to determine if an alarm condition exists. If these alarms are listed in the PSI as safety systems, their function should be tested for each alarm condition. The test procedure should include steps to ensure that the controller or other alarming mechanisms have all of the proper alarm setpoints and that related audible and visual alarms are activated and cleared as appropriate.

11.0 INTERLOCKS AND EMERGENCY SHUTDOWN SYSTEMS

11.1 **Scope** – All process interlocks and emergency shutdown systems (ESSs) used to isolate flow of hazardous chemicals, interrupt power, mitigate the effects of the release of hazardous chemicals, or are otherwise listed as a safety system in the PSI shall be included in the MI program for periodic maintenance and testing. By design, ESSs are safety systems.

Interlocks and ESSs may serve additional functions such as activating notification or alarm systems. Test requirements specified below apply to all safety functions served by an ESS.

For the purposes of this guideline, interlocks and ESSs do not include mechanical and electromechanical safety interlocks that are not related to prevention or mitigation of accidents involving hazardous chemicals. For example, equipment access panel switches that protect maintenance personnel from rotating hardware hazards are not covered by this guideline.

11.2 **Inspection and Test Requirements** – There are no generally accepted engineering standards that directly prescribe test frequencies and methods for interlocks and ESSs. Limited information on test requirements for safety instrumented systems is given in Sections 9.7 and B.15 of ISA-S84.01-1996. Table 11.1 provides general guidelines for inspection and test methods and frequencies. Sites should specifically justify any test interval greater than 3 years for interlocks and ESSs included in the MI program.

If a risk assessment has been performed for a process that specifies or assumes a probability of failure on demand (also called safety integrity level, or SIL) for an interlock or emergency shutdown system, see ISA-S84.01-1996 for guidance on system design and testing requirements to ensure that the assumed SIL is achieved and maintained.

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| --- | --- | --- |
| Table 11.1 – Test and Inspection Methods and Frequencies forInterlocks and Emergency Shutdown Systems | | |
| **System Design** | **Component Maintenance and Testing** | **Functional Test** |
| Direct-wired, fail-safe, interlocks and ESSs | Per manufacturer recommendations | Function test required, test interval nte annually, unless site history indicates otherwise |
| All other interlocks and ESSs | Per manufacturer recommendations | Full system test required, test interval based on system design |

11.3 **Component Maintenance and Testing** – Interlocks and ESSs include some sort of sensor or activation mechanism and some sort of final control element. These may be directly coupled together or may be linked through a control device.

All components that are required for proper operation of each interlock or ESS should be identified and maintained per manufacturers recommendations. Sensors and activation mechanisms include (1) mushroom E-stop switches, (2) discrete sensors or field switches for high or low level, flow, temperature, or pressure, or (3) analog sensors for level, flow, temperature, pressure, or composition. Manufacturer recommendations may range from no specific maintenance (e.g., for switches) to frequent calibration for certain analog sensors.

Signals from sensors or other activation mechanisms may be analyzed in some form of logic solver such as a programmable logic controller that will control one or more final control elements. In this case, the logic solver and its components such as a battery backup system become part of the system and each component required for proper operation must be identified and tested according to manufacturer recommendations.

The final control element of an interlock or ESS is typically some sort of motor relay or isolation valve. These elements are often electro-mechanical, pneumatic, or hydraulic devices and must be maintained according to manufacturer recommendations to ensure proper operation.

11.4 **Function Testing** – Interlocks and ESSs shall be function tested at a frequency based on system design, equipment history, and operational considerations. No generally accepted code applies to testing of ESSs installed before 1996. ISA S84.01-1996 may apply to design and testing of certain safety systems installed during or after 1996. Consult the PSI to determine if the list of design codes and standards for the process includes ISA S84.01-1996.

11.4.1 **Operator-activated ESSs** – Operator-activated ESSs typically include one or more switches that are wired in series such that opening any switch will trip a number of valves and motors to their “fail safe” condition (e.g., valves will typically shut and pump motors will typically turn off).

These systems are highly reliable and typically not susceptible to calibration error or software logic failure (i.e., by design, failures should cause the system to return to a safe condition). However, they may be inadvertently defeated during maintenance activities. The procedures for testing these systems should ensure that all activation points are tested periodically and all final control elements function as designed. These systems are typically tested annually unless site history or other conditions indicate otherwise.

11.4.2 **Direct-Wired, Fail-Safe Interlocks** – Direct-wired, fail-safe interlocks include direct-wired systems that use a fail-safe switch to prove a condition, do not have multiple relays or a logic solver, and directly remove power to solenoids or motor contactors. A common example is the permissive controls systems for a process hot oil heater that may include a wide range of process parameters such as air flow, gas pressure, and hot oil flow to be in certain ranges prior to startup and during operation.

These systems are highly reliable and typically less susceptible to sensor calibration error or software logic failure (i.e., by design, failures should cause the system to return to a safe condition). However, they may be inadvertently defeated during maintenance activities, or the sensors or final control elements may fail to function. The procedures for testing these systems should ensure that all sensors and activation points are tested, all final control elements function as designed, and that the control elements are not being forced to the safe position by some other interlock. These systems are typically tested annually unless site history or other conditions indicate otherwise.

11.4.3 **Other Interlocks and ESSs** – All other interlocks and ESSs should be individually evaluated to determine test procedures and test frequency. It is nearly impossible to test complex software-driven systems under all potential operational conditions and failure modes. Procedures should ensure that all of the safety-related functions are performed under all probable conditions or modes, with particular attention paid to potential common-cause failure modes such as (1) power failures, (2) electrical interference, or (3) similar equipment or technology for sensors, logic solvers, or final control elements that might fail due to a single event.

12.0 BUILDING VENTILATION SYSTEMS

12.1 **Scope** – This section provides guidelines for test and inspection methods and frequencies for building and room ventilation systems listed as safety systems in the PSI. Typical ventilation systems that meet this definition include:

* Ventilation systems designed to protect workers in the event of a process-related emergency (e.g., systems to provide clean, positive pressure air to a control room where operators are assigned to remain on duty to control the process)
* Ventilation systems designed to protect personnel in the event of an emergency (e.g., safe havens)
* Ventilation systems designed to provide clean pressurized air to electrical equipment that would otherwise require specially-designed enclosures under NFPA 497 or NFPA 499 (electrical classification codes for environments containing flammable liquids, gases, or vapors, and combustible dusts, respectively)
* Ventilation systems designed to meet the requirements of Section 17.11 of NFPA 30 for enclosed process areas handling liquids above their flashpoint temperature
* Ventilation systems designed to protect building occupants by maintaining negative pressure in a room containing toxic chemicals or positive pressure in adjacent areas of the building

This section does not apply to:

* Ventilation systems for clean rooms or other systems designed to ensure product quality
* Ventilation systems for laboratory hoods or other similar environments

12.2 **Inspection and Test Requirements** – There are no generally recognized codes or standards for test and inspection of ventilation systems covered by this section. Sites should use manufacturer recommendations, Lilly Engineering Guidelines, and site-specific procedures to determine test methods and frequencies. If none of these are available, Table 12.1 gives guidance for test and inspection frequencies.

12.3 **Routine Inspection** – Routine visual inspection shall be conducted on all ventilation systems that are listed as safety systems in the PSI. These inspections shall be conducted by any trained employee or contractor, and shall focus on the following:

* Damage to ductwork, including broken, corroded, or collapsed ducting
* Static pressure measurements taken at the same locations and conditions as the initial or baseline test
* Calibration of sensors for alarmed systems
* Function and proper test points for alarms and interlocks

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| Table 12.1 – Inspection Methods and Frequencies for Ventilation Systems | | |
| **Service and Operating Conditions** | **Routine Inspection/ Inspection Interval** | **Preventive and Predictive Maintenance/Test Interval** |
| Ventilation systems in services listed in Section 12.1 without continuous monitor or alarms | Inspect for physical damage to ductwork and test static pressure/nte once per quarter  See note regarding static pressure testing | PM required per manufacturer recommendations. PdM required/nte once per quarter |
| Ventilation systems in services listed in Section 12.1 with continuous monitors and alarms | Inspect for physical damage to ductwork, calibrate sensors, and test function test alarms/nte once per quarter | Same as above |

Note: Results of static pressure tests should be compared to pressure measurements taken during initial or baseline tests to determine if the system is operating properly. If any modifications are made to the system, new static pressure criteria must be established based on repeating initial tests.

In some cases, ventilation systems are interlocked with other control systems to start or stop under certain conditions. Test and inspection procedures and frequencies for safety systems interlocked with other process systems should also comply with the guidelines given in Section 11.

Additional information on design and testing of ventilation systems can be found in *Industrial Ventilation – A Manual of Recommended Practice*.

12.4 **Preventive and Predictive Maintenance** – Sites shall perform preventive maintenance on ventilation systems listed in the PSI in accordance with manufacturer recommendations. PM activities typically include replacing filters, cleaning blowers and fans, inspecting couplings and belts, and servicing motors, drivers, and other moving parts. Sites shall determine appropriate predictive maintenance activities and apply them based on equipment history and manufacturer recommendations. In many cases, vibration monitoring methodology used for process pumps can be directly applied to blowers and fans.

13.0 FIRE PREVENTION AND MITIGATION SYSTEMS

13.1 **Scope** – Fixed fire detection, alarm, and protection systems in use in U.S.-regulated and Lilly high hazard processes are part of the MI program. The codes and standards that apply to these systems include a number of NFPA codes. There are no risk categories for fire detection, alarm, and protection systems. By design, they are safety systems. In addition, any device installed in a US-regulated or high risk process to detect, alarm, or mitigate the effects of a fire becomes part of the MI program, regardless of whether the NFPA code required the device. For example, if an automatic shutoff valve is installed on a solvent tank that isolates the tank in the event of a fire, it must be included on the test and inspection plan and inspected per manufacturer recommendations even \*if an automatic tank isolation valve is not required by Section \*27 of NPFA 30.

13.2 **Inspection and Test Requirements** – Consult with the site Loss Prevention Officer for a complete list of fire detection, alarm, and protection systems and the relevant NFPA codes and standards.

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| **Table 13.1 – Test and Inspection Methods and Frequencies**  **for Fire Detection, Alarm, and Detection Systems** | | |
| **System Design** | **Component Maintenance and Testing** | **Functional Test** |
| Detection, alarm, and protection systems required by the NFPA Code | Per requirements of the relevant NFPA Code | Per requirements of the relevant NFPA Code  See also Lilly Engineering Technical Guideline 16770 |
| All other detection, alarm, and protection systems | Per manufacturer recommendations | Required, see manufacturer recommendations or consult with site Loss Prevention Officer |

13.3 **NFPA-Covered Equipment** – NFPA Codes include detailed test and inspection procedures for covered equipment. These tests should already be in place and audited frequently as part of insurance audits and other loss prevention activities. The inspection and test plan may simply reference an existing document or plan rather than duplicating an existing system.

13.4 **Function Testing of Non-NFPA Equipment** – Fire detection, alarm, and protection equipment not covered by an NFPA standard shall be function tested at a frequency based on system design, equipment history, and operational considerations. If manufacturer recommendations are not available and no generally accepted code applies to the equipment, function testing should be conducted at frequencies used for similar interlock, alarm, and emergency shutdown equipment.

14.0 EMERGENCY RESPONSE EQUIPMENT

14.1 **Scope** – Emergency response equipment in use at sites with U.S. EPA 112(r) regulated processes are part of the MI program. The codes and standards that apply to these systems include a number of NFPA codes and equipment-specific requirements. There are no risk categories for emergency response equipment. By design, they are safety systems.

14.2 **Inspection and Test Requirements** – Consult with the site Loss Prevention Officer for a complete list of emergency response equipment and the relevant codes and standards.

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| **Table 14.1 – Test and Inspection Methods and Frequencies**  **for Emergency Response Equipment** | | |
| **System Design** | **Component Maintenance, Testing, or Replacement** | **Functional Test** |
| Crew-served equipment such as the responder vehicle | Per manufacturer recommendations | Required, per manufacturer recommendations |
| Individual equipment such as SCBA tanks and regulators, vapor detection equipment, and medical response equipment | Per manufacturer recommendations | Required, see manufacturer recommendations or consult with site Emergency Response Team Leader |

14.3 **Component Maintenance, Testing, or Replacement** – Many emergency response items require periodic maintenance, testing or replacement. These requirements range from replacing detection cells on vapor sensors to test and inspection of SCBA tanks. These tests should already be in place and audited frequently as part of insurance audits and other loss prevention activities. The inspection and test plan may simply reference an existing document or plan rather than duplicating an existing system.

14.4 **Function Tests** – Equipment should be function tested per NFPA codes and manufacturer recommendations. Function testing should include exercising emergency response trucks and related equipment.

15.0 UTILITIES

15.1 **Scope** – Utilities include systems such as process air and nitrogen, instrument air, steam, tempered water, cooling water, chilled water, heat transfer oil systems, electrical power, and backup electrical power supply. Ventilation and fire protection systems are addressed in Sections 12 and 13, respectively.

The scope of this MITI guide is limited to utilities that are required by safety systems to prevent or mitigate process-related incidents involving hazardous chemicals. Teams charged with conducting PHRs or FMEAs should determine which utility systems meet these criteria. If a utility such as instrument air is required to move an isolation valve to the “fail safe” position in the event of an emergency, then the instrument air system should be considered for inclusion in the MI program. Likewise, if nitrogen padding is used to protect against internal fire, the nitrogen delivery system should be considered for inclusion in the MI program.

In some cases, stored energy in the utility system is adequate to maintain function for sufficient time to allow operators to take actions to bring the process to a stable condition. For example, there may be enough residual pressurized air in the instrument air system to hold valves and controls in position until alternate administrative controls can be activated (e.g., switching to backup bottled air or nitrogen). In this case, the bottled air or nitrogen becomes the safety system (as opposed to the air compressor). Therefore, the operator rounds list should include checking the inventory of the backup air supply. Likewise, stored energy in steam, hot oil, and cooling water systems is often adequate to allow for safe shutdown of the process and are therefore the MI program is limited to pumps and other systems to deliver utilities.

Backup utility systems are almost always safety systems and are therefore included in the MI program. These systems may include:

* Engine-driven backup cooling water pumps
* Backup power supplies for control systems
* Inert gas storage and delivery systems
* Engine driven backup fire water pumps (if not already addressed in Section 13)

This guideline is not intended to address equipment that is not required to prevent or mitigate accidents involving hazardous chemicals. For example, an inline spare cooling water pump may be excluded from the MI program if cooling water is not required to prevent or mitigate an accident involving a hazardous chemical, or if an engine-driven backup is designated as the emergency backup pump (but the backup pump might be part of the MI program). However, all utility systems should be maintained according to manufacturer recommendations, which may include periodic function tests or other maintenance activities.

15.2 **Inspection and Test Requirements** – There are no comprehensive generally accepted engineering standards that directly prescribe test frequencies and methods for utility systems. Test frequencies should be based on manufacturer recommendations, equipment history, and guidelines for similar equipment given in other sections of this document, and recommendations from FMEA and PHR teams.

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| **Table 15.1 – Test and Inspection Methods and Frequencies**  **for Utility Systems Listed as Safety Systems in the PSI** | | |
| **System Design** | **Component Maintenance, Testing, or Replacement** | **Functional Test** |
| Battery-powered backup systems for controls and interlocks described in Sections 10 and 11 of this document | Per manufacturer recommendations | Required, per manufacturer recommendations |
| Engine-powered electrical generators | Per manufacturer recommendations | Required, per manufacturer recommendations |
| Engine-powered pumps, compressors, and other systems | Per manufacturer recommendations; see also Section 7 for pump test and inspections | Required, per manufacturer recommendations; see also Section 7 for pump test and inspections |
| Backup steam generators listed as safety systems in the PSI | Per manufacturer recommendations | Required, per manufacturer recommendations |
| Inert gas storage and delivery systems | Visual inspection of system, valve lineup, and inventory. See Section 2 for requirements for pressure vessels | Normally not required |

15.3 **Component Maintenance and Testing** – All components that are required for proper operation of utility and backup utility systems listed as safety systems in the PSI should be identified and maintained per manufacturer recommendations. In many cases, methods used to maintain similar process equipment can be directly applied to these systems.

15.4 **Function Testing** – In limited cases, NFPA or other codes may establish certain functional testing requirements. However, in most cases methods and frequencies for functional testing will be based on manufacturer recommendations and equipment history.

Many backup utility systems require operator action for startup and shutdown. In most cases, (1) this is performed infrequently, (2) there is little time to consult procedures in the event of a utility failure, and (3) failure to properly startup the backup system in a timely manner can have significant negative impacts on process safety and product quality. Sites should consider scheduling functional tests in such a way that all operating teams are involved in the startup of these utilities.

One frequent failure mode of emergency backup systems is failure on demand. For example, batteries used to power a starter motor on an engine will fail in time. Without a function test, this failure will go undetected. Moreover, many systems such as engines to drive pumps and generators will be more reliable if they are operated on a regular basis, and operating them may directly address the root cause of failure on demand (e.g., batteries used to power a starter on an engine are recharged during operation). Therefore, sites should consider testing backup systems powered by gasoline, natural gas, or diesel engines at least once per month.

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