7

Process Equipment Integrity

7.1 Overview

Assuring the integrity of process equipment must start with equipment design and continue through its fabrication, installation, and operation. Since the responsibility for these activities generally lies with the engineering, construction, and maintenance departments of a facility, the auditor should interview personnel from those departments. On the other hand, a large number of facilities rely on staff from their corporate engineering and construction departments, or outside contractors, for these services. If this is the case, the auditor should include interviews with individuals in those organizations as part of the audit.

In preparing for the audit, the auditor should identify the key individuals in the appropriate facility, corporate and contractor organizations. These individuals should have the following documentation available for review by the auditor:

- Design standards, specifications and records
- Fabrication specifications and records
- Installation procedures and records
- Inspection procedures and records
- Maintenance procedures and records

In addition, information from audits of other process safety management elements may be useful (see Figure 7-1), for example,

- Design standards and equipment specifications (from Chapter 4, Process Safety Knowledge)
- Specification of fabrication/installation tests and inspections (from Chapter 5, Project Safety Reviews)
- Critical equipment identification (from Chapter 5, Project Safety Reviews)
- Process changes which were initiated because of equipment failures (from Chapter 6, Management of Change)
- Review of incidents to develop the preventive maintenance program (from Chapter 9 Incident Investigation)
- Training of maintenance personnel and inspectors (from Chapter 11, Training)

The audit of process equipment integrity should include the following steps:
• Review of standards and procedures for format and content (see Section 3.2.2)
• Interviews with operations and maintenance department personnel to understand the PSM systems in place
• Interviews with construction/maintenance personnel (including contractors) to verify qualifications
• Sampling of equipment records for completeness and compliance with procedures
• Observation of new construction and maintenance work in progress for compliance with procedures

The auditor should have a clear understanding of the corporate and facility policies that specify what equipment must be included in the process equipment integrity program. The criteria for deciding what equipment should require a process integrity program should be based on how critical that piece of equipment is to ensuring the safety of the process. Most regulations and industry guidelines specify the processes to which they apply in terms of the chemicals handled in those processes. For those processes, the auditor should verify that critical equipment has been included in the process equipment integrity program. Some examples are

• Vessels and tanks
• Pumps and compressors
• Heat exchangers
• Piping systems
• Flexible connections (e.g., hoses, bellows, expansion joints or loading arms)
• Relief and vent systems
• Check valves and other backflow-prevention devices
• Emergency shutdown systems
• Controls, alarms, and interlocks
• Electrical distribution and other utilities
• Detection systems for flammable gas, toxic gas, and fire
• Fixed fire protection systems
• Grounding/bonding and cathodic protection systems

7.2 New Equipment Design, Fabrication, and Installation

Information detailing the design codes and specifications for new equipment should be contained in the design package. This package should include equipment specifications, data sheets, calculations, and detailed equipment drawings. The existence and completeness of this information should be audited as part of the process safety knowledge element (see Chapter 4).

The auditor should verify that the required tests and inspections, and acceptable limits for new equipment have been included in the design package. The auditor should also confirm that fabrication and installation recommendations from the project safety reviews (see Chapter 5) have been addressed. This information would typically be made available by the project engineering staff or manager.

For fabrication of new equipment the auditor should confirm that there is a quality assurance program that meets the project requirements. Contractors responsible for
fabrication or installation may develop these criteria. The auditor should also verify that where applicable the following activities are specified prior to start of fabrication:

- Welding, fabrication, and non-destructive examination requirements
- Required approvals
- Qualification of employees (e.g., welder certification)
- Hold and witness points
- Quality assurance audits

Examples of quality assurance tests and inspections which may be conducted during fabrication include

- Radiographic examination of welds
- Mill tests for materials of construction
- Stress relieving
- Impact (Charpy V notch) tests
- Hydrostatic testing or pneumatic strength tests
- Nondestructive examination (NDE)
- Verification of dimensions and tolerances

The auditor should interview the personnel responsible for reviewing or participating in quality assurance programs and ensure, by sampling equipment records, that tests and inspections have been performed as specified in the requirements. Additional tests and inspections may be required during installation of equipment. Most of these requirements should be part of the design package or established with the installation contractor. Where manufacturers of critical equipment have specific installation instructions, the auditor should ensure that there is a mechanism for ensuring that they have been considered.

The range of tests and inspections that may be conducted during installation include

- Soil compaction
- Protection against frost heaves
- Strength of concrete
- Structural steel integrity
- Radiographic examination of field welds
- Bolting techniques
- Materials of construction for piping, gaskets, and packing
- Integrity of coatings/linings/refractory
- Leak testing of connections
- Testing of relief devices
- Function testing of instrumentation and controls, fire and gas detection systems, and emergency shutdown systems
- Proof testing of cathodic protection and grounding systems
- Electrical load testing of emergency equipment
The auditor should verify that fabrication and installation records include the date of the test/inspection, the name of the person who conducted the test, the test results and their acceptability.

Test/inspection records should be filed to facilitate retrieval. The auditor should verify there is a system in place to forward a copy of these records to the maintenance organization before startup of the equipment (see Chapter 5).

7.3 Preventive Maintenance

Critical equipment requires a preventive maintenance program to prevent or identify defects and minor failures before they can develop into more serious failures.

The auditor should verify that there is a mechanism for identifying critical equipment. He should also verify that any required tests and inspections, and their frequency and acceptable limits have been specified; and that there are written procedures for conducting each test or inspection. The auditor should also assure that there is a process for setting preventive maintenance frequencies. One method is to start with a conservative frequency and change inspection intervals based on test results. The manufacturer’s recommendations for preventive maintenance should be a starting point unless there is experience on similar equipment. Incident history should also influence the need for, or frequency of, preventive maintenance. Some examples of preventive maintenance for equipment that may be critical to the process are:

- Test and reset pressure relief valves
- Inspect and clean flame arresters and conservation vents
- Replace pump/compressor seals
- Inspect vessels and tanks
- Measure wall thickness or pressure-test piping and heat-exchanger tubes
- Proof test detectors, controls, alarms, interlocks and shutdown systems
- Function test emergency isolation and vent valves
- Replace rupture discs
- Replace or test hoses and other flexible connections
- Test/inspect emergency equipment and fixed fire protection equipment
- Analyze pumps and compressors for vibration
- Conduct thermographic analysis of electrical equipment

The auditor should verify that there is a system in place to analyze the maintenance history of equipment for trends, so that changes in the procedures, techniques, or frequency of testing, or the design of a piece of equipment can be made (e.g., a line that is found to require replacement every few years should be considered for a change of materials of construction rather than increasing the inspection frequency).

The auditor should then sample equipment records to verify that the appropriate tests/inspections have been carried out at the specified frequency and that the results fall within acceptable limits. If the equipment does not pass a required test, the auditor
should verify that this information is communicated to the appropriate personnel, and that any repairs deemed necessary were made.

The auditor should also verify that there is a training program in place for maintenance personnel who conduct preventive maintenance (see Chapter 11).

7.4 Maintenance Procedures

7.4.1 Work Authorization

Process-related maintenance activities should require a written authorization. This authorization is particularly important to ensure that process changes are identified (see Chapter 6). It is equally important that maintenance work on equipment be documented to provide a record that can be analyzed as part of the reliability program.

The auditor should verify that process-related maintenance work requires a written description of the work and appropriate authorization. He should also verify that there is a mechanism for the quality assurance of materials and spare parts used for repair.

For critical service, or in instances where special materials of construction are required, there should be a method for verification of materials of construction. The pressure and temperature rating of equipment should also be confirmed by the maintenance coordinator or contractor personnel responsible for preparing material lists for maintenance jobs. Spare equipment, particularly portable or temporary equipment, should be inspected prior to use to ensure that it meets the design standards for the system in which it is to be used. If equipment or spare parts that are not replacements in kind are used, this would constitute a change which would require a safety review under the Management of Change element (Chapter 6).

Documentation of repairs to equipment should be retrievable. This documentation may include individual work orders authorizing the repairs.

The auditor should verify that there is a system to ensure that safety-related work will be given priority over routine maintenance. Maintenance procedures should specify that when work is completed, the job should be inspected to ensure that the equipment is safe to start up. This inspection should include verification that all valves are in the proper position and all associated alarms and interlocks are active.

7.4.2 Safe Work Practices

A critical part of any maintenance or project work on existing equipment is a set of safe work practices for preparing equipment for maintenance or tie-ins. Some examples of safe work practices are

- Hot work
- Line break
- Confined space entry
- Lockout/isolation
• Identification of underground process lines or utilities prior to excavation
• Lifting over active equipment or piping

The auditor should verify that safe work practices exist to control facility process hazards. Often permits or authorization forms are used as documentation that required tests and inspections have been performed. These would typically include testing for flammable or toxic vapors and oxygen concentration. Such permits should only be valid for a specified time, typically a work shift.

The auditor should identify maintenance or project work in progress that requires compliance with safe work practices, and verify that these procedures are being followed and that permits are complete and current. In addition, the auditor should sample maintenance records to verify that work authorizations and safe work permits have been completed as required.

7.5 Contractors

The use of contractors for equipment maintenance is common. A study has been completed on the use of contract labor in the U.S. petrochemical industry (John Gray Institute, 1991). This study found that contract labor is used to conduct approximately one-third of routine maintenance and one-half of the maintenance required during turnarounds. Reliance on contractors makes it important that contractors are aware of hazards in the workplace and comply with each facility’s safe work practices. A facility may use a number of contractors, some for routine maintenance and others for special tasks. The auditor should verify that the safety record of contractors is considered prior to award of contracts. The auditor should also verify that a system exists for contractor orientation and that it includes a review of the emergency plan, hazard communication, and the facility’s safe work practices. The auditor should verify there is a system for ensuring that the contractor has trained his employees in the procedures necessary to work safely at the facility. If the auditor has the opportunity to observe maintenance or tie-in work (see Section 7.4), she should also verify that contractors are following the facility’s safe work practices.

7.6 Decommissioning and Demolition

When a piece of equipment is no longer needed for operation, it should be decommissioned. Unused equipment can be a potential hazard if not isolated and/or cleaned properly.

The auditor should verify that there are procedures in place that specify the requirements for isolation and cleaning of equipment to be taken out of service. She should evaluate how equipment recently taken out of service was handled, and determine if special procedures for cleaning and disposal of hazardous residues or materials have been written (e.g., disposal of asbestos). The auditor should verify that
if equipment is subsequently recommissioned it has had the appropriate safety reviews (see Chapter 6).

When equipment has served its useful life, it should be dismantled, removed, and/or demolished.

7.7 Summary

Process equipment integrity must be considered in all phases of equipment life from its initial design, through fabrication, installation and operation until it is demolished. The audit of this element must include quality assurance systems during fabrication, installation, and repair of equipment as well as systems for preventive maintenance during the useful life of the equipment.