6.11 Inspection & Testing

Introduction

Maintaining the integrity of phosgene handling systems is of the utmost importance. This section outlines common practices for inspecting and testing phosgene system equipment, piping and vessels. Inspection and testing practices can help by preventing failures in these components.

The information provided in this section should not be considered as a directive or as an industry standard that readers must adopt or follow. Instead, the information is intended to provide helpful ideas and guidance that users may wish to consider in a general sense (See Section 1.1 *Preface and Legal Notice*). Also included is a reference list of useful resources.

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6.11.1 Inspection & Testing During Operation

This section outlines techniques commonly used to inspect and test phosgene-containing process equipment while in operation. The methodologies listed are to be considered only as references for additional consideration and are based on historical data from phosgene manufacturers involved in preparing the Guidelines.

Users must develop their own inspection methodologies and frequencies based on their specific needs and circumstances. Local regulations, design codes, and plant history are among the factors to consider in developing appropriate inspection methodologies and frequencies. Local regulations may require emission testing after any line breaks or equipment repairs. Additional precautions need to be considered prior to conducting Inspections while equipment is in operation including but not limited to PPE, enclosure entry, hot work, potential interference (with operations, instruments and operator access), electrical safety and safe work permitting.

Equipment Type	Methodology
Process Equipment	Visual inspection has been used when observing for signs of corrosion, leaks, condition of paint, and condition of structural support (*e.g.*, pipe hangers, I-beams, etc.).
Rotating Equipment	Testing that has been performed: • Vibration measurement • Fugitive emission testing of seals, tubing, and flanged connections
Piping	Thickness measurements (TMs) have been performed to check integrity and estimate corrosion rates. The thickness measurements have been done using ultrasonic or radiographic methods. Areas frequently checked for thickness include elbows, downstream of valves and welds, branches, turbulent areas, dead legs, injection points and the small end of reducers. Piping, including connections and flanges, has been visually inspected for installation of the correct gasket, gasket condition, signs of leakage, paint condition, and the presence of corrosion under insulation (CUI). Profile radiography has been used to identify corrosion under insulation without having to remove the insulation. Suspect areas for corrosion under insulation have included low points on vertical piping runs, areas where insulation is altered to fit valves, branches, fittings, or areas where insulation is damaged/uncovered. Areas of operating temperatures between 140oF to 350oF (60°C to 176.7°C)3 and intermittent operation have also warranted focus.

Equipment Type	Methodology
Relief Devices	Visual inspection has been used to inspect for signs of leakage or corrosion of bolts, holders, etc.
Vessels, Pressure & Low/No Pressure	Thickness measurements have been used to check integrity and estimate corrosion rates. The thickness measurements have been done using ultrasonic or radiographic methods. (Note the diameter size of the vessel does not exceed the capability of the radiographic methodology. Consider appropriate locations for establishing specific thickness measurements.) Visual inspections and profile radiography (on small vessels) have been used to identify corrosion under insulation. Suspect areas for corrosion under insulation have included vessel skirts, insulation support rings, and areas where insulation is altered to fit valves, fittings, etc. Areas of operating temperatures between 140°F to 350°F (60°C to 176.7°C)[3] and intermittent operation have also warranted focus. The seam between tank bottom and support pad has also been visually inspected for damage to the sealer.
Valves, Flanges, Fittings, & Tubing, Hoses and Flexible Connectors	Visual inspections have been used for the following: • Gasket and bolt condition • Packing condition • Paint condition • Support condition • Abrasion and crimping (tubing) • Signs of leakage

6.11.2 Inspection & Testing During Maintenance/Turnarounds

This section outlines commonly used techniques to inspect and test phosgene-containing process equipment during maintenance and turnarounds. The methodologies listed are to be considered only as references for additional consideration and are based on historical data from major phosgene manufacturers. Users must develop their own inspection methodologies and frequencies based on their specific needs and circumstances. Local regulations, design codes, and plant history are among the factors to consider in developing appropriate inspection methodologies and frequencies. Local regulations may require emission testing after any line breaks or equipment repairs. Additional precautions need to be considered prior to conducting Inspections during maintenance and turnaround periods, including but not limited to PPE, enclosure entry, decontamination, hot work, potential interference (with other ongoing operations, instruments and operator access), electrical safety and safe work permitting.

Equipment Type	Methodology
All Process Equipment	Visual inspection has been used when observing for signs of corrosion, leaks, condition of paint, and condition of structural support (*e.g.*, pipe hangers, I-beams, etc).
Rotating Equipment	Testing that has been performed: • Coupling inspection & alignment • Leak testing of seals, tubing, and flanged connections • Internal inspection for casing erosion and corrosion
Piping	Thickness measurements have been performed to check integrity and estimate corrosion rates. The thickness measurements have been done using ultrasonic or radiographic methods. Common areas checked for thickness have included elbows, downstream of valves and welds, branches, turbulent areas, dead legs, injection points and the small end of reducers. Piping, including connections and flange faces, has been visually inspected for installation of the correct gasket, gasket condition, signs of leakage, paint condition, and the presence of corrosion under insulation. Profile radiography has been used to identify corrosion under insulation without having to remove the insulation. Suspect areas for corrosion under insulation have included low points on vertical piping runs areas where insulation is altered to fit valves, branches, fittings, etc. Areas of operating temperatures between 140ºF to 350ºF (60°C to 176.7°C)[3] and intermittent operation have also warranted focus. Inspection tools such as a boroscope have been used to internally inspect piping for signs of corrosion or erosion. Welds have been inspected for stress cracking using dye penetrant or eddy current. Areas of concern have included welds that experience high loading or high vibration.

Equipment Type	Methodology
Relief Devices (including rupture disks and pressure/ vacuum relief valves)	Activities for rupture disks have included: • Inspected holder & bolts for corrosion • Inspected disk for corrosion or other mechanical defects to check correct material selection • Checked piping for blockage • Replaced disk Activities for pressure or vacuum relief valves have included: • Tested set pressure (not while installed) • Inspected packing, seat, bolts, and gasket surfaces for corrosion or other mechanical defects • Checked piping for blockage • Looked for signs of leakage
Vessels, Pressure & Low/No Pressure	Thickness measurements have been used to check integrity and estimate corrosion rates. The thickness measurements have been done using ultrasonic or radiographic methods. Consider appropriate locations for establishing specific thickness measurements. Eddy current has been used to check integrity of tubes. Visual inspections and profile radiography (on small vessels) have been used to identify corrosion under insulation. Suspect areas for corrosion under insulation have included vessel skirts, insulation support rings, and areas where insulation is altered to fit valves, fittings, etc. Areas of operating temperatures between 140oF to 350oF (60°C to 176.7°C)[3] and intermittent operation have also warranted focus. Internal inspections have been used to visually identify pitting of the base metal and condition of the welds. Stainless steel alloy welds have been inspected by dye penetrant or eddy current to identify stress corrosion cracking. Welds that experience high loading or high vibration have often been areas of concern. Examples include piping connections, seam welds, and tray supports. The internal inspection has also been used to check the integrity of tank bottoms that cannot be externally inspected. Thickness measurements have been taken to identify areas of thinning or corrosion between the tank bottom and tank pad.

Equipment Type	Methodology
Valves, Flanges, Fittings, Tubing, Hoses , Flexible Connectors	Critical isolation valves and valves in solids or high velocity service have been internally inspected to check for corrosion/erosion and seat condition. These isolation valves have also been pressure-tested to check sealing integrity. Profile radiography has also been used on certain valves to determine if there is erosion or corrosion. This can help identify items to repair prior to turnarounds. Check whether the size of the valve exceeds the capability of the radiography methodology.

6.11.3 Commissioning Equipment

This section includes common techniques for checking system integrity prior to and following installation, repair, or turnaround of equipment and systems. Local regulations may require a combination of several of these techniques or alternative methods.

An inspection of equipment and valves prior to installation can help prevent future failures and leaks. This inspection frequently consists of verifying appropriate materials of construction, gasket material, and lubricants. During the installation or assembly process, proper bolt torquing is important to ensure the integrity of connections.

Once installation or repair work is complete, a visual inspection can be used to help verify system integrity. This visual inspection evaluates that correct gaskets are used, all flanges and connections are tight, instrumentation is installed, and that no open connections or drains exist. The visual inspection is often followed by cleaning or flushing to remove trash and debris. This cleaning has been done with compressed gas (*e.g.*, nitrogen or air) or with a fluid. One benefit to using a fluid wash is that some instrumentation can be functionally tested. Consider an acid flush for carbon steel equipment to reduce iron content in the product. Draining and blowing the system clear following a fluid wash removes free-standing liquid and minimizes corrosion.

The procedures described above help prepare the system for a rigorous integrity test. The integrity tests are commonly referred to as “pressure tests” or “leak tests.” Available integrity tests for piping and equipment systems include: (a) hydrostatic tests, (b) pneumatic tests, and (c) sensitive leak tests. Generally, a hydrostatic or pneumatic test is performed on repaired or new piping and vessels, and then a sensitive leak test is performed on equipment that was opened or repaired during the maintenance/turnaround. Each test method will be described in more detail below.

Hydrostatic Testing
A hydrostatic test is frequently performed on new or repaired piping and vessels. In this test method, the vessel and/or piping is pressurized with a fluid (*e.g.*, water) up to or slightly above design pressure. A h ydrostatic test helps verify that the repaired or new vessels and piping can withstand the design pressures.

A hydrostatic test does not provide many clues as to the actual condition of the vessel. Unknown factors such as flaws, corrosion, metal loss in heat affected zones of the welds, poor weld fusion or lack of penetration, cracks in weld seams, or de-lamination of plates are, for the most part, undetected by hydrostatic testing. The external and internal inspections discussed previously in this Section provide information on detection of these items.

Repeated hydrostatic testing can shorten the fatigue life of the vessel because it applies close to yield level stresses to small cracks or flaws that may have developed over time by cyclic stresses. Thus, the hydrostatic test method is not often used for routine inspections. As discussed above, in many cases, it is only performed on new or repaired piping and vessels to help ensure the integrity of welds and connections.

Also, careful development of the test procedure helps prevent damaging equipment due to over-pressure. American Society of Mechanical Engineers Code B31.3[1] provides further information relating to the test parameters. Questions often considered include:

- Is other equipment to be tested at the same time or to be included in the same test? If no, then has the equipment been properly isolated for the test?

- Are there any issues with the water weight of the equipment to be hydrostatically tested (vessel may normally be filled with lighter weight organics or vapor)? This would include equipment supports or building floor/steel.
- Will the testing exceed the maximum allowable working pressure (MAWP) of the equipment?
- What are the test-acceptance criteria, including duration and gauge errors?
- Who needs to witness the test?
- Is overpressure protection required?
- Are redundant gauges installed?
- What measures are in place to ensure that all air is purged through high point vents to prevent equipment damage or personal injury?
- Consider steps to insure adequate drying to remove any residual water from the hydrotest.

Note: The chemistry of the fluid used in the hydrostatic test is important in preventing corrosion of carbon steel and stress cracking of stainless steel.

Pneumatic Testing

The use of pneumatic testing requires special consideration because of the potential dangers associated with the stored energy of the compressed gas involved in the test. Pneumatic testing is often only used when a hydrostatic test is undesirable because of concerns over moisture in the piping and vessels. A pneumatic test involves pressuring the vessel and/or piping with a compressed gas up to or slightly above design pressures.

Like hydrostatic testing, pneumatic testing can shorten fatigue life, or damage equipment and injure people if performed improperly. Thus, it is often only performed on new or repaired equipment to help verify the integrity of welds and connections. The precautions listed in the Hydrostatic Testing discussion above are commonly considered in pneumatic testing as well.

Sensitive Leak Testing

Sensitive leak tests are commonly used in phosgene services because they can detect very small leaks that may go undetected during hydrostatic or pneumatic leak tests. Examples of sensitive leak tests include helium leak test and bubble leak testing (ASME B31.3).[1]

Helium leak testing consists of adding a small volume of helium to the system, followed by a larger quantity of nitrogen. A helium mass spectrometer is then used to detect for leaks.

Advantages of helium testing:

- Very little fatigue on the equipment.
- Helium testing is a more sensitive test. It can identify more leaks than water or air.
- The test equipment is portable.
- Decreased risk to health or environment.

Disadvantages of helium testing:

- Needs specially trained test equipment operators.
- The test can be very slow as you must wait for the helium to travel though the vessel.
- Absent a pre-pressure check could impact background readings in event of leakage.
- Bubble testing consists of slightly pressurizing the process lines and checking for bubbles using a soapy solution.

Advantages of bubble testing:

- Little fatigue on the equipment.
- Easy to use.

Disadvantages with bubble testing:

- Needs specially trained operators.
- Difficult to do on large flanges or heated systems.

Ultrasonic testing consists of pressuring up the system with nitrogen or compressed air and then using a high frequency sonic leak detection device to detect leaks. The sonic leak detector is used to detect leaks at welds, seams, joints, and any other areas of possible leakage. Sonic leak detectors with a detection frequency range of 20 kHz to 100 kHz have been used previously.

Advantages of ultrasonic testing:

- Simplicity.
- Little fatigue on the equipment.
- The test equipment is portable.
- High sensitivity relative to hydrostatic or pneumatic tests.

- Low cost.

Disadvantages of ultrasonic testing:

- Not as effective in finding leaks in large systems.
- Sensitive to environmental conditions, especially wind.
- Not considered by industry standard as "sensitive." For more information, see ASME B31.3 Process Piping.[1]

Before Startup

After testing, dry the equipment before returning to service. If the equipment is not dried, HCl can form and corrosion may occur. Section 9.3. Preparation of Service of the Guidelines provides information on drying.

6.11.4 Certification & Training Requirements for Non Destructive Testing (NDT) Inspectors

It is important to consider training and qualifications when selecting an inspector. Properly qualified inspectors can help in developing an inspection plan and in interpreting the results. The American Society for Nondestructive Testing (ASNT)[2] offers information on testing.. Local regulations may also define specific requirements.

The following inspection methods commonly require qualification and are addressed by the materials of the American Society for Nondestructive Testing:

Radiographic Testing w/ Film Interpretation (RT-FI)
Magnetic Particle Testing (MT)
Liquid or Dye Penetrant Testing (PT)
Eddy Current Testing (ET)
IRIS Testing (Magnetic MOC)
Remote Field Testing (Magnetic MOC)
Magnetic Flux Exclusion (MFE)
Visual Testing (VT)
Ultrasonic Testing – Thickness Measurements (UT-THK)
Ultrasonic Testing – Flaw Detection (UT-DET)
Ultrasonic Testing – Flaw Sizing (UT-SIZ)
Ultrasonic Testing – Weld Examining (UT-SW)

6.11.5 Recordkeeping

Maintaining accurate inspection records for vessels, piping, and equipment facilitates inspection and testing operations, and is often required by local regulations. These records can be used to determine future inspection intervals and repair methods. Information often kept in these records includes:

- Original design details of the equipment (*e.g.*, design code, fabrication drawings, materials of construction, capacity, chemical service, operating conditions)
- Procedures for safely and effectively performing external and internal inspections, including preferred inspection methods
- Results of previous inspections and corresponding repair recommendations
- Procedures and details of any vessel repairs or changes of chemical service

Local regulation may define record retention rules. Frequently, these records are retained for the life of the equipment or longer.

References

[1]American Society of Mechanical Engineers Code B31.3
https://www.asme.org/products/codes-standards/b313-2016-process-piping

[2]American Society for NonDestructive Testing
https://asnt.org/

[3]API 571 reference
https://protect-us.mimecast.com/s/qKzICo26kjswGBrt1pohw?domain=api.org