Mechanical Integrity Inspections for Ammonia Refrigeration Systems

Keys for Establishing Protocols at Food Industry Facilities

By Don Hendrickson, P.E., Randy Peterson, P.E., and Kerry Goforth, P.E.

Issued in 1992, the Occupational Safety and Health Administration (OSHA) Process Safety Management (PSM) regulation was designed to guide facilities in the safe management of processes that use highly hazardous chemicals.

One of the major impacts on the food industry is the regulation's application to ammonia refrigeration systems, which are widely used in food processing, storage and distribution facilities. The regulation applies to refrigeration systems that contain more than 10,000 pounds of ammonia. It requires owners to perform periodic mechanical integrity inspections on refrigeration systems to ensure the continued reliability of equipment and systems and minimize the risk of accidental release of ammonia.

PSM is a performance-based standard. As such, it does not prescribe specific methods to control hazardous chemicals. Rather, owners are required to meet performance requirements by implementing management programs within an overall PSM program. This approach requires owners to use inspection and testing procedures for mechanical integrity (MI) that are recognized and generally accepted good engineering practices.

The International Institute of Ammonia Refrigeration (IIAR) has published a series of mechanical integrity inspection documents oriented to ammonia refrigeration systems that describe why an MI program is required and what the components should be. Other industries that handle hazardous chemicals have created inspection guidelines for many of the same types of equipment used in ammonia refrigeration systems.

Organizations such as the American Petroleum Institute (API), American National Standards Institute (ANSI), American Society of Nondestructive Testing and American Society of Mechanical Engineers (ASME) have developed and issued codes, guidelines and recommended practices for determining acceptable testing methods and allowances for corrosion and deterioration of materials.

While many of these guidelines and recommended practices were not written for the ammonia refrigeration industry, the techniques and protocols can be used in establishing and maintaining an MI program.

Ammonia system equipment affected by the mechanical integrity provisions of PSM is shown in Table 1.

Inspection Guidelines

While the regulation does not contain specific inspection requirements, industry mechanical integrity guidelines include both periodic visual inspections of equipment and non-destructive testing. Visual inspections are usually conducted by trained plant maintenance personnel and are recommended on an annual basis.

Pressure Vessels	High-pressure receivers, low-pressure receivers, accumulators, intercoolers, thermosiphon pilot receivers, chillers, surge drums, transfer stations
Piping Systems	Refrigerant piping and valves, safety relief valves and vent systems
Emergency Systems	Fire protection system components, emergency shutdown systems, emergency ventilation, alarms and interlocks, ammonia detection systems
Equipment	Compressors, heat exchangers, evaporators, condensers, desuperheaters, pumps, refrigerant pumps, water pumps
Protective Systems	Insulation systems, vapor retarder, insulation media, jackets, protective coatings
Supports	Foundations, hangers, brackets, stands, anchor bolts, structural supports

Table 1: Ammonia system equipment affected by the mechanical integrity provisions of PSM.

Ultrasonic thickness testing (UT)	Uses ultrasound waves to penetrate material and detect surface or subsurface discontinuities. Also used to measure material thickness.
Radiographic testing (RT)	Uses electromagnetic rays (X-rays and gamma rays) to penetrate material and records on film discontinuities in the material. Used to find surface or subsurface discontinuities.
Magnetic particle testing (MT)	Uses electrical current to create a magnetic field in a specimen while magnetic particles indicate where the field is broken by a discontinuity.
Liquid penetrant testing (PT)	Uses a penetrating liquid to seep into a surface discontinuity and provides a visible indication.

Table 2: Non-destructive testing methods.

Non-destructive testing on ammonia systems may be employed to measure the thickness of pipe and vessel walls and predict useful life. This testing is typically done by third-party, certified firms with the training and equipment to ensure an accurate test.

Documentation of inspections or tests is critical to an owner's ability to identify at-risk equipment, schedule corrective action, maintain an equipment history, and keep a compliance log. Each history should include:

- Date of inspection or test
- Name of person performing the inspection or test
- Serial number or other equipment identifier
- Description of the inspection or test
- Results of the inspection or test

The effectiveness of an inspection and testing program is enhanced by careful selection of inspection points. Knowledge of the operation of refrigeration systems helps to identify the critical points on the system most susceptible to corrosion, expansion or contraction, physical damage, leakage, or exposure to weather or process elements. Based on the inspection results, a determination of deficient components can be made, as well as an estimate of remaining life once a corrosion rate has been established.

Non-destructive Testing (NDT). There are several acceptable testing methods available for the equipment components in a typical refrigeration system at a food plant: ultrasonic thickness testing; radiographic testing; magnetic particle testing; and liquid penetrant testing. Table 2 gives a summary of each of these methods. More advanced inspection methods are available if required.

These test procedures should be conducted and results interpreted by a qualified NDT technician in compliance with these standards:

- IIAR Bulletin 109 Guidelines for IIAR Minimum Safety Criteria for a Safety Ammonia Refrigeration System
- IIAR Bulletin 110 Guidelines for Start-up, Inspection and Maintenance of Ammonia Mechanical Refrigerating Systems
- ANSI/IIAR Standard 2 Equipment, Design, and Installation of Ammonia Mechanical Refrigerating Systems
- ANSI/ASME B31.3 Process Piping
- ANSI/ASME B31.5 Refrigeration Piping and Heat Transfer Components
- ANSI/NBIC-23 NBBI 2001 National Board Inspection Code

Pressure Vessels. Annual inspection of pressure vessels consists of visual inspection of the external surface of the vessel to determine soundness of the vessel and to ensure deficiencies are investigated and corrected. If the vessel insulation is materially damaged, the underlying area should be cleaned, inspected and treated before reinstatement of the protective finish, insulation and vapor barrier.

Vessels of unknown origin or those that have been subjected to major repairs without proper documentation should be replaced.

For uninsulated pressure vessels, surface corrosion that does not materially alter the thickness of the wall should be cleaned and repainted. Where pits or material loss have occurred, the thickness of remaining metal should be measured. On insulated vessels, where insulation is unsound or damaged, the insulation should be removed and the thickness of remaining metal should be measured.

Piping. Critical piping may include but is not limited to any piping that is exposed to freeze/

Kerry Goforth, P.E., is a project manager in the Food & Consumer Products group of Burns & McDonnell's Process & Industrial division. He has over 20 years of experience in the food processing industry. He received his bachelor's degree in agricultural engineering from New Mexico State University and his master's from Texas A&M University.

Vapor barrier	Consideration should be given to alternative test methods that do not require compromising the vapor barrier of an insulation system. Vapor barrier damage can allow infiltration of moisture to a system, which may result in corrosion problems.
Insulation	Wet or damaged insulation should be replaced.
Undocumented vessels	Vessels of unknown origin should be replaced.
Documentation program	A strong program of initiating, tracking and archiving inspection and corrective action results needs to be established.
Training	Training on inspection procedures should reinforce the importance of the inspections and safety.
NDT services	Contract with certified inspectors to perform non-destructive testing services.

Table 3: Lessons learned from implementing a mechanical integrity program.

thaw cycles, cold but above freezing, hot gas piping in cold rooms, defrost return lines or vessel fill lines. Each of these types of piping is exposed to condensation or temperature changes that result in expansion or contraction, making the piping more susceptible to fatigue and leakage.

Inspection and testing guidelines for uninsulated piping call for a visual inspection of all piping and associated components for damage or deterioration. Areas affected by slight corrosion should be cleaned and treated before reinstating the protective finish. Where pitting or material loss has occurred, thickness of the remaining metal should be measured.

For insulated piping, the external condition of piping insulation and supports should be visually inspected. Where insulation is unsound or damaged, the insulation should be removed and the thickness of the exposed piping should be measured.

Enhanced inspection includes removal of insulation and the thickness of metal measured at 100 ft. intervals and on each section of piping that can be exposed to moisture.

Air-cooled Finned Heat Exchangers and Evaporative Condensers. Inspection guidelines call for visual inspection of accessible refrigerant-containing tubes and headers. Where pits or material loss has occurred, the thickness of remaining metal should be measured.

Corrosion Rate/Remaining Life Determination. Corrosion rate of vessels and piping may be determined by one of several methods. Calculation from data collected on vessels in the same or similar service provides a reasonable baseline for life estimates. Vessel life may also be established by experience or published data. Finally, testing the wall thickness of materials after 1,000 hours of service and then using an accepted life calculation, as in API 570 for piping or API RP579 for pressure vessels, will provide a reasonable estimate of vessel integrity.

Best Practices for Mechanical Integrity Programs

Table 3 contains ideas and lessons learned from experience of drafting and implementing a mechanical integrity program.

Mechanical integrity programs are a required part of the OSHA PSM regulations. Ammonia refrigeration system owners must develop and implement MI programs to ensure the continued reliability of system components and prevent the accidental release of ammonia.

By using experienced refrigeration professionals and trained personnel, owners can identify potential risks and determine the appropriate level of inspection for each system. By using industry best practices, owners can ensure their MI programs are sufficient to document the reliability of their refrigeration systems.

Don Hendrickson, P.E., is a senior mechanical engineer in Burns & McDonnell's Process & Industrial division. He has 15 years of experience. He received his bachelor's degree in mechanical engineering from Kansas State University.

Randy Peterson, P.E., is a project manager in Burns & McDonnell's Food & Consumer Products group. He is an ammonia refrigeration specialist with 20 years of experience in the frozen foods industry. He received his bachelor's degree from Missouri Western State University.

For more information, please e-mail: dhendrickson@burnsmcd.com, rpeterson@burnsmcd.com or kgoforth@burnsmcd.com