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Guidelines for:

Start-up, Inspection and Maintenance of Ammonia Mechanical Refrigerating Systems

International Institute of Ammonia Refrigeration

NOTICE

The information contained in these guidelines has been obtained from sources believed to be reliable. However, it should not be assumed that all acceptable methods or procedures are contained in this document, or that additional measures may not be required under certain circumstances or conditions.

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Note that the various building codes and regulations referenced in this document may be amended from time to time and it should not be assumed that the versions referenced herein are the most current versions of such codes and regulations. Please consult the appropriate regulatory authorities for the most up to date versions.

FOREWORD

This Bulletin providing Guidelines for Start-up, Inspection, and Maintenance of Ammonia Mechanical Refrigerating Systems has been prepared according to the format of the American National Standards Institute (ANSI).

It is not intended that this bulletin specify where ammonia refrigerating systems are to be used.

The Standards Review Committee of IIAR has the responsibility of interpreting and reviewing the bulletin to keep abreast of advancements in the ammonia refrigeration industry. When applicable, the committee will publish revisions to the Bulletin.

March 2002, the IIAR Board of Directors, upon the recommendation of the Standards Review Committee, approved a revision to Bulletin 110, replacing section 6.6.3 as it was published in March 1993. In February 2004 another revision was approved revising section 6.4, Pressure Vessels and Heat Exchangers, in its entirety. In June 2007 section 6.6.3, Pressure Relief Devices, was revised again in its entirety.

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Guidelines for Start-Up, Inspection, and Maintenance of Ammonia Mechanical Refrigerating Systems

1.0 GENERAL

1.1 Scope

This bulletin provides basic requirements for the safe start-up, inspection and maintenance of ammonia refrigerating systems. The specific requirements for a particular system must be considered when applying the general recommendations expressed in this document to a particular system.

All maintenance should be performed in accordance with equipment manufacturer's instruction manuals. This bulletin focuses on maintenance which promotes safety.

1.2 Limitations

The words "shall" and "should" have been used throughout this bulletin as follows:

a. "shall": where "shall" or "shall not" is used for a specified requirement, that requirement is intended to be mandatory based on law, regulations, standards, or sound technical judgement.

b. "should": where "should" or "should not" is used for a specified requirement, that requirement is not intended to be mandatory but is recommended good practice.

This bulletin refers to those parts of a refrigerating system which are in contact with ammonia.

The safe start-up, inspection and maintenance of an ammonia refrigerating system is based on correctly designed, fabricated and installed equipment, interconnecting piping, wiring and controls.

Further information can be found in ANSI/IIAR 2-2008 (includes Addendum B), American National Standard for Equipment, Design, and Installation of Closed Circuit Ammonia Mechanical Refrigerating Systems (see 7.1), ANSI/ASHRAE 15-2010, Safety Standard for Refrigeration Systems (see 7.2), and IIAR Bulletin No. 109, *Minimum Safety Criteria for a Safe Ammonia Refrigeration System* (see 7.3).

2.0 DEFINITIONS

The words and meanings used in this bulletin are generally compatible with those defined and used in ANSI/IIAR 2-2008 (includes Addendum B) (see 7.1). Listed below are those words and phrases which are particularly relevant to this bulletin.

AIR COOLED CONDENSER A refrigerant condenser in which heat removal is accomplished entirely by heat absorption by the air flowing over condensing surfaces.

AIR COOLED DESUPERHEATER That part of the system designed to cool the ammonia refrigerant vapor after it is discharged from the compressor and before it enters the condenser. It is provided with a means of forcing air circulation over the external surface of the desuperheater coil for the heat removal necessary to cool the refrigerant vapor on the inside of the tubes.

AIR DUCT A tube or conduit used for conveying air. (The air passages of self-contained systems are not to be construed as air ducts.)

APPROVED Acceptable to the authorities having jurisdiction.

APPROVED NATIONALLY RECOGNIZED TESTING LABORATORY One acceptable to the authorities having jurisdiction, that provides uniform testing and examination procedures under established standards, is properly organized, equipped and qualified for testing, and has a follow-up inspection service of the current production of the listed products.

AUTOMATIC EXPANSION VALVE A controlling device which regulates the flow of volatile liquid refrigerant into an evaporator of a refrigeration system and which is actuated toward opening by evaporator pressure.

AUTOMATIC LIQUID REFRIGERANT DRAIN VALVE Refer to definition of HIGHSIDE FLOAT VALVE.

AUTHORIZED INSPECTION AGENCY (authorized inspection) An established and recognized agency or individual regularly engaged in conducting tests or furnishing inspection services, when such agency or individual has been approved by the jurisdiction involved.

BRINE Any liquid used for the transmission of heat without a change in its state.

CHECK VALVE A valve allowing flow in one direction only.

COMPANION OR BLOCK VALVES Pairs of mating stop valves, valving off sections of systems and arranged so that these sections may be joined before opening these valves or separated after closing them.

COMPRESSOR A specific machine, with or without accessories, for compressing refrigerant vapor. A BOOSTER COMPRESSOR is a compressor, with or without accessories, for compressing ammonia refrigerant vapor and discharging to the suction system of a higher stage compressor.

COMPRESSOR UNIT A condensing unit less the condenser and liquid receiver.

CONDENSER That part of the refrigerating system where refrigerant is liquified by the removal of heat.

CONDENSER COIL That part of a condenser constructed of pipe or tubing not enclosed in a pressure vessel.

CONDENSING UNIT A specific refrigeration machine combination consisting of one or more power-driven compressors, condensers, liquid receivers (when required), and the regularly furnished accessories.

CONTAINER A cylinder used for the transportation of ammonia refrigerant.

CONTRACTOR The organization or corporation that assumes contractual responsibility for installation, setting and tying together of the various components of the refrigerating system in its final operating form.

DESIGN PRESSURE The maximum allowable working pressure for which a specific part of a system is designed.

DOWNSTREAM PRESSURE REGULATOR A controlling device which regulates the flow of refrigerant gas or liquid or oil through the device from a section of the system to a lower pressure section of the system and which is actuated toward open by a pressure falling below regulator setpoint downstream of the regulator orifice.

ENGINEERING CODE AUTHORITY Any group or body recognized by the jurisdiction involved, and who has authority over the rules and regulations governing design, fabrication, testing and assembly of refrigeration and related equipment.

EVAPORATOR That part of the system designed to vaporize liquid refrigerant to produce refrigeration.

EVAPORATOR COIL That part of an evaporator constructed of pipe or tubing not enclosed in a pressure vessel.

EVAPORATIVE CONDENSER A condenser that obtains cooling effect by the evaporation of water in an air stream on the external surface of the tubes for the heat removal necessary to liquefy refrigerant vapor on the inside of the tubes.

EVAPORATOR PRESSURE REGULATOR A controlling device which regulates the flow of primarily gaseous refrigerant from an evaporator section and which is actuated toward open by a pressure above setpoint upstream of the valve.

EXIT A confined passageway adjacent to the door through which people leave a building.

FIELD TEST A test performed in the field to prove system tightness.

FORCED FEED OIL LUBRICATION Where oil is positively provided for purposes of lubrication by means of an internal or external mechanical oil pump. This does not include splash type or drip type compressor lubrication systems.

FLOW REGULATOR A controlling device which regulates the flow of liquid refrigerant through the device from a section of the system to a lower pressure section of the system and which is actuated by flow rate changes to maintain a predetermined flow rate.

GAUGE PRESSURE The part of the pressure differing from the atmospheric pressure which is generally assumed to be 1.013 Bar absolute (14.7 psig) at sea level.

HEADER A pipe or tube component of a refrigerating system to which are connected several other pipes or tubes.

HIGH SIDE Those parts of a refrigerating system subjected to approximately condenser pressure.

HIGH SIDE FLOAT VALVE A controlling device which regulates the flow of volatile liquid refrigerant from a higher pressure section of the system into a lower pressure section and which is actuated toward open by a rising liquid level upstream of the valve.

HOT GAS BYPASS REGULATOR A controlling device which regulates the flow of refrigerant hot gas through the device from a higher pressure section of the system to a lower pressure section of the system and which is actuated toward open by a pressure falling below regulator setpoint downstream of the regulator orifice.

INTERNAL GROSS VOLUME The volume as determined from internal dimensions of the container with no allowance for the internal parts.

LEAK TEST PRESSURE The pressure which is applied to test a system or any part of it for pressure tightness.

LISTED Equipment that has been tested and is identified as acceptable by an approved nationally recognized testing laboratory.

LIQUID RECEIVER A vessel permanently connected to a refrigerating system by inlet and outlet pipes for storage of liquid refrigerant.

LOW SIDE The parts of a refrigerating system subjected to approximately evaporator pressure.

LOW SIDE FLOAT VALVE A controlling device which regulates the flow of volatile liquid refrigerant into an evaporator pressure section of the system from a higher pressure section and which is actuated toward closed by a rising liquid level downstream of the valve.

MACHINERY The refrigerating equipment forming a part of the refrigerating system, including but not limited to any or all of the following: compressor, condenser, liquid receiver, evaporator and connecting piping.

MACHINERY ROOM A space that is designed to safely house compressors and pressure vessels.

MANUFACTURER The company or organization which evidences its responsibility by affixing its name, trademark or trade name to the refrigerating equipment.

MECHANICAL INTEGRITY A system is considered to possess mechanical integrity when it can exist under all likely conditions without hazard.

MECHANICAL JOINT A gas-tight joint, obtained by the joining of metal parts through a positive holding mechanical construction.

MECHANICAL REFRIGERATING SYSTEM A refrigerating system using mechanical compression to remove the refrigerant from the low pressure side and to deliver it to the high pressure side of the system.

MOTORIZED VALVE A valve operated by an electric motor.

NONPOSITIVE DISPLACEMENT COMPRESSOR A compressor in which increase in vapor pressure is attained by means other than changing the internal volume of the compression chamber.

OIL DRAIN FLOAT VALVE Refer to definition of HIGHSIDE FLOAT VALVE, except controlling oil.

PILOT OPERATIVE VALVE A valve which regulates flow in response to a signal from a pilot.

PIPING The pipe or tube mains for interconnecting the various parts of a refrigerating system. Piping includes pipe, flanges, bolting, gaskets, valves, fittings, the pressure containing parts of other components such as expansion joints, strainers and devices which serve such purposes as mixing, separating, snubbing, distributing, metering or controlling flow, pipe supporting fixtures and structural attachments.

POSITIVE DISPLACEMENT COMPRESSOR A compressor in which increase in pressure is attained by changing the internal volume of the compression chamber.

PRESSURE-IMPOSING ELEMENT Any device or portion of the equipment used to increase the refrigerant pressure.

PRESSURE-LIMITING DEVICE A pressure responsive mechanism designed to automatically stop the operation of the pressure-imposing element at a predetermined pressure.

PRESSURE-RELIEF DEVICE A pressure actuated valve or rupture member designed to automatically relieve excessive pressure.

PRESSURE-RELIEF VALVE A pressure actuated valve held closed by a spring or other means and designed to automatically relieve pressure in excess of its setting; also called a safety valve.

PRESSURE VESSEL Any refrigerant containing receptacle in a refrigerating system. This does not include evaporators where each separate section does not exceed 0.5 ft^3 (0.014 m^3) of refrigerant-containing volume, evaporator coils, compressors, condenser coils, controls, headers, pumps and piping.

PROPERTY INSURANCE UNDERWRITER An insurance company licensed to write insurance for the property in question in the jurisdiction concerned.

REFRIGERANT A substance used to produce refrigeration by its expansion or vaporization.

REFRIGERATING SYSTEM A combination of interconnected refrigerant-containing parts constituting one closed refrigerant circuit in which a refrigerant is circulated for the purpose of extracting heat.

REFRIGERANT PRESSURE ACTIVATED CONDENSER WATER REGULATOR A device which regulates the flow of cooling water through a condenser and which is actuated toward open by refrigerant high side pressure rising above the regulator setpoint.

REFRIGERANT PUMP A mechanical device for moving liquid ammonia refrigerant within a closed circuit mechanical refrigerating system.

RUPTURE MEMBER A device that will rupture at a pre-determined pressure differential.

SATURATION PRESSURE The pressure at which vapor and liquid can exist in equilibrium at a given temperature.

SELF-CONTAINED SYSTEM A complete factory-tested system that is shipped in one or more sections and has no refrigerant-containing parts that are joined in the field by other than companion or block valves.

SHELL AND TUBE CONDENSER A refrigerant condenser with tubes secured into a tube sheet at one end or both ends of an enclosing shell.

SHELL AND TUBE EVAPORATOR A type of evaporator where tubes are enclosed in a shell. Refrigerant can be either in the shell or tubes.

SOLENOID VALVE A valve which is opened or closed by the magnetic action of an electrically energized coil. The opposite action is accomplished by gravity, pressure or spring action.

STOP VALVE A device used to shut off the flow of refrigerant.

STRENGTH TEST PRESSURE The pressure which is applied to test the strength of a refrigerating system or any part of it.

SUPPLIER The individual or organization from whom title for equipment or material passes to the purchaser.

TEST PRESSURE The pressure to which a piece of equipment or a system is subjected, according to pressure test or leak test procedures.

THERMOSTATIC EXPANSION VALVE A controlling device which regulates the flow of volatile refrigerant into an evaporator of a refrigerating system and which is actuated by changes in evaporator pressure and superheat of the refrigerant gas leaving the evaporator. The basic response is to superheat.

THREE-WAY TYPE STOP VALVE A manually operated valve with one inlet which alternately can stop flow to either of two outlets.

TRAINED START-UP TECHNICIAN An individual having adequate training and experience which qualifies that individual to start-up and operate a refrigerating installation with which he has become acquainted before actual start-up.

ULTIMATE STRENGTH The highest stress level which the component can tolerate without rupture.

UNPROTECTED TUBING Tubing which is not protected by enclosure or suitable location so that it is exposed to crushing, abrasion, puncture or similar mechanical damage under installed conditions.

UPSTREAM PRESSURE REGULATOR A controlling device which regulates the flow of refrigerant gas, or liquid or oil through the device from a section of the system to a lower pressure section of the system and which is actuated toward open by a pressure rising above regulator setpoint upstream of the regular orifice.

WELDED JOINT A gas-tight joint, obtained by the joining of metal parts in molten state.

3.0 AMMONIA CHARACTERISTICS AND HAZARDS

3.1 Ammonia

The term "anhydrous ammonia," as used in this bulletin, refers to the compound formed by a combination of two gaseous elements, nitrogen and hydrogen. Anhydrous ammonia may be in either gaseous or liquid form. It is not to be confused with aqua ammonia, which is a solution of ammonia gas in water. Whenever the term "ammonia" appears in this bulletin, it is understood to mean refrigerant grade anhydrous ammonia.

Experience has shown that ammonia is extremely hard to ignite and, under normal conditions, is a very stable compound. It takes temperatures of 840-930°F (449-499°C) to cause it to dissociate slightly at atmospheric pressure. The flammable limits at atmospheric pressure are 16% to 25% by volume of ammonia in air. An ammonia-air mixture at these concentrations in an iron flask does not ignite below 1204°F (651°C).

Ammonia is classified by the United States Department of Transportation and the United States Coast Guard as a non-flammable compressed gas for the purpose of transportation (see 7.4).

Because ammonia is self alarming, it serves as its own warning agent so that a person is not likely to voluntarily remain in concentrations which are hazardous. Ammonia gas is lighter than air and adequate ventilation is the best means of preventing its accumulation.

In the United States, a Permissible Exposure Limit (PEL) is specified by the Occupational Safety and Health Administration, U.S. Department of Labor for workplace exposure (see 7.5). However, this specification is subject to change. Therefore, those responsible for adherence to this and other such specifications here and elsewhere should consult OSHA periodically and be guided by them.

It is important that personnel understand the properties of this gas and that they be thoroughly trained in safe practices for its use and application. The physical properties and specifications of refrigerant grade ammonia are listed in Section 3.2 and Section 3.3.

3.2 Physical Properties of Ammonia:

	English	Common Metric	S.I.
Molecular symbol	NH_3	NH_3	NH_3
Molecular weight	17.032	17.032	17.032
Boiling point at one atmosphere*	-28°F	-33.3°C	239.85°K
Freezing point at one atmosphere*	-108°F	-77.6°C	195.55°K
Critical temperature	271.4°F	133°C	406.15°K
Critical pressure	1657 psig	166.2 kg/cm^2	11.41 MPa
Latent heat at -28°F (-33.3°C) and one atmosphere*	589.3 Btu/lb	332.4 cal/gm	13.92 MJ/kg
Relative density of vapor compared to dry air at 32°F (0°C) and one atmosphere*	0.5963	0.5963	0.5963
Vapor density at -28°F (-33.3°C) and one atmosphere*	0.05555 lb/ft^3	0.889 kg/m^3	0.889 kg/m^3
Specific gravity of liquid at -28°F (-33.3°C) compared to water at 39.2°F (4°C)	0.6821	0.6821	0.6821
Liquid density at -28°F (-33.3°C) and one atmosphere*	42.56 lb/ft^3	681.9 kg/m^3	681.9 kg/m^3
Specific volume of vapor at 32°F (0°C) and one atmosphere*	20.78 ft^3/lb	1.29 m^3/kg	1.29 m^3/kg
Flammable limits by volume in air at atmospheric pressure	16% to 25%	16% to 25%	16% to 25%
Ignition temperatures	1204°F	651°C	924.15°K
Specific heat, Gas, at 15°C, (59°F) and one atmosphere*			
at constant pressure, C_p	0.519 Btu/lb°F	0.519 cal/gm°C	2189 J/kg°K
at constant volume, C_v	0.3995 Btu/lb°F	.3995 cal/gm°C	1672 J/kg°K
*One atmosphere =	14.696 psig	1.033 kg/cm^2	101.4 kPa

3.3 Refrigerant Grade Ammonia Specifications:

3.3.1 This material shall be a clear colorless liquid or gas, free from visible impurities.

3.3.2 Refrigeration grade anhydrous ammonia shall contain 99.95 percent minimum pure ammonia for charging both new and old refrigerating systems and shall equal or exceed the minimum requirements of Federal Specification O-A-445B, Ammonia, Technical (see 7.6).

3.3.3 The use of a grade specifying less than 99.95 percent ammonia shall not be approved.

3.3.4 Purity requirements are:

Ammonia Content (determined by evaporative residue test)	99.95% Min.
Non-Basic Gas in Vapor Phase	25 ppm Max.
Non-Basic Gas in Liquid Phase	10 ppm Max.
Water	33 ppm Max.
Oil (as soluble in petroleum ether)	2 ppm Max.
Salt (calculated as NaCl)	None
Pyridine, Hydrogen Sulfide, Naphthalene	None

3.4 Characteristics and Hazards

Ammonia has several distinct characteristics which differentiate it significantly from other refrigerants. These characteristics must be thoroughly understood and respected by anyone charged with the responsibility of operating and maintaining an ammonia mechanical refrigerating system.

Ammonia readily dissolves in water, liberating heat and forming a strongly alkaline solution. With trace water, it attacks copper, zinc, tin, cadmium and most of their alloys and also many rubbers and plastics. Explosives or unstable compounds can be formed by its reactions with mercury, halogens, hypochlorites, oxides of nitrogen and some organic compounds.

Ammonia gas is toxic and long-term exposure in sufficient concentration can be damaging to human tissue or even lethal. Short-term exposure to concentrations of approximately 100 parts per million by volume (ppm) will cause moderate irritation and discomfort of the mucous membrane and the eyes, but with no lasting consequences. Exposure to concentrations above 1500 ppm will damage or destroy body tissue while exposure to 2500 ppm and above increases the risk of fatality. Liquid ammonia splashes on the skin can cause both chemical and frost burns.

It is essential that ammonia refrigerating system operating personnel be familiar with the proper handling of ammonia and its dangers. Reference to the following documents and publications is essential:

IIAR Bulletin R-1:	*A Guide to Good Practices for the Operation of an Ammonia Refrigeration System* (see 7.7),
IIAR Bulletin No. 105:	*Guidelines for: Application and Maintenance of Safety Pressure Relief Valves for Refrigerant Systems* (see 7.8),
IIAR Bulletin No.106:	*Guidelines for: Prevention, Preparation, Response and Cleanup of Ammonia Releases* (see 7.9),
IIAR Bulletin No. 109:	*Minimum Safety Criteria for a Safe Ammonia Refrigeration System* (see 7.3),
IIAR Bulletin No. 116:	*Guidelines for: Avoiding Component Failure in Industrial Refrigerating Systems Caused By Abnormal Pressure or Shock* (see 7.10),
IIAR Poster P-1:	*Ammonia Mechanical Refrigeration Systems — Safety Practices and First Aid* (see 7.11),
IIAR Ammonia Data Book	(see 7.12).

3.5 General Precautions

The boiling point of anhydrous ammonia at atmospheric pressure is -28°F (-33.3°C). During operation or when at rest all parts of a charged ammonia refrigerating system may be at a pressure above atmospheric. The system components such as compressors, piping and vessels are designed to contain the ammonia at pressure. In normal operation the integrity of the system shall be maintained at all times. No attempt to break piping joints or to remove valves or components shall be made without having first ensured that the relevant parts of the system have been relieved of pressure and purged completely of ammonia.

The refrigerating system contains ammonia in both liquid and gaseous states. It is possible under abnormal conditions for liquid refrigerant to enter the compressor, for example, by way of faulty controls or by overcharge of refrigerant to the system. A compressor is designed to compress refrigerant gas and not pump liquids; if excess liquid does enter a compressor damage can occur, with a possible release of ammonia. Liquid refrigerant is liable to damage all types of compressors.

Worn, poorly aligned and out of balance machinery can cause excessive vibration and premature failure of piping and components, again with possible release of ammonia.

Liquid ammonia has a high coefficient of thermal expansion. Care should be taken to ensure that liquid ammonia is not trapped in pipelines or fittings between shut-off devices. A rise in ambient temperature may be sufficient to expand trapped liquid, generate excess pressure and rupture components.

Welding and all sources of flame in contact with a refrigerating system constitute hazard. The probability exists of a flammable ammonia/oil/air mixture being present within parts being modified. The precautions to be taken when entering an ammonia refrigerating system are outlined in IIAR Bulletin No. 107 (see 7.13).

Because of the particularly pungent odor of ammonia, particular care must be taken when servicing systems to ensure that no inadvertent release of ammonia takes place in areas where process operators are working to avoid risk or undue alarm.

In the event that a release of 100 pounds or more of ammonia occurs in a 24-hour period, it is necessary to follow the procedures outlined in the Emergency Planning and Community Right-to-Know Act (EPCRA), Title III of the Superfund Amendments and Reauthorization Act (SARA). The National Emergency Response Center is to be notified immediately at 1-800-424-8802.

Corrosion can occur on the external surfaces of the steel piping and vessels used for ammonia refrigerating systems, reducing the strength of the containment and eventually producing leaks. Corrosion of unprotected steelwork can be rapid in wet or damp conditions; such conditions often occur on the low pressure side of the system when metal temperatures are below the dew point of the ambient atmosphere. Insulation where the vapor seal is defective or incomplete will not prevent condensation and may enhance corrosion; corrosion usually occurs relatively slowly on lines permanently below 32°F (0°C) but has been found to be particularly rapid on pipes such as hot gas defrost lines where dampness and heat are present together.

Internal metal surfaces of ammonia refrigerating systems characteristically have a protective oil coating by virtue of the compressor lubricating oil becoming entrained within the refrigerant flow. It is, therefore, rare to find internal corrosion in operating systems (see Appendix F). However, systems out of operation for long periods can corrode, particularly if open to atmosphere.

In systems deliberately designed to be oil free, internal corrosion may occur.

Where heat-transferring liquids such as calcium chloride or sodium chloride solutions are present, they may form an additional source of corrosion. Chemical treatments of such solutions are prescribed by the suppliers of the chemicals and should be adhered to rigorously.

4.0 RECORDS

The ammonia refrigerating system shall have been designed by, and installed under the supervision of, persons who by reason of knowledge, training and experience are competent for the tasks. Such persons typically include:

a. experienced refrigeration contractors, possibly in combination with an engineering code authority, authorized inspection agency or property insurance underwriter

b. in-house design/engineering staff of the user

c. consulting engineers, acting on behalf of the user

d. refrigeration equipment supplier

All essential records and documentation relevant to the system shall be obtained by the user and maintained by the user in a safe place and be readily available for examination so that the standards and details to which the system was designed are available to those concerned with inspection, maintenance and operation.

A system component inventory list should include: compressors, condensers, evaporators, pressure vessels, liquid ammonia pumps, pipework and fittings, ammonia machinery room ventilation system, and other control and safety devices.

For each system component included on the inventory list, the specifications and details of the following shall be included in the records:

a. description

b. name plate data (see Appendix B)

c. test and fabrication certificates, where applicable

d. pressure relief devices; type and set pressure; date of installation/replacement (if externally installed)

e. manufacturer's instruction manual

f. materials of construction

g. electrical classification

h. piping and instrumentation diagrams

i. relief system design and design basis

j. design codes and standards employed

k. safety systems including safety devices, interlocks, switches, and detectors

l. year of construction

In addition the following items from the inventory list require the additional records indicated:

a. pipework and fittings

   1) pressure test verification in accordance with Section 537.3 of the current edition of ANSI/ASME B31.5 (see 7.14)

   2) design pressure

b. ammonia machinery room ventilation systems

   1) ventilation air flow diagrams

c. control and safety devices

   1) ammonia vapor detection system

   2) calibration schedule

The inventory list shall contain a record of the maximum working pressure(s) applicable to all parts of the system.

The inventory list shall be kept up to date with reports covering at least the mandatory inspections and safety device checks called for in this Bulletin and IIAR Bulletin No. 109 (see 7.3), plus those of any government regulations for pressurized systems, together with the due date of the next inspection.

The inventory list may form part of a broader set of records for the refrigerating system, such as those covering a planned maintenance scheme.

The records shall contain a schematic refrigeration circuit or flow diagram for the refrigerating system. Controls and valves which are most likely to be of importance in an emergency shall be clearly identified on the diagram which shall be updated when changes are made to the system.

5.0 START-UP OF NEW INSTALLATIONS

5.1 General

A typical procedure to be followed during start-up is given below for guidance, but it is emphasized that the procedure may need to be varied to suit the machinery, location and duty of any individual refrigerating system.

5.2 Pre-Startup Safety Review

Prior to introduction of ammonia into the process, the following items shall be confirmed in accordance with OSHA regulations for Process Safety Management of Highly Hazardous Chemicals (see 7.15).

5.2.1 Process Hazard Analysis

The Owner shall confirm that a Process Hazard Analysis has been completed and that the recommendations have been resolved or implemented. The owner shall also confirm that the Process Hazard Analysis is available to the operators responsible for operating the process.

5.2.2 Operating Procedures

Confirm that the operating procedures are complete and address steps for each operating phase. Ensure that the operating procedures include operating limits, safety and health considerations, and safety systems and their functions.

The operating procedures shall be readily accessible to the employees who work in or maintain the process. The employer shall certify that the operating procedures are current and accurate. Safe work practices shall be implemented that control hazards such as lockout/tagout (see 7.16), confined space entry (see 7.17), hot work (see 7.18), opening of equipment or piping, and control of entrance into the facility.

5.2.3 Training

The Employer shall verify that training has been completed for the following items and personnel:

a. Employees involved in operating the process shall be trained in an overview of the process and the operating procedures. The training shall include safety and health hazards, emergency operations and safe work practices. The training shall be documented and it shall be verified that the employees understood the training.

b. Employees involved in maintaining the on-going integrity of the equipment shall be trained in an overview of the process and its hazards. The training shall include the procedures applicable to the employees' tasks.

c. Employees involved in the emergency plan or the emergency response shall be properly trained to fulfill their duties in this regard.

5.3 Initial Status and Safety Provisions

For the purposes of this Section, it is assumed that the installation has been correctly designed for the duty that it is to perform, that all piping, electrical equipment and insulation has been installed, all protection devices tested and set, that the system has been pressure tested and adequate connections for the start-up and test instruments have been provided.

The installing contractor shall have relevant drawings, including a refrigeration circuit or flow diagram and an electrical circuit diagram, available on site together with data relating to the designed performance and the normal working and limiting design conditions. The installing contractor should be provided with ready access to those responsible for the design of the refrigerating system and associated equipment.

Before the system is charged with ammonia, it shall be verified that the machinery room and any other spaces containing parts of the system and their access shall have been built in accordance with the requirements set out in this Bulletin. These spaces shall have been cleared of all portable equipment and obstructions which could impede access or escape in an emergency. Emergency lighting and ventilation fans shall be ready for operation. Required first aid and safety equipment shall be available. For further guidance on the requirements in relation to machinery rooms and safety equipment, see Appendix D. These requirements shall be met prior to charging with ammonia and continued compliance with them shall be confirmed as part of a maintenance routine during the life of the system.

In particular, the trained start-up technician shall ensure that eye and water wash facilities are available and the technician shall be in possession of a full facial respirator which will give protection against minor leaks. Protective clothing, respirators (gas masks) or compressed air breathing sets, and protective gloves, carefully and safely stored and free from improper interference shall be readily available in the vicinity of the installation but externally to the area of risk. During start-up, one compressed air breathing set should be available immediately outside the area where start-up is taking place, with an additional breathing set safely stored but available as above (these may form part of the permanent safety equipment at the installation as listed above or be brought in specifically for start-up).

Before any refrigerating system within the scope of this Bulletin is charged and brought into service, it should be confirmed that the local emergency authorities are aware that ammonia is used or is to be used at that location.

Notices shall be placed to ensure that all other personnel on the site are aware of the fact that the system is about to be charged with ammonia and that the area in which the machinery room and charging equipment is located will, therefore, become an area closed to unauthorized persons.

The trained start-up technician should have ready access to those responsible for the installation of the refrigerating system and associated equipment.

A visual inspection shall be carried out on all piping joints, electrical wiring and brackets for piping and cables to ensure, prior to commencement of start-up, that no incorrect connections, loose brackets, contacts between cables and potentially hot pipes, missing covers, guards, etc. have been overlooked.

Some components of the refrigerating system such as evaporators and evaporative condensers may be located remote or exterior to the machinery room. Care must be taken during charging and start-up to include this equipment and related piping in all inspections. Refer to the equipment checklist in Appendix C.

5.4 Electrical Equipment

Following visual inspection of electrical wiring and its supports, the control panel(s) should be inspected both internally and externally to ensure that all specified equipment has been correctly installed and that all fuses or circuit breakers fitted in the panel(s) are of the correct rating as indicated in the specification.

Before any electrical supply is connected to any part of the electrical control system, the trained start-up technician should witness an insulation test of all cables to ensure that no faults exist, or receive an appropriate test certificate.

All main drive motor, pump and auxiliary equipment fuses shall then be removed, allowing only the control circuit to be energized (where the main drive is other than by electric motor, appropriate alternative procedures should be adopted to ensure that it cannot be started).

With the control circuit operational, all circuits shall be tested individually to ensure they are in the correct state in all situations. All safety devices shall be manually operated to ensure they make or break the necessary circuits.

With main drive fuses still removed, the coupling or V-belts between the prime mover(s) and the compressor(s) shall be disconnected; the machinery should be rotated by hand to ensure that it revolves freely.

Fuses shall be fitted individually to auxiliary equipment drives and these tested for direction and operation. Estimates should be made of the expected current consumptions and motor overload settings confirmed or adjusted accordingly.

The main drive motor fuses shall be fitted and the motor rotated electrically and checked for direction. In certain cases, it will be necessary to bypass various electrical interlocks in order to test run the motor. If the direction of rotation is correct, the motor supply shall be securely isolated, then the drive reconnected, correctly aligned and covered with the appropriate guards.

When the above circuit tests are satisfactorily completed, all safety cutout settings shall be inspected to ensure that they have been set during installation to the values required in the specification.

Records should be kept of these tests, which shall be completed before the system is charged with ammonia.

5.5 Evacuation, Dehydration and Leak Checking

Upon completion of installation, the ammonia refrigerating system shall have been tested for leaks in accordance with Section 5.6 of ANSI/IIAR 2-2008 (includes Addendum B) (see 7.1). All parts of the system not factory tested shall have been exposed to leak test pressures equal to those minimum design pressures listed in Appendix A or actual high and low side design pressures, whichever are greater. All visible leaks shall have been repaired and defective material shall have been replaced.

Oxygen or any combustible gas or combustible mixture of gases shall not be used within the system for testing. Carbon dioxide or halocarbon refrigerants shall not be used as a testing gas in an ammonia system. Dry nitrogen or dry air shall be used to raise the pressure in the ammonia system to the proper level of the test.

After the piping has been pressure tested and proven tight and before insulation is applied, the entire system shall be evacuated with a vacuum pump to remove air and moisture. Pressure switches should be valved off or disconnected since some switches may not have vacuum protection. All manual valves except those open to atmosphere must be opened and all control valves, such as solenoids, should be jacked open or electrically energized (if normally closed). Air or motor operated valves must also be open. All seal volumes and other components requiring an oil charge for sealing should be charged with the specified oil and any rotating devices should be turned over by hand to assure distribution of this seal oil, etc. to the seal faces. Refer to the manufacturer's recommendations for any special considerations to be followed during pressure testing and/or evacuation.

All reasonable measures should be taken to drain or blow out any free standing water in the system. Evacuation should be performed with the ambient temperature at 55°F (13°C) or above.

Connect a suitably sized vacuum pump to appropriately located valves. Start the pump and evacuate until an absolute pressure of 10,000 microns is attained. Evacuation to this point should be rather rapid but if free water is present the process will be slowed as evaporation of the water takes place. Check low points, traps, etc. for cold spots indicating the presence of water and apply heat as needed to speed up the evaporation of water.

Continue evacuation to 5,000 microns and then break vacuum with dry nitrogen to slightly above atmospheric pressure. Repeat evacuation procedure until an absolute pressure of 1500 microns is reached. It may be necessary to change the vacuum oil frequently, depending on the amount of water in the system.

When an absolute pressure of 1500 microns has been reached, shut off vacuum pump and allow system to stand for 24 hours. Allow no more than 1000 microns rise in pressure over the 24 hour period, assuming a relatively constant ambient temperature.

At the completion of evacuation, break the vacuum with gaseous ammonia and introduce a sufficient amount to subject the system to 100 psi gauge (7.03 kg/cm^2 gauge) (689.5 kPa gauge) ammonia pressure. During this period, the system shall be carefully inspected for leaks using sulphur tapers or litmus paper. Approved ammonia masks shall be available during this test in case of emergency. If any leaks are found, they shall be repaired.

At the completion of evacuation and final leak check, return all automatic and electrically controlled valves to their normal operating positions. Any other controls or valves which were jacked open for the evacuation procedure shall also be returned to their normal operating state.

5.6 Charging Procedure

The trained start-up technician shall fit to the system pressure gauges and thermometers to be used during charging and startup. All such instrumentation shall be calibrated and tested for accuracy.

For some refrigerating installations, the ammonia is usually delivered in large cylinders and only one cylinder should be connected to the system at a time during charging.

Should it be necessary to use a number of cylinders together, they shall be so connected as to prevent backfilling.

The connection of the charging line to the system is normally to an appropriate valve supplied by the installer. If no such valve is fitted, the line should be connected to the low pressure side of the system at a point where it will not cause liquid refrigerant to enter the compressor.

The cylinder from which the charging is effected should be located in the open air in a position where it will not cause hazard to other personnel involved on the site. A notice should be posted stating that the cylinder is being used for charging.

Ammonia refrigerant delivered in bulk delivery trucks should be pumped into the receiver using the pumps mounted on the truck. A flexible charging line suitable for transferring liquid ammonia refrigerant from the bulk delivery truck to the receiver should be used. Particular care shall be taken that the trained operator who unloads the ammonia refrigerant stays close to the truck so in case of an emergency, the necessary valves can be closed.

Particular care shall be taken to avoid trapping liquid ammonia between isolating valves.

During this procedure the operation of the compressor shall be monitored because, until such time as an adequate level of ammonia is charged into the system, the compressor will be operating outside the normal working range of pressures and temperatures for which the system was designed. The system shall not be left unattended during charging.

The total weight of refrigerant charged into the system shall be recorded.

When the system has been sufficiently charged, the protection devices shall be tested.

5.7 Testing of Protection Devices

5.7.1 High Pressure Cutout

The high pressure cutout shall be tested first. The compressor discharge pressure shall be increased slowly until the trained start-up technician can confirm that the cutout operates at the required setting. If the high pressure exceeds that at which the cutout is intended to operate, the compressor shall be stopped immediately.

If any cutout fails to operate when tested, the fault(s) shall be traced and correct electrical and mechanical function confirmed before the refrigerating system is put back into operation.

Set cutout pressure to 90% of set pressure of any safety relief device that has a common pressure to the safety cutout.

5.7.2 Low Pressure Cutout

The low pressure cutout, if supplied, shall be tested by gradually reducing suction pressure by progressively closing a valve. It shall be confirmed that the cutout operates at the required pressure. If the suction pressure reaches the minimum recommended by the manufacturer and the cutout has not operated, either the compressor shall be stopped or the suction pressure increased by gradually opening the partially closed valve.

5.7.3 Oil Differential Pressure Cutout

Oil pressure cutouts sometimes have an associated delay, giving necessary time for minimum oil pressure to be obtained on start-up; this should be taken into consideration during test procedures. There are two main types:

a. electrical bimetal heater within cutout

b. separate electrical bypass by mechanical or electronic time delay

The timer should be tested by either (i) isolating the compressor main drive and simulating a start with the control circuitry, or (ii) isolating the oil pressure switch from the lubricating oil circuitry, if suitably valved, or (iii) if supplied, using a built-in test facility.

The oil switch pressure setting should be tested by an appropriate method, for example, by adjusting the lubricating system oil pressure down to a pressure just below the oil switch setting, but not below the manufacturer's recommended minimum oil pressure for the compressor. If the switch fails to operate, the oil pressure shall be restored or the compressor stopped.

5.7.4 High Temperature Cutouts

Over-temperature cutouts such as discharge vapor or oil temperature cutouts may be tested by increasing the temperature of the relevant part of the system; where necessary, they shall be tested, e.g., by immersion in a heated oil bath.

5.7.5 Other Protection Devices

All other compressor shutdown and alarm devices such as liquid level controls and low temperature cutouts shall be tested for operation and setting to manufacturer's recommendations.

5.7.6 Further Monitoring

When the above tests have been completed satisfactorily, the start-up may proceed with the adjustment of regulating and control valves to achieve correct function. Throughout the whole start-up procedure, there shall be frequent monitoring of pressures and temperatures in the system and vigilance for ammonia leakage. At any abnormal indication, the compressor shall be stopped immediately.

5.7.7 Demonstration Run

The system shall be run under the available heat load to demonstrate correct function. During the run, pressures and temperatures shall be recorded and all level controls shall be checked for satisfactory operation. Liquid levels in sight glasses should be established (for the heat load available) and recorded.

Start-up as defined here does not necessarily include a full performance demonstration; this might need to be specified separately, if required.

During a period when the compressor has been switched off, all solenoid and automatic shut-off valves shall be inspected to ensure that, where appropriate, these are holding satisfactorily and not allowing migration of refrigerant to parts of the system at a lower pressure.

During the demonstration test run, the trained start-up technician should involve the persons that will be responsible for the day-to-day running of the system. The installation should be handed over after safety and function have been demonstrated and there has been a period of continuous and fault free running.

The operating staff should continue to log pressures, temperatures and levels, and inspect the system for leaks, oil consumption and other abnormalities at frequent intervals. This should not be confined to the machinery room but should also include the whole refrigerating system.

The manufacturer's instructions on oil and filter changes during start-up and the first weeks of operation shall be observed.

5.7.8 Purging

A non-condensible gas separator (purge unit) may be useful in all ammonia refrigerating plants. Non-condensibles can enter a system through inadequate evacuation of air from system after system test, valve stem packing, piping repairs, piping leaks, especially with suction levels below atmospheric pressure, and the normal breakdown of ammonia gas.

These non-condensible gases will collect on the high side of the system, usually the top of the receiver; an increase in the normal discharge pressure will result.

In an emergency, the system can be shut down and non-condensibles purged from the top of highside vessels and evaporative condenser coils. Bleed this gas slowly into an open container of water.

When a permanent purge unit is installed on a system, follow the manufacturer's recommended installation and operating instructions carefully. Refer to page 4.7, Chapter 4, ASHRAE 1990 Refrigeration Handbook for additional information (see 7.19).

5.7.9 Hand Over of Information

The trained start-up technician and installing contractor shall hand over to the user any information relevant to the design, maintenance, working pressure and safety aspects of the system provided by the manufacturer or supplier of the equipment in accordance with OSHA, U.S. Department of Labor, General Requirement for Machines, 29 CFR 1910.212 and Mechanical Power Transmission Apparatus, 29 CFR 1910.219 (see 7.20).

This may include:

a. a manual containing operating instructions, recommended spare parts list, etc.

b. a refrigerating system drawing

c. a starting and stopping procedure, including emergency stop instructions

d. stopping procedure for prolonged shut-down

e. details of safety procedures to be used in the event of an emergency

f. recommended list of oils and lubricants to be used and recommended frequency of change

In addition, the trained start-up technician shall hand over data which has been compiled during the start-up. This shall include a complete log taken during the test period to ensure that a standard of operation is available at all times for the operating staff.

The user of the system has a duty to arrange instruction for his staff so that the system can be operated and maintained in safety. The trained start-up technician or other representative of the installer can assist in providing appropriate information or instruction by agreement with the purchaser.

6.0 INSPECTION AND MAINTENANCE

6.1 General

This section contains recommendations on the type and frequency of inspection and maintenance required to ensure the safety of refrigerating systems. Subsections 6.3 to 6.7 cover the major groups of equipment likely to be incorporated in systems and within those subsections are details of routine inspection (and maintenance where applicable) to be carried out with the system in normal use and more detailed inspection and maintenance to be undertaken periodically. Hazards particular to the equipment and requirements in relation to protection devices are also included in the appropriate subsection.

A supplier's instruction manual covering the refrigerating system and its components shall be available for consultation, together with the records referred to in Section 4.

For any particular refrigerating system, the inspection and maintenance program shall account for specific recommendations for the equipment comprising that system, found in the supplier's instruction manual and relevant supplementary information. The type and frequency of inspection and maintenance will also depend on the effectiveness of previous maintenance, the age of the system, the environment in which the system is located and the duty of the system.

Particular attention shall be paid to systems in the period immediately following installation and after any prolonged period of non-operation.

The provision of the necessary first aid and safety equipment as detailed in Appendix D shall be ensured before service and maintenance work is carried out. Appropriate protective clothing shall be worn by all personnel working on ammonia systems where opening of the system for maintenance, charging or purging is involved. An approved respirator (see 7.21) suitable for use with ammonia shall be immediately available (see Appendix D).

6.2 System Log

A regular log is important in establishing normal operating conditions for a system over varying duties and ambient temperatures. Inspection of a log allows departures from normal to be identified and the cause determined and corrected.

Preferably every four hours, but at least daily, the system should be observed in normal operation and a full log taken of operating conditions. These should be compared with seasonal design operating conditions and with the safe limits of operation. If any significant departure from expected condition or performance is found, the cause shall be established and corrective measures taken.

Recognizing that a refrigerating system is designed to be a sealed system, the log should include a record of any quantities of oil or ammonia added to or purged from the system and any purging of non-condensible gases.

Typical contents of a system log are included in Appendix I.

Systems designed for unmanned operation under automatic control may include automatic logging and fault annunciation; the recorded data shall be scrutinized and the correct operation of the equipment verified at appropriate intervals.

6.3 Compressors

6.3.1 Operational Inspection

This inspection is at the same interval as, and may conveniently be combined with, taking the system log as in 6.2.

With the system in normal operation, the refrigerant suction and discharge pressures and temperatures, the interstage pressure and temperature (where applicable) and the oil pressure should be compared with the permissible and normal operating conditions. Oil level should be observed and oil added (or removed) if required; it is potentially dangerous to have an oil level either above or below the level recommended by the supplier.

The type of oil available shall be of a suitable grade.

Where oil separators are installed, it should be verified that oil does return and is supplied to each compressor in suitable quantities. The log should be examined to ensure that the rate of oil added to compressors is not excessive and is matched by oil drained from the system after sufficient time has elapsed for stable conditions to be established.

The compressor and associated piping and equipment shall be examined for abnormal vibration. Excessive vibration can cause piping to fail and can also cause failure of the internal moving parts of the compressor, with dangerous consequences. For example, the cause of any excessive vibration, drive misalignment or failure of supports or foundations shall be identified and the fault(s) corrected. Any pipes which have been subjected to excessive vibration should be tested for crack formation.

Rotating equipment, particularly compressors, should be monitored separately for vibration at start-up. A vibration reference level, within satisfactory levels established by the equipment manufacturer, should be recorded. These levels establish the reference point upon which future measurements will be based.

6.3.2 Major Inspection and Maintenance

At least every three months, the compressor motive power shall be securely isolated and the mechanical condition of the drive shall be inspected. Where a belt drive is fitted, the condition of the belts shall be examined and tension checked to ensure correct setting with no overtightening. All drive guards shall be inspected to ensure adequate protection is given and that nothing is bearing on the shafts or belts. The edge of a displaced belt or coupling guard can cause sufficient wear on a shaft cover over a period of time to produce a significant stress concentration.

At least annually, in addition to the above, the drive alignment and the condition and tightness of the foundation bolts shall be checked. Where applicable, the drive shaft end float shall be checked.

The interval between compressor inspections and maintenance involving opening up of the compressor is usually on the basis of hours run, and the manufacturer's instructions should be consulted.

Before any inspection or overhaul involving dismantling of a compressor is undertaken, the compressor shall be isolated from the ammonia circuit, the ammonia evacuated and the compressor motive power securely isolated to prevent the compressor being started.

Fracture of compressor casings is most likely to occur as a result of gross internal failure while running. Possible initial causes of such failure in reciprocating machines are compressor valve failure, loss of lubricating oil pressure, connecting rod bearing failure or wrist pin failure leading to fractured connecting rods or connecting rod bolts. The manufacturer's recommendations shall be followed concerning frequency and method of inspection and renewal of such components. Special attention shall be paid to connecting rods and connecting rod bolts of two stage machines which might be subjected to excess tension if the compressor has run at high intermediate pressure.

Components which might suffer fatigue should be replaced when they have reached the manufacturer's recommended life.

Another cause of fracture is weakening of the casing by corrosion. This is most likely to occur in water jackets which shall be examined with this in mind; they shall also be examined for fouling by deposits from the cooling water and any necessary corrective action shall be taken.

6.3.3 Protection Devices

All cutouts and protection devices, including HP cutouts, oil pressure differential switches and, where fitted, LP and IP (interstage pressure) cutouts, discharge and oil temperature cutouts, shall be tested at yearly intervals. Procedures for testing are given in Section 5.7.

Some pressure relief devices cannot be satisfactorily tested in place. Replacement intervals are given in 6.6.3.

6.4 Pressure Vessels and Heat Exchangers

6.4.1 General

This subsection covers routine maintenance and inspection of pressure vessels and heat exchangers. For the purpose of description in this Section 6.4:
- "pressure vessels" include pressure vessels with or without internal coils
- "heat exchangers" include shell-and-tube heat exchangers, evaporative condensers and air-cooled finned heat exchangers, hereinafter collectively termed

The frequency and type of checking, monitoring and inspection will vary with the particular conditions affecting the specific application and refrigerating system concerned. For the purpose of description in this Section 6.4:
- "regularly checking" is observation as a function of the refrigerating system and operator's routine activities
- "monitoring" is observation as a function of the operator's routine activities which includes recording the specifically observed condition, status or operating parameter in the daily log
- "inspection" is a task-specific observation leading to an evaluation and written record of the findings

It is recommended that particular attention be given to systems in the period immediately following major alterations, major service or breakdown work, change of refrigerant, or start-up following any prolonged period of non-operation.

The frequency and type of inspection of pressure vessels and heat exchangers will vary with the application and location of individual systems. More-frequent inspections may be appropriate for the following cases:

- Re-commissioning of a refrigerating system
- Significant alteration of refrigerating system components
- Corrosive or adverse environmental conditions
- Information derived from current service conditions on the system or on similar systems
- Possible adverse effects of cyclic loading

Major repair or alterations to a pressure vessel or shell-and-tube heat exchanger are required to be undertaken in compliance with the National Board Inspection Code (NBIC) (see 7.27) and the resulting compliance documents should be filed in the maintenance records.

6.4.2 Routine Operational Maintenance

The system should be checked regularly for the presence of non-condensable gases which should be purged as necessary from the receiver(s) and/or condenser(s), preferably into a non-condensable gas remover or purger but alternatively into water. Where an automatic purger is fitted, its correct operation should be monitored. If there is a large accumulation of non-condensable gases the reason should be investigated and the cause should be corrected.

At regular intervals indicated by the rate of oil addition to the compressor(s), accumulated oil should be drained from oil collection points, preferably into a regenerator to remove refrigerant. The procedures outlined in IIAR Poster No. P5: IIAR Recommended Oil Draining Guideline should be followed (see 7.26).

Heat-transferring liquids (example: brine, water) should be checked at regular intervals for concentration, pH and contamination, and treated as necessary.

The presence of contamination due to water ingress should be checked at regular intervals where this risk can occur. The procedures outlined in IIAR Bulletin No. 108 for water content testing should be followed (see 7.22).

6.4.2.1 Pressure Vessels and Shell-and-Tube Heat Exchangers

While the system is operational, the external appearance of the surface of pressure vessels or shell-and-tube heat exchangers, or of the insulation applied to such pressure vessels or shell-and-tube heat exchangers, should be regularly checked by the system operating staff for deterioration. Any deterioration found should be recorded in the system log, and repair(s) should be arranged.

Liquid level gauges should be regularly checked for oil build-up and the oil drained as necessary.

6.4.2.2 Air-cooled Finned Heat Exchangers

Cooling coils and defrost water drains on air-cooled finned heat exchangers should be regularly checked for frost build-up and defrosted as necessary. Settings and operation of automatic defrost controls should be adjusted as necessary.

Air-cooled finned heat exchangers should be regularly checked for:

- Buildup of dirt or other contamination on tubes, fins, drive components and fans
- Fin damage
- Coupling wear on direct-driven fans
- Belt tension on belt-driven fans

Cleaning and/or adjustment and/or repairs should be undertaken as necessary.

Lubricate fan motor and shaft bearings according to manufacturer's instructions. Correct direction of air flow and fan rotation should be verified after every disconnection from the power supply. All guards should be correctly installed.

6.4.2.3 Evaporative Condensers

Evaporative condensers should be regularly checked for:
- Water operating level
- Correct operation of pan strainer and bleed valve
- Buildup of dirt or other contamination in the pan
- Correct operation of water distribution system and drift eliminators
- Buildup of dirt or other contamination on the drive components or fans
- Coupling wear on direct-driven fans
- Belt tension on belt-driven fans

Cleaning and/or adjustment and/or repair should be undertaken as necessary.

Lubricate pump motor and fan motor and shaft bearings according to manufacturer's instructions. Correct direction of air flow and fan rotation should be verified after every disconnection from the power supply. All guards should be correctly installed.

6.4.3 Annual Inspection

The external surface or the insulation and associated vapor barrier applied to the external surface of vessels and heat exchangers should be inspected no less than once every 12 months.

A system that has not been in use for three months or more should be given an annual inspection before bringing it into service.

The purpose of the inspection should be to discover whether the overall condition of the pressure vessels and heat exchangers, following a period of service under operational conditions, is sound and to ensure that any deficiencies are thoroughly investigated and corrected. The results of each inspection should be recorded and any corrective action noted.

6.4.3.1 Pressure Vessels and Shell-and-Tube Heat Exchangers

Where visual inspection shows the vapor barrier seal on the thermal insulation to be intact, no further inspection action is necessary and this should be recorded on the annual inspection record.

Where a section of insulation is materially damaged, it should be repaired or replaced. Underlying areas affected by surface corrosion should be cleaned off, inspected, and appropriately treated before reinstatement of the protective finish, insulation and vapor barrier.

Where the annual inspection reveals that external corrosion has formed pits or caused material loss that reduces the thickness of the vessel or shell-and-tube heat exchanger, then that pressure vessel or shell-and-tube heat exchanger should be dealt with in accordance with Section 6.4.4: Independent Inspection.

When accessible, the process side of tube bundles in shell-and-tube heat exchangers should be inspected and cleaned if necessary. Exception: shell-and-tube thermosiphon compressor oil coolers and shell-and-tube heat exchangers on secondary refrigerant applications which are either sealed or where the secondary refrigerant quality has been monitored and maintained.

The inspection frequency for pressure vessels or shell-and-tube heat exchangers operated intermittently may require modification due to:

- External corrosion
- Internal corrosion if opened to the atmosphere
- Fouling of the water or process side of the heat exchange surfaces

6.4.3.2 Air-cooled Finned Heat Exchangers and Evaporative Condensers

The annual inspection of air-cooled finned heat exchangers and evaporative condensers is limited to the visibly accessible refrigerant-containing tubes and headers.

Heavy pitting or loss of metal should be recorded in the system log and arrangements made for non-destructive testing, using an appropriate testing technique, example: ultrasonic measurements.

6.4.4 Independent Inspection

6.4.4.1 General

Pressure vessels and shell-and-tube heat exchangers should be given an independent inspection at least once every five years except where the authority having jurisdiction requires less than the five-year interval. This inspection should be carried out by a person who has the training and knowledge for this task, for example:

- An employee of the owner, competent to perform inspections and who is independent of the daily operating responsibilities for that installation
- An independent organization or individual competent to perform inspections
- An inspector from the insurance company who is licensed to write pressure vessel insurance
- A licensed inspector from the jurisdiction where the pressure vessel or shell-and-tube heat exchanger is located.

This independent person should carry out such examinations and tests required to determine if the equipment is safe and recommend any necessary action. Attention should be paid to possible deterioration of areas around supports and the attachments.

Inspections of shell-and-tube heat exchangers should include the process side of tubes and tube sheets, when they are accessible. Exceptions:

- Shell-and-tube thermosiphon compressor oil coolers
- Shell-and-tube heat exchangers on secondary refrigerant applications which are either sealed or where the secondary refrigerant quality has been monitored and maintained.

Pressure vessels and shell-and-tube heat exchangers of unknown origin should be replaced. If a pressure vessel or shell-and-tube heat exchangers has been subjected to major repairs or alterations without proper documentation as required by the authority having jurisdiction, it should be replaced.

6.4.4.2 Uninsulated Pressure Vessels and Shell-and-Tube Heat Exchangers

Uninsulated pressure vessels and shell-and-tube heat exchangers should be given a thorough external visual examination.

Where there is no indication that the mechanical integrity of the pressure vessel or shell-and-tube heat exchanger has materially deteriorated since installation or the last independent full inspection and where the maximum allowable working pressure for the pressure vessel or shell-and-tube heat exchanger is clearly recorded together with evidence of an earlier strength pressure test (example: at time of manufacture), no further action is required.

Where surface corrosion that does not materially alter the thickness of the pressure-containing wall is found, the pressure vessel or shell-and-tube heat exchanger should be cleaned and repainted to limit further deterioration.

Where external corrosion has formed pits or caused material loss that reduces the thickness of the pressure vessel or shell-and-tube heat exchanger, the inspecting person should measure or cause to be measured the thickness of the remaining metal to determine whether the replacement is necessary. In arriving at such a decision, the design records associated with the pressure vessel or shell-and-tube heat exchanger, the design codes that were in effect at the time of manufacture, the calculated minimum wall thickness, and the NBIC rules or other appropriate guidance for evaluating corrosion should be considered.

Actual metal thickness should be determined using an appropriate non-destructive testing technique, example: ultrasonic measurements. If the pressure vessel or shell-and-tube heat exchanger is accepted as suitable for further use, reports from all non-destructive testing should be filed in the maintenance records.

6.4.4.3 Insulated Pressure Vessels and Shell-and-Tube Heat Exchangers

Special considerations arise in connection with insulated pressure vessels and shell-and-tube heat exchangers because inspection without removal of insulation is usually not practical and partial removal and replacement of insulation can often impair the vapor barrier and therefore resistance to corrosion.

Experience has shown that the surface of insulated pressure vessels and shell-and-tube heat exchangers with sound insulation and vapor barrier seal that operate continuously at temperatures below 32°F (0°C) show no degradation. For such a pressure vessel or shell-and-tube heat exchanger for which annual inspection records are available and where visual inspection shows the vapor barrier seal to be intact, no further inspection action is necessary and this should be recorded on the inspection record.

Particular attention should be given to insulation and vapor barrier integrity on insulated pressure vessels and shell-and-tube heat exchangers operating above 32° F (0°C) but below the dew point. All wet insulation should be removed and the affected surface of the pressure vessel or shell-and-tube heat exchanger examined. The pressure vessel surface should be appropriately treated with rust preventative coating before being re-insulated. No attempt should be made to apply a protective coating or re-insulate while the pressure vessel or shell-and-tube heat exchanger surface or adjacent sound insulation is wet or frosted.

At any major repair or renewal of the insulation, the opportunity should be taken to examine the pressure vessel or shell-and-tube heat exchanger surface for external corrosion.

Where insulation is unsound or damaged, the insulation should be removed and the underlying pressure vessel or shell-and-tube heat exchanger inspected in accordance with Section 6.4.4.2.

6.5 Ammonia Pumps

6.5.1 General

Both positive displacement and centrifugal pumps are commonly used. General guidance on inspection and overhaul to ensure safety is given below but where available the manufacturer's specific recommendations should be followed.

6.5.2 Operational Inspection

Access to the pump and its adjacent valves shall be ensured, for example, by alternating duty and standby pumps or by stopping the pump as necessary to prevent excessive ice buildup. Avoid rapid temperature change induced by the application of external heat sources.

Pumps should be isolated, vented and defrosted at least monthly. The exterior and adjacent lines should be examined for possible damage and corrosion. Do not run positive displacement pumps while the refrigerant shut-off valves are closed.

System design and maintenance should prevent large quantities of oil from reaching the pump as neither the pump nor the safety valve may have been selected to pass oil in large quantities.

6.5.3 Inspection and Overhaul

During start-up, and again after any disconnection of the power supply to a pump or to the system as a whole, the correct direction of rotation of the pump shall be verified.

At yearly intervals, or as may be recommended by the manufacturer(s), open and examine positive displacement pumps for any wear or damage, for example at the bearings, which could affect operation or the alignment of the rotary drum relative to the outer case. Any parts outside the manufacturer's tolerances shall be changed. End covers of centrifugal pumps shall be removed and impellers and bearings inspected; any parts which are damaged or outside the manufacturer's tolerances shall be changed.

6.5.4 Protection Devices

Pressure relief valves shall be replaced with a recalibrated valve or cartridge at intervals not exceeding five years.

6.6 Valves and Sensing Devices

6.6.1 Shut-off Valves

Visual inspection of shut-off valves associated with machinery such as compressors and vessels should be included in the operational inspection of such machinery (see 6.3.1, 6.4.2.1, 6.4.2.2 and 6.5.2). Any fault such as accidental damage or icing which could prevent the operation of a shut-off valve when required should be corrected promptly.

Every six months, for valves with exposed stems, the condition of the stem and of the gland seal should be inspected and the stem cleaned and regreased. Valves which are normally open should be moved off the back-seated (fully open) position to subject the gland seal to refrigerant pressure. Seals should be inspected for leakage which, if found, should be corrected. Take particular care in inspecting and operating valves not in regular use; if seals are defective leakage can be sudden and violent.

Externally inspect valves annually; this can be done conveniently as part of the regular inspection of piping (see 6.7). Where valve spindles are without handwheel and capped, the valve cap shall be removed and condition of stem and gland seal checked as in the preceding paragraph. The gasket shall be in place and any pressure relieving vents clear before the cap is replaced. Handwheels, and flange securing bolts and valve cover (bonnet) bolts where fitted and uninsulated, shall be inspected and defects due to damage or corrosion shall be corrected. Bodies and bolts of insulated valves should be inspected as part of the associated piping (see 6.7.2).

Seals should be replaced at intervals as recommended by the valve manufacturer.

Test all shut-off valves for function every five years. Seatings or seals of all shut-off valves essential for the safe operation and maintenance of the system shall, if found faulty, be overhauled as necessary to restore full function or be replaced.

6.6.2 Control Valves

Most automatic control valves have no external moving parts requiring maintenance; they shall be dismantled and overhauled when recommended by their manufacturer(s), or when found faulty in service or when tested.

Valves which are automatically controlled should be tested annually for correct function; this is often done by changing the setting of the controlling device and observing the response. Care should be taken to avoid producing conditions which could cause damage to other parts of the system such as freezing of a liquid. Any changed settings shall be corrected at the end of the test. Filters are installed ahead of many control valves and should be inspected and cleaned.

Take precautions to avoid hazard from pressure or residual ammonia when filters are opened or control valves dismantled. Liquid refrigerant may be trapped in assemblies which have become choked with dirt. Fastenings of covers shall only be loosened and not removed completely before unseating the seal or gasket to ensure that gas or liquid is not released in an uncontrolled manner.

Leaking floats from defective float valves may contain a substantial quantity of liquid ammonia; there is a risk of bursting as temperature rises. Any floats found to contain liquid shall promptly be put in a safe place, for example by returning the float to its housing and continuing to vent the latter.

6.6.3 Pressure Relief Devices

Pressure-relief devices are generally one of two types: rupture discs or spring-loaded valves. Rupture discs are membranes that open at a set pressure and cannot reseal. Once ruptured, these devices must be replaced.

Spring-loaded relief valves open to relieve pressure when a set pressure is exceeded. After opening, these valves are designed to re-seat when pressure in the protected component drops below the valve’s closing pressure. If a spring-loaded relief valve opens, the valve shall be replaced or recertified in a safe and timely manner. If re-seating is not complete, the valve shall be taken out of service immediately.

Relief valve vent lines shall be visually inspected annually to ensure that the vent line piping is intact and that vent outlets terminated to atmosphere are unobstructed and piped to prevent foreign matter from entering the vent line piping. If equipped, drip pockets shall be checked for water accumulation.

Pressure relief devices shall be replaced or recertified in accordance with one of these three options:

1) Every five (5) years from the date of installation

   IIAR original recommended (in 1978) that pressure relief valves be replaced every five years from the date of installation. This recommendation represents good engineering practice considering the design and performance of pressure relief devices; or

2) An alternative to the prescriptive replacement interval, i.e., five years, can be developed based on documented in-service relief valve life for specific applications using industry accepted good practices of relief valve evaluation; or

3) The manufacturer's recommendations on replacement frequency of pressure relief devices shall be followed.

Exception: Relief devices discharging into another part of the closed-loop refrigeration system are not subject to the relief valve replacement practices.

All replacement pressure-relief devices shall be correctly selected in accordance with current editions of ANSI/IIAR 2 and ANSI/ASHRAE 15.

6.6.4 Sensing Devices, Monitoring Devices, Sensors, Alarms, Interlocks, and Emergency Shutdown Systems

These devices or systems may take the form of pressure, temperature or level operated switches or controls, Bourdon tube pressure gauges or ammonia vapor detectors. It also includes remote level indicators, data collection systems, annunciators or other automatic devices connected to these other devices. Manufacturer's instructions for inspection, testing, calibration, and overhaul shall be followed.

At least annually, safety cutouts shall be tested. Pressure gauges used in the testing of any safety cutouts shall be calibrated.

6.7 Piping

6.7.1 Uninsulated Piping

All uninsulated piping and associated components such as flanges and supports shall be inspected annually for any damage to or deterioration of the piping or its protective finish; take remedial action where necessary. Areas affected by slight corrosion should be cleaned off and appropriately treated before reinstating the protective finish. Deeper pitting or loss of metal, where considered by subjective assessment to be greater than 10% of original wall thickness, should be checked accurately by using techniques such as ultrasonic measurements. If such wall thinning is confirmed, expert advice should be sought, for example from an authorized inspection agency, to determine the need for, and the extent and timing of, any replacements.

6.7.2 Insulated Piping

Any mechanical damage to insulation should be repaired immediately and the vapor seal reinstated to prevent access of water or water vapor which will lead to breakdown of insulation and corrosion of the pipework.

At least as part of the annual piping inspection, but preferably more frequently, the external condition of the insulation and supports shall be inspected. Condensation or frosting on the surface of insulated finishes indicates a deterioration or breakdown of the insulation or vapor barrier. Sections of insulation which are obviously in poor condition shall be removed and the integrity of the exposed piping determined with the aid of non-destructive testing techniques, as appropriate. Piping shall be replaced as necessary, and protective coatings, insulation and vapor seal re-applied.

Routine inspection of piping under sound insulation is not expected but a program for inspecting sample areas may be adopted at the discretion of the competent person carrying out the independent full inspection (see 6.4.4).

6.7.3 Piping Replacement

When any piping is repaired or replaced, particular care should be taken to ensure that the piping materials used are appropriate for the lowest working temperature and maximum working pressure of that part of the refrigerating system. Welding or jointing shall also be to the appropriate standard, such as ANSI/IIAR 2-2008 (includes Addendum B) (see 7.1) and after installation the piping shall be tested for leakage to the pressures given in Appendix A.

6.8 Oil Maintenance and Removal

The main purpose of oil is for lubrication and sealing of a compressor's rotating parts.

Oil can be found in all the parts of a refrigerating system. Oil is heavier than ammonia and is not very miscible; therefore, oil settles to the lowest part of a system. It is difficult to find oil and remove it from each part of the system.

In the case of a rotary screw compressor package, the final oil separation device is normally a very high efficient coalescent filter bank and, in normal operation, a very small amount of oil will get into the system.

With a reciprocating compressor, the oil separator vessel in its discharge line will usually have an internal stainless steel demister pad. This pad is efficient but will allow a small amount of oil to pass.

Most rotary vane compressor units used as booster compressors are lubricated with a drip type of system. This oil goes to the system.

The rotary screw and reciprocating oil separators recirculate the oil they separate back to the compressor; some rotary vane compressors do not.

In all instances, the removal of oil must be done very carefully. You must remember liquid ammonia can be present behind the oil, or that there may not be oil present, only liquid ammonia. The oil drain valve should be a rapid closing valve.

On the high side of the system, oil to be drained can be found in:

a. The compressor discharge oil separator. If the oil return float fails, oil will fill the vessel. Isolate and pump down the vessel to drain oil and check float return system.

b. The high pressure receiver. Excess oil will show in the sightglass. Drain oil off with oil drain valve on bottom of vessel or through an oil pot.

c. Low pressure vessels, i.e., intercooler, suction accumulators, recirculators, and heat exchangers.

1) With vessels operating below 32°F (0°C), the excess oil level will be easy to see because the oil will be at a higher temperature than the ammonia and no frost will be present.

2) Most low pressure vessels will have a separate oil pot to which oil drains. These pots can be isolated and the oil drained. If pot is equipped with a heater to promote oil draining, follow the manufacturers and installing contractors recommendations carefully.

3) Vessels that operate below atmospheric pressure should have a separate oil pot. If they do not, attempting to drain oil will open the system to ambient air which is undesirable.

4) Vessels with a float switch column will collect oil in the column. Excess oil will show in the sightglass or frost line. Isolate column and drain oil off bottom.

Large pipe headers on the high and low side of the system will collect oil. Oil drain valves should be checked periodically.

A pressure relief valve should be installed on all oil pots.

It is important to keep an oil log of the amount of oil put in and removed. Excess oil is detrimental to refrigerating capacity if left in the heat exchangers.

The oil drained from a system can be put through a regenerator and filtering system and returned to the system. Refer to compressor manufacturer's recommendations and warranty policy before returning oil that has to be drained from system, regenerated, filtered and reclaimed to a compressor.

If oil is to be disposed of, check with the proper governmental authorities.

6.9 Motors and Drivers

Periodic inspection and maintenance of electric motors and other drivers such as steam turbines, gas turbines and internal combustion engines shall be carried out according to the instructions of the manufacturers of such motors or drivers.

Of particular importance are lubrication requirements. Requirements for bearings, for example, may differ significantly from manufacturer to manufacturer and application to application, even though such bearings may appear to be applied in similar ways. Avoid adopting a uniform greasing frequency for all equipment unless all such requirements are similar or identical. Over greasing in certain instances may be as harmful as insufficient greasing.

7.0 TITLES AND SOURCES OF REFERENCES

The following listing identifies published standards, articles or books to which this bulletin refers.

7.1 American National Standards Institute/International Institute of Ammonia Refrigeration, ANSI/IIAR 2-2008 (includes Addendum B), American National Standard for Equipment, Design, and Installation of Closed Circuit Ammonia Mechanical Refrigerating Systems (a,b).

7.2 American National Standards Institute/American Society of Heating, Refrigerating and Air Conditioning Engineers, Inc., ANSI/ASHRAE 15-2010, Safety Standard for Refrigeration Systems (a,c).

7.3 IIAR Bulletin No. 109, Minimum Safety Criteria for a Safe Ammonia Refrigeration System, International Institute of Ammonia Refrigeration (b).

7.4 U.S. Department of Transportation, 49 CFR Part 172, Hazardous Materials Regulations (d).

7.5 Occupational Safety and Health Administration, U.S. Department of Labor, 29 CFR 1910.1000, Air Contaminants, Table Z-1-A (e).

7.6 Federal Specification O-A-445b, Ammonia, Technical (f).

7.7 IIAR Bulletin R-1, A Guide to Good Practices for the Operation of an Ammonia Refrigeration System, International Institute of Ammonia Refrigeration (b).

7.8 IIAR Bulletin No. 105, Guidelines for: Application and Maintenance of Safety Pressure Relief Valves for Refrigerant Systems, International Institute of Ammonia Refrigeration (b).

7.9 IIAR Bulletin No.106, Guidelines for: Prevention, Preparation, Response and Cleanup of Ammonia Releases, International Institute of Ammonia Refrigeration (b).

7.10 IIAR Bulletin No. 116, Guidelines for: Avoiding Component Failure in Industrial Refrigerating Systems Caused By Abnormal Pressure or Shock, International Institute of Ammonia Refrigeration (b).

7.11 IIAR Poster P-1, “First Aid for Ammonia Exposure,” International Institute of Ammonia Refrigeration (b).

7.12 IIAR Ammonia Data Book, International Institute of Ammonia Refrigeration (b).

7.13 IIAR Bulletin No. 107, “Suggested Safety and Operating Procedures When Making Ammonia Refrigeration Plant Tie-Ins,” International Institute of Ammonia Refrigeration (b).

7.14 American Society of Mechanical Engineers/American National Standards Institute, ASME/ANSI B31.5-1987, Refrigerant Piping (g).

7.15 Occupational Safety and Health Administration, U.S. Department of Labor, 29 CFR 1910.119, Process Safety Management of Highly Hazardous Chemicals (e).

7.16 Occupational Safety and Health Administration, U.S. Department of Labor, 29 CFR 1910.147, The Control of Hazardous Energy (lockout/tagout) (e).

7.17 Occupational Safety and Health Administration, U.S. Department of Labor, 29 CFR 1910.146, Permit-required Confined Spaces (e).

7.18 Occupational Safety and Health Administration, U.S. Department of Labor, 29 CFR 1910.252, Hot Work Fire Prevention and Protection (e).

7.19 American Society of Heating, Refrigerating and Air Conditioning Engineers, Inc., 1990 Refrigeration Handbook (c).

7.20 Occupational Safety and Health Administration, U.S. Department of Labor, 29 CFR 1910.212, General Requirement for all Machines, and 29 CFR 1910.219, Mechanical Power-transmission Apparatus (e).

7.21 National Institute for Occupational Safety and Health, Department of Health and Human Services, "NIOSH Certified Equipment List" (h).

7.22 IIAR Bulletin No. 108, "Water Contamination in Ammonia Refrigeration Systems," International Institute of Ammonia Refrigeration (b).

7.23 American Society of Mechanical Engineers, Section VIII, Division 1, Latest Edition, ASME Boiler and Pressure Vessel Code, Pressure Vessels (g).

7.24 Occupational Safety and Health Administration, U.S. Department of Labor, subpart I, Personal Protective Equipment: 29 CFR 1910.132, General Requirements; 29 CFR 1910.133, Eye and Face Protection; and 29 CFR 1910.134, Respiratory Protection (e).

7.25 IIAR Bulletin No. 111, Guidelines for Ammonia Machinery Room Ventilation, International Institute of Ammonia Refrigeration (b).

7.26 IIAR Poster No. P5, "IIAR Recommended Oil Draining Guideline" (b).

7.27 National Board of Boiler and Pressure Vessel Inspectors, The National Board Inspection Code (i).

i. National Board of Boiler and Pressure Vessel Inspectors
1055 Crupper Avenue
Columbus, OH 43229

REFERENCE SOURCES

a. American National Standards Institute (ANSI)
25 West 43rd Street, 4th Floor
New York, NY 10036

b. International Institute of Ammonia Refrigeration (IIAR)
1001 North Fairfax St., Suite 503
Alexandria, VA 22314

c. American Society of Heating, Refrigerating and Air-Conditioning Engineers, (ASHRAE)
1791 Tullie Circle, NE
Atlanta, GA 30329

d. U.S. Department of Transportation (DOT)
Material Transportation Bureau
Office of the Secretary
1200 New Jersey Ave., SE
Washington, DC 20590

e. Occupational Safety and Health Administration (OSHA)
U.S. Department of Labor
200 Constitution Ave., NW
Washington, DC 20210

f. Superintendent of Documents
U.S. Government Printing Office (GPO)
732 N. Capitol St., NW
Washington, DC 20401

g. American Society of Mechanical Engineers (ASME)
United Engineering Center
Three Park Avenue
New York, NY 10016

h. National Institute for Occupational Safety and Health
4676 Columbia Parkway
Cincinnati, OH 45226

Reference OSHA Standards of the Series 29 CFR 1910 are available through:

Technical Data Center
U.S. Department of Labor
Room 2625
200 Constitution Avenue, NW
Washington, DC 20210

APPENDIX A - PRESSURES

For systems designed and installed in accordance with ANSI/IIAR 2-1992 (see 7.1), minimum values of design pressures apply to refrigerating machinery supplied for use within the system. These minimum values together with the corresponding minimum strength test pressure and leak test pressure range are summarized in the table below. Note that the maximum working pressure of particular systems may require higher design pressures and the strength and leak test pressure will be accordingly higher.

MINIMUM VALUES OF DESIGN PRESSURE WITH CORRESPONDING STRENGTH TEST AND LEAK TEST PRESSURES - NH_3

	Compressors			HP Machinery Including Valves and Sensing Devices Heat Exchangers, Condensers, Pumps	
	LP Side and Boosters	HP Side	LP Machinery, Including Vessels, Heat Exchangers, Evaporators* Pumps	Water Cooled Systems	Air Cooled Systems
Minimum design pressure					
psig	150	300	150	250	300
(kg/cm^2 gauge)	(10.54)	(21.09)	(10.54)	(17.57)	(21.09)
(kPa gauge)	(1034.2)	(2068.4)	(1034.2)	(1723.7)	(2068.4)
Strength test pressure					
psig	225	450	225	375	450
(kg/cm^2 gauge)	(15.82)	(31.64)	(15.82)	(26.36)	(31.64)
(kPa gauge)	(1551.3)	(3102.7)	(1551.3)	(2585.6)	(3102.7)
Leak test pressure					
psig	150	300	150	250	300
(kg/cm^2 gauge)	(10.54)	(21.09)	(10.54)	(17.57)	(21.09)
(kPa gauge)	(1034.2)	(2068.4)	(1034.2)	(1723.7)	(2068.4)

* In the case where hot gas defrost is utilized, minimum design pressure shall be 250 psi gauge (17.57 kg/cm^2 gauge) (1724.0 kPa gauge) or the design of the high side source of hot gas, whichever is greater.

APPENDIX B - NAME PLATE DATA

The following information shall be provided on the name plates attached to the component. Reference is made to ANSI/IIAR 2-2008 (includes Addendum B) (see 7.1).

INFORMATION	COMPRESSORS	PRESSURE VESSELS*	Shell & Tube Exchangers*			TUBULAR HEAT EXCHANGERS	REFRIGERANT PUMPS	CONTROL VALVES & SENSING DEVICES	EVAPORATIVE CONDENSERS	FINNED HEAT EXCHANGERS
			Condenser	Evaporator Refrigerant In:						
				Shell	Tube					
Manufacturers' name	X	X	X	X	X	X	X	X	X	X
Manufacturers' serial and model number	X	X	X	X	X	X	X	X	X	X
Year of manufacture	X	X	X	X	X	X			X	X
Design pressure	X	X	X	X	X	X	X		X	X
Shell side pressure ____ at ____ temperature			X		X					
Tube side pressure ____ at ____ temperature			X		X					
Maximum allowable pressure ____ at ____ temperature				X						
Minimum design metal temperature ____ at ____ pressure				X						
Test pressure applied			X	X	X					
Maximum Design Working Pressure		X				X				
National Board Number		X	X	X	X					
Name and stamp of inspecting authority	*Provide in every case where there is such authority*									
Refrigerant - "Ammonia"	X						X			
Rotation speed - rpm (maximum)	X						X			
Direction of rotation	X						X		X	X
Electric motor size (maximum)							X		X	X
Electric supply - volts, full load amps, hertz, phase							X	X	X	X
Flow direction	X							X		

* AN ADDITIONAL PRESSURE AND TEMPERATURE STAMPING MAY BE REQUIRED WITH REFERENCE TO VESSELS USED BELOW -20°F (-28.9°C) WHICH ARE NOT IMPACT TESTED. SEE LATEST EDITION OF RELEVANT SECTION OF SECTION VIII, DIVISION 1, ASME BOILER AND PRESSURE VESSEL CODE (see 7.23).

APPENDIX C
EQUIPMENT START-UP CHECK LIST

Component Group ______________________

Site Location ______________________

Date ______________________

No.	CHECKED ITEM	READY	NOT READY	COMMENT
1	LEAK CHECK			
2	EVACUATION			
3	BASE			
4	LUBRICATION			
5	RELIEF VALVES			
6	CONTROL VALVES			
7	SAFETY DEVICES			
8	ELECTRIC PANELS			
9	SHAFT ALIGNMENT			
10	ROTATION			
11	GUARDS			
12	INSULATION			
13	GAUGES			
14	THERMOMETERS			
15	FLUID LEVELS			
16	PIPE SUPPORTS			
17				
18				
19				
20				

SYSTEM COMPONENT GROUP LIST - USE CHECK LIST ABOVE FOR EACH COMPONENT GROUP

Group 1	Compressor Package
Group 2	Condensers
Group 3	High Pressure Vessels
Group 4	Intermediate and Low Pressure Vessels
Group 5	Piping Mains
Group 6	Piping Branches
Group 7	Evaporators

APPENDIX D - MACHINERY ROOMS AND AUXILIARY SAFETY EQUIPMENT

D.1 General

Inspection at start-up and as part of maintenance shall ensure that the following requirements are met prior to charging with ammonia and continue to be met during the operation of the system.

D.2 Access, Exit and Containment

Refrigerating machinery rooms shall be dimensioned so that all parts are easily accessible with adequate space for proper service, maintenance and operation. There shall be clear headroom of not less than 6 ft. 6 in. (2 m) below equipment situated over gangways. Rooms shall have doors opening outwards (self-closing and well fitting if opening to other parts of the building) and adequate in number to ensure freedom for persons to escape in an emergency. At least one safe emergency exit giving direct access to the open air, or through a vestibule with doors (air lock) shall be provided. Gangways and exits shall be clear of any obstruction and clearly marked.

Machinery rooms shall be ventilated to the outside air by mechanical ventilation as in D.6 below, possibly in conjunction with natural ventilation via grilles, windows or door openings. Exterior openings shall not be under emergency exits.

There shall be no partition or openings that could permit passage of escaping refrigerant to other parts of the building. The points of passage of all piping and cable ducts through walls, ceilings and floors shall be tightly sealed.

D.3 Instructions

Operating and maintenance personnel shall be carefully instructed both in the operation of the system and on possible hazards.

Concisely worded operational instructions for normal starting and stopping and for the emergency stopping of the equipment shall be prominently displayed in the machinery room.

Warning and first aid notices appropriate to ammonia and to the equipment shall be displayed in the machinery room and its accesses.

The system instruction manual should be readily available, located at a place external to the area of immediate risk. This should include at least the following:

a. full details of the system

b. description of the machinery

c. detailed starting, stopping and running instructions

d. information on possible faults, repair and maintenance schedules

e. a refrigeration flow diagram and an electrical circuit diagram

D.4 Protective Equipment

Protective clothing, goggles, respirators and gloves, carefully and safely stored, shall be readily available in the vicinity of the system but externally to the area of risk. Eye and face protection and its use shall conform to OSHA 29 CFR 1910.132 and 133; respirators and their use shall conform to 29 CFR 1910.134 (see 7.24).

Self-contained breathing sets, full protective clothing and lifeline should be available external to area of risk for use by trained personnel where rescue work or emergency isolation of equipment may have to be undertaken.

Fire fighting equipment appropriate to the system and to ammonia shall be provided. Adequate first aid equipment shall be provided in the same safe area as protective equipment and self-contained breathing sets.

Concise and precise first aid instructions shall be clearly displayed in the machinery rooms and their accesses. Any regular first aid personnel shall be made fully aware of the special problems of ammonia accidents.

The location of protective, first aid and rescue equipment shall be clearly indicated on notices within and external to the areas of risk.

Irrigation facilities, and/or eye wash bottles containing an eye wash solution or distilled water shall be available at all ammonia handling points. The facilities shall be inspected and/or the solution changed at least at six month intervals. In the machinery rooms adequate supplies of clean water shall be available by hand or foot operated douches or in open containers.

D.5 Electrical

Lighting shall be of adequate brightness and disposition to allow free circulation of personnel in safety. An emergency lighting system should be provided to allow evacuation of personnel and any necessary urgent operation of controls, or portable lighting shall be provided. Lighting intended to remain in operation following an accidental release of ammonia shall be suitably protected for use in hazardous areas.

Independent or standby supplies of electricity (e.g. batteries) for emergency and warning systems shall be tested at weekly intervals.

Audible alarms should be available which are activated manually, by operation of the emergency stop button or by an automatic ammonia detection system. Ammonia/air mixtures can deflagrate but only at the unusually high concentration of 16% to 25% by volume if ignited by a high temperature source; a low concentration of 100 ppm is readily detected by smell and by suitable detectors. Accordingly the following precautions are recommended:

a. In areas or enclosed spaces housing compressors or other non-static parts of refrigerating systems containing ammonia, isolation of electrical circuits shall be effected by circuit breaker(s) installed in a safe place. The circuit breakers shall be controlled either:

    1) by one or more detector devices operative at a pre-determined low level or concentration located over non-static items of equipment from which a leakage might occur and arranged to give a visual and audible alarm, to switch on equipment for ventilation in accordance with D.6 below and flameproof lighting (if installed), or

2) if the area or enclosed space is continuously manned and occupied, by pushbuttons immediately outside it and arranged to give a visual and audible alarm, to switch on equipment for ventilation in accordance with D.6 below and emergency lighting (if installed). The pushbuttons shall be of the breakglass type and shall be located outside exit doors on a similar basis to the provision of fire alarm buttons for hazardous areas.

b. Where fan motors, emergency lighting or ammonia detectors are required to operate after a leakage has been detected, they shall comply with the requirements of the area in which they are situated.

The installation of one or more clearly labeled additional emergency pushbuttons remote from the area or enclosed space but duplicating the action of those in D.5.a.2 above should be considered. Regular tests of the effectiveness of detection and isolation systems should be made at intervals not exceeding three months.

D.6 Ventilation

Mechanical ventilation in accordance with ANSI/IIAR 2-2008 (includes Addendum B) (see 7.1) shall be installed and be capable of exhausting from the room at least the amount of air as given in that standard. Inlets to the extraction system shall be free from obstruction, near the machinery and suitably guarded. Discharge to the outside of the building shall be free from obstruction and shall not cause danger. Provision shall be made for adequate replacement fresh air to be introduced throughout the room.

The ventilation system shall be activated by an independent emergency control outside and near the machinery room door (with another at ground level if the machinery room is not at ground level); this may be additional or combined with the requirements of D.5 above.

Where natural ventilation is inadequate, falling below the level required by ANSI/IIAR 2-2008 (includes Addendum B) (see 7.1), sufficient proportion of the mechanical ventilation shall be in continuous operation to ensure the health and safety of occupants. Control should be by a normal (non-emergency) switch.

For additional information, refer to IIAR Bulletin No. 111 (see 7.25).

D.7 Guards

Guards shall be adequate to prevent access to and injury from all rotating machinery, injury from electrical items and dangerously hot or cold surfaces.

D.8 Refrigerant Storage

The quantity of refrigerant stored in the machinery room, apart from the charge in the system, shall not exceed 300 lb. (135 kg) or 20% of the charge, whichever is the lesser. It shall be stored only in approved storage containers.

APPENDIX E - STRESS CORROSION CRACKING

E.1 Introduction

Stress corrosion cracking (SCC) is a form of stress corrosion which results in tiny cracks and has occurred in ferritic steels associated with ammonia containment vessels. In some instances, SCC has resulted in catastrophic failures but these major failures, as of the publication of this bulletin, have only occurred in ammonia bulk storage and handling vessels, which are outside the scope of this bulletin.

Stress corrosion cracking can and has been known to occur within refrigerating systems although only isolated incidents have been reported, with ammonia weeping from a crack in the worst case. The problem is sufficiently serious to warrant caution and in respect of this potential hazard some notes are therefore given, based on the limited data on and understanding of the problem to date.

E.2 Occurrence

It is generally accepted that oxygen levels of more than a few ppm in liquid ammonia or a few thousand ppm in gaseous ammonia can promote cracking in steels. Therefore, care should be taken to ensure the effectiveness of air evacuation so that contamination by oxygen from the air is minimized.

It is also generally accepted that 0.2% minimum water content in ammonia acts as an effective inhibitor. From random tests it appears that the water level is often below 0.2% on the high pressure side of the system and above 0.2% on the low pressure side of the system. Therefore, it would seem that the high pressure side of the system is more at risk than the low pressure side of the system.

Like most chemical actions, SCC will proceed more rapidly at high temperatures, therefore the warmest areas are most at risk. On the basis of the limited data available to date, SCC is unlikely to occur at temperatures below 23°F (-5°C).

E.3 Inspection Surveys

There are major difficulties in inspecting refrigerating system components for stress corrosion cracking. The cracks are very fine and not generally visible to the naked eye; they will occur on the interior of pipes and vessels and it is unlikely that refrigerating systems have or can have adequate access to all internal parts for inspection. In view of these difficulties and because leaks in refrigerating systems due to SCC have been rare and have not resulted in major failure, no requirement is made here for regular inspections.

Where inspections are desired and system construction is such that they can be made, present guidance is that areas of inspection should include cold formed stress areas and weld seams, e.g., at dished end sections of vessels. It is obvious from the discussion in E.2 that the warm part of the high pressure side of the system is most at risk. However, it would also be prudent to include vessels on the low pressure side of the system even though the operating temperatures will usually be below 32°F (0°C).

While stress corrosion cracks have been detected by ultrasonics and by dye penetrant techniques, a magnetic particle method is preferred, but it depends on the experience of the operator.

An ammonia sample can be taken from the system and analyzed for oxygen and water content.

To ensure safety in sampling and meaningful results, the ammonia supplier should be consulted on the method to be employed or reference may be made to IIAR Bulletin No. 108 (see 7.22).

E.4 Preventive Measures

Available information on SCC indicates that certain measures may be taken to minimize the risk of this occurrence. In summary, the following data may be of value to designers and users of ammonia refrigerating systems:

a. Lower yield strength steels, such as those listed below, appear to be less susceptible to stress corrosion cracking.

Vessel Shells, Tube Sheets and Heads	SA-285 Grade C SA-516 Grade 70
Heat Exchanger Tubes	SA-179 SA 214
Piping and Small Diameter Shells	SA-53 Grade B SA-106 Grade B
Flanges and Fittings	SA-105

b. Hot formed or stress relieved heads reduce the chance of high stress concentrations that exist with cold formed heads. Stress corrosion cracking appears to take place in areas of high stress concentration.

c. Oxygen (air) appears to be a catalyst in creating stress corrosion cracking. Extensive initial evacuation and constant purging is necessary to minimize the presence of air.

APPENDIX F - PRESSURE TESTS

Where a pneumatic test is called for, e.g. as part of the independent full inspection, the test shall be carried out using dry air, nitrogen or a mixture of dry air or nitrogen and ammonia vapor.

A vessel to be tested pneumatically shall carry a plate or other certification confirming an earlier strength test at a higher pressure as defined in 6.4.4.2. A full visual inspection of the vessel shall precede a pneumatic test and, if necessary, the visual inspection should be supplemented by radiographic or other non-destructive testing. Where no record of a recent strength test exists, a hydraulic test for strength to the pressure as defined in 6.4.4.2 should be carried out; where the condition of the vessel indicates deterioration, the hydraulic form of test shall be mandatory.

The vessel to be tested shall be emptied of liquid refrigerant and isolated effectively from the remainder of the system; the use of blanking plates between flanges, or sections of line open to atmosphere beyond stop valves, are typical of means required to ensure no leakage of the test medium into the remainder of the system.

Pressure relief valves or bursting discs, which will be set at the maximum working pressure and could therefore operate, shall be removed and all connections adequately sealed prior to a test. It may be appropriate to use the relief valve connection to accommodate a test pressure gauge (see below) and it may be convenient to carry out the replacement of relief valves (6.6.3) following a pressure test.

Provide a means to ensure that the intended test pressure is not exceeded. If the source of pressure is at a higher pressure than the test pressure, use a reducing valve together with a safety valve. Equip the vessel to be tested with a pressure gauge connected to the vessel other than at the test pressure connection (in addition to a gauge at the reducing valve).

Both test pressure connection and gauge shall be so located that testing can proceed without exposing the operator to danger.

Pressure shall be raised gradually to avoid shock. An initial examination for major leaks, for example at connections, may be made at a low pressure (typically 10% of final pressure), but during further pressurization and for the first few minutes at test pressure, no one shall approach the vessel.

Following a successful test, the pressure shall be reduced to atmospheric and pressure relief devices replaced. Connections to these should be leak tested (for example by testing for refrigerant leakage when ammonia is readmitted). The test conditions and date, together with any comments, shall be entered in the system records.

APPENDIX G - TYPICAL SCHEDULE FOR INSPECTION AND MAINTENANCE

The following table shows one format for an inspection and maintenance schedule. It is emphasized that the refrigerating system user should draw up a scheme appropriate to the range of equipment installed and identify the relevant grade of staff within or external to their organization to carry out the tasks.

All items should be recorded in the system log; items marked * are typical of those where an entry in the register is required. The register shall be updated when any major item of equipment is repaired or replaced.

TYPE OF EQUIPMENT	TYPE OF INSPECTION	CARRIED OUT BY	FREQUENCY (AT LEAST)	ITEMS REQUIRING ATTENTION INCLUDE
COMPRESSORS	Operational inspection	Operating staff	Daily to 72 hours max.	Pressure and temperature readings Oil Level Oil return Noise/vibration
	Major inspection/	Operating or maintenance	Every 3 mos. maintenance staff	* Drive condition including guards
		Maintenance or safety staff	Bi-annually	* All safety cutouts
		Maintenance staff	Annually or to manufacturer's instructions	Drive alignment Foundation bolts * Valves and cylinder heads: further dismantling/inspection as manufacturer's instructions specify Oil change Clean/change filters/ strainers

TYPE OF EQUIPMENT	TYPE OF INSPECTION	CARRIED OUT BY	FREQUENCY (AT LEAST)	ITEMS REQUIRING ATTENTION INCLUDE
VESSELS, SHELL & TUBE EXCHANGERS, FINNED EXCHANGERS, EVAPORATIVE CONDENSERS	Operational maintenance	Operating or maintenance staff	Weekly	External condition Condition of heat transferring liquids, water conditions Proper defrost of air coolers Check pan strainers, bleed-off
		Maintenance staff	Weekly	Oil draining Purging
		Operating or maintenance staff	Monthly	Inspect and clean as necessary finned heat exchanger surfaces Clean pan, water distribution system, check float valve, belt tension
			Bi-annually	Check associated equipment, e.g., fans, impellers and guards. Lubrication as recommended by manufacturer.
	Annual inspection	Maintenance supervisor or engineering manager	Annually or after extended period of service	* Detailed inspection external condition: vessels and insulation Tube bundles Associated equipment, e.g., fans, bearings, shafts, impellers, controls, safety provisions
		Maintenance staff	Annually	Clean filters/strainers and heat exchanger surfaces
	Independent Full Inspection	Independent competent person	Every five years	As determined by the competent person, but typically: * External inspection of supports * NDT as required * Pressure test if required * Insulated vessels * Inspect vessel or test if insulation unsound

TYPE OF EQUIPMENT	TYPE OF INSPECTION	CARRIED OUT BY	FREQUENCY (AT LEAST)	ITEMS REQUIRING ATTENTION INCLUDE
AMMONIA PUMPS	Operational inspection	Operating or maintenance staff	Monthly	Defrost and external inspection
	Major inspection/ maintenance	Maintenance staff	Annually	* Open and inspect for possible wear or damage
VALVES AND SENSING DEVICES	Inspection/ maintenance	Maintenance staff	Bi-annually	Stems and glands of uncapped valves
		Maintenance supervisor or safety staff	Annually	Test all safety cutouts
		Maintenance supervisor or staff	Annually	Check stems, glands and external condition of all stop valves * Control valves for function Clean all filters
			Every five years	* Test all stop valves for function overall or replace as necessary
PRESSURE RELIEF DEVICES	Inspection/ maintenance	Maintenance supervisor or safety staff	Annually	* Inspect external condition including vent lines
			Every five years	* Renew all relief valves (or cartridges) or bursting discs
PIPING	Inspection/ maintenance	Maintenance supervisor or engineering manager	Annually	* Inspect all uninsulated piping and supports, arrange to repair as required
			Annually	* Inspect all insulation; if any deterioration remove, inspect and repair as necessary Check supports
AMMONIA CHARGE	Inspection/ maintenance	Maintenance staff	Bi-annually	Test for purity, refer to IIAR Bulletin No. 108 (see 7.22)
SYSTEM OIL	Inspection/ maintenance	Maintenance staff	Refer to manufacturers recommendation	Test for quality

APPENDIX H - SAMPLE DETAILS FOR REGISTER

In view of the variety of machinery employed in various refrigerating systems and the different forms of records and depth of information appropriate to the users and their sites, a full sample register is not given here. One example of the type of information which may be included in a register is given below for pressure vessels:

EQUIPMENT REGISTRATION - PRESSURE VESSEL

Location: ________________ Company: ________________________ Division: _______________

Equipment Description: ____

National Board # _________________ Year Built: ___________________

Manufacturer: _______________ Drawing No. _________________ Serial No. _______________

Design Code/Class: ___________________ Data Report (Attached): ________________________

Design Data	**Shell**	**Tubes**
Design Working Pressure		
Design Temperature		
Test Pressure Applied		
Material and Thickness		
Corrosion Allowance		
Operating Fluid		

Inspection Data Log*
This log tracks activity related to Appendix G.

Date	Type of Inspection	Frequency of Activity	Carried Out By	Results	Signature

** Note: In addition to entering brief details here, a more comprehensive Report of Examination should also be included with the Vessel Record Sheet in the Register following each inspection.*

APPENDIX I - SAMPLE SYSTEM LOG

COMPRESSOR NO.

	Suction			Discharge			Oil					
Date Time	Pressure PSI	Sat. Temp °F	Gas Temp °F	Pressure PSI	Sat. Temp °F	Gas Temp °F	Pressure PSI	Level	Amount Added	Motor Amps	Hours Run	Remarks/ Maintenance Signature

SYSTEM LOG (CHILLED WATER SYSTEM)

	Chilled Water			Evaporator		Condenser	Receiver		Oil Drained			
Date Time	To Process °F	From Process °F	Differential Pressure	Refrigerant Pressure	Liquid Level	Pressure PSI	Pressure PSI	Level	Evaporator	Receiver	Refrigerant Added	Remarks/ Maintenance Signature

Note: Modify and expand log to suit system and process. Include details of: equipment running/on or standby time, process heat loads, ambient weather conditions, etc.

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