THE AMMONIA QUESTION FOR ICE RINKS
RISKS & REWARDS

Industry Expert Report By John Burley

Ammonia Refrigerant and U.S. Safety Standards

The interest in ammonia-based refrigeration systems has experienced resurgence in recent years as the nation has been focused on the adverse environmental impact of "freon", a trade name associated with the halocarbon industry. Contributing further has been the enactment of North American Free Trade Agreement (NAFTA) and the strength of the U.S. dollar. These two factors are great incentives for outside companies to sell to the U.S. market.

Outside companies often do not meet U.S. safety standards and frequently recommend ammonia type systems that result in safety code violations. This translates to non-code compliant structures, additional construction costs and unplanned refrigeration system modifications. Changing a refrigeration system built for ammonia to a halocarbon system is complicated and costly.

In addition our own comments, we urge you to read through the two attached design manuals from the IIAR (International Institute of Ammonia Refrigeration) entitled “Ammonia Machinery Room Design” and “Ammonia Machinery Room Ventilation”. These manuals outline the danger of ammonia refrigerant use and the importance of following all design guidelines. The stringent design guidelines in these booklets are produced by advocacy group, designed to promote ammonia use. To encourage the use of ammonia, they minimize design guidelines and associated dangers. Seemingly less expensive in start-up and operational costs, long-term, it is not.

What risk does the architect of record take?

Non-code compliant design issues remain unchallenged by local officials, however, once the complex obtains its final certificate of occupancy, this does not diminish the liability for the designers of record for the complex, which carry a seven year liability for issues resulting because of improper design. At any point, a code enforcement agency can insist the complex be brought up to standards.

Every newly built structure undergoes an inspection by the insurance company who underwrites the policy. The insurance inspector will identify code deficiencies and refuse to honor policies until such problems are brought up to code. The insurance company's position on this matter is fully legal whether or not the complex has received its final certificate of occupancy. Should an accident occur in future years, the first issue evaluated is whether the original design was in compliance with code.

In addition, it is important to confirm the safety and compliance of the ice-making system with local and national codes concerning the safety of a public assembly building.

Why ammonia is considered as a refrigerant option?

The two primary factors most promoted for the use of ammonia are:

- improved energy efficiencies, and
- environmental restrictions of “freons”

The energy improvement fallacy of ammonia use

Ammonia refrigerant is more efficient than halocarbon refrigerants, however, ammonia based refrigeration systems are not more energy efficient then a properly designed halocarbon system. Complexes, regions and electrical billing rates considered, endless case studies demonstrate ammonia-based refrigeration systems can run up twice the monthly utility billing. The refrigerant is only one factor

in the overall energy efficiency of the total refrigerant plant.
Factors listed below all play a large role in utility costs:

- oil recovery system within the chiller
- unloading efficiencies
- system losses from inefficient drive systems
- heat exchanger efficiencies

Ammonia technology was the foundation for modern day refrigeration. With the exception of large industrial applications, ammonia was greatly abandoned in the U.S. in the 1950s in favor of halocarbons because of its increased safety. Since the adoption of halocarbons, great innovative strides have taken place in the development of compressors, control valves and components that are simply not available for ammonia systems. (See performance chart and results of the Mycom system).

Alleged energy efficiency is inaccurate and diametrically opposed to the reality of how an ammonia system will operate under real-world applications. An ammonia system, said to be more energy efficient, in reality will cost up to twice that of a properly designed halocarbon system.

The standard halocarbon system does not feature the TurboChiller™ technology or design. Ammonia system salespeople will never show comparisons against a TurboChiller™ system.

Installing an ammonia system will be costly in the long-term.

Environmental concerns of freon

The background of the media hype is politically driven more so than driven by scientific fact. The goal of the designer must be to install a system that will not impact the ownership adversely for the next 30 plus years of use.

The term 'freon' is loosely used and often associated with all types of halocarbon refrigerants. In fact, there are many different types of halocarbons, some of which impact the environment, and many that do not.

Freon is a trade name Dupont used for its brand of refrigerants. Halocarbons come in many chemical variations. The ones most responsible for the environmental destruction of the ozone layer are known as Chlorofluorocarbons (CFCs).

Some common CFC's known to the general public are:

- R-12 - previously used in automobiles
- R-11 - used in centrifugal chiller applications for large air conditioning units
- R-502 - used for low temperature chiller applications (ice rinks)

These CFC refrigerants are chlorine based chemical formulas which break down slowly in open environmental conditions. When they finally decompose, the release of the chlorine component leads to ozone depletion.

The government phased out these refrigerants and imposed an escalating tax that drove up their price, and as a result, vendors ceased installing equipment with these refrigerants. Most of the applications changed from CFC refrigerants to Hydro chlorofluorocarbon (HCFC) refrigerants. HCFC refrigerants feature a different molecular structure, making them quicker to decompose with far less impact on the ozone. HCFCs are estimated to cause 95% less potential ozone damage than those caused by CFCs.

The most common HCFC used today is R-22. Most equipment designed to operate with CFC refrigerants, were redesigned, or re-rated to operate on the R-22 refrigerant. The R-22 was interpreted then, and continues to be used today, as a bridge refrigerant while newer 0% ozone depleting refrigerants were created.

There is no longer a crisis. Over the last few years, great strides in refrigerant development have been made, which eliminates any possibility of problems, should the government want to totally ban ozone-depleting refrigerants.

New HCFC refrigerants, which have been developed over the last few years, include R-134a, R 404 and R-507. These refrigerants are efficient, reliable and safe by comparison to an ammonia application. They do not have stringent code requirements for mechanical room design and work well with the innovative technologies that have been developed in the halocarbon industry to improve system efficiencies. Best of all, they are 0% ozone depleting elements and free of any taxes or restrictions.

The ban on freons has been long resolved and is not a reason to install a extremely dangerous refrigerant despite what a foreign ammonia refrigeration promoter may say.

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Benefits and disadvantages of ammonia systems

BENEFITS:

1. Ammonia will not impact the environment – except in the event of a large leak.
2. Ammonia is an efficient refrigerant – in context of limited design options.
3. Ammonia is inexpensive – except in the event of flooding.
4. Ammonia will run even if contaminated with large amounts of water in the refrigerant circuit – however, diluted ammonia severely compromises energy efficiency and water and ammonia combine to make ammonium.

DISADVANTAGES:

The list of disadvantages are derived based on past code reviews and performance data, which have been presented to Burleys over the years. Some installations have ignored the code. Some have interpreted it in unique ways to justify its violation.

Some local jurisdictions may have a more severe or open code requirements. All of our comments must be prefaced with these unknowns of how different places will interpret the code. Regardless of how strict local jurisdiction will be, we know there are many specialized construction issues, which must be addressed if an ammonia-based system is used.

According to American Society of Heating, Refrigerating & Air Conditioning Engineers (ASHRAE), refrigerants have two classifications:

- Class A: non-toxic refrigerant
- Class B: toxic refrigerant

Flammability classification is rated by a number:

- 1: non-flammable refrigerants
- 2: flammable refrigerants

Ammonia is considered a B2 type refrigerant meaning it is both toxic and flammable. It has the ability to be extremely harmful and even lethal.

Some insurance companies will not write policies for ammonia based systems used in ice rinks. Ice rinks are public assembly buildings. When it comes to public safety, flirting with safety when no benefits of ammonia systems can be identified makes little sense.

Ice rink chillers, which use ammonia with a flooded chiller, have one large refrigerant circuit. Normal volume of refrigerant is from 1500#'s too as much as 3000#'s of ammonia depending on the project and the chiller size. If the unit has a leak, the entire refrigerant charge can be lost in a short amount of time. A leak can result from a weld breaking, a valves packing letting loose or a shaft seal failure on a compressor, which is not an infrequent event.

Code requirements are in place for a reason. Ammonia is a dangerous refrigerant. While safety codes do vary from state to state, municipality to municipality, in some locations ammonia systems for ice rinks are simply prohibited.

Some disadvantages for installing an ammonia system with the primary focus on code issues include but may not be limited to the following:

1. Because of national fire codes for this type of refrigerant in a public assembly building, the mechanical room must be a minimum one to four hour fire rated room. Many localities prohibit the ammonia use in a public assembly building.
2. With a four hour rating, no doors can exist between the mechanical room and other rooms in the space.
3. Breathing apparatus devices must be installed in the complex for the operator in the event of an emergency. Occupational Safety & Health Administration (OSHA) requires any employees, which may have to use this equipment must be fully trained.
4. The system must be fitted with a dump valve and large water tank in the event that a catastrophic purge be required. When a large leak occurs, the purge valve discharges the remaining charge into a large water tank, which would dilute the ammonia charge so that it is not toxic or flammable.
5. For a four hour room or the use of a flammable refrigerant, code officials usually require that all electrical devices within the room must be explosion proof.
6. A large wall ventilation fan with an explosion proof motor, is required to ventilate the room in the event of a leak condition.
7. In many states the complex must employ an operating engineer to run the refrigeration system.

Other disadvantages, which are system related more so than just related to the ammonia refrigerant, are as follows: if this same type of two-compressor, flooded chiller were used with a halocarbon refrigerant, many of these same issues would pertain:

8. A flooded chiller barrel has only one large refrigerant circuit. Should there be a leak, the entire large operating refrigerant charge could be lost.
   - A TuboChiller™ system is like having two totally separate refrigeration systems installed. Regardless of the problem or service requirement, 100% stand-by capacity is always available with the TurboChiller™.
9. Open-drive compressors run with belt-driven motors and have high-side loading which promote compressor bearing and seal failure. Both types of failure are expensive to repair and can create a substantial leak from a shaft seal failure.
   - TurboChiller™ units are direct driven without any possibility of shaft seal failure, or bearing failures from side loading.
10. Belt drives are an inefficient drive method. Belt driven compressors will experience a 3% to 7% efficiency loss because of the belt drives.
    - The TurboChiller™ systems do not have the belt drive loss or maintenance.
11. The application of only two compressors restricts the system's ability to run efficiently at low-load conditions. Most of the time the complex is operating, one compressor will be operating at 50% cooling capacity. While operating at 50% cooling capacity, the compressor will still experience 100% wear, an and efficiency loss of 4% to 6% from half the pistons going up and down without producing work. While some pistons may not be pumping, it still takes energy to move them up and down inside the compressor body.

- The TurboChiller™ features four compressors for low kW/ton performance during extreme low load conditions.

12. If a flooded system is installed with a halocarbon charge, its skim type oil recovery system is inefficient and results in system losses.
13. If a flooded halocarbon system is installed, and an R-22 refrigerant charge is used, it is very difficult, if not impossible to convert the system to an R-507 refrigerant charge.
    - The TurboChiller™ system is easily convertible at any time.
14. Ammonia system towers do not feature a variable speed fan arrangement that saves money during normal or lower-than-full load operating conditions.
    - The TurboChiller™ features a variable speed fan, which saves approximately 7 hp during the operational period.
15. Ammonia systems have a fixed flow condition which hurts electrical consumption.
    - The TurboChiller™ can maintain a full size ice sheet with a 2 hp pump compared to ammonia systems' 20 to 30 hp pumps.
16. Ammonia systems' evaporative condenser does not have an active sub-cooling loop.
    - The TurboChiller™ features a separate sub-cooling loop, which saves from 3% to 6% energy consumption depending on outdoor weather conditions.
17. Larger motors and fewer compressors mean larger monthly electrical demand charges.
18. Ammonia system rink piping systems cannot accommodate a variable flow rate system. These systems will trap air at low flow conditions creating substandard ice quality conditions.
19. Burleys can provide a calcium chloride fluid or glycol secondary fluid for the same price. The calcium is a higher maintenance, corrosive fluid that will deteriorate the rink floor if not maintained properly.

In conclusion, an ammonia system will cost approximately twice the monthly utility billing compared to a TurboChiller™ system. This has nothing to do with the refrigerant. It is the ammonia system that is substantially less efficient than a TurboChiller™ system.

Today's innovative halocarbon industry has a wide variety of components, permitting far more flexibility in the design of the overall refrigeration package. This increased flexibility permits us to produce a system that can match the normal running load of the ice sheet better than an ammonia system, while incorporating new patent features that make the compressors operate with far more energy efficiently.

Attachments: EPA Publication – "Hazards Of Ammonia Release At Ammonia Refrigeration Facilities"
IIAR Publication – "Guidelines For Ammonia Machinery Room Design"
IIAR Publication – "Guidelines For Ammonia Machinery Room Ventilation"

Biography: John S. Burley has been in the ice arena industry for over 25 years and has built over 600 ice rinks. In addition to the construction activities of arenas, he has pioneered many new arena technologies and is primarily responsible for more currently used ice rink related/refrigeration patents than any other single individual in the industry being awarded over 15 patents.

Credits: Credits are extended to the entire staff of Burleys who has worked with John Burley over the last 25 years to develop the Burleys products and for Heather Roustan for grammatical help with this report.

United States Environmental Protection Agency
Office of Solid Waste and Emergency Response (5104)
EPA 550-F-98-017
August 1998
www.epa.gov/ceppo

EPA
CEPPO

HAZARDS OF AMMONIA RELEASES AT AMMONIA REFRIGERATION FACILITIES

The Environmental Protection Agency (EPA) is issuing this *Alert* as part of its ongoing effort to protect human health and the environment. EPA is striving to learn the causes and contributing factors associated with chemical accidents and to prevent their recurrence. Major chemical accidents cannot be prevented solely through command and control regulatory requirements, but by understanding the fundamental root causes, widely disseminating the lessons learned, and integrating these lessons learned into safe operations. EPA will publish *Alerts* to increase awareness of possible hazards. It is important that personnel who operate refrigeration systems, managers of facilities, SERCs, LEPCs, emergency responders and others review this information and take appropriate steps to minimize risk.

CHEMICAL SAFETY ALERT

PROBLEM

Anhydrous ammonia is used as a refrigerant in mechanical compression systems at a large number of industrial facilities. Ammonia is a toxic gas under ambient conditions. Many parts of a refrigeration system contain ammonia liquefied under pressure. Releases of ammonia have the potential for harmful effects on workers and the public; if the ammonia is under pressure, larger quantities may be released rapidly into the air. Also, some explosions have been attributed to releases of ammonia contaminated with lubricating oil. This *Alert* further discusses these potential hazards and the steps that can be taken to minimize risks. This *Alert* should be reviewed by personnel who operate and maintain refrigeration systems, managers of facilities, and emergency responders (e.g., haz mat teams).

ACCIDENTS

A number of accidental releases of ammonia have occurred from refrigeration facilities in the past. Causes of these releases include plant upsets, leading to the lifting of relief valves; leaks in rotating seals; pipeline failures; vehicular traffic hitting pipes, valves, and evaporators; and failures during ammonia delivery, such as hose leaks. Some of these releases have killed and injured workers, caused injuries off site, or resulted in evacuations. The following describes several recent incidents in more detail.

A specific incident demonstrates the need for mechanical protection to protect refrigeration equipment from impact. In a 1992 incident at a meat packing plant, a forklift struck and ruptured a pipe carrying ammonia for refrigeration. Workers were evacuated when the leak was detected. A short time later, an explosion occurred that caused extensive damage, including large holes in two sides of the building. The forklift was believed to be the source of ignition. In this incident, physical barriers would have provided mechanical protection to the refrigeration system and prevented a release.

Another incident highlights the need for an adequate preventive maintenance program and scheduling. In a 1996 incident in a produce cold storage facility, oil pressure got low over a long weekend in an older ammonia refrigeration system. The low oil pressure cutout switch failed and the compressor tore itself apart, resulting in a significant ammonia release. The periodic testing of the low oil pressure cutout switch against a known standard would have prevented this incident.

Two other incidents illustrate the potential for serious effects from accidental releases from ammonia refrigeration systems, although the causes of these releases were not reported. In a 1986 incident in a packing plant slaughterhouse, a refrigeration line ruptured, releasing ammonia. Eight workers were critically injured, suffering respiratory burns from ammonia inhalation, and 17 others were less severely hurt. A 1989 ammonia release in a frozen pizza plant led to the evacuation of nearly all of the 6,500 residents of the town where the plant was located. The release started when an end cap of a 16-inch suction line of the ammonia refrigeration system was knocked off. Up to 45,000 pounds of ammonia was released, forming a cloud 24 city blocks long. About 50 area residents were taken to hospitals, where they were treated with oxygen and released, while dozens of others were treated with oxygen at evacuation centers.

HAZARD AWARENESS

Ammonia is used widely and in large quantities for a variety of purposes. More than 80% of ammonia produced is used for agricultural purposes; less than two percent is used for refrigeration. Use of ammonia is generally safe provided appropriate maintenance and operating controls are exercised. It is important to recognize, however, that ammonia is toxic and can be a hazard to human health. It may be harmful if inhaled at high concentrations. The Occupational Safety and Health Administration (OSHA) Permissible Exposure Level (PEL) is 50 parts per million (ppm), 8-hour time-weighted average. Effects of inhalation of ammonia range from irritation to severe respiratory injuries, with possible fatality at higher concentrations. The National Institute of Occupational Safety and Health (NIOSH) has established an Immediately Dangerous to Life and Health (IDLH) level of 300 ppm for the purposes of respirator selection. Ammonia is corrosive and can burn the skin and eyes. Liquefied ammonia can cause frostbite.

The American Industrial Hygiene Association (AIHA) has developed Emergency Response Planning Guidelines (ERPGs) for a number of substances to assist in planning for catastrophic releases to the community. The ERPG-2 represents the concentration below which it is believed nearly all individuals could be exposed for up to one hour without irreversible or serious health effects. The ERPG-2 for ammonia is 200 ppm. EPA has adopted the ERPG-2 as the toxic endpoint for ammonia for the offsite consequence analysis required by the Risk Management Program (RMP) Rule under section 112(r) of the Clean Air Act.

In refrigeration systems, ammonia is liquefied under pressure. Liquid ammonia that is accidentally released may aerosolize (i.e., small liquid droplets may be released along with ammonia gas) and behave as a dense gas, even though it is normally lighter than air (i.e., it may travel along the ground instead of immediately rising into the air). This behavior may increase the potential for exposure of workers and the public.

Although pure ammonia vapors are not flammable at concentrations of less than 16%, they may be a fire and explosion hazard at concentrations between 16 and 25%. Mixtures involving ammonia contaminated with lubricating oil from the system, however, may have a much broader explosive range. A study conducted to determine the influence of oil on the flammability limits of ammonia found that oil reduced the lower flammability limit as low as 8%, depending on the type and concentration of oil (Fenton, et al., 1995).

An important property of ammonia is its pungent odor. Odor threshold varies with the individual but ammonia can be usually detected at concentrations in the range of about 5 ppm to 50 ppm. Concentrations above about 100 ppm are uncomfortable to most people; concentrations in the range of 300 to 500 ppm will cause people to leave the area immediately.

HAZARD REDUCTION

The Chemical Accident Prevention Group of EPA's Region III (Pennsylvania, Maryland, Virginia, West Virginia, Delaware, and the District of Columbia) has been evaluating facilities in Region III with ammonia refrigeration systems to gather information on safety practices and technologies and to share its knowledge with these facilities. Region III has conducted more than 120 audits from 1995 to the present of both large and small facilities using ammonia for refrigeration. To share their findings from the audits, including both the deficiencies observed and the actions that facilities are taking to increase safety, Region III has made presentations to the Refrigerating Engineers and Technicians Association (RETA). This *Alert* is intended to communicate these findings to a wider audience.

Ammonia refrigeration facilities should be aware of the potential hazards of ammonia releases and of the steps that can be taken to prevent such releases. They should be prepared to respond appropriately if releases do occur. Here are steps that ammonia refrigeration facilities could take to prevent releases and reduce the severity of releases that do occur include:

- Establish training programs to ensure that the ammonia refrigeration system is operated and maintained by knowledgeable personnel.

- Consider using a spring-loaded ball valve (dead-man valve) in conjunction with the oil drain valve on all oil out pots (used to collect oil that leaks through seals) as an "emergency stop valve."

- Develop written standard operating procedures for removing oil from the oil out pots. Consider developing an in-house checklist to guide mechanics through the procedure.

- Remove refrigeration oil from the refrigeration system on a regular basis. Never remove oil directly from the refrigeration system without pumping down and properly isolating that component.

- Provide barriers to protect refrigeration equipment, i.e., lines, valves, and refrigeration coils, from impact in areas where forklifts are used. Consider starting a forklift driver training program.

- Develop and maintain a written preventive maintenance program and schedule based on the manufacturer's recommendations for all of the refrigeration equipment. The preventive maintenance program should include, but not be limited to:
  a) compressors
  b) pumps
  c) evaporators
  d) condensers
  e) control valves
  f) all electrical safety(s), including
    1) high pressure cutouts
    2) high temperature cutouts
    3) low pressure cutouts
    4) low temperature cutouts
    5) low oil pressure cutouts
  g) ammonia detectors
  h) emergency response equipment, including,
    1) air monitoring equipment
    2) self-contained breathing apparatus (SCBA)
    3) level A suit
    4) air- purifying respirators

- Perform vibration testing on compressors. Document and analyze results for trends.

- Maintain a leak-free ammonia refrigeration system. Investigate all reports of an ammonia odor and repair all leaks immediately. Leak test all piping, valves, seals, flanges, etc., at least four times a year. Some methods which can be used for leak testing are sulfur sticks, litmus paper, or a portable monitor equipped with a flexible probe.

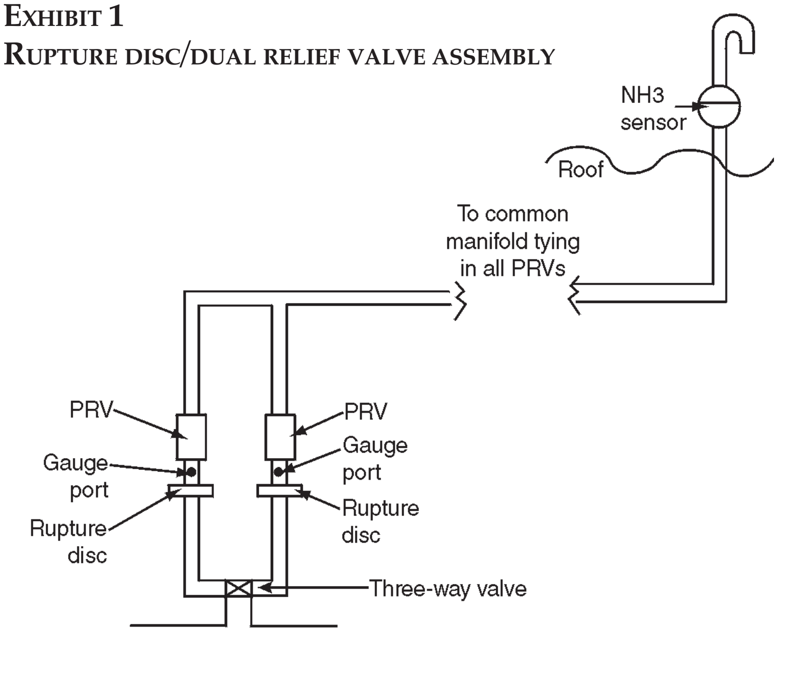
- Consider installing ammonia detectors in areas where a substantial leak could occur or if the facility is not manned 24 hours/day. The ammonia detectors should be monitored by a local alarm company or tied into a call-down system. Ensure that the ammonia detectors are calibrated regularly against a known standard. Check the operation of ammonia sensors and alarms regularly.

- Replace pressure relief valves (PRVs) on a five-year schedule; document replacement dates by stamping the replacement date onto each unit's tag.

- Replace single PRVs with dual relief valves. A dual relief valve installation consists of one three-way dual shut-off valve with two pressure safety relief valves.

- For large systems with many PRVs, consider using the arrangement shown in Exhibit 1 for detecting leakage. This arrangement includes installation of a rupture disc upstream of each PRV with a gauge port or transducer in between the disc and PRV and installation of an ammonia sensor in the PRV common manifold. In case of leakage from a PRV, the sensor would set off an alarm. A check of either the pressure gauge or transducer signal would permit easy identification of which PRV has popped.

EXHIBIT 1
RUPTURE DISC/DUAL RELIEF VALVE ASSEMBLY



- Consider installing a low water level probe with an alarm in the water sump for the evaporative condenser(s) to warn of water supply failure.

- Ensure that the ammonia refrigeration system is routinely monitored. Consider using a daily engine room log, recording process parameters (e.g., temperature and pressure levels) and reviewing the log on a regular basis. Consider having the chief engineer and the refrigeration technician sign the daily engine room log. In designing new systems or retrofitting existing systems, consider the use of computer controls to monitor the process parameters.

- Keep an accurate record of the amount of ammonia that is purchased for the initial charge to the refrigeration system(s) and the amount that is replaced. Consider keeping a record of the amount of lubricating oil added to the system and removed from the system.

- Ensure that good housekeeping procedures are followed in the compressor rooms.

- Ensure that refrigeration system lines and valves are adequately identified (e.g., by color coding or labeling) by using an in-house system.

- Properly post ammonia placards (i.e. NFPA 704 NH_3 diamond) and warning signs in areas where ammonia is being used as a refrigerant or being stored (for example, compressor room doors). Properly identify the chemicals within the piping system(s); label all process piping, i.e. piping containing ammonia, as "AMMONIA." Label must use black letters with yellow background. (This requirement is not the same as the in-house color coding system.)

- Periodically inspect all ammonia refrigeration piping for failed insulation/vapor barrier, rust, and corrosion. Inspect any ammonia refrigeration piping underneath any failed insulation systems for rust and corrosion. Replace all deteriorated refrigeration piping as needed. Protect all un-insulated refrigeration piping from rust and/or corrosion by cleaning, priming, and painting with an appropriate coating.

- Carry out regular inspections of emergency equipment and keep respirators, including air-purifying and self-contained breathing apparatus (SCBA), and other equipment in good shape; ensure that personnel are trained in proper use of this equipment. For SCBA, it is important to ensure that air is bone dry. For air-purifying respirators, replace cartridges as needed and check expiration dates.

- Consider using the compressor room ammonia detector to control the ventilation fans.

- Identify the king valve and other emergency isolation valves with a large placard so that they can easily be identified by emergency responders, in case of an emergency. These valves should be clearly indicated on the piping and instrumentation diagrams (P&IDs) and/or process flow diagrams.

- Establish emergency shutdown procedures and instructions on what to do during and after a power failure.

- Establish written emergency procedures and instructions on what to do in the event of an ammonia release.
- Mount a compressor room ventilation fan manual switch outside of the compressor room and identify it with a placard for use in an emergency. Good practice would be to have ventilation switches located outside and inside of each door to the compressor room.
- Mount windsocks in appropriate places and incorporate their use into the facility emergency response plan. In addition to the emergency response plan, consider developing additional materials (posters, signs, etc.) to provide useful information to employees and emergency responders in case of an emergency.
- Keep piping and instrumentation diagrams (P&IDs), process flow diagrams, ladder diagrams, or single lines up-to-date and incorporate them into training programs for operators.
- Stage a realistic emergency response spill exercise with the local fire company.

References

Fenton, D.L., K.S. Chapman, R.D. Kelley, and A.S. Khan. 1995. Operating Characteristics of a flare/ oxidizer for the disposal of ammonia from and industrial refrigeration facility. ASHRAE Transactions, 101 (2), pp. 463-475. Atlanta, GA: American Society of Heating, Refrigeration, and Air-Conditioning Engineers.

INFORMATION RESOURCES

General References

The Alaska DEC fact sheet on preventing accidental releases of anhydrous ammonia is available at: http://es.inel.gov/techinfo/facts/alaska/ak-fs03.html.

CEPPO has prepared a general advisory on ammonia (OSWER 91-008.2 Series 8 No. 2), available at: http://www.epa.gov/ceppo/acc-his.html.

Statutes and Regulations

The following are a list of federal statutes and regulations related to process safety, accident prevention, emergency planning, and release reporting.

EPA

Clean Air Act (CAA)

- General Duty Clause [Section 112(r) of the Act]- Facilities have a general duty to prevent and mitigate accidental releases of extremely hazardous substances, including ammonia.
- Risk Management Program (RMP) Rule [40 CFR 68]- Facilities that have anhydrous ammonia in quantities greater than 10,000 pounds are required to develop a hazard assessment, a prevention program, and an emergency response program. EPA has developed a model guidance to assist ammonia refrigeration facilities comply with the RMP rule.

Emergency Planning and Community Right-to-Know (EPCRA)

- Emergency Planning [40 CFR Part 355] - Facilities that have ammonia at or above 500 pounds must report to their LEPC and SERC and comply with certain requirements for emergency planning.
- Emergency Release Notification [40 CFR Part 355]- Facilities that release100 pounds or more of ammonia must immediately report the release to the LEPC and the SERC.
- Hazardous Chemical Reporting [40 CFR Part 370]- Facilities that have ammonia at or above 500 pounds must submit a MSDS to their LEPC, SERC, and local fire department and comply with the Tier I/ Tier II inventory reporting requirements.
- Toxic Chemicals Release Inventory [40 CFR Part 372] - Manufacturing businesses with ten or more employees that manufacture, process, or otherwise use ammonia above an applicable threshold must file annually a Toxic Chemical Release form with EPA and the state.

Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA)

- Hazardous Substance Release Reporting [40 CFR Part 302]- Facilities must report to the National Response Center (NRC) any environmental release of ammonia which exceeds 100 pounds. A release may trigger a response by EPA, or by one or more Federal or State emergency response authorities.

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OSHA

- *Process Safety Management (PSM)* Standard [29 CFR 1910] Ammonia (anhydrous) is listed as a highly hazardous substance. Facilities that have ammonia in quantities at or above the threshold quantity of 10,000 pounds are subject to a number of requirements for management of hazards, including performing a process hazards analysis and maintaining mechanical integrity of equipment.
- *Hazard Communication* [29 CFR 1910.1200] - Requires that the potential hazards of toxic and hazardous chemicals be evaluated and that employers transmit this information to their employees .

For additional information, contact OSHA Public Information at (202) 219- 8151.

Web site: http://www.osha.gov

Codes and Standards

There are a number of American National Standards Institute (ANSI) Standards available for refrigeration systems. Some examples are given below.

ANSI/ASHRAE Standard 15-1994 - Safety Code for Mechanical Refrigeration

Available for purchase from the American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE) International Headquarters, 1791 Tullie Circle, NE, Atlanta, GA 30329-2305. Customer service: 1-800-527- 4723

ANSI/IIAR 2-1992 - Equipment, Design, and Installation of Ammonia Mechanical Refrigeration Systems

Available from the International Institute of Ammonia Refrigeration (IIAR)
1200 19th Street, NW
Suite 300
Washington, DC 22036-2422
(202) 857-1110

Web site: http://www.iiar.org

ISO 5149-1993 - Mechanical Refrigerating Systems Used for Cooling and Heating -- Safety Requirements

Available from the American National Standards Institute (ANSI)
11 West 42nd Street
New York, NY 10036
(212) 642-4900

Web site: http://www.ansi.org

FOR MORE INFORMATION...

CONTACT THE EMERGENCY PLANNING AND COMMUNITY RIGHT-TO-KNOW HOTLINE

(800) 424-9346 OR (703) 412-9810
TDD (800) 553-7672

MONDAY-FRIDAY, 9 AM TO 6 PM, EASTERN TIME

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HTTP://WWW.EPA.GOV/CEPPO/

NOTICE

The statements in this document are intended solely as guidance. This document does not substitute for EPA's or other agency regulations, nor is it a regulation itself. Site-specific application of the guidance may vary depending on process activities, and may not apply to a given situation. EPA may revoke, modify, or suspend this guidance in the future, as appropriate

Bulletin No. 112 6/98

Guidelines for:

Ammonia Machinery Room Design

International Institute of Ammonia Refrigeration

NOTICE

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METRIC UNITS

IIAR employs the common English system of engineering units (the "inch-pound" system) for publications. Common metric and/or SI unit equivalents are sometimes provided for reference, but all conversions are approximate.

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1.0 INTRODUCTION

The refrigeration machinery room contains much of the fixed equipment for a refrigerated facility. Proper machinery room design will afford a safe and efficient ammonia refrigeration system. While the mechanical code and other codes and standards provide minimum safety requirements for machinery rooms, there are other recommended practices generally accepted in the industry.

2.0 SCOPE

This guideline summarizes generally accepted industry practice for ammonia machinery rooms and references relevant codes and standards where instructive. The recommendations in this guideline are most applicable to completely new ammonia machinery rooms. Application to the evaluation and/or renovation of existing machinery rooms may be impractical for a variety of reasons and should be done only with careful consideration.

3.0 REFERENCE SOURCES

The information in this bulletin is intended to summarize generally accepted industry practices. The bulletin does not provide a comprehensive treatment of existing code and standard requirements, as these vary from place to place. It is not intended to impose new requirements beyond those in existing codes and standards. It should be noted that certain jurisdictions have specific code requirements that are more stringent than the practices described herein.

Reference documents used in the development of this bulletin include:

- ANSI/ASHRAE 15-1994, *Safety Code for Mechanical Refrigeration*
- ANSI/IIAR 2-1992, *Equipment, Design, and Installation of Ammonia Mechanical Refrigeration Systems*
- IIAR Bulletin 109, *Minimum Safety Criteria for a Safe Ammonia Refrigeration System*
- IIAR Bulletin 110, *Startup, Inspection, and Maintenance of Ammonia Mechanical Refrigeration Systems*
- IIAR Bulletin 111, *Ammonia Machinery Room Ventilation*
- ANSI/NFPA 68, *Guide to Venting of Deflagrations*
- ANSI/NFPA 70, *National Electric Code*
- *International Mechanical Code 1997*
- ANSI/NFPA 1-1997, *Fire Prevention Code*
- *Standard Mechanical Code 1994, Standard Building Code 1994, Standard Fire Code 1994*
- *National Mechanical Code 1993, National Building Code 1996, National Fire Code 1996*
- *Uniform Mechanical Code 1997, Uniform Building Code 1997, Uniform Fire Code 1997*
- IIAR *Ammonia Data Book*

4.0 DESIGN REQUIREMENTS AND CONSIDERATIONS

4.1 General

Design requirements and considerations are categorized into the main engineering disciplines. Note that machinery room ventilation is specifically addressed by IIAR Bulletin 111 (10/91) so this bulletin does not provide the same level of detail. The terms "must" and "shall" are used to indicate that an item is a requirement in some code or standard. Where possible, a reference to the relevant code or standard is given in italics, but these are not all-inclusive, particularly where the requirement exists in several codes and standards. Any requirement referenced applies only to systems in jurisdictions where the referenced code or standard has been adopted by law. The term "should" indicates that an item is discretionary but normally recommended.

4.2 Site Considerations

Site considerations would be applicable to situations where a totally new refrigerated facility is to be constructed. Other than for any specific state or local building codes or zoning ordinances, the following site considerations are discretionary as opposed to being code requirements.

(a.) **Proximity to Surface Waters.** Topography of the site should prevent any possibility of an ammonia spill reaching surface waters such as creeks, streams, rivers, lakes, or ponds per all state and federal regulations. Federal regulation includes section 311(b)(2)(A) of the Federal Water Pollution Control Act and 40 CFR Part 116 Section 4, Designation of Hazardous Substance and 40 CFR Part 117 Section 3, Reportable Quantities of Hazardous Substances Designated Pursuant to Section 311 of the Clean Water Act. State regulations may also apply to on-site ponds used for decorative or fire protection purposes. Check with your local authority. A site drainage plan shall be prepared per the USEPA National Pollutant Discharge Elimination System, 40 CFR Part 122, Section 26, Storm Water Discharges, and any applicable State NPDES program.

(b.) **Proximity to Off-Site and Major Traffic Thoroughfares.** Machinery rooms should be located on the site with due consideration for proximity to off-site major traffic thoroughfares as well as to nearby neighbors and prevailing winds. Machinery room location considerations should include safety, noise hazards and off-site effects. U.S. Environmental Protection Agency Risk Management Program regulations require that facilities with greater than 10,000 lb ammonia consider off-site public receptors. (See IIAR *Process Safety Management and Risk Management Program Guidelines for Ammonia Refrigeration* for more detail.) Refer to local and state codes for requirements on this topic.

(c.) **Arrangement of Machinery Room to Overall Facility.** The machinery room location relative to the rest of the refrigerated facility is important. Following are lists of preferred locations.

Preferred Locations:

- Ground level
- Separate building (or sharing a building with another utility system)
- Peninsular part of main building with three exposed walls and exposed roof

remote from heavily occupied areas

- Along exterior of main building having one or two exposed walls and exposed roof remote from heavily occupied areas

Least Desirable:

- Inner areas of building with no exterior wall exposure
- Adjacent to (horizontally or vertically) heavily occupied areas such as office and employee welfare facilities
- Basement of building
- Building floors above ground level

(d.) **Access for Emergency Response Vehicles.** Emergency access (i.e., fire lanes) shall be in accordance with all state and local codes, and if practicable, special consideration should be given to direct machinery room access.

4.2.1 Machinery Room Content, Layout and Construction Features

Machinery Room Content, Layout and Construction shall conform to ANSI/IIAR 2-1992, *Equipment, Design and Installation of Ammonia Mechanical Refrigeration Systems*, Section 4, Machinery Room Design with special consideration to the following:

(a.) **Machinery Room Contents.** Preferably the ammonia refrigeration machinery room houses only ammonia refrigeration equipment and direct ancillary equipment such as condenser water pumps. The following equipment shall not be located within a ammonia refrigeration machinery room:

- Boilers and other open flame producing equipment, including open flame space heaters, must not be located in the machinery room.
- Equipment with surface temperatures in excess of 800°F shall not be located in the room without special precautions. (For example, some cogeneration facilities obtain "alternate methods and materials" code variances in order to place turbines and steam boilers in refrigeration areas. Such approvals are considered by code officials on a case-by-case basis and usually require demonstration of equivalent safety to the code requirements.)
- Lubricants or other combustible materials shall not be stored in the machinery room.

(b.) **Machinery Room Layout.** Sufficient space shall be provided to allow access to equipment for maintenance purposes. Adequate clearance for personnel is recommended between equipment.

A minimum of two (2) exits must be provided from the machinery room, and all exits shall be in compliance with all federal, state and local codes and regulations. Exit doors shall swing outward, be equipped with panic-type hardware, and shall not be locked while machinery room is occupied. Doors shall be tight-fitting, and self-closing. An unobstructed path to exit is to be clearly marked.

(c.) **Building Structural Capabilities.** Machinery room structural systems should include provision for concentrated loading from piping, vessels, and equipment. Elevated structural systems should be specifically designed for the actual loads of main headers and hanging vessels, in addition to live loads (snow/water) on the roofing system.

Floor systems should be designed to accommodate the specific static and/or vibrational loads imposed by equipment and vessels, and equipment for servicing (fork truck, portable crane, etc.). Concrete pads may be necessary for major pieces of reciprocating equipment per manufacturer's recommendations.

(d.) **Explosion Venting.** Explosion venting may be required by the facility's insurance company. Factory Mutual System Loss Prevention Data Sheet 7-13 defines a vent area and internal release pressure for these systems and references ANSI/NFPA 68, *Guide to Venting of Deflagrations*, for further information. ANSI/NFPA 68 calculates a conservatively large vent area, which may be difficult to accommodate if the equipment room does not have any outside walls. If the new equipment room is designed for explosion venting with adequate outside wall area, the construction cost increment over designs without explosion venting is generally not large, although special blow-out panels may be necessary.

Explosion-venting design is intended to reduce the possibility of damage from an ammonia deflagration (propagation of a combustion zone at a speed slower than the speed of sound in the unburned mixture). Certain insurance companies have promoted explosion venting design to reduce their risk in insuring an ammonia mechanical room. The deflagration risk of ammonia is normally addressed by ventilation requirements rather than by installing explosion vents. ANSI/ASHRAE 15-1994, ANSI/IIAR 2-1992, and the mechanical and fire codes require ventilation that reduces the probability of ammonia accumulating to explosive levels.

(e.) **Wall Construction.** Walls, floor, and ceiling separating the refrigerating machinery room from other occupied spaces shall be of at least 1 hour fire-resistive construction. *[ANSI/ASHRAE 15-1994, 8.14c]*

(f.) **Floors.** Machinery room floors should be slip-resistant and should be sloped to floor drains. All floor drains shall comply with state or local codes and regulation pertaining to chemicals releases into the environment. Slopes and drain locations should be coordinated with equipment layouts.

(g.) **Access Platforms.** Elevated equipment and branch hand valves located more than seven feet above floor level should be provided with OSHA-approved access platforms and/or ladders, chain operators accessible from the floor, or manually-controlled solenoid valves controlled by a stop switch accessible just outside of the machine room.

4.3 Mechanical

A major part of the mechanical design associated with the construction of an ammonia machinery room is the ventilation system. This subject is addressed in detail in IIAR Bulletin 111, *Ammonia Machinery Room Ventilation*. Bulletin 112 does not attempt to address the design issues of the ammonia refrigeration system itself.

(a.) **Ventilation.** ASHRAE-15, Safety Code for Mechanical Refrigeration Systems, and IIAR-2 are typically the most stringent codes for ventilation requirements. In IIAR Bulletin 111, ventilation volumes are recommended which generally exceed the requirements in the above two codes: intermittent emergency ventilation equal to 10 ft^3/min per ft^2 and a minimum of 20,000 ft^3/min, triggered by an automatic ammonia detector. Additionally, a continuous ventilation rate of 1-2 ft^3/min per ft^2 is recommended.

(b.) **Emergency Eyewash and Shower Facilities.** Because of the potential for eye and skin exposure to ammonia, accessible eyewash and body shower facilities shall be provided. Because of the importance of quick flushing of the eyes in the event of a spray or splash of liquid ammonia, eyewash facilities should be located in the area of the machinery room.

(c.) **Fire Protection Systems.** Insurance underwriters and local building and fire codes typically address the requirements for basic fire protection. Special considerations should be given to providing sprinklers over any major ammonia vessels to keep them cool in the event of a fire.

(d.) **Drainage Systems.** In the event of a spill in the machinery room, liquid ammonia can enter the waste system. High concentrations of ammonia can cause disruption of waste treatment plants, particularly in smaller treatment plants.

(e.) **Critical Ammonia Valves.** Critical hand valves which control the flow of all liquid ammonia and all hot gas to the plant must be located so as to be readily accessible from floor level or access platforms. A "master" solenoid valve controlled by a manual stop button from the floor located by the main machinery room door may be used. Permanent valve tags with reflective trim are recommended. A drawing showing the location of critical valves should be posted outside the machinery room.

(f.) **Identification and Signage.** All ammonia vessels, equipment and piping should be labeled. Identification of piping should include in-house, process color coded descriptive labels, and flow direction arrows. The in-house color coding system should have an index, posted in color in two locations outside the machinery room area.

ANSI/ASHRAE 15-1994 and ANSI/IIAR 2-1992 require signage which is to include:

- Name and address of installing contractor
- Kind and quantity of refrigerant in system
- Field test pressures applied
- Instructions for emergency shutdown
- Name, addresses, and phone numbers for service
- Name, address, and phone number of municipal inspection department

(g.) **Emergency Refrigerant Control Box.** ANSI/IIAR 2-1992 describes (in an informational Appendix) an "Emergency Refrigerant Control Box" to be installed outside the machinery room. This installation, formerly required by several mechanical and fire codes, is intended to provide a firefighter with the means to manually vent the contents of the refrigeration pressure vessels either to other parts of the system, to atmosphere, or to a water absorption system. Although model fire and mechanical codes have dropped this requirement, it may still be required in some jurisdictions. When an emergency refrigerant control box is required by local (usually fire) code for the manual emergency discharge of ammonia refrigerant, refer to the design guidelines provided by ANSI/ASHRAE 15-1994 Appendix B and ANSI/IIAR 2-1992 Appendix A.

4.4 Electrical

(a.) **Electrical Classification.** So long as the ventilation requirements of ANSI/ASHRAE-15 and ANSI/IIAR-2 (See IIAR Bulletin 111) are satisfied, the machinery room is classified as a "Non-Hazardous Location" by the National Electric Code (NEC). If such ventilation is not provided, all electrical equipment must comply with the requirements for a Class I Division 2 location (which would require specialized electrical gear).

(b.) **Minimize Electrical Equipment.** No electrical equipment should be powered or controlled from the machinery room unless it is directly associated with the refrigeration system.

(c.) **Emergency Remote Control.** While an "emergency refrigerant control box" is no longer required in modern codes, an emergency *refrigeration system* control box is still recommended. This installation, required in some jurisdictions, provides the emergency responder with the controls to (a) perform a safe emergency shutdown of the refrigeration system (or that part which is not Class I Division 2 Group D electrical classification) and (b) start the emergency ventilation system in the refrigeration machinery room.

All emergency remote electrical controls shall be in full compliance with state or local codes and regulations. The following design is recommended as a minimum:

- Remote shut down of nonhazardous-duty machinery room electrical equipment. Proper sequencing of the shutdown can be important.
- Remote activation of exhaust fans.

The emergency switch or switches should be located just outside of the principal exterior exit. The emergency switch should be of the "break-glass" type or in a glass-front control box and should be well identified.

(d.) **Ventilation Equipment Power and Control.** All emergency ventilation system equipment should be powered from a source remote from the machinery room, preferably from an emergency power circuit. Consideration should be given to the electrical classification of the emergency ventilation system; some codes require Class I Group D Division 1 electrical equipment.

(e.) **Lighting.** Machinery room lighting shall be designed to provide a minimum of 30 ft-candle at normal working height. Emergency lighting and exit lighting should be powered from a source external to the room, preferably from an emergency power circuit and should be of waterproof construction. Lighting should also be provided for equipment located outdoors adjacent to the machinery room.

Bulletin No. 111 10/91

Guidelines for:

Ammonia Machinery Room Ventilation

International Institute of Ammonia Refrigeration

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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.

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Guidelines for Ammonia Machinery Room Ventilation

1.0 INTRODUCTION

There currently are no uniform requirements for the design of ventilation systems in machinery rooms where ammonia is used as a refrigerant.

These guidelines include a review of the pertinent codes and standards for ventilation requirements for Ammonia Machinery Rooms. The requirements of these codes and standards are summarized, and a recommended design scheme for providing a minimum amount of ventilation is outlined.

2.0 SCOPE

The scope of this bulletin is to provide guidelines for designing ventilation systems for Ammonia Machinery Rooms used in large industrial refrigeration facilities. It is not intended for any other purpose or application of ammonia.

The recommended design scheme and minimum ventilation levels suggested in these guidelines are generally applicable to refrigeration systems with large quantities of ammonia, exceeding several thousand pounds, located in a machinery room. The recommendations in this bulletin may not be appropriate for smaller systems or equipment used for other applications.

3.0 REFERENCE SOURCES

Major codes and standards, and other reference sources, were reviewed to prepare these guidelines. The following resource materials have been consulted for this bulletin:

ANSI/IIAR-2, "Equipment, Design and Installation of Ammonia Mechanical Refrigeration Systems"

ANSI/ASHRAE-15, "Safety Code for Mechanical Refrigeration"

Uniform Mechanical Code, ICBO

BOCA National Mechanical Code

Factory Mutual, "Loss Prevention - Mechanical Refrigeration", DS 7-13

National Electrical Code, NFPA Standard 70

4.0 SUMMARY OF VENTILATION REQUIREMENTS

Existing codes and standards, including those shown in paragraph 3.0, contain a number of requirements for the ventilation systems of machinery rooms used for mechanical refrigeration equipment. These requirements cover electrical classification, minimum ventilation and other provisions.

4.1 Non-Hazardous Location

It is assumed that everyone will want to have an Ammonia Machinery Room classified as a "Non-Hazardous (Unclassified) Location" for National Electrical Code (NEC) compliance purposes. In simple terms, this eliminates the requirement that all electrical equipment be an explosion-proof design under class I, division 2. Article 500 of the NEC refers to ANSI/ASHRAE-15, which requires that two different types of ventilation systems be provided in order for a machinery room to be considered a "Non-Hazardous Location":

a. *Continuously operated mechanical exhaust ventilation system.* ANSI/ASHRAE-15 requires continuous ventilation at a minimum rate of 0.5 cfm per square foot [9.14 m^3/hr per sq. meter] of machinery room area. Factory Mutual is the only other reference which specifies a volume requirement for continuous ventilation with a rate of at least 1 cfm per square foot [18.28 m^3/hr per sq. meter] of room area. In addition, failure of this ventilation system must initiate a supervised alarm.

b. *Independent emergency ventilation system.* While this system may be operated for temperature control purposes, the primary purpose is to keep ammonia concentrations below potentially explosive levels in the event of a leak.

   The system must be automatically activated at or below a level of 40,000 ppm by an ammonia detector, regardless of the position or action of any other types of manual or thermostatic controls. The detector must also initiate a supervised alarm.

   Note that the 40,000 ppm maximum concentration limit is strictly associated with prevention of deflagrations, not maintaining conditions suitable for human occupancy. Consideration can be given to setting the detector at much lower levels. Trigger levels of 400 ppm or less are commonly used.

4.2 Minimum Volume Requirements

Some of the existing codes and standards contain minimum ventilation levels for emergency systems. The minimum ventilation volume requirements for a machinery room listed by the various references are as follows:

a. Volume required to limit temperature rise to 18°F [10°C] above ambient, considering internal room heat gain from equipment (ANSI/IIAR-2).

b. Volume as required by the following formula for the amount of refrigerant in the largest system (ANSI/ASHRAE-15):

   $$\text{cfm} = 100 \times \sqrt{\text{pounds of ammonia}} \quad [\text{lps} = 70 \times \sqrt{\text{kilograms of ammonia}}]$$

c. Volume based on room volume with twelve air changes per hour (Uniform Mechanical Code):

   $$\text{cfm} = \frac{\text{Room Volume (cubic feet)}}{5 \text{ (minutes per air change)}}$$

d. Volume based on room volume with six air changes per hour (BOCA National Mechanical Code):

   $$\text{cfm} = \frac{\text{Room Volume (cubic feet)}}{10 \text{ (minutes per air change)}}$$

4.3 Other Requirements

In addition to automatic initiation by a leak detector, the emergency ventilation system must be operable manually from a well-identified emergency switch outside of the machinery room exit.

Although ANSI/IIAR-2 mentions water washing of the exhaust stream if air discharge is impractical, it is discretionary and is not typically done.

5.0 RECOMMENDED DESIGN SCHEME

The lower explosive limit for ammonia/air mixtures is reported in numerous sources to be about 16 percent, or 160,000 ppm. The National Fire Protection Association (NFPA) has adopted 25 percent of the lower explosive limit as a safety threshold from an explosion perspective. Therefore, emergency ventilation systems should be designed to keep ammonia concentrations below 4 percent or 40,000 ppm if a leak occurs. The key to such a design is predicting the leakage rate of ammonia that may be encountered. Once a leakage rate of ammonia in the vapor phase is known, it is a simple matter to realize that at least 24 volumes of air need to be mixed with each volume of ammonia vapor in order to keep the concentration in the machinery room at or below 4 percent.

Code bodies, insurance underwriters, and sponsors of standards containing ventilation requirements obviously have had a difficult time deciding how much ventilation should be required. Since ANSI/ASHRAE-15 is referenced by the National Electric Code, and it is typically the most demanding of any of the referenced codes and standards, it is recognized as the highest authority on ventilation for Ammonia Machinery Rooms.

With further analysis, however, it is apparent that there are also some inherent problems with the ASHRAE approach, which bases ventilation volume on the total weight of ammonia in the largest system. Weight of ammonia in a system does not usually have any direct bearing on a leakage rate that might be encountered. For example, an analysis of the expected release and vaporization rates from the rupture of a relatively small (less than 1" [25mm]) high pressure liquid line indicates that ventilation rates on the order of 20,000 cfm [33,980 m^3 /hr] would be needed to keep the concentration below 4 percent. Using the ANSI/ASHRAE-15 formula, 20,000 cfm of ventilation would only be required for systems containing 40,000 pounds [18,144 kg] or more of ammonia.

The recommended design scheme for emergency ventilation systems is to use 10 cfm per square foot [182.88 m^3/hr per sq. meter] of machinery room space, with a minimum threshold of 20,000 cfm [33,980 m^3/hr], regardless of room size. In almost all cases, this will result in a greater amount of ventilation than any of the referenced codes and standards currently require.

5.1 Step 1 - Determine Code Minimums

Although it is intended that code minimums be exceeded by these guidelines, the first step must always be to determine what codes are applicable to the facility in question, and to interpret the requirements of those codes. To determine the code minimums, the following is required:

a. Establish the specifications for of the Ammonia Machinery Room to be ventilated, including:

Room Floor Area (square feet)
Room Height (feet)
Refrigerant Charge (pounds in largest system with piping or vessels in room)
Motor Nameplate Power (brake horsepower)
Non-Motor Heat Sources (btuh)
Summer, Winter Design Temp (°F)

b. Calculate the minimum ventilation volumes using the worksheet in Appendix A. If a local code uses a different method for volume determination, it should be computed under "other". Select the highest of the computed cfms which is applicable. The Uniform Mechanical Code or BOCA National Mechanical Code is only applicable if the local jurisdiction uses it.

5.2 Step 2 - Design Process

The following are considerations which the designer should address as the ventilation design progresses:

a. Select a "Maximum Cfm" for the design, which must be at least as great as the minimum code requirement. Ten cfm/square foot, with a minimum of 20,000 cfm, is recommended.

b. Determine the amount of "Continuous CFM" ventilation to be provided. One to two cfm/square foot is recommended.

c. Select air handling equipment which will satisfy the ventilation volume requirements for both "Maximum CFM" and "Continuous CFM" conditions. This typically requires two or more fans. Consider the following when selecting equipment:

   1) Upblast, high velocity discharge fans will disperse ammonia more effectively. Fans specially designed for this type of application are available. They employ very high discharge velocities and entrainment nozzles which result in better dispersion of ammonia into the atmosphere.

   2) Do not use intake louvers with manual dampers. Any dampers should be the fail-open type. Design filters for very low pressure drop.

   3) Keep the fan motor out of the airstream, if possible.

   4) In cold climates, heat must be provided to satisfy the envelope heat loss and ventilation loads. Do not use gas or electric heating units in the machinery room.

d. Locate intake louvers and exhaust fans to promote mixing and to avoid short circuiting of air. Consider the following when locating intakes and exhausts:

   1) Keep exhaust fan discharge away from doors, windows or air intakes.

   2) Locate intake louvers low on side walls. Space them evenly along outside walls.

   3) Do not locate exhaust fans close to large doors; short circuiting could occur if a door is open. Locate exhaust fans at ceiling level and across the room from air intakes to produce a "sweeping" effect.

e. Design a control and power scheme that meets code requirements and is highly reliable:

   1) Wire as directly as possible, avoiding programmable controllers, relays, timers, etc.

   2) Power fans from a source outside of the machinery room so that shutdown of power in the machinery room does not affect the fans. Power fans from an emergency power circuit if one is available.

3) Use quality ammonia detectors capable of sensing levels at less than 500 ppm.

4) Provide for remote actuation of ventilation from outside of the machinery room.

5) Use a sail switch to activate an alarm if flow in the continuous ventilation system stops.

6.0 OPERATION AND MAINTENANCE

Assure that the continuous ventilation system is in operation at all times.

Perform routine maintenance on fan belts, bearings, dampers and filters. At least every three months, perform the following system checks:

a. Stop the continuous ventilation fan using the disconnect. Confirm that the alarm works properly.

b. Expose the ammonia detector to ammonia concentrations above the trigger level. Cylinders of pre-mixed test gas are available from various sources. Confirm that detector, control circuitry, ventilation fans, dampers and alarms all function properly.

7.0 VENTILATION DESIGN EXAMPLE

To illustrate the application of these guidelines, an example of a typical ventilation design problem will be used to compare the various minimum code requirements with the recommended design scheme of this bulletin.

7.1 Machinery Room Specifications

Assume that a new ammonia refrigeration machinery room is to be constructed. Design specifications are as follows:

Room is 40 feet by 60 feet by 20 feet high at ground level.
Room is designed to house four 200 hp compressors.
Motors, other than compressors, total 100 hp.
Non-motor heat gain is 20,000 btuh.
System charge of ammonia is 15,000 pounds.
Summer design temperature is 95°F.
Winter design temperature is 20°F.
Uniform Mechanical Code and Factory Mutual requirements apply.

Refer to the following pages for an example of the Minimum Ventilation Worksheet and a Ventilation System Illustration.

7.2 Design Procedure

The ventilation system design is made following the recommended design scheme in paragraph 5.0, as follows.

a. Code minimums are checked (see sample worksheet). The ANSI/ASHRAE-15 requirement is the most demanding at 12,247 cfm.

b. The recommended ventilation rate of 10 cfm per square foot results in a "Maximum Cfm" of 24,000 cfm, which exceeds any of the code requirements and the recommended 20,000 cfm minimum. The "Continuous Cfm" is calculated at 3,600 cfm. The heating required just for ventilation air heating is calculated at about 155,000 btuh. Assuming wall and roof losses of 90,000 btuh, the total heating need is about 250,000 btuh. Two steam unit heaters, each rated at 200,000 btuh, are selected.

c. Two exhaust fans are selected, one sized for 7,000 cfm and the other for 17,000 cfm at 1/4" w.g. static pressure. The small fan is selected with an 1800/900 rpm drive motor for two-speed operation. Based on 600 fpm velocity through the free area of the intake louvers, four louver sections are selected with 10 square feet of free area each. They are equipped with fail-open motorized dampers which are interlocked to the exhaust fans.

d. Equipment is located per the Ventilation System Illustration. Note that the intake louvers and exhaust fans are located to minimize short circuiting of air. Also note the location of the emergency ventilation switch just outside of the exit door.

e. The two-speed fan operates continuously on low speed, unless temperature controls or the ammonia detector call for high speed operation, at which time the second fan also starts. Note that temperature controls and the ammonia detector are located in reasonable proximity to this exhaust fan to get more representative indication of temperature and ammonia concentration in the room.

7.3 Minimum Ventilation Worksheet Example

(Dimensions in feet)

BOCA National Mechanical Code:

Room Volume = ______ (length) X ______ (width) X ______ (height) = ______ (volume)

6 air changes = ______ (volume) x 0.1 = [   ] cfm

Uniform Mechanical Code:

Room Volume = 60 (length) X 40 (width) X 20 (height) = 48,000 (volume)

12 air changes = 48,000 (volume) x 0.2 = [9,600] cfm

ANSI/ASHRAE - 15:

System Charge = 15,000 (pounds of ammonia)

100 X $\sqrt{\# NH_3}$ = [12,247] cfm

ANSI/IIAR - 2:

Nameplate Motor Horsepower in Room = 900 (bhp)

Other Heat Gain in Room = 20,000 (btuh)

900 (bhp) X 0.1 X 2545 + 20,000 (btuh) = 249,050 (Total btuh)

249,050 (Total btuh) / (1.08 X 18° F) = [12,811] cfm

Other (refer to other applicable codes or guidelines):

"Maximum Cfm" @ 10 cfm/ft² = 60 (length) X 40 (width) X 10 = [24,000] cfm

"Continuous Cfm" @ 1.5 cfm/ft² = 60 (length) X 40 (width) X 1.5 = [3,600] cfm

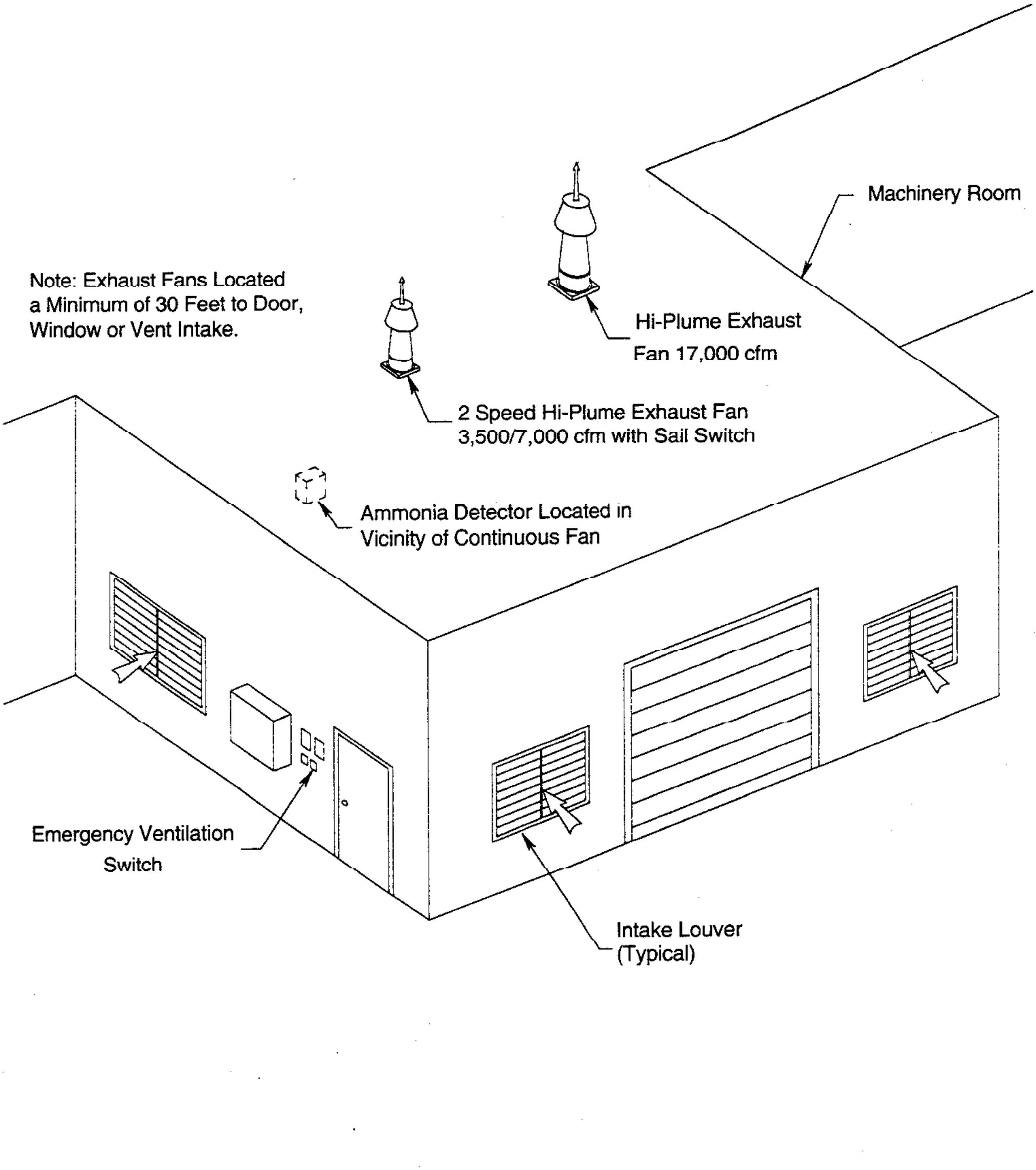
Heat Required to maintain 60°F with 20°F outdoor temperature:

3,600 (cfm) X 1.08 X (60 - 20) (▲T) = 155,520 btuh (fresh air heating)

\+ 90,000 btuh (wall and roof losses)

245,520 btuh (Total heat required)

7.4 Ventilation System Illustration



Appendix A

MINIMUM VENTILATION WORKSHEET

(Dimensions in Feet)

BOCA National Mechanical Code:

Room Volume = ________ (length) X ________ (width) X ________ (height) = ________ (volume)

6 air changes = ________ (volume) x 0.1 = [ ] cfm

Uniform Mechanical Code:

Room Volume = ________ (length) X ________ (width) X ________ (height) = ________ (volume)

12 air changes = ________ (volume) x 0.2 = [ ] cfm

ANSI/ASHRAE - 15:

System Charge = ________ (pounds of ammonia)

$100 \times \sqrt{\# NH_3}$ = [ ] cfm

ANSI/ASHRAE - 2:

Nameplate Motor Horsepower in Room = ______ (bhp)

Other Heat Gain in Room = ______ (btuh)

______ (bhp) X 0.1 X 2545 + ______ (btuh) = ______ (Total btuh)

________ (Total btuh) / (1.08 X 18° deg F) = [ ] cfm

Other (refer to other applicable codes or guidelines):

"Maximum Cfm" @ 10 cfm/ft² = ________ (length) X ________ (width) X 10 = [ ] cfm

"Continuous Cfm" @ 1.5 cfm/ft² = ________ (length) X ________ (width) X 1.5 = [ ] cfm

Heat required to maintain temperature:

______ (cfm) X 1.08 X ______ (▲T) = btuh (fresh air heating)