Ammonia in Refrigeration Systems

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WorkSafeBC was born out of a compromise between B.C.'s workers and employers in 1917 where workers gave up the right to sue their employers or fellow workers for injuries on the job in return for a no-fault insurance program fully paid for by employers. WorkSafeBC is committed to a safe and healthy workplace, and to providing return-to-work rehabilitation and legislated compensation benefits to workers injured as a result of their employment.

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Introduction

When used as a refrigerant, pure ammonia gas is compressed to form pure liquid ammonia. Unlike ammonia compounds, pure ammonia, in both gas and liquid forms, is a toxic substance that presents a number of hazards. If proper precautions are not taken while working with or around pure ammonia, serious injury or even death can result. In order to prevent injury, WorkSafeBC has developed requirements detailed in the Occupational Health and Safety Regulation.

This manual is mainly for two groups: employers whose business includes the use of ammonia as a refrigerant (in ice rinks or ice-manufacturing plants, for example), and workers who work with or around ammonia, including those who repair or maintain ammonia systems. Employers will find information on what they need to do to comply with the Occupational Health and Safety Regulation and to ensure a safe environment both for workers and for communities around facilities in which ammonia is stored or used. Workers will find information that will help them work safely around ammonia.

Employers whose business involves ammonia for uses other than as a refrigerant will also find this manual useful. Compressed ammonia gas is used in blueprinting, die hardening, and the manufacture of cleaning products. Liquid ammonia is occasionally used in water treatment plants and in the manufacture of agricultural fertilizers. Liquid ammonia itself is also used directly as a fertilizer.

Engineers and architects will also find information on building design for facilities in which ammonia is to be used or stored.

This manual does not replace the Occupational Health and Safety Regulation. It complements the Regulation and is a tool to help industry work safely. In this manual, the word *must* means that a particular safety step is specified in the Occupational Health and Safety Regulation. The word *should* indicates that a particular action, although not specified in the Regulation, will improve safety in the workplace. Please note also that the word *worker* includes supervisors, managers, and workers.

In addition to the information in this manual, you can get specific information from manufacturers, suppliers, and *CSA Standard B52-05, Mechanical Refrigeration Code*. Worksites should have a copy of this CSA standard and the Power Engineer, Boiler, Pressure Vessel and Refrigeration Safety Regulation (PEBPV and RSR).

WorkSafeBC has produced a number of related safe practices manuals such as *Breathe Safer,* a respirator manual. For copies, please contact the WorkSafeBC Store (WorkSafeBCStore.com).

What is ammonia?

Pure ammonia comes in two forms: gas and liquid.

Ammonia gas is colourless and has a suffocating, pungent, penetrating odour. It is also much lighter than air. If ammonia gas escapes from a refrigeration system or a storage container, it tends to collect in high areas or ceilings. As the amount of ammonia gas in the air decreases to parts per million (ppm) quantities, natural air convection currents spread the gas throughout the confined area.

Ammonia gas is easily liquefied under pressure.

Liquid ammonia is a clear fluid that evaporates quickly at room temperature. Liquid ammonia also has a high compression ratio. The ratio of liquid to gas is 1 to 800, which means that 1 litre of liquid ammonia expands to form 800 litres of gas. A major ammonia spill is potentially disastrous because liquid ammonia evaporates quickly when exposed to air and creates an explosive fire hazard at high concentrations.

If all the liquid ammonia in a 1,000 lb. refrigeration system escaped, it would release so much pure ammonia gas that it would take 14 times the amount of air in BC Place stadium to dilute the gas concentration to 25 ppm, the maximum allowable concentration a person can be exposed to in an eight-hour period.

Pure ammonia versus household ammonia

The liquid ammonia referred to in this manual should not be confused with the "liquid ammonia" commonly found in households. Household ammonia is actually a diluted mixture of ammonia and water. The liquid ammonia used in refrigeration systems is ammonia gas that has been compressed into a pure liquefied form, sometimes referred to as *anhydrous ammonia.*

Hazard alert: Do not heat ammonia systems

Never apply heat to any part of an ammonia system containing liquid ammonia. The immediate increase in pressure can rupture the tank or pipe.

Health

Ammonia gas is very irritating to the eyes, nose, and respiratory system, which makes it easy to detect low concentrations in the air. Because the gas is physically irritating, it is unlikely that any person will remain in an area contaminated with a detectable concentration of ammonia, unless the person is trapped or unconscious.

If you have been exposed to ammonia repeatedly, however, your ability to smell it may be significantly reduced. Workers who have worked regularly with ammonia have shown decreased ability to detect its odour at concentrations immediately dangerous to life and health (IDLH).

Note The IDLH exposure level is the point at which a person without appropriate respiratory protection could be fatally injured or could suffer irreversible or incapacitating health effects.

Depending on the concentration, ammonia can cause coughing, chest pain, breathing difficulty, bronchopneumonia, pulmonary edema, and death from bronchial spasm. Ammonia is a severe eye irritant; it can penetrate the eye quickly, causing permanent blindness. Contact with the skin or eyes can cause severe and potentially fatal burns.

Toxic effects of ammonia

Ammonia concentration (parts per million)	Effect
2–55 ppm	Normal range of odour threshold*
70 ppm	Stinging or burning in eyes, nose, or throat; can cause watering of eyes, sneezing, and coughing*
300 ppm	Severe irritation of eyes, nose, or respiratory tract, which becomes intolerable after a few minutes; difficulty breathing; possible burning in lungs (IDLH level)*
2,000 ppm or more	Can be fatal after a few breaths

* The concentrations listed in this table do not apply to those who have become desensitized by long-term exposure to ammonia. These people may notice initial health effects only at higher concentrations. **Long-term exposure to ammonia will not help you develop a tolerance to it; it will only weaken your ability to detect ammonia.**

Exposure limits of ammonia

Exposure level (parts per million)	Exposure limit
25 ppm	Maximum allowable concentration averaged over an eight-hour period
35 ppm	Maximum allowable short-term exposure (15 minutes)
300 ppm or more	Immediately dangerous to life and health (IDLH)

Fire

Ammonia's fire hazard rating is usually stated as "slight." Ammonia is explosive in air at concentrations of 16–27 percent (by volume).

Ammonia is extremely reactive, however, which means it easily combines with other materials to form products that are often more hazardous than ammonia alone. The presence of oil or other combustible materials increases ammonia's fire hazard. Ammonia can form explosive mixtures when it comes into contact with strong oxidizers such as chlorine, bromine, iodine, calcium, gold, mercury, silver, and hypochlorite bleaches.

Corrosive action

Ammonia can cause chemical burns on all body surfaces. Ammonia vapour reacts with moisture in the air to form *moist ammonia,* which attacks copper, zinc, tin, cadmium, and most of their alloys. Ammonia will also corrode many rubbers and plastics.

Hazard alert: Electrical spark ignites ammonia vapour

For several hours, no one noticed a leak of liquid ammonia from a deteriorated seal. When the engineer smelled ammonia in the area, he entered the machine room and found pools of liquid on the floor. He immediately activated the fire valve. A spark inside the electrical switch ignited the ammonia vapour, causing an explosion that blew out two walls. Amazingly, the engineer suffered only minor injuries.

According to the Occupational Health and Safety Regulation, employers must develop and implement an effective health and safety program, which includes training workers and supervisors in relevant sections of the program.

Health and safety program

A health and safety program helps ensure a safe, productive workplace by describing specific tasks and responsibilities for many different aspects of an employer's operation. An effective health and safety program for any workplace in which ammonia is used or stored must include:

- A written occupational health and safety policy that:
  - States the employer's commitment to health and safety
  - States the program's objectives
  - Defines the responsibilities and roles of the employer, supervisors, and workers
- Written safe work procedures and emergency response procedures
- Training for supervisors and workers
- Regular worksite inspections
- Regular health and safety meetings
- Accident investigation
- Records and statistics
- A joint health and safety committee or representative, if required

It is important to remember that every worksite is different. Although these general elements may be common to health and safety programs across the province, employers cannot expect to copy a program from another worksite. Instead, they must develop and implement a health and safety program unique to their own operation.

Written safe work procedures

A health and safety program is an overall program that includes a number of individual written safe work procedures and specific, smaller programs. Written safe work procedures and programs tell workers how to perform their duties safely. Employers must ensure that all workers understand these procedures well enough to perform their duties competently. Employers and workers must review all written safe work and emergency procedures jointly at least once a year.

WHMIS program

A Workplace Hazardous Materials Information System (WHMIS) program helps ensure that workers who work with or near ammonia are instructed in its safe use, storage, handling, and disposal. This includes the use of labels or other means of identifying ammonia containers or systems. For more information, see Part 5 of the Occupational Health and Safety Regulation.

Exposure control plan

Written exposure control plans explain the work procedures and other controls that will be used to reduce workers' risk of exposure to ammonia. Strict adherence to ammonia exposure limits and appropriate respiratory and skin protection are essential elements of such a plan. Employers must also ensure that qualified persons perform a formal risk assessment to determine which workers may be affected by exposure to ammonia and the extent of any exposure. For more information about the elements of exposure control plans, see Section 5.54 of the Regulation.

For more detailed information on preventing exposure (through building design, ventilation, and monitoring/alarm systems) and controlling exposure (using eye, skin, and respiratory protection), see *Preventing and controlling exposure,* page 20.

Respirator program (personal protective equipment)

Providing protective equipment and ensuring that workers use it are essential to any effective occupational health and safety program. Employers must develop and implement a written respiratory protection program that is acceptable to WorkSafeBC and that meets the requirements of the Regulation. (For more information on personal protective equipment and clothing, see Part 8 of the Regulation.)

Employers must ensure that workers are trained in proper use and care of respirators. Employers must also provide fit-testing (using a WorkSafeBC-accepted protocol, such as described in *CSA Standard Z94.4-02*) when a worker is first fitted with a respirator, and once a year thereafter. (One type of test, the qualitative fit-test, determines if the worker can detect any amount of a test compound leaking through the respirator.) Employers must keep records of the fit-test program. Fit-test kits are available from respirator suppliers.

Respiratory, eye, and skin protection are all covered in more detail under *Personal protective equipment,* on page 25. You can also find more information on respiratory protection programs in other WorkSafeBC safe practices guides, available through the WorkSafeBC web site (WorkSafeBC.com).

Written emergency procedures

Employers must conduct a risk assessment and prepare emergency procedures, including escape and evacuation, drills, and notification of emergency services. For more information on written emergency procedures, see *Preparing for emergencies,* page 13.

Written preventive maintenance procedures

Employers, in consultation with equipment manufacturers or suppliers, must ensure that all equipment is inspected regularly and replaced when necessary. Employers must ensure that written preventive maintenance procedures *and* written emergency procedures are readily available to and understood by all people required to work on the ammonia system.

Employers must also include plans for testing and replacing, where required, all ancillary (secondary) safety equipment, such as monitors and alarm systems, detection equipment, radios, eye washes, respiratory and skin protection equipment, and first aid kits. To ensure that nothing is missed, employers may find it useful to develop checklists for inspecting and testing equipment. All use and maintenance of safety equipment must be recorded in a suitable log book.

For more information on preventive maintenance, see *Repair and maintenance,* page 19.

Checking on a worker working alone

Employers must establish a system with written procedures to ensure the continued well-being of workers who enter an ammonia enclosure on their own or who work in isolation. Depending on the situation, the check system may consist of either visual checks, radio contact, or a telephone call-in procedure. The check system must include:

- A set interval between checks
- A record of each check
- A check at the end of the work shift
- Procedures to follow if the worker cannot be contacted or is injured

Training, instruction, and supervision

Although workers may have special certification or other external training, employers are responsible for providing them with thorough, site-specific training and continued instruction in the programs and procedures outlined above. Written safe work procedures form the basis of an employer's ongoing training program.

Employers must document training and instruction, and workers must be able to demonstrate competency in doing their work according to the work procedures. See the next section, *Examples of written safe work procedures,* for more information and samples.

Safe handling of ammonia: Where to look in the Regulation

Employers can use several elements of their health and safety program to help ensure the safe handling of ammonia. For the purposes of this manual, these key elements (and their location in the Regulation) include:

- Emergency preparedness (Parts 4–6)
- Equipment preventive maintenance; critical parts inspections (Parts 4 and 6)
- WHMIS; exposure control programs (Part 5)
- Respiratory protection programs (Part 8)
- First aid requirements (Part 3)

Examples of written safe work procedures

Hazard alert: Lack of written procedure results in ammonia leak

A heavy buildup of ice had formed on the outside of the main ammonia feed-line. One of the maintenance staff was told to remove the ice. There was no written safe work procedure, so the employee attempted to break the ice away with an axe. He hit a pipe elbow, snapping it off and releasing liquid ammonia into the area. The emergency procedures had to be activated, and the plant was evacuated.

Some tasks that require written safe work procedures include (but are not limited to):

- Cylinder hookup
- Leak detection and control
- Draining the chiller
- Checking on a worker working alone
- Respirator program
- Disposal of damaged containers
- System shut-down procedure
- Routine maintenance of equipment (such as pumps and piping)

Written safe work procedures must be detailed and complete, and must not assume that the worker will know or remember any unlisted tasks. The following examples demonstrate the amount of detail required.

These examples will not apply to all worksites. Employers must create their own detailed, written safe work procedures to suit each individual worksite.

Example 1: Leak detection and control

Situation 1: A minor leak occurs during routine operation (with an alarm system in place).

- If the alarm has been activated, leave the area and follow emergency procedures.
- If the alarm has not been activated (for example, when ammonia concentration is less than 35 ppm), follow these steps:
  1. Moisten a strip of indicator paper with water (see notes on next page), then check for the approximate area of the leak.
  2. After locating the approximate area of the leak, use fresh strips of indicator paper to determine the exact source of the leak.
  3. Do not attempt to stop the leak until a second worker is present.
  4. Put on appropriate respiratory protection (see the respirator selection table, page 27).
  5. Perform minor maintenance to stop the leak (for example, tighten the flange).
  6. Wait a few minutes, then re-test the leak with indicator paper.
  7. If minor procedures do not stop the leak, initiate the shutdown procedure to prepare for repair.

Notes

1. The indicator paper contains phenolphthalein—do not attempt to moisten the strip using your mouth.
2. Indicator paper can be used only for detecting leaks, not for measuring airborne ammonia concentrations. The indicator paper changes colour to pink when near ammonia. The colour change is slow at 6 ppm and moderately quick at 15 ppm.
3. Do not store indicator paper in the machine room.

Situation 2: A minor leak occurs during routine operation (with no alarm system in place).

1. If you smell ammonia and/or feel eye irritation, leave the area.
2. Notify the supervisor.
3. Wearing appropriate respiratory protection (see the respirator selection table, page 27), measure the airborne ammonia concentration using a detector tube.
4. Moisten a strip of indicator paper with water (see notes below), then check for the approximate area of the leak.
5. After locating the approximate area of the leak, use fresh strips of indicator paper to determine the exact source of the leak.
6. Perform minor maintenance to stop the leak.
7. Wait a few minutes, then re-test the leak with indicator paper.
8. If minor procedures do not stop the leak, initiate the shutdown procedure to prepare for repair.

Notes

1. The indicator paper contains phenolphthalein—do not attempt to moisten the strip using your mouth.
2. Indicator paper can be used only for detecting leaks, not for measuring airborne ammonia concentrations. The indicator paper changes colour to pink when near ammonia. The colour change is slow at 6 ppm and moderately quick at 15 ppm.
3. Do not store indicator paper in the machine room.
4. If the exhaust ventilation is not automatically triggered (see *Ventilation,* page 22), the designated supervisor will determine when it is safe to ventilate the contaminated area.

Hazard alert: No respirators and inadequate training result in major ammonia spill

A 25-litre (5-gallon) bucket collecting oil froth was about to overflow. The operator left his untrained assistant holding the hose and crossed the room to fetch a second bucket. The assistant held the hose up out of the bucket by mistake, sending ammonia vapour into his own face. Physically distressed, he dropped the hose and ran. Liquid ammonia started to drain into the room. The operator was unable to approach the shut-off valve and also left the room. He was coughing and had trouble breathing, and his eyes and nose were burning. Had the operator realized that he had been acting as a supervisor in this instance, he might have properly instructed the untrained assistant.

Situation 3: A leak occurs during routine operation, and no method of determining the airborne ammonia concentration is immediately available.

When no method of determining the airborne ammonia concentration is immediately available, *all* leaks must be considered major leaks and full emergency procedures must be activated.

Example 2: Draining the chiller oil

This is a routine maintenance procedure that involves the release of ammonia gas. When writing procedures, consider the following steps to minimize the amount of ammonia released:

- While this procedure is being performed, the ventilation system must be switched on and operating.
- The work procedure must specify how often this job will be done. Draining the chiller oil on a regular basis reduces the amount of oil drained, which will reduce the amount of ammonia released.
- Measurements of ammonia levels in the air must be recorded to ensure that the work procedure maintains these levels below 35 ppm.
- Draining the chiller oil through a length of tubing into a bucket of water also helps to significantly reduce the amount of ammonia gas released.
- All workers in the machine room must wear appropriate respirators.
- At least two workers must be present during this procedure, unless the system is equipped with a shut-off valve (*deadman switch*).
- Always close the drain valve before leaving the immediate area for any reason (except during emergency escape).

Note There are a number of different methods for isolating the oil-trap from the system by using an intervening valve (a valve between the oil-trap and the system). If an accident occurs, only the oil-trap will be drained, not the whole system.

Preparing for emergencies

Preparing for emergencies includes planning for ammonia spills that may require procedures such as evacuation and notification of local emergency response units. The preparation required for these types of emergencies is detailed below under *Written emergency procedures.*

Preparing for emergencies also includes making appropriate emergency equipment available to workers and ensuring that they know how to use it. This equipment—eye wash and shower facilities and first aid kits—is discussed under *Emergency equipment.*

Written emergency procedures

Formal written emergency procedures provide workers with detailed directions in case of an emergency. A detailed emergency plan is not enough by itself, however. Employers must also conduct emergency drills to determine whether the procedures work in practice and to thoroughly familiarize workers with their roles in an actual emergency. Employers must keep records of these drills to monitor efficiency.

The written emergency procedures must include specific details concerning the following:

- Notifying workers of the emergency location
- Controlling materials that may become dangerous during the emergency
- Emergency personal protective equipment and its location
- Location of the system fire valve
- Emergency lighting
- Evacuation procedure and a check system to ensure that all personnel are evacuated
- Search and rescue
- Notifying police, fire department, hospital, and other emergency response units (such as suppliers)
- Notifying adjacent worksites and private homes of the emergency

As soon as the written emergency procedures are created, the employer must:

- Provide each worker with a copy of the plan, and provide enough training to ensure that workers clearly understand the procedures
- Post the procedures and other relevant information (such as telephone numbers) in appropriate, conspicuous locations
- Conduct regular tests of the procedures, including drills
- Notify the fire department and other emergency response units of any specialized information

Hazard alert: Fire valve vents into emergency gathering area

The arena is located next to a school, separated from it by a narrow parking area. The arena staff are aware of the need to notify the school in the event of a major emergency. The parking area is an emergency gathering point for the students, however, and the arena's ammonia fire valve is located beside this area.

- Provide nearby worksites and private homes that could be affected in an emergency with information about the nature of the hazard and with a copy of appropriate emergency procedures

Besides these general emergency procedures, employers must have specific procedures to cover concerns such as:

- Response to an alarm signal
- Leak control
- First aid response
- Dispersal of leaked ammonia inside the plant
- Dispersal of ammonia dumped (vented) through the fire valve
- Accident investigation

Emergency equipment

Eye wash and shower facilities

Sections 5.85 to 5.96 of the Regulation describe requirements for emergency washing facilities. Employers must conduct a risk assessment for each workplace hazard. In the Regulation, use Table 5-2: Risk Assessment to help determine risk levels relating to hazardous materials, including ammonia. Use Table 5-3: Provision and Location of Emergency Washing Equipment to help determine the type of eye wash equipment required and where it must be located.

Employers must consider the following when conducting a risk assessment:

- The nature of the workplace chemical (corrosive or irritant)
- The state of the substance (gas, liquid, or solid)
- The potential for exposure to skin or eyes and the extent of any exposure
- The number of potentially affected workers
- The availability of first aid and professional medical help

Employers must follow these requirements for eye wash and shower facilities:

- Ensure that the facilities have a supply of tempered water—not running cold water. Ensure that workers cannot mistakenly turn on hot water alone.
- Determine the most appropriate location for emergency equipment. It is not appropriate, for example, to install emergency equipment in the machinery room.
- Take into account the geographical location of the facility when deciding whether or not an outdoor location will be practicable during the winter.
- Do not locate emergency equipment where the public may access and possibly damage it.

First aid kit

Workers must have immediate access to an appropriate first aid kit at each ammonia location. To determine the appropriate first aid kit required for a particular worksite, see Part 3 of the Occupational Health and Safety Regulation.

Investigating accidents

Investigation of accidents is important for preventing future accidents, and for education of workers and employers. According to the Occupational Health and Safety Regulation, employers must immediately notify WorkSafeBC of any major release of a toxic substance. In the case of ammonia, a major release is:

- A leak or spill resulting in at least one person receiving professional medical attention

  or
- A leak or spill resulting in at least three people receiving first aid

Any time enough ammonia is released to set off the alarm, the employer must conduct a formal investigation to discover the causes of the accident. This investigation must also examine measures that will prevent similar situations in the future. Employers must forward copies of the investigation report to their occupational health and safety committee and to WorkSafeBC.

Working safely around ammonia

This section will be useful to anyone who works with or around ammonia. It includes information on storing ammonia, handling ammonia, and repair and maintenance of ammonia systems.

Personal protective equipment—particularly eye, skin, and respiratory protection—is essential to working safely around ammonia. For more information, see *Personal protective equipment,* page 25.

Storing ammonia

Liquid ammonia is stored in a variety of containers: cylinders, pressure vessels, and tank trucks. This section describes what you must and must not do when storing ammonia.

Note All ammonia and refrigeration equipment must meet the requirements of the *Safety Standards Act*, the Electrical Safety Regulation, the Power Engineers, Boiler, Pressure Vessel and Refrigeration Safety Regulation (PEBPV and RSR), and applicable CSA standards (such as *B52-05* and *B339-02*).

Signage

- Use signs to clearly identify all ammonia storage areas. Only qualified personnel are permitted to enter an ammonia storage area.
- Indicate the total weight of ammonia contained in the system using a readable, accessible sign.

Note See *CSA Standard B52-05* for other sign-posting requirements.

Quantity and location

- Do not allow the amount of stored ammonia to exceed 136 kg (300 lb.) or 20 percent of the normal ammonia charge (total amount in system), whichever is less.
- Store ammonia cylinders and containers in a cool, dry, and relatively isolated area, protected from weather and extreme temperatures. If cylinders and containers are stored outside, shield them from direct sunlight unless they are specifically designed for unshaded, outdoor storage.

Note Never apply heat to containers or their valves.

- When storing inside, store ammonia cylinders and containers in a well-ventilated building, away from any heat sources. Never allow cylinders and containers to reach 50°C.

- Store cylinders upright, and secure them against falling. Cylinders will discharge vapour when upright, and liquid when upside-down.

Housekeeping

- Do not store materials that may react violently with ammonia (for example, iodine, bromine, chlorine, calcium, gold, mercury, silver, and hypochlorite bleaches) in the same room as ammonia.
- Do not block access to emergency equipment and doors.
- Use cylinders on a "first-in, first-out" basis.

Empty cylinders

- Clearly tag or mark empty cylinders, and separate them from full cylinders.
- Do not consider cylinders or other ammonia system containers empty and safe until they have been thoroughly purged with nitrogen, steam, or water.

Fire precautions

- Do not use open flames in ammonia storage or holding areas.
- Do not smoke in ammonia storage or holding areas.
- Always ground storage containers to minimize the buildup of static electricity.

Handling ammonia

This section describes what you must and must not do when handling ammonia.

Moving cylinders

- Handle cylinders with care when moving or storing them. Do not allow cylinders to strike objects, and do not drop cylinders.
- Do not use slings or magnetic devices to move ammonia cylinders.
- Do not stand in line with valve or fitting openings, particularly pressure relief valve openings.

Valves

- Ensure that cylinders have valve protection hoods in place when not connected to a system.

- Do not lift a cylinder by its valve protection hood. The hood is not designed to carry the weight of a cylinder.
- Do not modify, alter, or repair cylinders and valves. Only the supplier should carry out these tasks.

Repair and maintenance

Employers are responsible for providing written preventive maintenance procedures and written emergency procedures to any person who works on an ammonia system. Workers should be familiar with these procedures before carrying out repairs or maintenance on the ammonia system.

Qualified personnel must supervise the cleaning and repair of ammonia systems. They must be familiar with all the hazards and the safeguards necessary to safely perform the work.

The ammonia system must be shut off if repairs present an ammonia hazard. The part needing repair must be isolated from the system, either by physically removing it or by effective *blanking* (blocking off lines to cut off the flow of ammonia). Before any work is done, the isolated part must be thoroughly purged with water or steam to remove all traces of ammonia.

Welding hazard

Welding or any other heating of an ammonia system is extremely hazardous. Isolate and purge system parts before welding.

Engineering and administrative controls are the first line of defence against exposure to ammonia. Proper building design and ventilation are important engineering considerations. Monitoring/alarm systems are also essential in preventing ammonia exposure.

Personal protective equipment is the last line of defence. It is vital in controlling exposure when an ammonia leak has occurred or there is a possibility of such a leak. Personal protective equipment includes eye, skin, and respiratory protection. It also includes emergency equipment such as eye wash and shower facilities and first aid kits.

Engineering control (building design)

This section is mainly for engineers and architects who are involved in designing ammonia systems and storage facilities.

Machine rooms

Ammonia machine rooms must conform to *CSA Standard C22.1-06, Canadian Electrical Code Part 1*, unless an inspector has designated the room a Class "T" room under the *Safety Standards Act* and the Power Engineers, Boiler, Pressure Vessel and Refrigeration Safety Regulation (PEBPV and RSR). Class "T" room requirements are outlined in a separate section on the next page.

Consider the following points when designing an ammonia system or storage facility:

- All electrical installations must be explosion-proof.
- Shipping containers and equipment containing ammonia must be located indoors in a suitable fire-resistant building. If a separate building is not provided, containers and equipment must be located in an enclosure with fire-resistant floors and walls.
- The machine room must be sealed from the rest of the building. All pipe openings must also be sealed.
- Machine rooms with a floor area larger than 60 sq. m (200 sq. ft.) must have two or more exit doors to ensure accessible escape routes.
- The machine room must provide free and unrestricted access to exit doors. At least one exit door must open to the outside of the building.
- All exit doors must open outward and must be fitted with *panic hardware* (a crash bar for easy exit).
- Doors should not be self-locking.
- If the room is heated for comfort, ammonia containers and equipment must not be overheated.

- The machine room or storage rooms must not be designed or used for:
  - Storage of other materials (such as ice skates, in the case of arenas)
  - Any other work processes
  - A worker rest area
- Emergency controls to shut down the ammonia compressor must be located outside the machine room.
- Cold storage rooms must have a door that opens easily from the inside. These rooms must also have a means of alerting other workers if a person is unable to exit the room.
- The machine room must be equipped with emergency lighting.
- Hazardous material contained in a piping system must be identified. "Identification of material contained in a piping system shall be by background colour marking and legend. For controlled products, pictograms shall also be used. The background colour marking and coloured pictograms are used to designate whether the contained material is hazardous, or for fire protection." (CGSB Standards 5.1 and 6.1.2)

TABLE 1: Background and Legend Colour

Material	Background Colour*	Legend Colour*
Hazardous	Yellow 505-101	Black 512-101
Inherently Low Hazard	Green 503-107	White 513-101
Fire Protection	Red 509-102	White 513-101

* Colour numbers are those in CGSB Standard 1-GP-12.

Class "T" Machine Rooms

Consider the following points for Class "T" ammonia machine rooms:

- The room must not contain any permanently installed flame-producing devices or hot surfaces over 427°C.
- The room's walls, floor, and ceiling must be sealed from the rest of the building and must be constructed to have at least a one-hour fire-resistance rating. All pipe openings must also be sealed.
- At least one exit door must open to the outside of the building. Any exit to another area in the building must be through a vestibule equipped with approved self-closing, tight-fitting fire doors.
- Exterior openings must not be under any fire escape or open stairway.
- Emergency controls to shut down the mechanical equipment must be located outside the machine room.

- The purpose of all valves must be conspicuously marked, and a schematic diagram of the system should be available.
- All electrical installations inside a building containing ammonia must be explosion-proof and must conform to the requirements of the applicable regulatory authority and *CSA Standard C22.1-06, Canadian Electrical Code Part 1*.
- The machine room must have an independent mechanical ventilation system. If the machine room is in a basement, the ventilation system must operate continuously. Machine rooms in any other locations must have
  - Continuous ventilation when they are operating or occupied, and
  - Mechanical ventilation to exhaust a potential accumulation of refrigerant if the ammonia detector is activated
- Ventilation fans must have a control switch on a separate circuit located outside the machine room. Ventilation fans must be allowed to run as long as power is available.

For more specific building design information, refer to the:

- Province of British Columbia Building Code
- Ammonia system manufacturer/supplier
- B.C. Safety Authority
- Power Engineers, Boiler, Pressure Vessel and Refrigeration Safety Regulation (PEBPV and RSR)
- *CSA Standard B52-05, Mechanical Refrigeration Code*

Ventilation

A suitable fan must ventilate the machine room and storage rooms. All ventilating fans must provide at least 15 air changes per hour, and must have switches outside the machine room even when an inside switch is installed.

Because ammonia gas is lighter than air and tends to collect at ceiling level, the suction of ventilating fans must be at or near ceiling level. Air inlets must be located to provide cross-ventilation using outside air.

Ammonia must not be discharged into areas where it may cause damage or injury, such as schools, worksites, private homes, or shopping centres. Ventilation exhaust must not be positioned where it can be captured by the air intake system of the same or another building.

As per *CSA Standard B52-05*, ventilation exhaust from a machinery room must be vertically upward from the roof. The system must have rated ducts with an upblast fan. The required rate of ventilation must be calculated

from the information contained in the Standard. The minimum stack height will be determined by the distance from the edge of the roof, in accordance with *Industrial Ventilation: A Manual of Recommended Practice.*

If a machinery room is not vented upward from the roof, modifications to the exhaust system are required to meet the specifications of *CSA Standard B52-05*.

Administrative control

Monitoring/alarm systems

An effective alarm system includes a monitor that constantly tracks ammonia levels and an alarm that responds if ammonia concentrations reach a certain preset level.

A 24-hour continuous ammonia monitor must be connected to the alarm system. In case of an ammonia leak or emergency, all facilities must have a working alarm that can be heard and seen by workers.

The continuous monitor needs to have a direct readout that can be seen from outside the enclosed hazard area. A digital readout is preferable, but a needle/scale is acceptable. The readout ensures that emergency response personnel know the actual concentration inside the enclosure. Knowing that the leak has developed an atmosphere below 35 ppm, between 35 and 300 ppm, or above 300 ppm allows emergency response personnel to make an informed decision with respect to the proper respiratory protection to be worn.

Without a direct readout from the monitor, every leak must be considered IDLH, as the ammonia concentration is unknown. This requires SCBA to be worn, with emergency backup, as outlined in the detailed emergency response procedures.

There are several commercial monitoring/alarm systems. Each type has advantages and disadvantages. Before buying an alarm system, consider its:

- Reliability
- Accuracy
- Response speed
- Calibration and system drift
- Operating temperature range
- Sensors (**Note** A monitor with an electrochemical sensor must have the sensor replaced after every alarm)

- Service and maintenance
- System testing

It is also important to determine what other gases may activate the alarm. You may need a more selective system if interfering compounds may be present in the facility. Equipment suppliers and other alarm system users can provide more information.

Basic alarm system requirements

- The system must be installed according to the manufacturer's instructions. Routine maintenance procedures and tests must follow a strict timetable, and records must be kept.
- Qualified workers must test and calibrate the system using the manufacturer's instructions. Systems must be tested for proper operation at least monthly and calibrated at least annually. Systems must also be tested and calibrated after any significant exposure. (See the manufacturer's instructions to determine what a significant exposure is.)
- Workers must know the ***alarm level*** (the ammonia concentration that triggers the alarm), and this information must be clearly posted outside the enclosure. Necessary safety precautions for any given concentration level must also be posted.
- The preset alarm level must be at or below 35 ppm. Alarm response procedures must account for minor leaks, which may not require the services of an emergency response team.
- The system must include a visible and audible alarm at the ammonia location, preferably connected to a radio or telephone system to alert the operator in case of an emergency.
- The system must be able to trigger exhaust ventilation automatically, although this will not be appropriate in all locations.
- If the alarm system reacts to compounds other than ammonia, it must be determined whether these interfering gases are present and, if so, whether they will affect the alarm's response to ammonia.

Detector tubes

Several hand-held ammonia detection systems are available. These systems use detector tubes to give a direct reading of ammonia concentration.

Workers must be properly trained in the use and maintenance of detector tubes. Unused detector tubes should be discarded after a shelf life of two years. Before each use, the pump must be checked using an unopened detector tube.

When taking measurements to determine the extent and severity of a leak outside the enclosure, workers must wear appropriate respiratory protection. (See *Choosing the right respirator,* page 27.)

Personal protective equipment

Controlling exposure requires strict attention to ammonia exposure limits. Appropriate respiratory, eye, and skin protection are essential. Workers should be familiar with and understand the requirements of their employer's written exposure control plan.

Eye protection

Because eye irritation from exposure to ammonia gas normally does not occur until concentrations reach about 70 ppm, eye protection is not mandatory under normal working conditions (in other words, below 25 ppm). All respirators, however, except escape respirators, must provide full face protection or be used with effective eye protection.

Skin protection

Workers who are controlling any liquid ammonia leak must have access to full-body protective suits. This equipment must also be available to workers exposed to airborne ammonia concentrations above 300 ppm for more than a few minutes, which causes immediate irritation of moist body areas. (Ammonia reacts instantly with moisture.)

Respiratory protection

This section outlines the types of respirators available to protect workers from exposure to ammonia, and the limitations of each respirator. Choosing the right respirator must be based on both the needs of each individual worksite and the requirements of the employer's written safe work procedures.

Full facepiece respirators with cartridges

When the ammonia concentration is shown to be greater than 35 ppm, workers must wear a full facepiece respirator fitted with a chemical cartridge that protects against ammonia exposure. Full facepiece respirators with cartridges are also appropriate for leak control where tests show the ammonia concentration to be less than 300 ppm (IDLH level).

Full facepiece respirators with canisters

Although cartridges are both adequate and preferable, workers may use a full facepiece respirator fitted with an air-purifying canister for leak control and repair or maintenance procedures in ammonia concentrations less than 300 ppm.

Notes

1. If the concentration of ammonia is greater than 300 ppm, cartridges or canisters cannot be worn, and a self-contained breathing apparatus (SCBA) must be used.
2. Canisters with an indicator window must be replaced when the material in the window has changed colour. Canisters or cartridges without an indicator window must be replaced after each use. In either case, canisters must never be used after the expiration date stamped on the label.

To ensure that the respirator fits properly, workers must be clean-shaven where the respirator seals with the face.

Half facepiece respirators with goggles

Workers working in air contaminated by ammonia vapour in concentrations up to 250 ppm may use half facepiece respirators. Because ammonia vapour causes immediate eye irritation, workers must always use gas-rated, vapour-tight chemical goggles with half facepiece respirators.

Self-Contained Breathing Apparatus (SCBAs)

Workers must use SCBAs when the ammonia concentration is unknown or is measured at more than 300 ppm. A worker wearing an SCBA must not enter a contaminated atmosphere until a second qualified person is present, also equipped with an SCBA and ready to perform a rescue.

Escape respirators

Two types of escape respirators are acceptable: bite-block respirators and half facepiece cartridge respirators. Bite-block respirators must be worn with a nose plug. Anyone entering an ammonia enclosure for any reason must carry an escape respirator and keep it within arm's reach at all times.

Bite blocks are often used by workers in pulp mills and chemical manufacturing plants.

SCBAs provide air from a cylinder that is carried by the wearer.

Choosing the right respirator

The correct selection of respiratory protection requires an accurate knowledge of the ammonia concentration in the hazard area.

Situation	Ammonia concentration	Respirator choice
Routine work in ammonia room; leak occurs	Unknown; exit room immediately	Escape respirator
Working on ammonia system; chance of leak	Unknown; exit room immediately if leak occurs	Full facepiece respirator
Leak occurs; enter to repair	35–300 ppm	Full facepiece respirator
	300 ppm or more*	SCBA
	Unknown; always assume IDLH level	SCBA

* Concentrations above 300 ppm also require full skin protection.

Person-check radio/telephone

Employers must establish a check system to ensure the continued well-being of workers who are working alone or at an isolated worksite. Where visual checks are not possible, the check system may require a radio or telephone. Workers who will need to use such a system must be trained in the written procedure.

Emergency equipment

Emergency equipment includes eye wash and shower facilities and first aid kits. Workers must have immediate access to each of these items and must know how to use them in case of emergency. Emergency equipment is covered in more detail on page 14. For first aid information, see page 29.

For more detailed information on personal protective equipment, contact:

- Ammonia suppliers
- Equipment manufacturers
- Safety equipment suppliers
- WorkSafeBC offices (listed at the end of this manual)

First aid

When someone is injured in an ammonia-related accident, first aid can help reduce the impact of their injuries and prevent further injuries from occurring. The following steps apply to any situation in which someone is injured:

1. Do not panic.
2. Ensure that there is no more danger to yourself or the victim.
3. Using appropriate safety gear, remove the victim from the contaminated area.
4. Send for medical help.

Ammonia inhalation

Someone who has inhaled ammonia may be unconscious, and may have difficulty breathing or may have stopped breathing completely. Follow these steps when treating a victim of ammonia inhalation:

1. Assess the victim's breathing:
   - If breathing has stopped, begin artificial respiration and continue until the victim resumes breathing. (Mouth-to-mouth and pocket masks are the most effective methods of artificial respiration.)
   - If the victim is having difficulty breathing (gasping, coughing), place the victim in the most comfortable position, usually semi-sitting.
2. If an oxygen therapy unit and trained personnel are available, administer oxygen at a 10-litre flow.
3. Ensure that the victim is transported to hospital in case the victim suffers a delayed reaction in the form of pulmonary edema. Any physical exertion, excitement, or apprehension increases the chances and severity of a delayed reaction. Keep the victim warm and completely at rest. Reassure the victim while waiting for assistance and transportation to hospital by ambulance.

Unconscious patients

As soon as they resume breathing, always place unconscious patients in the drainage position (on their side, so fluids can drain from the mouth and airways). Never give an unconscious patient anything by mouth.

Skin contact

Skin contact with ammonia can result in severe—even fatal—burns. Before attempting to flush a victim's contaminated skin, make sure the victim is breathing properly. Follow these steps:

1. Assess the victim's breathing:
   - If breathing has stopped, begin artificial respiration and continue until the victim resumes breathing. (Pocket masks are recommended for artificial respiration, although the mouth-to-mouth method may also be used.)

- If the victim is having difficulty breathing (gasping, coughing), place the victim in the most comfortable position, usually semi-sitting.

2. As soon as the victim resumes breathing, flush the victim's contaminated skin and clothing with large amounts of water for 30 minutes.
3. Remove all contaminated clothing while flushing.
4. Continue flushing until all traces of ammonia have been removed.
5. Dress obvious burns with sterile gauze and bandage them loosely. Apply insulated cold packs to help reduce pain.
6. Call for an ambulance to take the victim to a hospital.

Notes

1. Do not attempt to neutralize the ammonia with other chemicals.
2. Do not apply salves, ointments, or medications unless prescribed by a doctor.
3. Skin contact with liquid ammonia or an ammonia gas stream leaking under high pressure can cause frostbite. Pure liquid ammonia can cause severe burns.

Eye contact

Eye contact with liquid ammonia for even a short period can cause permanent disability such as blindness. Flushing must begin within 10 seconds. Follow these steps:

1. Flush the eyes immediately with large amounts of running water (preferably lukewarm) if:
   - Any amount of liquid ammonia has entered the eyes
   - Exposure to gaseous ammonia causes persistent eye irritation
2. Hold the eyelids apart forcibly to ensure full flushing of the eyes and eyelids.
3. After flushing has removed all traces of ammonia, cover both eyes with moistened sterile gauze pads and bandage enough to keep light out.
4. Apply insulated cold packs to help reduce pain.
5. Call for an ambulance to take the victim to a hospital.

Notes

1. Do not attempt to neutralize the ammonia with other chemicals.
2. Do not apply oils, ointments, or medications to the eyes.

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