Ammonia Handling Manual

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Ammonia Handling Manual
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Warning

- Ammonia is a hazardous chemical that can cause injury and death if not handled properly. This manual contains only general information on the physical properties, storage, and handling of ammonia containers and relevant equipment. It is not intended to replace or limit safety procedures in your facility.
- Safety procedures in an industrial setting must be designed in accordance with all governmental regulations and national safety codes, after giving full consideration to the specific needs of the industrial facility involved. Under no circumstances should the information in this manual be construed as substituting or superseding any local, state, or federal laws and regulations.
- Hydro Instruments cannot anticipate the specific safety procedures required at every industrial facility. Accordingly, Hydro Instruments does not guarantee that safety procedures designed in accordance with this manual will completely eliminate hazards and thus assumes no liability for accidents that may occur in your facility.
- Read this entire manual and be fully familiar with your equipment and your entire industrial system so that the safety procedures you establish will meet the needs of the employees in you facility. Reading only part of the manual will not help you analyze the needs of your facility. Contact your ammonia suppliers, and other similar organizations to obtain any MSDS and/or more information.
- All information in this manual was current at time of printing. Please note the date of printing and possible obsolescence of material as a result of scientific and medical developments after the date of publication. This applies to all materials you review in the course of developing safety procedures for use at you facility.

When working with Ammonia

- Ensure that approved, self-contained breathing apparatuses are always available and personnel are properly trained for its use.
- Safety equipment should be inspected and maintained in accordance with the manufacturer's instructions.
- Ensure that all warning signs and placards are in their appropriate place and can clearly be displayed.
- In the event of a leak, use proper safety equipment and trained personnel to respond to the leak immediately. Evacuate all personnel in a dangerous area to a safe space. If breathing has stopped perform respiration immediately. If heart has stopped perform CPR.
- Knowledgeable design personnel should oversee and approve equipment installation and suitability of the system for which it is intended. Qualified personnel should also perform routine equipment checks and maintenance in accordance with manufactures recommendations and instructions.

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I. INTRODUCTION

Warning: Ammonia is a hazardous and dangerous chemical. Take extreme care when handling and follow all pertinent safety rules and regulations.

This manual was designed for the reader to understand the proper handling, storage, service and delivery of ammonia. This manual should be read fully and understood before handling any containers or equipment. It is also suggested that the reader read all relevant material safety data sheets and contact your chemical supplier for more information.

II. AMMONIA USES AND PROPERTIES

Ammonia is widely used in the water and wastewater treatment industry to create chloramines for disinfectant purposes. Chloramines can provide adequate disinfection without as much generation of the harmful disinfectant by-products. Ammonia is also used in the production of fertilizer, as the primary ingredient in smelling salt, and many other chemical industries.

In commerce, ammonia is stored as a liquefied gas under pressure. It is colorless in both the gas and liquid phases, but ammonia gas is easily detected by its characteristic sharp, pungent odor at high enough concentrations. In the absence of moisture, ammonia is a relatively non-corrosive substance. However, in the presence of moisture is becomes a highly corrosive compound. This is important as there are many grades of ammonia available, all with different moisture content. Review with the chemical supplier as to what grade should be used. Ammonia gas and liquid can be lethal to human life above certain concentrations (see section III) by attacking the skin and lungs/respiratory system. Ammonia is not considered a fire hazard at normal operating conditions. However, at temperatures above 1562 ˚F (850 ˚C) fires can occur in air at ammonia concentrations of 16-25 %. Ammonia can also form explosive compounds with bromine, chlorine, iodine, mercury, silver oxide, or hypochlorites so exposure and the potential of exposure of ammonia to chemicals should be avoided. Extreme caution should be used when dealing with ammonia and material safety data sheets should be read and understood before handling. Other important properties can be found in table 1.

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Table 1. Chemical Properties of Gaseous and Liquid Ammonia

Property	English Units	SI Units
Ammonia, gas		
Density	0.045 lb./ft^3 (15 psia; 60 ˚F)	0.73 kg/m^3 (1.013 bar; 15 ˚C)
Compressibility factor	0.9929 (15 psia; 60 ˚F)	0.9929 (1.013 bar; 15 ˚C)
Heat capacity (C_p)	0.523 Btu/(lb. F) (15 psia; 60 ˚F)	0.037 kJ/(mol K) (1 bar; 15 ˚C)
Thermal conductivity	.013 Btu/(hr. ft. F) (15 psia ; 32 ˚F)	22.19 mW/(m K) (1 bar; 0 ˚C)
Ammonia, liquid		
Density	42.6 lb./ft^3 (15 psia; -28.2 ˚F)	682 kg/m^3(1.013 bar; -33.5 ˚C)
Liquid/gas equivalent	1:947 vol/vol (15 psia; 60 ˚F)	1:947 vol/vol (1.013 bar; 15 ˚C)
Latent Heat of Vaporization	589.5 Btu/lb. (15 psia; -28.2˚F)	1371.2 kJ/kg (1.013 bar; -33.5 ˚C)

Figure 1. Vapor Pressure Curve of Ammonia Gas

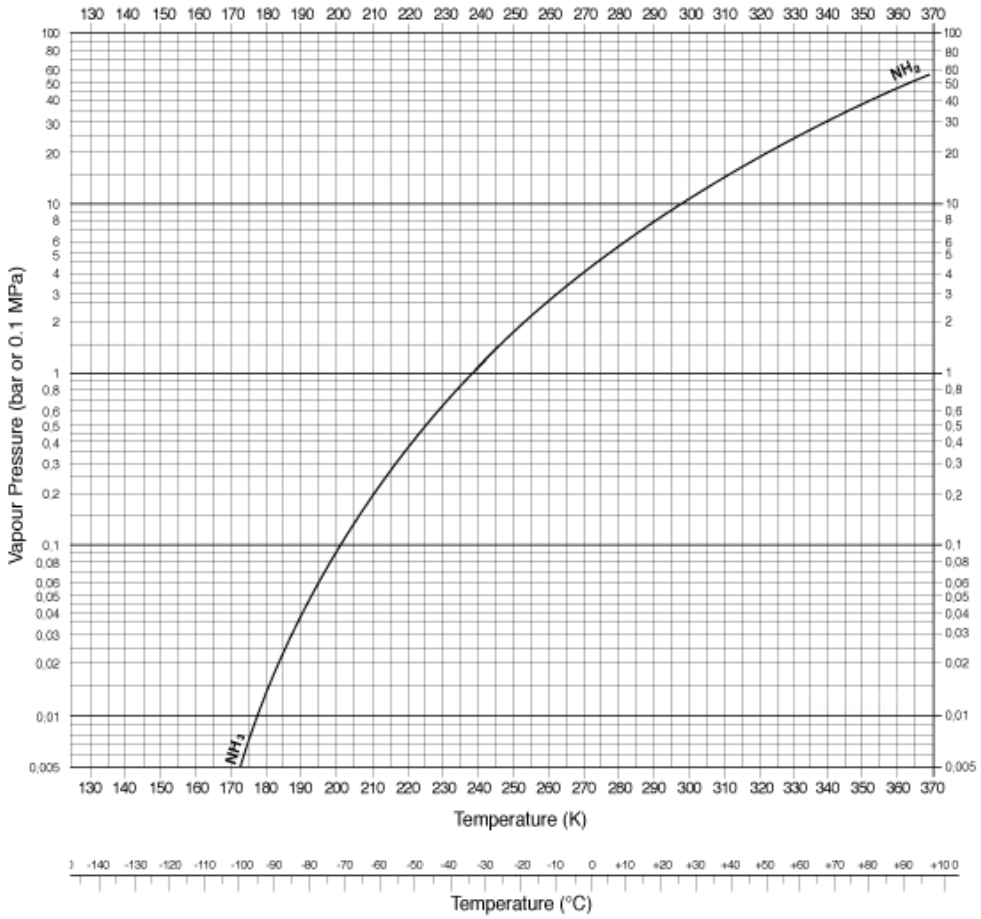

Image from: encyclopedia.airliquide.com. Air liquide

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III. SAFETY INFORMATION

1. General Health Hazards, Emergency Equipment & Emergency Action Plans:

Ammonia's primary health concern is that it will attack the respiratory system, mucous membranes in the eyes, and the skin leading to severe injury or death. Ammonia's odor is strong enough that it can be detected at levels around 5 ppm and most people will detect it around 20 ppm. Symptoms of ammonia gas inhalation include: eye irritation, coughing, throat irritation, vomiting, and labored and difficulty breathing. Contact with liquid ammonia can also cause burns, irritation and frostbite. If any of these symptoms exist leave the area immediately. **Ammonia gas sensors should be installed everywhere appropriate**. If conditions exist, notify the appropriate personnel. If breathing has stopped then qualified personnel should perform respiratory measures until a medical team arrives. If heart stops, perform CPR.

The American Conference of Governmental Industrial Hygienists (ACGIH) has established a threshold limit of exposure to ammonia gas to 25 ppm for a 8 hour a day, 40 hour work week (the threshold limit will change based on the amount of time spent in the environment). Once ammonia levels reach 35 ppm, the concentration is considered immediately dangerous to life and health and the room should be vacated immediately and not be entered unless wearing proper respiratory and other personal protective equipment (PPE) and should only be entered by appropriately trained personnel using the buddy system (a system in which two people are accountable for the welfare of each other). The best respirators for dealing with leaks can depend on the size of the leak, but they should meet the NIOSH safety requirements for dealing with ammonia. Air tank type pressure demand masks with a self contained air supply are a good choice as they can be used regardless of the size of the leak. Escape type respirators should also be available for any personnel in rooms where leaks may occur. All safety equipment should be located outside of the ammonia feed room and be easily accessed by all personnel. **Do not lock up equipment.**

Emergency kits are available that can seal off most leaking areas of ammonia containers. Only trained personnel familiar with this equipment should use these kits. If a ton container is leaking it is good practice to orient the container so that only gas is escaping.

Emergency action plans should be determined before setting up the ammonia system and reviewed by the chemical supplier and the agency in your area responsible for handling chemical disposal. For assistance developing an emergency action plan or providing respiratory and personal protective equipment, contact your chemical supplier, or OSHA. In the event of an emergency, you may also use CHEMTREC (United States). This is a 24/7 emergency response line, their number is 1-800-424-9300. Those who call this number should be able to provide the operator the name of the facility, the address, the phone number, contact information for other personnel, the type of leak, the action already taken, weather conditions, injuries, and directions. Leaks over 100 lbs. must also be reported to the National Response Center.

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It is always good to practice emergency action plans and provide proper and routine maintenance to the equipment in order to prevent and quickly respond to leaks. Be sure to always replace gaskets and check piping. **Ammonia leaks never get better, they should be responded to immediately.**

If the container is stored in the area of a fire, it should be removed to a safe area; if this is not possible then water should be sprayed on the container to keep it cool. Ammonia is flammable at high enough temperature, but also a pressure build up can occur resulting in an explosion if left in the area.

Warning: Never use water on a leaking ammonia container; this can cause rapid corrosion of the metals making the leak worse or increase the leak rate if the water temperature is hotter than the gas.

If ammonia is in contact with skin or clothes move to the nearest, safe emergency shower and use immediately. Clothing should be removed while showering and skin should be washed with large amounts of water for at least 15 minutes. Do not attempt chemical neutralization on skin unless recommended by an appropriate physician.

If ammonia is in contact with the eyes move to the nearest, safe eye wash or sink (if no eye wash is available) flush eyes with large amounts of warm, low flow water. Do not attempt chemical neutralization on the eyes unless recommended by an appropriate physician.

Material safety data sheets, as well as other important ammonia documentation should be on site for operator and emergency personnel reference.

2. Ammonia Storage Facilities:

Buildings used to hold ammonia containers and equipment should comply with all local building and fire codes. If the storage facility is to have any flammable materials inside then a fire wall must be built to segregate the two areas. Non-combustible building material is recommended and ammonia gas monitors should be installed in the facility. Ammonia gas is lighter than air so gas monitors should be mounted approximately two feet below the ceiling for quick and accurate detection. All facilities should be designed with at least two outward opening exits. Ventilation should be installed in accordance with local building codes. The facility should not have any heavy objects placed above the containers, nor should the containers be placed near elevators or other quick leak paths. Ammonia storage facilities should be maintained at 60-70 ˚F (15-20 ˚C) to facilitate safe and consistent discharge rates of ammonia. **Never apply heat directly to a ammonia container** as a malfunction could result in a large pressure build up leading to an explosion/leak. Take special care to avoid restrictive spaces in working areas.

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IV. AMMONIA CONTAINERS

1. Containers

The most common ammonia cylinders contain 100 to 150 pounds of ammonia. All cylinders as well as other containers must conform to appropriate DOT standard to be certified for use. Common sizes and weights can be seen table 2.

Moving ammonia cylinders should be done with the utmost care and with a hand truck which has restraint chains to secure the cylinder. Never move a cylinder with a sling or magnetic devices or lift by the neck ring. If lifting is absolutely necessary, then there are specially designed slings that can be purchased. **Always handle cylinders with extreme care and avoid contact between cylinders.** Once the cylinders are in place, they should each be individually chained to the wall to prevent the cylinders from falling.

Table 2. Sizes and Dimension of Ammonia Containers

Type of Container	Net Weight	Tare Weight	Gross Weight	Outside Diameter	Length
Cylinder	100 150 lbs.	191-237 lbs. 288-348	291-337 lbs. 438-498	12.25”-12.5” 14.75”-15”	4’8”-4’11” 4’10”-5’
Ton Container	Vary	Vary	Vary	Vary	Vary
Tank Car	Vary	Vary	Vary	Vary	Vary

Ammonia cylinders do not commonly have fusible plugs or any type of pressure relief device on their cylinder valve, or container. Pressure relief devices for ammonia containers are only required for containers carrying an excess of 165 pounds.

Ammonia cylinders are only designed for gas withdrawal and have one header valve which can have many different CGA threads based on the container chosen. However, the most common is the CGA 240 valve which has an 3/8-18 NGT-RH-INT outlet thread.

Larger storage tanks, know as storage drums, ton containers, or in even larger applications tank cars can come in a wide variety of sizes. These containers must also be certified by the appropriate department of transportation before use. Storage tanks over 165 pound capacity must have some sort of pressure relief device located on the container. Outlet of tank cars are commonly 1” ANSI standard taper pipe thread. They commonly use 2 valves for liquid withdrawal and 2 valves for gas withdrawal. Contact your chemical supply or the compressed gas association for more information pertaining to your specific container.

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2. Withdrawal Rates

In general, a dependable withdrawal rate from a 100/150 pound cylinder is around 0.4 lb./day/(˚F), assuming a minimum liquid ammonia temperature of 70 ˚F. Withdrawal rates from larger container will vary based on size. Contact your chemical supplier for more information. Gas withdrawal rates can be increased for brief periods of time (usually at the start of feed) if necessary, but if prolonged will lead to pipe sweating and frost formation on the pipes. If a larger feed rate is required the best practice is to manifold containers together or use a vaporizer. **Never apply heat directly to a container**, in this case the gas temperature could get too hot and result in an explosion due to pressure build-up and/or a leak.

Liquid withdrawal from storage containers can reach feed rates considerably higher. Contact your chemical supply for liquid withdrawal rate information.

The withdrawal rates are primarily based on the temperature of the liquid in the cylinder, and thus the pressure of the gas. For low withdrawal rates, heat will be able to be transferred from the surrounding air to the container in time so that there is no drop in temperature or pressure, resulting in a constant withdrawal rate. If the feed rates are large enough, the air will not be able to transfer the heat quickly enough and the temperature (and pressure) of the ammonia will drop, thus resulting in a lower feed rate. If high enough and prolonged enough, this can even result in ice formation around the outside of the container, further decreasing the withdrawal rate. The most effective way to increase withdrawal rate from a single container is to circulate the surrounding air with a fan. Again, never apply heat to the containers.

If the gas withdrawal rate from one container is not enough, then multiple containers can be manifolded together.

V. STORAGE AND USE OF CONTAINERS

Any type of ammonia container should be kept in a cool, dry, temperature stable environment generally around 60-70 ˚F (15-50 ˚C). They should also be kept out of direct sunlight and securely mounted on either trunions (containers) or chained to a wall (cylinders). Operators, especially in earthquake prone areas, may want to secure containers to the ground by strapping them to the floor. The storage area should be well ventilated and free of flammable materials (see section III.2). If stored outdoors, the containers should be fenced off so that only proper personnel can reach them. Containers should not be stored below ground or in heavily trafficked areas. Anywhere ammonia is being stored or there is a possible chance for a leak. An ammonia gas monitor must always be installed. Measures should be taken to control the temperature of the chemical storage room to prevent abnormally high temperatures leading to dangerous pressure build-ups in the storage containers.

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Full and empty containers should be stored separately. Cylinders should always be stored in an upright position and properly secured using chains. Avoid contact between cylinders or any situations where objects will contact cylinders.

In most cases, state and/or local regulations will limit the amount of ammonia that can be stored on site, be sure to check with all the regulations before purchasing.

Do not remove the protective cap from cylinders or ton containers unless they are ready to be used. It is good practice to use the containers that have been in storage the longest before using newer ones.

When in use, it is ideal to have a separate scale for each container tared to its specific weight so that you can monitor chemical supply. There are many different types of scales for cylinders, containers, and even tank cars. Scales should be kept as flat with the floor as possible to minimize lifting of the containers. The only exception is with ton containers as they are normally stored on trunnions which are lifted off the ground.

If moving the containers from a storage area to a feed area, an adequate amount of time should be allowed to let the temperature and pressure of the cylinder stabilize before beginning to feed. All containers that are manifolded together should be at the same elevation, temperature and pressure before feeding.

If feeding from large containers make sure that two valves are in vertical alignment, and use the top valve for gas withdrawal and the bottom valve for liquid withdrawal.

VI. PRESSURE MANIFOLDING, PIPING AND OTHER AMMONIA LINE ACCESSORIES

In some instances, ammonia vacuum regulators can be mounted directly onto the cylinder/container valve using a specially designed yoke included with the unit and no pressurized piping is required. To mount the vacuum regulator onto the container valve, first place a lead gasket on the inlet assembly and then put the yoke around the container valve. Tighten the screw on the yoke with the specialty wrench until it is firmly sealed in place.

If larger feed rates are required and direct mounting is not feasible then manifolding the containers is required. There is special equipment that goes along with the procedure and it will be described in the remainder of this section.

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1. Auxiliary Valves

It is strongly recommended that auxiliary valves be used on all container header valves. This will greatly reduce the chances of ammonia leaks and increase the lifetime of the flexible connectors. Auxiliary valves can also be used to prevent air from entering the flexible connectors and manifold piping. Auxiliary valves come with a yoke for mounting onto the container valve with a lead gasket and an adapter to fit around the thread. This leads out into another header valve where the flexible connector can be attached. The auxiliary valve allows for gas to be shut off right at the container. See figure 6 for a detailed auxiliary valve drawing.

Figure 6. Auxiliary Valve for Container Connection

Hydro Instruments' IV-1A

2. Flexible Connectors

Flexible connectors are available in various lengths, but the most common are 4', 6', 10', and 16'. Flexible connectors are commonly constructed from steel tubing.

3. Manifold/Pressurized Piping

All piping that leads up to the vacuum regulator will be under pressure and must follow strict safety precautions and regulations. Pressurized piping lines should be kept as short as possible in order to minimize the chance of pressurized leaks. If constructing a manifold for ton container gas withdrawal the piping should also be equipped with a drip leg and heater to vaporize any liquid ammonia that may enter the line. Piping should consist of schedule 80 seamless carbon steel A-106, grade B and fittings should be 3000 psi rated carbon steel A-105. Teflon tape or litharge glue should be used on all joints, or they can be socket welded. The most common diameter piping is ¾" or 1" pipe.

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4. Valves

There are many varieties of ball valves that can be used for pressurized ammonia service such as ball valves, line valves, angle vales etc. They must be compatible with pressurized ammonia which usually makes their material of construction a carbon steel body, with stainless steel internals although other compatible materials may be available. Ball valves must also come with a provision for venting the cavity in the closed position to the upstream side.

5. Pressure Gauges

Many types of pressure gauges can be used. However, due to the corrosive nature of ammonia they should be diaphragm protected by a material suitable for ammonia use. The pressure gauge must remain connected to the diaphragm seal at all times or the gauge will not function accurately.

6. Expansion Chambers (for liquid service)

Expansion chamber are a necessary component of any liquid ammonia line. Due to ammonia's large coefficient of expansion, any liquid that is trapped in the pipeline could expand rapidly and burst the pipe should the temperature of the room increase. Expansion chambers provide pressure relief to avoid such a leak. They consist of a rupture disc and holder assembly, a pressure switch and an expansion chamber. The rupture disc is designed to burst should the pressure in the pipeline exceed safe limits, and then the gas will expand into the expansion chamber, thus relieving the pressure. The pressure switch is for indication that the disc has burst. The volume of the expansion chamber should cover at least 20% of the volume of pipeline it is to protect.

7. Pressure Reducing Valves:

Pressure reducing valves are used to help prevent liquefaction downstream of the valve, and to prevent inlet pressures into the regulator from being too high. Damage to regulators can occur at inlet pressures above 150 psig. To prevent liquefaction of ammonia gas, the pressure reducing valve should be set no higher than 40 psig. The pressure reducing valve must be of the self-actuating spring loaded type, or pneumatically, hydraulically or electrically actuated type.

8. Vaporizers:

Most liquid feed applications call for the use of an evaporator to vaporize the incoming liquid into a gas rather than inject liquid ammonia. Most commercial vaporizers can vaporize up to 2,500 PPD of liquid ammonia. Vaporizers usually consist of an ASME certified Carbon Steel welded pressure vessel immersed in hot water or steam. Appropriate control features are also included to monitor vaporizer performance and operating conditions.

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VII. PREPARING PIPING FOR USE

Often times in pressurized ammonia piping systems, oil, water and other chemicals can exist in the pipe before initial start-up. These dangerous components must be flushed out of the system before the ammonia is introduced or rapid pipe corrosion can be occur and create a leak. All equipment for handling ammonia received in an oily condition should be cleaned before use. Passing hot steam through the lines is a generally accepted method of cleaning. Contact your chemical supplier for more cleaning information.

Drying of the pipe is the most essential step in preparation for ammonia use. This will eliminate any moisture buildup inside the pipe. Drying can be performed after cleaning by passing dry air or an inert gas, such as nitrogen, through the lines while the pipe is still hot until the dew point of the discharge gas is below -40 F. Certain provisions must be followed when drying the pipes, especially when dealing with the high pressures of nitrogen gas. Contact your chemical supplier for more information.

ammonia piping systems should be pressure tested with an inert gas, such as nitrogen, before use and test pressures should 1.5 times the maximum operating pressure. All components which could become damaged during the pressure test should be isolated.

Leak testing with ammonia gas should also be perform after pressure testing with nitrogen. For this hook up the piping to the ammonia **GAS** lines, as using liquid lines can result in a more serious leak due to its coefficient of expansion. Once the piping is connected to the gas line open the valve temporarily and shut once the pressure reaches a sufficient level. Check for leaks around the piping by using either moist phenolphthalein or red litmus paper. If an ammonia gas leak is present the litmus paper and/or the phenolphthalein will change color. Take appropriate measures to fix the leak and retest.

VIII. VACUUM PIPING AND OTHER AMMONIA LINE ACCESSORIES

Vacuum lines consist of piping from the vacuum regulator to the ejector. The most common material used to Polyethylene. Table 3 shows a guide for the appropriate selection of tubing based on feed rate and distance. Tubing under ¾" is Polyethylene and larger is PVC.

Ball valves for vacuum piping can also be made from PVC but should also come with a provision for venting the cavity in the closed position to the upstream side.

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Table 3. Tube Diameter for Vacuum Feed

Gas Feed Rate	100 ft.	200 ft.	300 ft.	500 ft.	1000 ft.	1500 ft.
50 PPD / 1 kg/h	3/8”	3/8”	1/2”	1/2”	1/2”	5/8”
100 PPD / 2 kg/h	3/8”	1/2”	5/8”	5/8”	3/4”	3/4”
250 PPD / 5 kg/h	1/2”	5/8”	3/4”	3/4”	1”	1”
500 PPD / 10 kg/h	5/8”	3/4”	1”	1”	1-1/2”	1-1/2”
1000 PPD / 20 kg/h	1”	1”	1-1/2”	1-1/2”	1-1/2”	1-1/2”
2000 PPD / 40 kg/h	1”	1-1/2”	1-1/2”	2”	2”	2”
4000 PPD / 80 kg/h	1-1/2”	1-1/2”	2”	2”	2”	3”
6000 PPD / 120 kg/h	1-1/2”	2”	2”	2”	3”	3”

NOTES:
1. In the above table:
   a. 3/8”, 1/2” and 5/8” refer to the OD (outer diameter) of flexible polyethylene plastic tubing.
   b. 3/4”, 1”, 1-1/2”, 2” and 3” refer to Schedule 80 PVC rigid piping.

2. The above recommendations are based on calculations limiting friction loss to 0.5” Hg or less.

IX. AMMONIA ABSORPTION AND DISPOSAL

If a leak occurs at the facility, the best option if available would be to run the ammonia through the regular ammonia consuming/injection process, or run a temporary line to the consuming point. If the process cannot allow this, then an ammonia scrubber/absorption system should be considered.

A simple absorption system (scrubber) will consist of materials capable of holding a the materials and by-products present. Generally, this will hold a water solution which is capable of absorbing 1 pound of ammonia per 10pounds of water. Another common method is to use a dilute sulfuric acid solution which will neutralize the ammonia into a salt. Ammonia scrubber systems can be very complex and should be installed only after given appropriate engineering consideration.

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