

CGA G-2—2021

ANHYDROUS AMMONIA

NINTH EDITION

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NOTE—Technical changes from the previous edition are underlined.

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Contents	Page
1 Scope and purpose	1
1.1 Scope	1
1.2 Purpose	1
2 Definitions.....	1
3 Ammonia identification and classification numbers	6
4 Composition, synthesis, and specifications	7
4.1 Composition.....	7
4.2 Synthesis	7
4.3 Specifications	7
5 Properties	7
5.1 Physical properties	7
5.2 Chemical properties.....	14
6 Commercial uses.....	18
7 Jurisdictional authorities and general regulations	19
7.1 General.....	19
7.2 United States	20
7.3 Canada.....	21
7.4 International transportation.....	21
7.5 Shipping description and hazard class.....	21
7.6 Container qualification	22
7.7 Filling density	22
8 Ammonia exposure	22
8.1 General.....	22
8.2 First aid.....	23
8.3 Physiological effects	24
9 Emergency planning and response coordination	25
9.1 Controlling leaks	25
9.2 Fire exposure.....	26
9.3 Emergency response planning	26
10 Safety, security, and training	27
10.1 General safety	27
10.2 Safety equipment and protective clothing.....	27
10.3 Security.....	28
10.4 Training.....	29
11 Tank cars.....	29
11.1 Description.....	29
11.2 Fabrication.....	30
11.3 Stamping, stenciling, and marking.....	31
11.4 Placarding and painting	32
11.5 Filling density	32
11.6 Loading and shipping	32
11.7 Receiving.....	33
11.8 Handling and unloading.....	34
11.9 Preparing tank car for return.....	37
11.10 Repairs	37
11.11 Leaks	38
11.12 Incidents	38

12	Cargo tank motor vehicles.....	38
12.1	Description.....	38
12.2	Fabrication.....	39
12.3	Requalification and maintenance	43
12.4	Marking, placarding, and painting	45
12.5	Filling density.....	46
12.6	Loading and shipping	47
12.7	Receiving and unloading	49
12.8	Repairs	50
12.9	Leaks	50
12.10	Incidents	50
13	Portable tanks	51
13.1	Description.....	51
14	Cylinders	51
14.1	Description.....	51
14.2	Fabrication.....	52
14.3	Requalification, repair, and maintenance	55
14.4	Marking, labeling, and painting.....	58
14.5	Filling density	60
14.6	Filling authorization, transfilling, and filling	60
14.7	Shipping.....	62
14.8	Receiving, handling, and storage	63
14.9	Ammonia withdrawal	64
14.10	Empty cylinders	67
14.11	Leaks	68
14.12	Incidents	68
15	Barges and ships.....	68
16	Pipelines.....	69
16.1	General.....	69
16.2	Service.....	69
17	Stationary containers.....	69
17.1	Description.....	69
17.2	Fabrication.....	70
17.3	Supports	71
17.4	Appurtenances	71
17.5	Valves.....	74
17.6	Piping.....	74
17.7	Manway	75
17.8	Nameplate and marking	75
17.9	Manufacturer's data report	75
17.10	Painting.....	75
17.11	Installation	75
17.12	Location.....	76
17.13	Protection of container.....	77
17.14	Maintenance and periodic inspection	77
17.15	Filling density (volume).....	79
17.16	Ammonia filling	80
17.17	Ammonia withdrawal	81
17.18	Leaks	82
17.19	Incidents	82
17.20	Refrigerated containers	83

18	Piping and equipment.....	83
18.1	General.....	83
18.2	Piping.....	83
18.3	Gaskets	86
18.4	Pressure relief devices	86
18.5	Pressure gauges	86
18.6	Flow indicators.....	87
18.7	Strainers	87
18.8	Pressure regulators	87
18.9	Metering devices	88
18.10	Automatic vacuum breakers.....	88
18.11	Equipment	88
18.12	Electrical equipment and wiring.....	90
19	References	91

Figures

Figure 1—Vapor pressure temperature curve for ammonia (U.S. customary units) [22]	8
Figure 2—Vapor pressure temperature curve for ammonia (SI units) [22]	9
Figure 3—Density temperature curve for liquid ammonia (U.S. customary units) [22]	13
Figure 4—Density temperature curve for liquid ammonia (SI units) [22]	14
Figure 5—Solubility curve for ammonia in water (U.S. customary units) [32]	16
Figure 6—Solubility curve for ammonia in water (SI units) [32]	17
Figure 7—Tank car (80 ton capacity) DOT Specification 112S340-W.....	30
Figure 8—Manway and fittings arrangement for tank cars of classes DOT-105J, DOT-112J, and DOT-112S.....	31
Figure 9—Example of a piping arrangement for ammonia tank car unloading with vapor pump or compressor	36
Figure 10—DOT specification MC-331 tank truck.....	39
Figure 11—DOT specification MC-331 semitrailer transport	39
Figure 12—Typical ammonia cylinders	52
Figure 13—Ammonia cylinder valve with CGA standard outlet connection No. 240, 3/8-18NGT-RH-INT	54
Figure 14—Yoke connection to an ammonia cylinder valve	54
Figure 15—Example of an ammonia cylinder manifold system arrangement for supplying vapor	67
Figure 16—Storage tank for nonrefrigerated ammonia.....	70

Tables

Table 1—Physical properties [23, 24]	10
Table 2—Properties of liquid ammonia at various temperatures	11
Table 3—Thermodynamic properties of saturated liquid and vapor ammonia [25].....	12
Table 4—Human physiological response to various concentrations of ammonia in air	24
Table 5—Regulatory ammonia exposure limits [10]	24
Table 6—Emergency response planning guideline (ERPG) exposure limits [44]	25
Table 7—Maximum permitted filling volumes for nonrefrigerated storage containers	34
Table 8—Requalifying periods, re-inspections, and retests required for MC-330 and MC-331 cargo tanks authorized for ammonia service.....	45
Table 9—Nominal capacities, approximate tare weights, and dimensions of commonly available ammonia cylinders.....	52
Table 10—Requalifying periods, reinspection, and pressure retest required for typical cylinders authorized for ammonia service	56

1 Scope and purpose

1.1 Scope

The information in this publication is intended for use by ammonia shippers, carriers, distributors, consumers, equipment designers or installers, safety administrators, and others desiring introductory knowledge of the subject. Anyone requiring more detailed or specialized information should consult with an ammonia supplier.

1.2 Purpose

The purpose of this publication is to provide information regarding properties, production, shipping, storage, handling, and use of ammonia. It also describes regulatory requirements in the United States and in Canada as well as safety and security practices. This information is intended to complement, but not to supplant national, state, provincial, municipal, and insurance company codes or safety requirements.

2 Definitions

For the purpose of this publication, the following definitions apply.

2.1 Publication terminology

2.1.1 Shall

Indicates that the procedure is mandatory. It is used wherever the criterion for conformance to specific recommendations allows no deviation.

2.1.2 Should

Indicates that a procedure is recommended.

2.1.3 May

Indicates that the procedure is optional.

2.1.4 Will

Is used only to indicate the future, not a degree of requirement.

2.1.5 Can

Indicates a possibility or ability.

2.2 Technical definitions

2.2.1 Air purifying respirator

Air-purifying device with full face piece approved by the National Institute for Occupational Safety and Health (NIOSH) under the provisions of Title 30 of the U.S. *Code of Federal Regulations* (30 CFR) Part II, Subpart I for use in an ammonia contaminated atmosphere in compliance with Title 29 of the U.S. *Code of Federal Regulations* (29 CFR) 1910.134 and selected in accordance with ANSI Z88.2, *Respiratory Protection* [1, 2, 3].¹

NOTE—A respirator of the air-purifying type shall be used only in an atmosphere containing 19.5% to 22.0% oxygen by volume.

2.2.2 Approved

- listed by a recognized testing laboratory; or
- recommended by the manufacturer as suitable for use with anhydrous ammonia and so marked; or
- accepted by the authority having jurisdiction (AHJ). See 2.2.5.

¹ References are shown by bracketed numbers and are listed in order of appearance in the reference section.

2.2.3 Appurtenance

Any device such as, but not limited to, pressure relief devices (PRDs), liquid level gauging devices, valves, pressure gauges, pressure regulators, fittings, and metering or dispensing devices designed to be attached to an ammonia container or cylinder.

2.2.4 ASME Boiler and Pressure Vessel Code (ASME Code)

Edition of the American Society of Mechanical Engineers (ASME) *Boiler and Pressure Vessel Code*, Section VIII Division 1 to which a container was designed, constructed, and tested, including addenda and applicable Code Case Interpretations [4].

2.2.5 ASME Code container

Pressure vessel or tank designed, constructed, tested, and inspected in accordance with ASME Code requirements.

2.2.6 Authority having jurisdiction (AHJ)

Organization, office, or individual responsible for enforcing the requirements of a code or standard or responsible for approving equipment, materials, installations, or procedures.

2.2.7 Authorized inspection agency

Jurisdiction that has adopted and does administer one or more sections of the ASME Code as a legal requirement and has a representative serving as a member of the ASME Conference Committee or an insurance company that has been licensed or registered by the appropriate authority of a state of the United States or a province of Canada to write boiler and pressure vessel insurance in such state or province [5].

2.2.8 Authorized inspector

An Inspector who is currently commissioned by the National Board of Boiler and Pressure Vessel Inspectors and employed as an Inspector by an Authorized Inspection Agency.

2.2.9 Capacity

Total water volume of a container or cylinder measured in standard U.S. gallons at 60 °F, unless otherwise specified, and which when multiplied by the authorized filling density for ammonia equals the content capacity for ammonia in that container or cylinder. See 2.2.21.

2.2.10 Cargo tank

Any container designed to be permanently attached to, or forming a part of, a highway motor vehicle, or any container not permanently attached to a highway motor vehicle, that by reason of the container's size, construction, or attachment to a highway motor vehicle, shall be loaded or unloaded without being removed from the highway motor vehicle.

NOTE—This definition does not apply to cylinders and implements of husbandry or containers normally used for storage.

2.2.11 Cargo tank motor vehicle

Highway motor vehicle with one or more cargo tanks permanently attached to or forming an integral part of the motor vehicle.

2.2.12 Cargo vessel

Watercraft used, or capable of being used, as a means of transportation on water other than for passengers. Barges and ships are included in this definition.

2.2.13 Chemical splash goggles (or goggles)

Flexible fitting chemical-protective goggles with a hooded indirect ventilation system to provide primary protection of the eyes and eye sockets from the splash of hazardous liquids, which are designed to meet the requirements of ANSI/International Safety Equipment Association (ISEA) Z87.1, *American National Standard for Occupational and Educational Eye and Face Protection* [6].

NOTE—Direct vented goggles do not comply with this definition.

2.2.14 Compressed gas

Material that is entirely gaseous at 68 °F (20 °C) at standard pressure of 101.3 kPa and which when packaged under pressure for transportation is entirely gaseous at –50 °C with a critical temperature less than or equal to –50 °C or partially liquid at temperatures above –50 °C.²

NOTE—see also definitions for liquefied compressed gas.

2.2.15 Compressor

Power-driven machine that reduces the volume of gas vapor and increases its pressure in order to liquefy it or maintain it at a high pressure. See 2.2.53.

2.2.16 Container

All tanks, except cylinders as defined in 2.2.17, used for the transportation or storage of anhydrous ammonia.

2.2.17 Cylinder

Pressure vessel of 1000 lb (450 kg) water capacity or less constructed in accordance with DOT specifications for cylinders and authorized for the transportation of ammonia.

NOTE—This definition does not include storage tanks, cargo tanks, portable tanks, implements of husbandry, or tank cars.

2.2.18 Design pressure

Identical to the term maximum allowable working pressure (MAWP) used in the ASME Code [4].

2.2.19 Emergency shower

Shower unit permanently connected to a source of clean water that enables the user to have water cascading over the entire body and otherwise meeting the requirements of ANSI/ISEA Z358.1, *Emergency Eyewash and Shower Equipment* [8].

2.2.20 Eye wash unit

Device used to irrigate and flush the eyes with clean water.

NOTE—Depending upon the requirements set forth in this standard, the device may be a plumbed unit, permanently connected to a source of clean water, or it may be a self-contained unit, not permanently installed that shall be refilled, or replaced after use. Any eyewash device shall otherwise meet the requirements of ANSI/ISEA Z358.1 [8].

2.2.21 Filling density

Percent ratio of the weight of the ammonia permitted in a container to the weight of water at 60 °F (15.6 °C) that the container will hold when full. See 2.2.9 and 2.2.27.

NOTE—1 lb of water = 27.74 in³ (455 ml) at 60 °F (15.6 °C). For determining the water capacity of the tank in lbs, the weight of 1 gal (231 in³) (3.785 L) of water at 60 °F (15.6 °C) in air shall be 8.328 lb (3.778 kg).

2.2.22 Full face shield

Device meeting the requirements of ANSI/ISEA Z87.1, designed to provide protection to all of the face from hazards, but shall be worn only as secondary eye protection, supplementing the primary eye protection afforded by chemical splash goggles [6].

2.2.23 HC number

Hazard class number or division number that identifies a given class of hazardous materials listed by DOT under 49 CFR 173.2 and as is assigned to a hazardous material within a class and listed under 49 CFR 172.101 [9].

2.2.24 Hydrostatic relief valve

PRD for liquid service designed to prevent excessive pressure due to thermal expansion when a pipe or hose is filled with liquid such as between block valves or blinds.

² kPa shall indicate gauge pressure unless otherwise noted as (kPa, abs) for absolute pressure or (kPa, differential) for differential pressure. All kPa values are rounded off per CGA P-11, *Guideline for Metric Practice in the Compressed Gas Industry* [7].

2.2.25 Immediately Dangerous to Life or Health (IDLH)

Maximum concentration from which unprotected persons are able to escape within 30 minutes without escape-impairing symptoms or irreversible health effects [10].

2.2.26 Implement of husbandry

System, including a nurse tank, with a capacity of 3000 gal (11.35 m³) or less or an applicator tank, used for transporting and applying anhydrous ammonia containing 0.2% water exclusively for agricultural purposes.

NOTE—For more information on systems mounted on farm wagons for the transportation and application of ammonia, see ANSI/CGA G-2.1, *Requirements for the Storage and Handling of Anhydrous Ammonia* [11].

2.2.27 Liquefied compressed gas

Gas under the charged pressure that is partially liquid at 68 °F (20 °C).

NOTE—Liquefied compressed gas can be referred to as gas. See 2.2.14.

2.2.28 National Board Inspection Code (NBIC)

Manual published by the National Board of Boiler and Pressure Vessel Inspectors that provides the rules and guidelines for inspection by an authorized inspector of the repair, alteration, and rerating of ASME Code containers after being placed into service [5]. See 2.2.8 and 2.2.31.

2.2.29 Outage

Amount by which a container is less than 100% liquid full, usually expressed as a percentage of the total volume.

NOTE—Otherwise known as ullage.

2.2.30 Owner-user inspection agency

Owner or user of pressure vessels that maintains a regularly established inspection department, whose organization and inspection procedures meet the requirements of the National Board rules and are acceptable to the jurisdiction wherein the owner or user is located [5]. See 2.2.7, 2.2.28, and 2.2.31.

2.2.31 Owner-user inspector

Inspector of pressure vessels who holds a valid National Board Owner-User Commission and has qualified by written examination under the laws, rules, and regulations of a jurisdiction of a state of the United States or a province of Canada and is regularly employed as an inspector by an Owner-User Inspection Agency [5]. See 2.2.7, 2.2.28, 2.2.30.

2.2.32 Permanent storage installation

System employing a stationary (fixed) container used exclusively for storage or supply.

2.2.33 Permissible exposure limit (PEL)

Limit developed by the Occupational Safety and Health Administration (OSHA) for the maximum airborne concentration of a contaminant to which an employee may be exposed over the duration specified by the type of PEL assigned to that contaminant. PELs are set forth in 29 CFR 1910.1000 [2]. See Table 5.

2.2.34 Portable tank

Bulk packaging (except a cylinder having a water capacity of 1000 lb [450 kg] or less) designed primarily to be loaded onto, or on, or temporarily attached to a transport vehicle or ship and equipped with skids, mountings, or accessories to facilitate handling of the tank by mechanical means.

NOTE—It does not include a cargo tank, tank car, multi-unit tank, or trailer carrying 3AX, 3AAX, or 3T cylinders (as referenced in 49 CFR 171.8) [9].

NOTE—DOT-51 and United Nations (UN) T50 specification portable tanks are authorized for the transportation of ammonia by rail, highway, and cargo vessel.

2.2.35 Positive pressure self-contained breathing apparatus (SCBA)

Full facepiece respirator approved by NIOSH/MSHA for respiratory protection for both entry into or escape from oxygen-deficient atmospheres or concentrations of gases or vapors that are immediately dangerous to life or

health where the supply of air is carried by the wearer. The pressure inside the facepiece is higher than the air pressure outside the mask during exhalation and inhalation.

2.2.36 Pressure relief valve

Pressure relief device (PRD) designed to open to prevent an increase in internal fluid pressure in excess of a specified value due to an emergency or abnormal condition and to close and prevent further flow after normal conditions have been restored. Refer to ANSI/ASME B95.1, *Terminology for Pressure Relief Devices* [12].

2.2.37 Private track

Track located outside of a carrier's right-of-way, yard, or terminal where the carrier does not own the rails, ties, roadbed, or right-of-way and includes track or a portion of track that is devoted to the purpose of its use either by lease or written agreement, in which case the lease or written agreement is considered equivalent to ownership. A private track is also referred to as a private siding.

2.2.38 Protective gloves, boots, and suits

Items made from rubber or other materials impervious to ammonia.

NOTE—Gloves refer to hand protection of a gauntlet style of sufficient length to allow for cuffing, which provide thermal protection suitable for ammonia exposure.

2.2.39 Psi and psia

Pounds per square inch gauge (kPa) and pounds per square inch absolute (kPa, abs), respectively. Example: 0 psi (0 kPa gauge) = 14.71 psia (101.42 kPa, abs).

2.2.40 Repair

Work necessary to restore a container, cylinder, or system to a safe and satisfactory operating condition, provided there is, in all cases, no deviation from the original design.

NOTE—Repairs include the addition or replacement of pressure or nonpressure parts that do not change the design temperature or pressure of the container, cylinder, or system.

2.2.41 Reportable quantity (RQ)

Minimum amount of hazardous substance that when known to have been discharged into the environment within a 24-hour period, either accidentally or intentionally, shall be reported immediately to the National Response Center (NRC)³. Hazardous substances and their corresponding reportable quantities are listed in Table 302.4 of Title 40 of the *U.S. Code of Federal Regulations* (40 CFR) Part 302 and under section 101(14) of the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA; Pub. Law 96-510) [13, 14].

2.2.42 Residue

Hazardous material remaining in a container or cylinder after its contents have been unloaded to the maximum extent practicable, before it is either refilled or cleaned of hazardous material and purged to remove any hazardous vapors.

2.2.43 Safety data sheet (SDS)

Written or printed compilation of data and information on individual hazardous chemicals produced or imported by manufacturers or importers of that chemical, as required by OSHA's Hazard Communication Standard, 29 CFR 1910.1200 [2].

NOTE—A SDS contains data on chemical identification, current exposure limits, chemical reactivity, fire and exposure limits, information on health hazards and emergency procedures, spill, leak, and disposal procedures, and any needed special protection or precautions [2].

2.2.44 Semitrailer

Any highway motor vehicle without motive power designed to be drawn by another motor vehicle and so constructed that no part of its weight except the towing device rests upon the towing vehicle. See 2.2.49.

³ United States Coast Guard National Response Center, 1-800-424-8802.

2.2.45 Short-term exposure limit (STEL)

15 minute Time-Weighted Average (TWA) exposure to an air contaminant that should not be exceeded at any time during a workday and should not be repeated more than four times a day.

NOTE—Exposures at the STEL should not occur at less than 60 minute intervals [15]. See Table 5.

2.2.46 System

Assembly of equipment consisting essentially of a container or containers, or a cylinder or cylinders, including items such as hoses, appurtenances, pumps, compressors, and interconnecting piping.

2.2.47 Tank car

Assembly authorized for the transportation of hazardous materials by rail comprising a tank car tank and a rail car structure on which it is mounted or forms a part, all of which have been approved for the intended service with regard to design, construction, materials, and compliance with appropriate DOT specifications by the Association of American Railroads (AAR) Committee on Tank Cars. See 2.2.28 and 2.2.48. In Canada, Transport Canada (TC) regulations apply to tank cars and tank car tanks.

2.2.48 Tank car tank

Fusion-welded pressure tank built to DOT specifications as prescribed by 49 CFR Part 179, Subparts A, B, and C having ellipsoidal convex heads with all openings generally grouped in one location at the top center of the tank in the manway cover and enclosed in a protective housing with a hinged cover [9]. The tank is designed to be permanently mounted on or form a part of the rail car structure and used for the transportation of hazardous materials by rail. The tank is sometimes referred to as a single-unit tank car tank. See 2.2.16 and 2.2.47.

2.2.49 Trailer

Any highway motor vehicle with or without motive power designed to be drawn by another motor vehicle and so constructed that no part of its weight except the towing device rests upon the towing vehicle.

NOTE—Normally called a full trailer. See 2.2.44.

2.2.50 Transfer, fill, charge

Movement of a quantity of ammonia from one container to another container or cylinder, as contrasted to feeding ammonia to an application device or process.

NOTE—These terms may be used interchangeably.

2.2.51 Transport vehicle

Cargo-carrying vehicle such as an automobile, van, tractor, truck, semitrailer, tankcar, or rail car used for the transportation of cargo by any mode. Each cargo-carrying body (trailer, rail car, etc.) is a separate vehicle.

2.2.52 UN number

Identification number assigned to each hazardous materials description by the UN. UN numbers are appropriate for both domestic and international transportation.

2.2.53 Vapor pump

Power-driven machine that reduces the volume of gas vapor and increases its pressure in order to develop a differential pressure between container systems. The differential pressure is generally used to transfer liquefied gas between systems. See 2.2.15.

3 Ammonia identification and classification numbers

Various number designations are in use for ammonia. These are:

- American Society of Heating, Refrigeration, and Air Conditioning Engineers (ASHRAE) No. R717 [16];
- Chemical Abstracts Service (CAS) Registry Number 7664-41-7 [17];
- OSHA Health Standard No. 1021 [18];
- Registry of Toxic Effects of Chemical Substances (RTECS) No. BO0875000 [19];

- UN Number UN 1005 [20]; and
- DOT Hazard Division (Class) number is 2.2 (Nonflammable compressed gas) for domestic shipments and 2.3 (Toxic gas) for Canadian and international shipments. See 2.2.23 and 7.5. Refer to 49 CFR 172.101 and 173.2 [9].

4 Composition, synthesis, and specifications

4.1 Composition

4.1.1 Molecular structure

Ammonia is the compound formed by the chemical combination of the elements nitrogen and hydrogen in the molar proportion of one part nitrogen to three parts hydrogen. This relationship is shown by the chemical formula for ammonia, NH_3 . On a weight basis, the ratio is fourteen parts nitrogen to three parts hydrogen or approximately 82% nitrogen to 18% hydrogen.

4.2 Synthesis

Ammonia is manufactured using modifications of the Haber-Bosch process. Hydrogen from natural gas is reacted with nitrogen from air at high temperature and pressure in the presence of catalysts to produce ammonia.

4.3 Specifications

4.3.1

The generic term ammonia used throughout this publication refers to anhydrous ammonia and not to ammonium hydroxide (aqua ammonia). No commodity grade specifications for ammonia have been published as standards for industry. However, some generally accepted grade designations are:

Grade	Ammonia, weight percent minimum
Commercial	99.5
Agricultural	99.7 ¹⁾
Refrigeration	99.95
Technical	99.98
Metallurgical	99.995
Semiconductor	99.9999
¹⁾ When 82.0 weight percent minimum nitrogen is guaranteed.	

4.3.2

In these grade designations, the assay values are calculated as 100% minus the measured percentage of impurities such as water and oil. Federal government specifications for technical grade ammonia can be found in O-A-445B, *Federal Specification Ammonia, Technical* [21].

5 Properties

5.1 Physical properties

5.1.1

At room temperature and atmospheric pressure ammonia is a pungent, colorless gas. It can be compressed and cooled to a colorless liquid. Ammonia is normally stored and shipped as a liquefied gas under its vapor pressure. At atmospheric pressure, ammonia boils at -28°F (-33.3°C) and freezes to a white crystalline solid at -107.9°F (-77.72°C). When heated to greater than its critical temperature of 271.4°F (133.0°C), ammonia exists as a gas regardless of pressure. The relationship of vapor pressure to temperature is shown in Figures 1 and 2.

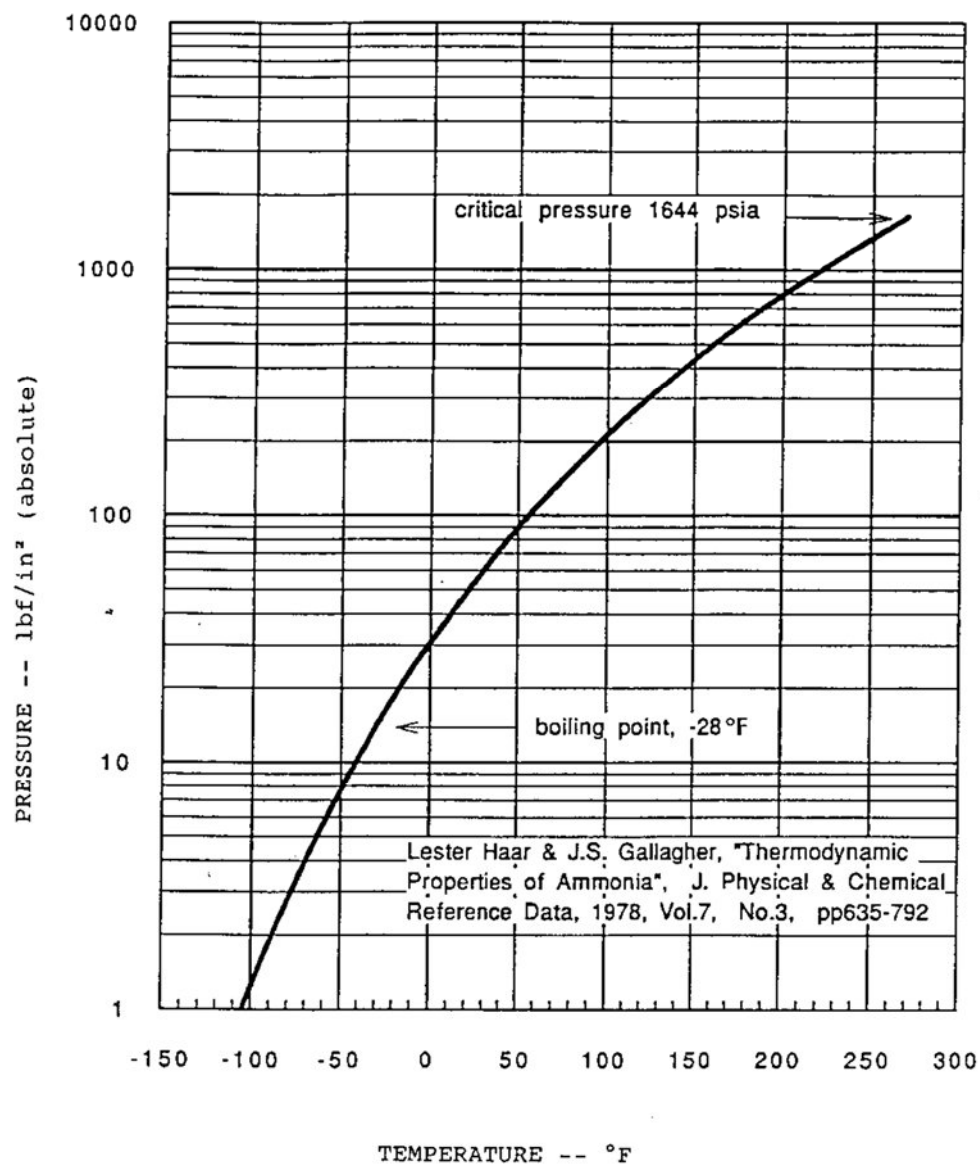


Figure 1—Vapor pressure temperature curve for ammonia
(U.S. customary units) [22]

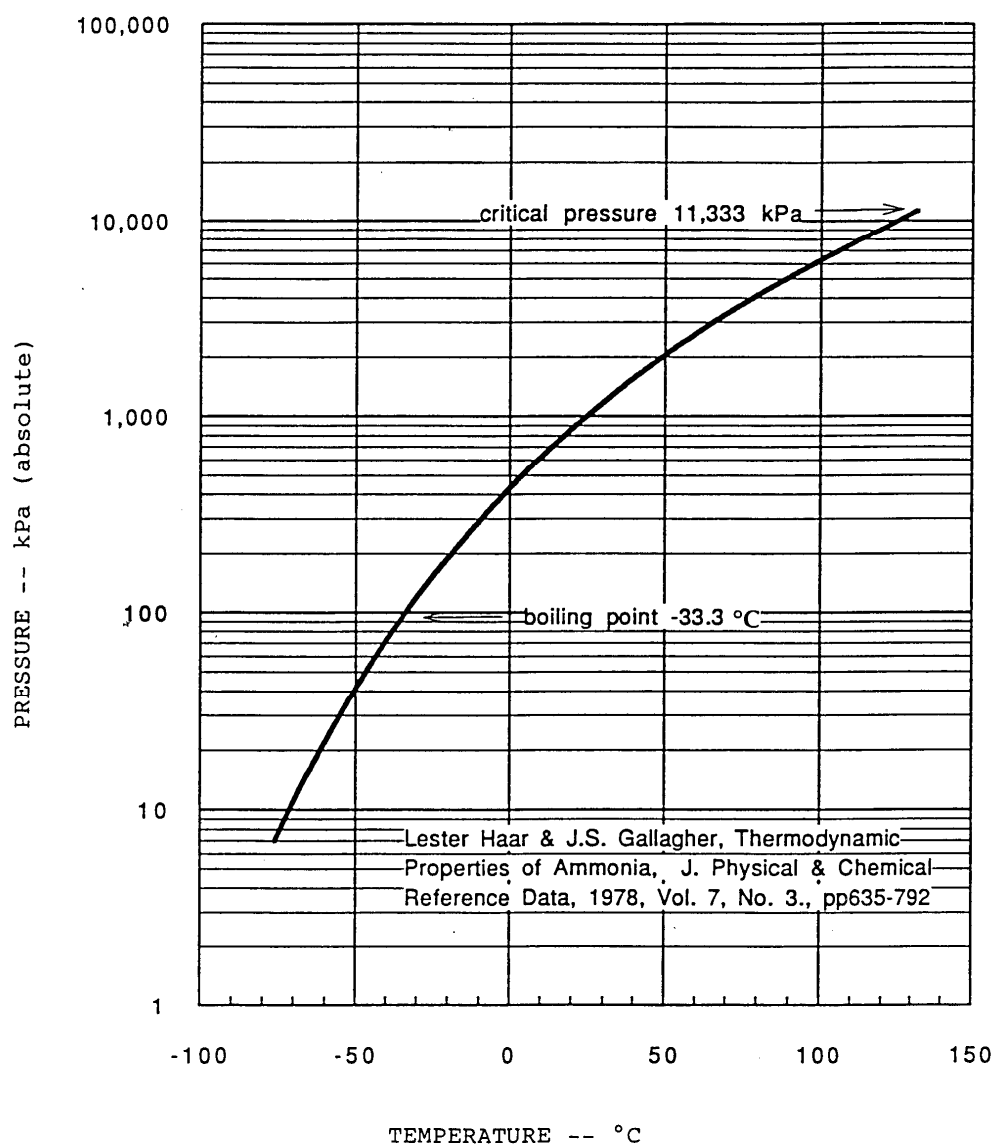


Figure 2—Vapor pressure temperature curve for ammonia (SI units) [22]

5.1.2

Liquid ammonia is lighter than water, having a density of 38.00 lb/ft³ at 70 °F (608.7 kg/m³ at 21.1 °C). As a gas, ammonia is lighter than air, having a specific gravity of 0.5970 compared to air at a pressure of one atmosphere and a temperature of 32 °F (0 °C). Under the latter conditions, one pound (0.4536 kg) of ammonia gas occupies a volume of 20.78 ft³ (0.5884 m³). These and other physical properties of ammonia are listed in Table 1.

5.1.3

Data for the physical and thermodynamic properties of ammonia presented in this publication are based upon a selected group of authoritative sources believed to be accurate and sound to the best knowledge of the Compressed Gas Association, Inc. No legal responsibility is assumed by CGA for any losses or liabilities incurred by persons or organizations acting in any way based on the data and other information set forth herein. Data given represent the properties of specially purified ammonia rather than those of grades available in usual industrial trade. Some variations between data may be noted depending upon the source referenced.

Table 1—Physical properties [23, 24]

Property	U.S. customary units	SI units
Chemical formula	NH ₃	
Molecular weight	17.031	
Boiling point	−28 °F	−33.3 °C
Critical density	14.7 lb/ft ³	236 kg/m ³
Critical pressure	1657 psia	11 425 kPa, abs
Critical temperature	271.4 °F	133.0 °C
Density of liquid at 70 °F (21.1 °C)	38 lb/ft ³	608.7 kg/m ³
Density of vapor at 32 °F (0 °C) and 1 atm	0.0481 lb/ft ³	0.771 kg/m ³
Flammable limits (in air by volume and 1 atm)	16% to 25%	
Freezing point at 1 atm	−107.9 °F	−77.72 °C
Heat of solution extrapolated to 0% concentration by weight at 28% concentration by weight	347.4 Btu/lb 214.9 Btu/lb	<u>8.081 x 10⁵ J/kg</u> <u>4.999 x 10⁵ J/kg</u>
Ignition temperature in presence of iron catalyst in standard quartz container	1204 °F 1562 °F	651.1 °C 850.0 °C
Latent heat of fusion at freezing point	142.8 Btu/lb	<u>332.2 kJ/kg</u>
Latent heat of vaporization at boiling point and 1 atm	589.3 Btu/lb	<u>13.71 kJ/kg</u>
Liquid density at −28 °F (−33.3 °C) and 1 atm	42.57 lb/ft ³	681.9 kg/m ³
Solubility in water vol(liq.)/vol(liq.) at 68 °F (20 °C)	0.848	
Specific gravity of the liquid at −28 °F (−33.3 °C) compared to water at 39.2 °F (4 °C)	0.6819	
Specific gravity of vapor at 32 °F (0 °C) and 1 atm (air = 1)	0.5970	
Specific heat of vapor at 59 °F (15 °C) and 1 atm At constant pressure, C _p At constant volume, C _v	0.5232 Btu/(lb)(°F) 0.3995 Btu/(lb)(°F)	2.191 kJ/(kg)(°C) 1.673 kJ/(kg)(°C)
Ratio of specific heats (C _p /C _v)	1.3096	
Specific volume of vapor at 32 °F (0 °C) and 1 atm	20.78 ft ³ /lb	1.297 m ³ /kg
Vapor density at −28 °F (−33.3 °C) and 1 atm	0.0555 lb/ft ³	0.8890 kg/m ³
Vapor pressure at 70 °F (21.1 °C)	114.1 psi	786.7 kPa
Triple point	−107.86 °F at 0.88 psia	−77.70 °C at 6.1 kPa, abs
Weight of liquid per gallon at 60 °F (15.5 °C)	5.147 lb/gal	616.8 kg/m ³

5.1.4

For many years, the standard reference data for ammonia have been those contained in the U.S. National Bureau of Standards (NBS) Circular No. 142, *Table of Thermodynamic Properties of Ammonia* [23]. Pressure temperature data for vapor and liquid ammonia presented in Circular No. 142 were in ft/lb/°F units only and were measured over a temperature range from the triple point to 271.4 °F (133 °C) and at various pressures to 1657 psia (11.4 MPa, abs). Data given in this section and Table 2 are generally based upon Circular No. 142 [23].

5.1.5

Thermodynamic data for saturated liquid and vapor presented in Table 3 are from *Thermodynamic Functions of Gases* [25].

Table 2—Properties of liquid ammonia at various temperatures

Temperature		Vapor pressure		Liquid density			Specific gravity of liquid	Latent heat	
°F	°C	psi ¹⁾	kPa	lb/ft ³ ¹⁾	lb/gal ¹⁾	kg/m ³	(Water @ 4 °C = 1) ¹⁾	Btu/lb ¹⁾	MJ/kg
−28	−33.3	0.0	0.0	42.57	5.69	681.9	0.682	589.3	1.371
−20	−28.9	3.6	25	42.22	5.64	676.3	0.676	583.6	1.358
−10	−23.3	9.0	62	41.78	5.59	669.3	0.669	576.4	1.341
0	−17.8	15.7	108	41.34	5.53	662.2	0.662	568.9	1.323
10	−12.2	23.8	164	40.89	5.47	655.0	0.655	561.1	1.305
20	−6.7	33.5	231	40.43	5.40	647.6	0.647	553.1	1.287
30	−1.1	45.0	310	39.96	5.34	640.1	0.640	544.8	1.267
40	4.4	58.6	404	39.49	5.28	632.6	0.633	536.2	1.247
50	10.0	74.5	514	39.00	5.21	624.7	0.625	527.3	1.227
60	15.6	92.9	641	38.50	5.15	616.7	0.617	518.1	1.205
65	18.3	103.1	710.8	38.25	5.11	612.7	0.613	513.4	1.194
70	21.1	114.1	786.7	38.00	5.08	608.7	0.609	508.6	1.183
75	23.9	125.8	867.7	37.74	5.05	604.5	0.605	503.7	1.172
80	26.7	138.3	953.5	37.48	5.01	600.4	0.600	498.7	1.160
85	29.4	151.7	1046	37.21	4.97	596.0	0.596	493.6	1.148
90	32.2	165.9	1144	36.95	4.94	591.9	0.592	488.5	1.136
95	35.0	181.1	1249	36.67	4.90	587.4	0.587	483.2	1.124
100	37.8	197.2	1360	36.40	4.87	583.1	0.583	477.8	1.111
105	40.6	214.2	1477	36.12	4.83	578.6	0.579	472.3	1.099
110	43.3	232.3	1602	35.84	4.79	574.1	0.574	466.7	1.085
115	46.1	251.5	1734	35.55	4.75	569.5	0.569	460.9	1.072
120	48.9	271.7	1873	35.26	4.71	564.8	0.565	455.0	1.058
125	51.7	293.1	2021	34.96	4.67	560.0	0.560	448.9	1.044
130	54.4	315.6	2176	34.66	4.63	555.2	0.555	443 ²⁾	1.030
135	57.2	339.4	2340	34.35	4.59	550.2	0.550	436 ²⁾	1.014
140	60.0	364.4	2512	34.04	4.55	545.3	0.545	430 ²⁾	1.000

NOTES

- ¹⁾ Data for customary units for vapor pressure (psi), liquid density (lb/ft³), and latent heat (Btu/lb) are taken from *Circular No. 142* [23]. Values for liquid density (lb/gal) and specific gravity of liquid are calculated from the vapor pressure (psi). Converted values for metric units are rounded.
- ²⁾ Values were calculated from empirical equations given in *Specific Heat of Liquid Ammonia* and *Latent Heat of Vaporization of Ammonia* and represent values obtained by extrapolation beyond the range covered in the experimental work [26, 27].

Table 3—Thermodynamic properties of saturated liquid and vapor ammonia [25]

Temperature		Pressure		Entropy J/(mol-K)		Enthalpy kJ/mol		Latent heat of vaporization	Specific volume cm ³ /mol		Density g/cm ³	
K	°F	kPa	atm	Liquid	Vapor	Liquid	Vapor	kJ/mol	Liquid	Vapor	Liquid	Vapor
195.42	−107.9	6.0765	0.05997	71.59	199.95	10.435	35.522	25.087				
200	−99.7	8.6663	0.08553	73.30	198.41	10.770	35.794	25.024	23.37	189 730	0.729	0.00009
210	−81.7	17.793	0.1756	76.90	194.26	11.510	36.158	24.648	23.74	96 858	0.717	0.00018
220	−63.7	33.91	0.3347	80.33	190.54	12.255	36.497	24.242	23.13	53 070	0.706	0.00032
230	−45.7	60.61	0.5982	83.68	187.11	13.008	36.794	23.786	24.55	30 895	0.694	0.00055
240	−27.7	102.58	1.0124	86.86	183.89	13.770	37.054	23.284	24.99	18 905	0.682	0.00090
250	−9.7	165.4	1.632	90.00	181.13	14.535	37.317	22.782	25.46	12 088	0.669	0.00141
260	8.3	255.9	2.526	93.01	178.57	15.309	37.560	22.251	25.96	8029	0.656	0.00212
270	26.3	381.9	3.769	95.94	176.23	16.096	37.773	21.677	26.50	5505	0.643	0.00309
280	44.3	551.8	5.446	98.78	174.05	16.887	37.961	21.074	27.07	3882	0.629	0.00439
290	62.3	775.3	7.652	101.59	172.00	17.694	38.120	20.426	27.70	2803	0.615	0.00608
300	80.3	1 062.4	10.485	104.31	170.08	18.506	38.238	19.732	28.39	2006	0.600	0.00824
310	98.3	1 424.9	14.063	106.98	168.24	19.330	38.317	18.987	29.14	1545	0.584	0.01102
320	116.3	1 873	18.49	109.62	166.40	20.171	38.388	18.217	29.98	1174	0.568	0.01451
330	134.3	2 420	23.90	112.21	164.77	21.033	38.380	17.347	30.92	900.1	0.551	0.01892
340	152.3	3 082	30.42	114.77	163.01	21.924	38.305	16.381	31.99	696.1	0.532	0.02447
350	170.3	3 870	38.19	117.32	161.00	22.840	38.137	15.297	33.24	540.4	0.512	0.03152
360	188.3	4 800	47.40	119.87	158.99	23.799	37.878	14.079	34.73	419.3	0.490	0.04062
370	206.3	5 891	58.14	122.47	156.73	24.807	37.472	12.665	36.58	323.9	0.466	0.05258
380	224.3	7 150	70.60	125.27	153.97	25.832	36.807	10.975	39.03	247.0	0.436	0.06895
390	242.3	8 607	84.94	128.28	150.58	27.087	35.736	8.649	42.61	182.6	0.400	0.09327
400	260.3	10 280	101.5	130.00	145.10	28.514	33.731	5.217	49.45	124.5	0.344	0.13680
405.6 ¹⁾	270.4 ¹⁾	11 300	111.5	138.24		31.066		0.0	72.47		0.235	
¹⁾ Critical temperature values.												

5.1.6

Figures 1 and 2 give pressure temperature relationships for vapor and liquid ammonia. Figures 3 and 4 show density temperature relationships for liquid ammonia. These correlations are based upon work by Haar and Gallagher, *Thermodynamic Properties of Ammonia* [22]. In this work, data are measured over a temperature range from the triple point to 760 Kelvin [908 °F (487 °C)] and at various pressures up to 5000 bar [72 519 psi (500 MPa)]. The authors find excellent agreement between the results of their work and the data measured in the equivalent pressure and temperature ranges upon which the Circular No. 142 was based [23]. They also conclude that data of recent origin are not necessarily of greater accuracy or better quality than data obtained from the works of earlier researchers. Haar and Gallagher contains an extensive list of reference sources and includes detailed data error analyses and comprehensive discussions of data comparisons with correlation's found in research works by others [22].

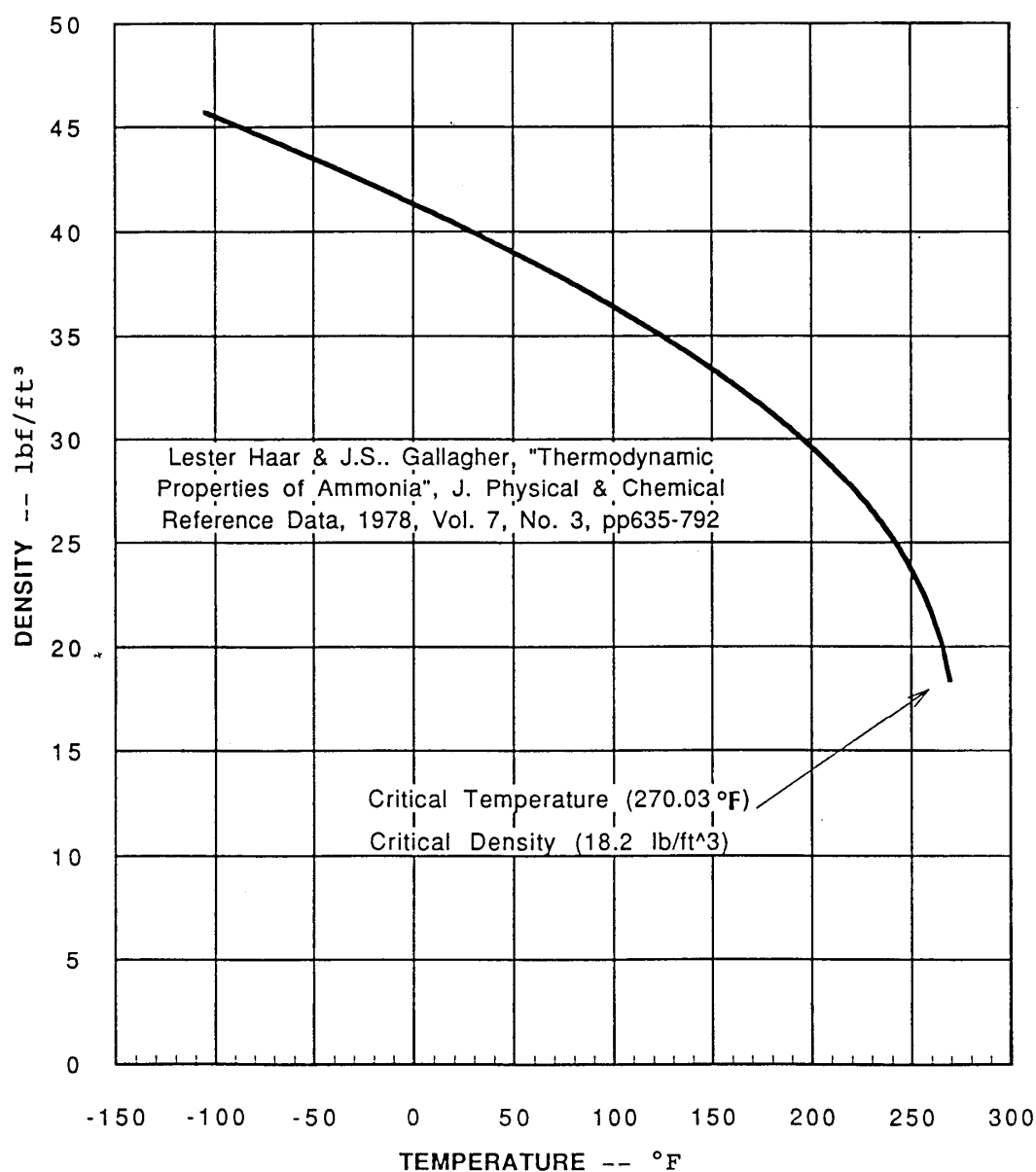


Figure 3—Density temperature curve for liquid ammonia (U.S. customary units) [22]

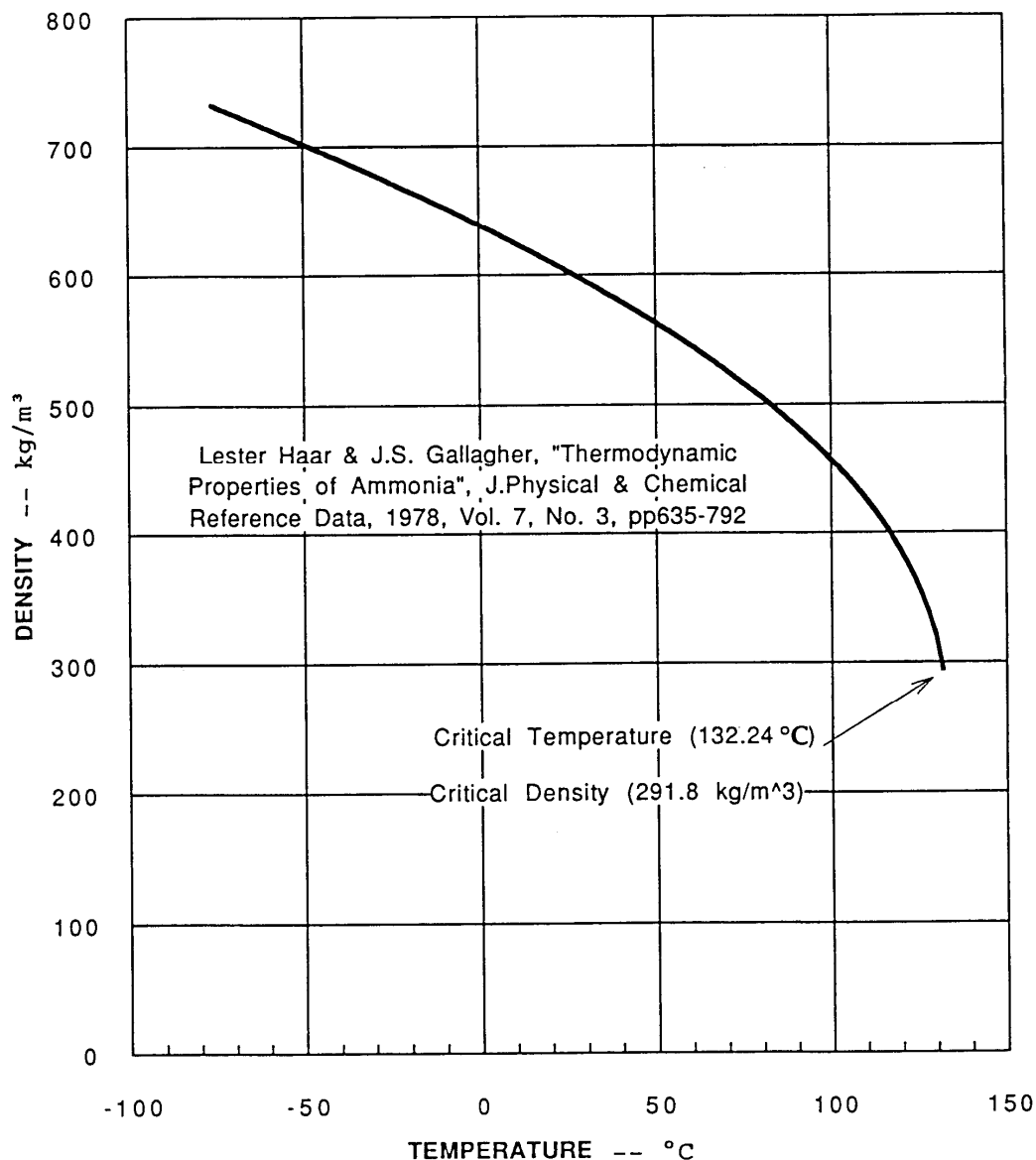


Figure 4—Density temperature curve for liquid ammonia (SI units) [22]

5.2 Chemical properties

5.2.1

Ammonia is a stable compound. It begins dissociating into nitrogen and hydrogen at approximately 850 °F (454 °C). In the presence of a suitable catalyst, dissociation takes place rapidly and is complete at 1700 °F (927 °C).

5.2.2

Experiments conducted by the Underwriters' Laboratories (UL) have shown that ammonia has an ignition temperature in air of 1562 °F (850 °C). In the presence of an iron catalyst, the ignition temperature is reduced to 1204 °F (651 °C). These ignition temperature values are greater than those for typical hydrocarbon liquids (1044 °F to 450 °F [562 °C to 232 °C]) and liquefied petroleum gases (1000 °F to 400 °F [538 °C to 204 °C]) [28, 29].

5.2.3

Ammonia vapor is flammable over a narrow range of 16% to 25% by volume in air. These flammable limits are greater than those found for hydrocarbon liquids, which typically range from approximately 1% to 8% or for liquefied petroleum gases, which generally range from approximately 2% to 12% by volume in air [29, 30].

5.2.4

The minimum ignition energy (MIE) for ammonia has been measured at 645 Btu (680 mJ). This amount of energy is much greater than that found for n-hexane (0.38 Btu [0.4 mJ]) or for n-heptane (0.28 Btu [0.3 mJ]). 645 Btu (680 MJ) is greater than the energy available from an electric motor spark and is at least ten times the spark energy used in automotive test engines. An open flame, an exposed hot filament of a broken light bulb, or an electric arc from a power switch can provide sufficient energy and temperature to ignite ammonia vapor when in the flammable range [30, 28].

5.2.5

Heat generated by the combustion of ammonia is low, being approximately half of values for common flammable liquids, which range from 16 000 Btu to 21 000 Btu (16.9 MJ to 22.2 MJ) [31, 28].

5.2.6

Ammonia released from containment presents a potential for combustion explosion and fire hazards. However, its high lower limit of flammability, high ignition energy, low flame propagation velocity, and low heat of combustion substantially minimize these hazards. Released outdoors, it is difficult for ammonia to reach its lower flammability limit except for small zones in the immediate vicinity of the leak. Even when large quantities of liquid are released, ignitable concentrations tend to be in discontinuous pockets. Coupled with its low heat of combustion and low flame velocity, the possibility of sustained ignition is reduced. The most likely result of an unconfined ammonia release is an unignited vapor cloud. Experience indicates that similar circumstances apply when ammonia is released indoors in reasonably well-ventilated buildings. In confined spaces such as refrigerated process or storage areas, however, the release of liquid or large quantities of vapor can result in the accumulation of a flammable mixture with potential for a combustion explosion with attendant major structural damage. Persons responding to an ammonia release under any conditions should be aware of the physiological hazards and use such safety equipment and protective clothing as may be necessary and appropriate. See Sections 8, 9, and 10.

5.2.7

Ammonia does not conform to DOT's definition of a flammable gas, i.e., a gas at atmospheric pressure that in a mixture of 13% or less by volume in air is ignitable; or which is flammable in air in a range of at least 12% regardless of the lower limit. DOT classification of ammonia as a NONFLAMMABLE GAS for purposes of domestic transportation reflects general overall release conditions with respect to ignition susceptibility. See Section 3 and 7.5. Refer to 49 CFR 173.115(a) and (b) [9].

5.2.8

Most common metals are not affected by dry ammonia. However, when water or water vapor is present, ammonia can attack copper and zinc or alloys of these metals so these materials should not be used. See 5.2.10 and 18.1.1.2.

5.2.9

Containers in liquefied ammonia service are usually made of carbon or low alloy steels. Such materials are susceptible to ammonia stress corrosion cracking (SCC). High tensile strength steels (quenched and tempered [QT] steels, for example) and coarse-grained materials are at greater risk of SCC than more moderate strength or fine-grained steels. However, there is no known threshold value of strength below which SCC does not occur. Postweld heat treatment of a new or weld-repaired container and the minimization of oxygen (air) contamination in the container are of benefit in substantially reducing the incidence of SCC. A water content of at least 0.2% by weight in ammonia serves to effectively inhibit SCC of the container surface in contact with the ammonia liquid phase. Such inhibitive effect will not be realized in the container vapor space and may not occur in the thin meniscus zone between the liquid and vapor phases due to the process of ammonia vapor condensation.

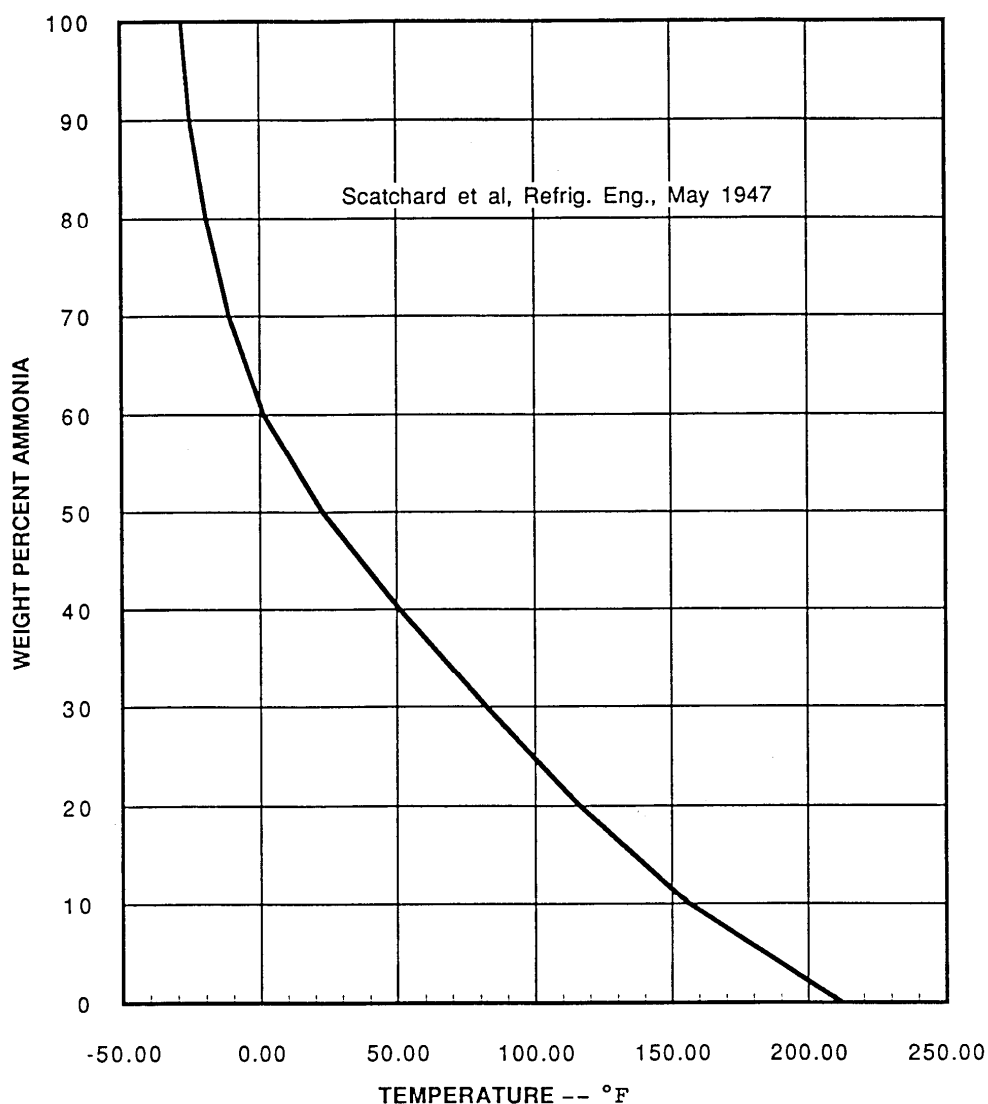
Depending upon an evaluation of the risk of SCC, procedures should be established to subject a container to one or more inspection methods performed on an appropriate periodic basis to detect cracks likely to impair product retention integrity. See Sections 12, 17, and 18. Refer to 49 CFR 180.407(g)(3) [9].

5.2.10

For details regarding recommended materials of construction for ammonia containers, piping, fittings, valves, tubing, and hose, see CGA G-2.1 [11]. See also Section 18.

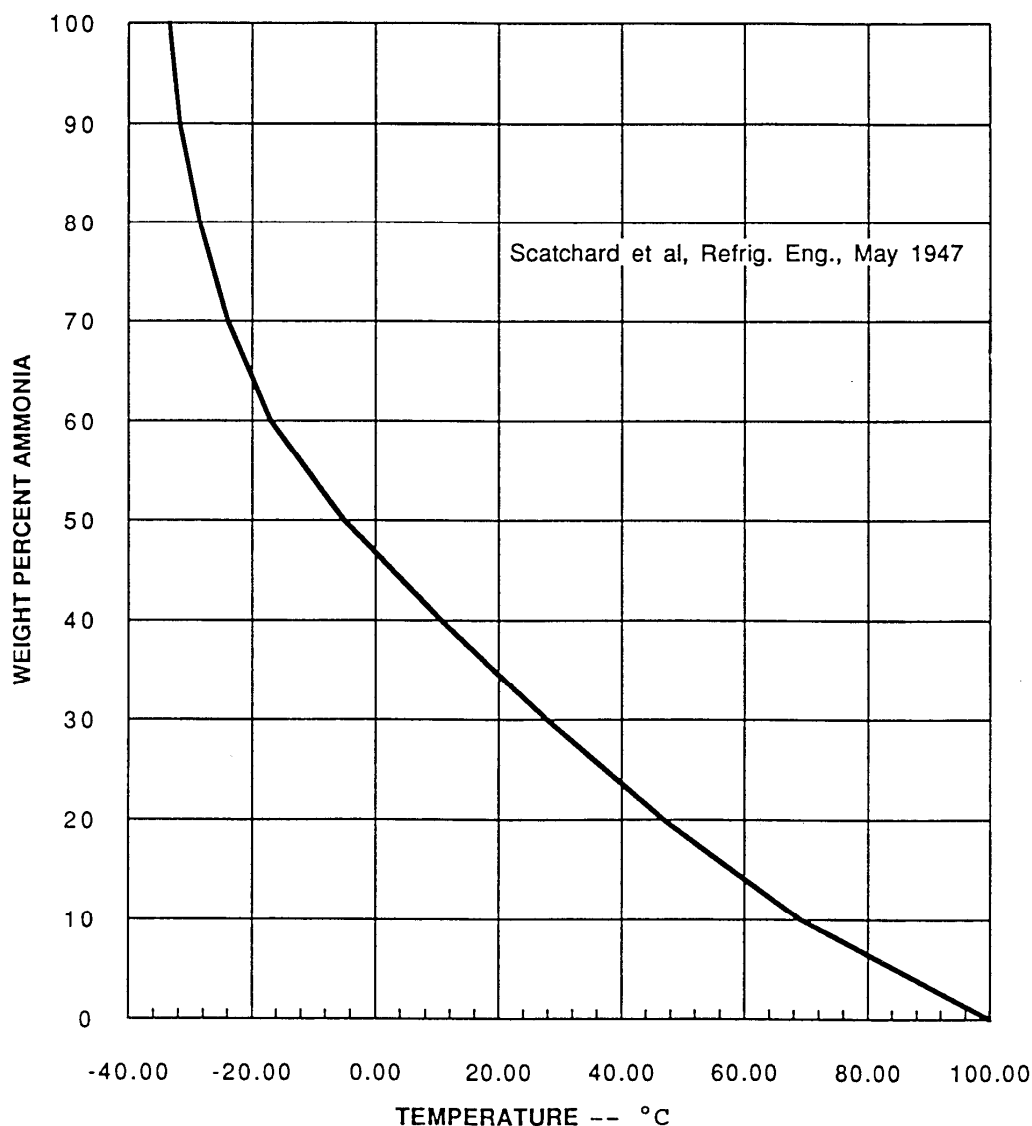
5.2.11

Ammonia is highly soluble in water, forming aqueous ammonia (ammonium hydroxide or aqua ammonia.) The solubility of ammonia in water at various temperatures is shown in Figure 5 and 6 [32].



NOTE—At one at atmosphere (101.325 kPa, abs) pressure including aqueous tension.

Figure 5—Solubility curve for ammonia in water (U.S. customary units) [32]



NOTE—At one at atmosphere (101.325 kPa, abs) pressure including aqueous tension.

Figure 6—Solubility curve for ammonia in water (SI units) [32]

5.2.12

Ammonia reacts chemically to form ammonium salts with inorganic and organic acids. It also forms amides in reaction with esters, acid anhydrides, acylhalides, carbon dioxide, or sulfonylchlorides, and forms amines in reaction with organic halogen compounds or with oxygen containing compounds such as polyhydric phenols, alcohols, aldehydes, and aliphatic ring oxides.

5.2.13

Ammonia can react violently with halogens such as chlorine, fluorine, and bromine. Gold, silver, and mercury can react with ammonia to form explosive compounds. Explosive metal hydrides are produced when hydrazine and alkali metals are mixed in liquid ammonia. Acetylene in the presence of ammoniacal solutions can form acetylides with copper, mercury, or silver salts. In the dry state, these acetylides are highly explosive.

6 Commercial uses

6.1

More than 80% of all ammonia produced in the United States is used in agriculture as a source of nitrogen, which is essential for plant growth. Nitrogen makes up approximately 16% of plant protein. When a fruit, vegetable, or grain crop is grown and harvested, nitrogen is removed from the soil. If the fertility of the land is to be maintained, nitrogen and other elements essential to plant growth such as potassium and phosphorus have to be restored to the soil by fertilization. Depending upon the particular crop, up to 200 lb (90.7 kg) of nitrogen may be economically applied per acre. In agriculture, the ammonia is injected at a depth of several inches below the surface of the soil by specially designed applicator equipment or it can be dissolved in irrigation water.

6.2

Ammonia is also used in the production of nitrogen fertilizer solutions that consist of ammonia, ammonium nitrate, urea, and water in various combinations. Some are pressure solutions and others are not. Nonpressure and low pressure solutions are widely used for direct application to the soil. Pressure solutions containing free ammonia are used in the manufacture of high analysis mixed fertilizers.

6.3

Ammonia is used extensively in the fertilizer industry to produce ammonium salts, nitrate salts, and urea. Ammonium sulfate, ammonium nitrate, and ammonium phosphate are made directly by neutralizing the corresponding acids (sulfuric acid, nitric acid, and phosphoric acid) with ammonia. Urea is an organic compound formed by combining ammonia and carbon dioxide. Ammonium sulfate, ammonium nitrate, sodium nitrate, ammonium phosphate, and urea are used for direct application to the soil in dry or liquid form and in combination with other phosphate and potassium salts.

6.4

In addition to their use as fertilizers, ammonia and urea are used as a source of protein in ruminant livestock feeds. Urea is used in mixed feed supplements to supply the nitrogen needed for the biosynthesis of proteins in animals such as cattle, sheep, and goats.

6.5

Ammonia is oxidized to produce nitric acid, which is the principal ammonia derivative used in making explosives. Both industrial and military explosives are divided into two main types:

- high explosives such as dynamite, nitroglycerin, and trinitrotoluene (TNT) that detonate rapidly to give a shattering blast for demolition purposes; and
- low explosives such as nitrocellulose that detonate slowly to give a heaving/pushing effect for propellant or blasting applications.

Dynamite, a general term for high explosives used in mining and construction, contains nitroglycerin or other organic nitrogen compounds absorbed in inert or combustible materials. In ammonia dynamites, ammonium nitrate replaces some of the nitroglycerin. Blasting gelatin dynamites consist of a colloidal mixture of nitroglycerin and nitrocellulose, which is made by treating cellulose with a mixture of nitric and sulfuric acids.

6.6

Ammonium nitrate is the principal base material in slurry explosives and lower cost blasting agents. Ammonium nitrate/fuel oil mixtures are used extensively in open pit mining and outdoor construction work because of safety, ease of handling, and availability. Unlike ammonium nitrate, ammonia cannot be used in explosives. Anhydrous ammonia is much less reactive and does not have the oxidizing potential of ammonium nitrate.

6.7

Ammonium salts, certain alkalis, dyes, pharmaceuticals, synthetic textile fibers and some plastics require ammonia as a reactant.

6.8

Used in both absorption and compression type systems, ammonia is the oldest, most efficient, and most economical refrigerant known.

6.9

Ammonia or dissociated ammonia is used in such metal treating operations as nitriding, carbonitriding, bright annealing, furnace brazing, sintering, and other applications where protective atmospheres are required.

6.10

Ammonia is used in pH control, in mineral beneficiation, and in neutralizing acidic components during petroleum refining.

6.11

Ammonia is used in extracting certain metals such as copper, nickel, vanadium, and molybdenum from their ores.

6.12

Ammonia vapor is used as the developing agent in the photomechanical process of whiteprinting and is also employed in the production of diazo-microfilm duplicates.

6.13

Ammonia is used in scrubbers to neutralize and remove sulfur oxides from stack gases at electric power generation stations and in furnace operations such as smelting. It also increases the efficiency of electrostatic precipitators used for the removal of particulate matter.

6.14

Ammonia dissolved in water has many applications. In a very dilute solution (2% to 5% ammonia), it is available as household ammonia. See 5.2.11.

6.15

Water solutions of ammonia are used to regenerate weak base anion exchange resins.

6.16

Ammonia is used in the chloramination of potable water supplies.

7 Jurisdictional authorities and general regulations

7.1 General

7.1.1

The production, exportation, importation, storage, transportation, handling, and use of ammonia are subject to a variety of governmental safety regulations in the United States, Canada, and other countries. These regulations are issued and enforced by various jurisdictional authorities at the federal, state, provincial, and other local levels of government in the different countries. The purpose of these regulations is to promote the protection of persons,

property, and the environment from injury, illness, or damage as can be caused by hazards inherent to the product.

7.1.2

The importation and transportation of ammonia between nations are also subject to regulations promulgated by international organizations established under UN auspices or as otherwise agreed upon under trade tariffs or treaties negotiated between individual countries.

7.2 United States

7.2.1

The transportation of ammonia by rail, highway, water, and air is regulated by federal authority under rules promulgated by DOT, OSHA, Department of Homeland Security (DHS), Environmental Protection Agency (EPA), and state and local jurisdictions. These rules are generally referred to as the Hazardous Materials Regulations (HMR), and include requirements for materials classification, packaging (including container and cylinder manufacture, continuing qualification, and maintenance), hazard communication (i.e., package marking, labeling, placarding, and shipping documentation), transportation and handling, and incident reporting. The HMR are set forth in:

Title 49 of the U.S. *Code of Federal Regulations* (49 CFR)

Parts 171 to 180—HMR

Parts 383, 390, 397—Highway Transportation

Parts 190 to 199 [9].

7.2.2

The bulk carriage of hazardous materials by water is governed under regulations as are set forth in:

Title 46 of the U.S. *Code of Federal Regulations* (46 CFR), Chapter I Coast Guard, Department of Homeland Security

Subchapters D, I, N, and O

Parts 1 to 199 [33].

7.2.3

For the protection of employees, the in-plant storage and handling of ammonia are governed by federal authority under rules promulgated by OSHA, Department of Labor (DOL) as authorized by the *Williams-Steiger Occupational and Health Act of 1970* (OSH Act). These specific regulations are set forth in:

Title 29 of the U. S. *Code of Federal Regulations* (29 CFR)

Part 1910—Occupational Safety and Health Standards

Subpart G—Occupational Health and Environmental Control

Subpart H—Hazardous Materials

Part 1910.111—Storage and Handling of Anhydrous Ammonia

Subpart I—Personal Protective Equipment

Subpart Z—Toxic and Hazardous Substances [2]

Employers shall become familiar with those provisions contained in regulations published by OSHA (DOL) and set forth under 29 CFR Parts 1900 to 1910 including the General Industry Standards, Part 1915 relating to Shipyard Employment, and Part 1926 related to Construction Industry Standards, that may be applicable to the conduct of their business activities [2]. For those employers or agents whose employees are engaged in either the manufacture, transportation, distribution, storage, handling, or use of ammonia, the following Parts, Subparts and Sections of the regulations may be of interest, although it shall be recognized that regulations set forth in other parts of the OSHA regulations may be applicable also.

The release of ammonia into the environment is regulated at the federal level under rules promulgated by EPA as authorized under several laws enacted by the Congress to protect human health and the environment from the harmful effects that can be caused by hazardous and toxic chemicals. These regulations are set forth in:

Title 40 of the U.S. *Code of Federal Regulations* (40 CFR)
Chapter I— Environmental Protection Agency
Parts 1 to 799 [13].

7.3 Canada

7.3.1

The transportation of ammonia by land, air, and water is regulated under the provisions of the *Transportation of Dangerous Goods Act* and TDG Regulations published by TC [34, 35].

7.3.2

Additionally, all highway motor vehicle carriers shall comply with the *National Safety Code*, which has been adopted in essentially similar form by all provinces. The Code covers driver's license standards, driver qualifications, driving rules, hours of service, and vehicle maintenance, inspections, and repairs [36].

7.3.3

Cylinder specification requirements are set forth in TDG Regulations [35]. Detailed cylinder specifications are provided for in the Canadian Standards Association (CSA) B339, *Cylinders, spheres, and tubes for the transportation of dangerous goods* and CSA B340, *Selection and use of cylinders, spheres, tubes, and other containers for the transportation of dangerous goods, Class 2* [37, 38].

NOTE—Cylinders stamped with DOT markings only are not acceptable for use in Canada unless the Canadian importer can show that the cylinders have previously been in Canada. For cylinder reciprocity, it is recommended that they be marked with both DOT and TC markings.

7.3.4

Cargo tank motor vehicles in Canada are currently regulated under the appropriate provincial jurisdictions. Most provinces are now using CSA B620, *Highway tanks and TC portable tanks for the transportation of dangerous goods* and CSA B622, *Selection and use of highway tanks, TC portable tanks, and ton containers for the transportation of dangerous goods, Class 2* for ammonia [39, 40].

7.4 International transportation

Titles of standards and advisory recommendations published by UN agencies and other organizations regarding the international transportation of hazardous materials including ammonia by various modes are as follows:

- Water transport—*International Maritime Dangerous Goods Code* (IMDG Code), International Maritime Organization (IMO) [41];
- Air transport—*Technical Instructions for the Safe Transport of Dangerous Goods by Air*, International Civil Aviation Organization (ICAO) [42]; and
- Various modes—*UN Recommendations on the Transport of Dangerous Goods* (UN Recommendations) [20].

7.5 Shipping description and hazard class

The basic description on shipping papers covering the domestic transportation of ammonia are as follows:

- DOT proper shipping name—Anhydrous Ammonia;
- DOT hazard class—2.2 (Nonflammable gas);

- DOT label—NONFLAMMABLE GAS; and
- UN number—UN 1005.

The words “Inhalation Hazard” shall be included on shipping papers and on containers and cylinders as required by Special Provision 13 in Column 7 of the Hazardous Materials Table [9].

If the quantity of ammonia shipped in a single container or cylinder equals or exceeds the reportable quantity (RQ) of 100 lb (45.4 kg), the letters “RQ” shall be entered on the shipping paper either before or after the basic description. The total quantity of the ammonia covered by the one description shall appear before or after, or both before and after the description. Refer to 49 CFR 171.14, Special Provision 13 in Column 7 of the Hazardous Materials Table in 172.102, 172.202, and 172.203 [9].

The basic description on shipping papers covering transportation of ammonia in Canada are as follows:

- TC proper shipping name—Ammonia, anhydrous;
- TC hazard class—2.3 (8);
- TC label—TOXIC GAS, CORROSIVE; and
- UN number—UN 1005.

For international transportation of ammonia, the proper shipping name is “Anhydrous, Ammonia” and the hazard division number is 2.3 (8).

7.6 Container qualification

7.6.1

In general, regulations require that the materials used in the fabrication of containers or cylinders for transportation or storage service, most often various types of steel, meet certain chemical and physical specifications. Upon fabrication, containers and cylinders shall be inspected and pass hydrostatic pressure tests as well as other tests as may be required by the regulations. Following placement into service, containers and cylinders are required by the regulations to be inspected and tested at specified periodic intervals in order to be requalified for continued service.

7.7 Filling density

7.7.1

Ammonia is routinely shipped and stored as a liquefied compressed gas. Liquid ammonia is essentially noncompressible and its volume expands with a rise in temperature. It is possible, therefore, for a container or cylinder of ammonia to become liquid full following a sufficient increase in temperature. The hydrostatic pressure resulting from this condition can cause a container or cylinder to rupture or cause ammonia to discharge through a PRD when such device is required to be installed. For this reason, DOT, TC, and UN regulations limit the amount of ammonia that may be put into shipping containers, cylinders, and storage tanks, respectively.

8 Ammonia exposure

8.1 General

8.1.1

Ammonia is not a cumulative metabolic toxin. Ammonium ions are important constituents of living systems. However, ammonia in the ambient atmosphere can have an intense irritating effect on the mucous membranes of the eyes, nose, throat, and lungs. High concentration levels of ammonia can produce corrosive effects on tissues and can cause laryngeal and bronchial spasm and edema to obstruct breathing. The pungent odor of ammonia affords a protective warning.

8.1.2

Since liquid ammonia vaporizes readily and has a great affinity for water, it can cause severe injury to the skin by freezing the tissue and subjecting it to caustic action. A severe chemical burn can result.

8.1.3

Seek medical assistance immediately for any person who has been burned or overcome by ammonia.

8.1.4

The patient should be removed to an area free from fumes. They should be placed in a reclined position with head and shoulders elevated and kept warm.

NOTE—Prior to medical aid, first aid measures should be taken. Those presented herein are based upon what is believed to be common practice in industry. Their adoption in any specific case should be subject to prior endorsement by a competent medical advisor.

8.2 First aid

8.2.1 Inhalation

8.2.1.1

A conscious person who has experienced minor irritation from ammonia fumes should breathe fresh air for relief.

8.2.1.2

A person overcome by ammonia should immediately be moved to area free from fumes. If breathing or heartbeat has ceased, cardiopulmonary resuscitation (CPR) shall be started immediately, preferably by trained personnel. If breathing is weak or has been restored by CPR, oxygen should be administered. Severe ammonia exposure can cause delayed lung edema and hospitalization could be required in these cases.

8.2.2 Eyes

If contacted by ammonia, the eyes shall be flooded immediately with copious quantities of clean water. In isolated areas, water in a squeeze bottle that can be carried in the pocket is helpful for emergency irrigation purposes. Eye fountains should be used but if they are not available, water can be poured over the eyes while on the way for medical attention. In any case, the eyelids shall be held open and irrigation shall continue for at least 15 minutes. The patient shall receive prompt attention from a physician, preferably an ophthalmologist. After eye irrigation, a physician should be consulted even if the ammonia did not affect the eyes because extensive irrigation can result in severe irritation or infection. Persons subject to ammonia exposure should not wear contact lenses.

8.2.3 Skin

If liquid ammonia contacts the skin, the area affected should be immediately flooded with water. If no safety shower is available, immerse in any available water. Water can have the effect of thawing out clothing that can be frozen to the skin. After thawing, contaminated clothing should be removed and the affected area flooded with water for at least 15 minutes. The injured area should be protected with clean cloth prior to medical care. Do not apply salves or ointments. Do not apply other materials in an attempt to neutralize the ammonia.

8.2.4 Ingestion

Ingestion is unlikely; however, if ammonia is ingested and the patient can swallow have them drink large quantities of water. Seek medical attention immediately.

CAUTION: *Never give anything by mouth to an unconscious person.*

8.3 Physiological effects

8.3.1

Persons having chronic respiratory disease or persons who have shown evidence of undue sensitivity to ammonia should not be employed where they can be exposed to ammonia.

8.3.2

At low concentrations, ammonia gas is irritating to the eyes, skin, and mucous membranes of the nose, throat, and lungs. At higher concentrations, ammonia is corrosive to human tissue and possibly life threatening. Table 4 indicates human physiological responses to various concentrations of ammonia in air.

Table 4—Human physiological response to various concentrations of ammonia in air

Concentration/time	% Ammonia/time	Effect
20 ppm to 50 ppm	0.002% to 0.005%	Mild discomfort, depending on whether an individual is accustomed to smelling ammonia
50 ppm to 80 ppm for 2 hr	0.005% to 0.008% for 2 hr	Perceptible eye and throat irritation
100 ppm for 2 hr	0.01% for 2 hr	Nuisance eye and throat irritation
134 ppm for 5 min	0.0134% for 5 min	Tearing of the eyes, eye irritation, nasal irritation, throat irritation, chest irritation
140 ppm for 2 hr	0.0140% for 2 hr	Severe irritation, need to leave exposure area
300 ppm to 500 ppm for 30 min [2]	0.03% to 0.05% for 30 min	Upper respiratory tract irritation, tearing of the eyes (lacrimation), hyperventilation
700 ppm to 1700 ppm	0.07% to 0.17%	Incapacitation from tearing of the eyes and coughing
5000 ppm to 10 000 ppm	0.5% to 1.0%	Rapidly fatal
10 000 ppm	1.0%	Promptly lethal

8.3.3 Ammonia exposure limits and guidelines

The pungent odor of ammonia is readily detectable by most people and serves as its own warning. Concentrations in the range of 5 ppm to 53 ppm as referenced in National Academies' *Acute Exposure Guideline Levels for Selected Airborne Chemicals* are readily detectable and it is therefore unlikely that any individual would become overexposed unknowingly [43]. Some exposure limits and guidelines for ammonia are shown in Tables 5 and 6. See *NIOSH Pocket Guide to Chemical Hazards*, 29 CFR 1910.1000, and American Industrial Hygiene Association (AIHA) *Emergency Response Planning Guidelines* (ERPG) [10, 2, 44].

Table 5—Regulatory ammonia exposure limits [10]

Regulation/Guideline	Exposure limit value
NIOSH Immediately dangerous to life or health (IDLH)	300 ppm
NIOSH Recommended Exposure Limit (REL)	25 ppm (18 mg/m ³) 10 hr Time-weighted average (TWA)
NIOSH Short-term exposure limit (STEL)	35 ppm (27 mg/m ³) 15 min TWA
OSHA PEL	50 ppm (35 mg/m ³) 8 hr TWA
NOTES	
1 IDLH, STEL, and PEL are defined in Section 2 of this publication.	
2 TWA—Time-Weighted Average concentration in contaminated air by volume for up to an 8 hr (OSHA) or 10 hr (NIOSH) workday during a 40 hr workweek.	

Table 6—Emergency response planning guideline (ERPG) exposure limits [44]

Level	Concentration	Description
ERPG-1	25 ppm	The maximum airborne concentration below which nearly all individuals could be exposed for up to 1 hr without experiencing other than mild, transient adverse health effects or without perceiving a clearly defined objectionable odor.
ERPG-2	150 ppm	The maximum airborne concentration below which nearly all individuals could be exposed for up to 1 hr without experiencing or developing irreversible or other serious health effects or symptoms that could impair an individual's ability to take protective action.
ERPG-3	750 ppm	The maximum airborne concentration below which nearly all individuals could be exposed for up to 1 hr without experiencing or developing life-threatening health effects.

9 **Emergency planning and response coordination**

9.1 **Controlling leaks**

9.1.1 **Leak detection**

Leak detection fluids are not recommended for use in ammonia service due to the creation of caustic byproducts and the ammonia can be absorbed into the leak detection solution, which can hide the leak.

While ammonia can be detected by its distinctive odor, the use of test paper or instruments is recommended to determine the location of leaks.

9.1.1.1 **Odor and test paper**

The location of a leak can be determined by using moist red litmus paper or moist filter paper impregnated with phenolphthalein. These chemical test papers change color in ammonia vapor.

9.1.1.2 **Instruments**

Electronic instrumentation is available to detect an ammonia leak and activate an alarm. Detectors can be placed in strategic locations at the facility to monitor the air so corrective action can be taken in the event of a leak.

9.1.2 **Action if a leak occurs**

9.1.2.1

Only personnel trained for and designated to handle emergencies should attempt to stop a leak. Refer to 29 CFR 1910.120 [2]. Respiratory equipment of a type suitable for ammonia shall be worn. All persons not so equipped shall leave the affected area until the leak has been stopped. See Section 10 for safety equipment information.

9.1.2.2

If ammonia vapor is released or detected, unprotected personnel should leave the area as quickly and safely as possible. To facilitate rapid evacuation, there should be sufficient well-marked and easily accessible exits.

9.1.2.3

With good ventilation or rapidly moving air currents, ammonia vapor, being lighter than air can be expected to dissipate readily to the upper atmosphere without further action being necessary. Lacking these conditions, the concentration of ammonia vapor in air can be reduced effectively by the use of adequate volumes of water applied through spray or fog nozzles. Do not put water on a liquid ammonia spill. A violent production of vapor can result. Instead, use spray or fog nozzles on the vapor downwind of the spill.