Ammonia Refrigeration Basics

Table of Contents

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AMMONIA REFRIGERATION BASICS

Lesson One

Ammonia Characteristics

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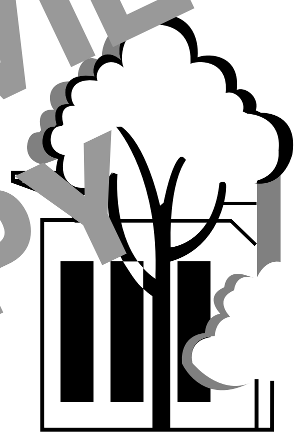

TPC Training Systems

46101

Lesson

1 Ammonia Characteristics

TOPICS

Ammonia Sources and Uses
Environmental Concerns
Chemical Characteristics of Ammonia
Hazardous Material Concerns
Ammonia Temperature-Pressure Relationships
Materials Compatibility
Ammonia MSDS Criteria
Ammonia Safety Cautions and First Aid

OBJECTIVES

After studying this Lesson, you should be able to…

- Name common uses of ammonia and describe benefits of ammonia refrigerant in terms of ozone depletion and global warming potentials (ODP and GWP).
- Describe the properties of ammonia and explain how they affect the use of ammonia as a refrigerant.
- Discuss the toxicity and flammability of ammonia and its classification as a hazardous material.
- Discuss important features of ammonia saturation curves, reactions with metals, and MSDS criteria.
- Name two standards governing ammonia refrigeration systems and describe the four main ammonia safety concerns, steps for their prevention, and first aid treatment in the event of exposure.

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KEY TECHNICAL TERMS

Ozone depletion potential (ODP) 1.08 the ability of a refrigerant to interfere with and participate in the destruction of the ozone layer in the stratosphere

Global warming potential (GWP) 1.11 the ability of a refrigerant to contribute to the harmful gaseous layer in the troposphere

Anhydrous ammonia 1.13 ammonia formed without water, thus protecting its refrigeration characteristics

Deflagration 1.23 sudden combustion that is less forceful than an explosion, with combustion velocity slower than the speed of sound

Saturation curve 1.29 a line on a graph indicating the temperatures at which boiling will take place for a liquid in a closed container at various pressures

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Mankind has been knowledgeable about ammonia since antiquity. Its name derives from the common term for ammonium chloride, *sal ammoniac*. Sal ammoniac was produced by the distillation of camel dung at the Temple of Ammon, in what is now Libya.

The use of ammonia as a refrigerant began in the 1850s, but refrigeration compressors were not commercially available until the late 1880s. Then ammonia became the refrigerant for the production of block ice, which was the primary requirement for mechanical refrigeration. Since that time, the efficiency, economics, and environmental aspects of ammonia have kept it as a refrigerant of choice, especially for large industrial food, beverage, pharmaceutical, and petrochemical facilities in ever-growing quantities to the present day.

Ammonia Sources and Uses

1.01 The commercial production of ammonia in the United States began around 1880, as a by-product formed during the production of coke and coal gas by the destructive distillation of coal. The quantity of ammonia was limited by the quantities of coke and coal gas required to meet the demands of the market. In 1913, Fritz Haber and Carl Bosch began production of ammonia in Europe by a direct synthesis process for which both men were presented the Nobel Prize in chemistry. By 1921, a Haber-Bosch plant was in operation in the United States.

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1.02 Ammonia is vital to both plant and animal life. Huge amounts of ammonia are produced naturally by both animals and humans. We each exhale a small amount of ammonia with every breath. Animals do likewise, especially grazing animals that chew their cud and release a high percentage of ammonia into the atmosphere. Ammonia is also generated by decaying excrement, vegetation, and animals. Anyone familiar with farm life, stables, poultry houses, and manure is aware of the particularly pungent odor of ammonia.

1.03 In addition to the production of ammonia by natural life processes, ammonia is also generated as a by-product of fossil-fuel power plants, sewage treatment, automotive and stationary internal combustion engines, some industrial processes, and a number of other industrial operations. Table 1-1 lists the breakdown of sources for ammonia released to the atmosphere in Southern California according to a Southern California Air Quality Management District (SCAQMD) report in 1982. Note that over 65% of the naturally occurring ammonia is generated by cattle and people.

1.04 Ammonia is also produced in abundance commercially for numerous requirements. The greatest quantities by far (approximately 80%) are used either directly for fertilizing or in the manufacture of fertilizer products. Other uses include the following:

- cotton preharvest defoliant
- antifungal agent
- ammonium nitrate, TNT explosives
- metal treatments, nitriding, carbo-nitriding, descaling
- petroleum refining
- metal-ore extraction
- water and wastewater treatment
- stack emission control, antismog agent
- chemical and pharmaceutical industries
- plastics and synthetic urea
- photochemical processes, white and blue printing
- rubber processing
- pulp and paper manufacture
- food and beverage industries (source of nitrogen required by yeast)
- household cleaning products

Table 1-1. SCAQMD ammonia source breakdown

Ammonia source	Contribution (%)
Stationary fuel combustion	1.9
Mobile fuel combustion	2.0
Industrial point sources	1.5
Sewage treatment plants	8.9
Soil surface	14.5
Fertilizer	5.4
Livestock	51.6
Domestic (humans)	14.2

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- curing and protective agent in leather manufacture
- refrigerant, primarily in large food, beverage, cold storage, and petrochemical industries.

1.05 It is estimated that there are a total of 2 billion metric tons of ammonia in the world, both natural and manufactured. Of those 2 billion metric tons, only about 5% (100 million metric tons) are manufactured. In North America, there are about 18 million metric tons, of which only 2% (roughly 350,000 metric tons) are used as a refrigerant.

Environmental Concerns

1.06 Ammonia, which is identified in ASHRAE Standard 34 as Refrigerant 717 and more commonly referred to as R-717, has no ozone depletion potential and no global warming potential when compared to the synthesized halocarbon CFC, HCFC, and HFC refrigerants. Upon release into the atmosphere, ammonia dissipates rapidly. Typically, within a week it will have reacted chemically to form other compounds or will have been broken down into its basic elements, hydrogen and nitrogen.

1.07 By comparison, the CFC, HCFC, and HFC refrigerants are extremely stable compounds, which upon release also dissipate similarly into the atmosphere, but will not react with components in the air nor break down under the influence of sunlight. These refrigerants have atmospheric life expectancies of up to 120 years. Table 1-2 indicates the ozone depletion potential (ODP) and global warming potential (GWP) of some of the common refrigerants.

1.08 **Ozone depletion.** *Ozone depletion potential (ODP)* refers to the ability of a stable refrigerant with a long atmospheric life to reach into the stratosphere, and while there to interfere with and participate in the destruction of the ozone layer. The stratosphere, typically 7 to 30 miles above the earth, contains approximately 90% of the earth's supply of ozone. Ozone (O_3) is an unstable form of oxygen, consisting of three oxygen atoms, whereas normal oxygen (O_2) has two atoms.

1.09 The ozone layer has a beneficial function, because it absorbs damaging ultraviolet rays from the sun and shields life on earth from the rays' harmful effects. The CFC refrigerants with high ODP factors have been found to interfere with the quantity of ozone by reacting with the ozone in a catalytic fashion. That is, the ozone (O_3) is converted to oxygen (O_2), thus reducing the effect of the ozone shield.

1.10 The HCFC refrigerants have also been found to react with the ozone layer in much the same manner, but to a lesser degree. The Montreal Protocol, a worldwide consortium of concerned governments, resulted in a total ban on the production of CFC refrigerants at the end of 1995. It also scheduled the HCFC refrigerants for decreased production and eventual cessation of manufacture by the year 2030. These restrictions also apply to a number of "Halon" fire-extinguishing compounds that have chemical properties that are similar to the affected refrigerants.

1.11 **Global warming.** The second environmental criterion noted, *global warming potential (GWP)*, is also important. This takes place in the troposphere, the atmospheric layer beneath the stratosphere, up to about 7 miles above the earth. The troposphere contains a gaseous layer of carbon dioxide, methane and chlorofluorocarbon (CFC, HCFC, and HFC) refrigerants. This gaseous layer absorbs heat and reflects infrared radiation from the earth back toward the earth. Excess amounts of these gases are expected to cause a gradual global warming with subsequent melting of polar ice and rising sea levels. Measures are being taken to reduce the production and release of additional quantities of these gases into the atmosphere.

1.12 As mentioned previously, ammonia is an ideal alternative for large refrigeration systems because it is a naturally occurring compound with an ozone depletion potential of zero and a global warming potential of zero. That is, ODP = 0.0 and GWP = 0.0.

Table 1-2. Ozone depletion and global warming potentials

Refrigerant	Chemical formula	ODP	GWP
R-717	NH_3	0.0	0.0
R-11 (CFC)	CCl_3F	1.0	1.0
R-12 (CFC)	CCl_2F_2	0.9	3.1
R-22 (HCFC)	$CHClF_2$	0.05	0.34
R-123 (HCFC)	$CHCl_2CF_3$	0.02	0.02
R-134a (HFC)	CF_3CH_3F	0.0	0.27

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Chemical Characteristics of Ammonia

1.13 *Anhydrous ammonia* (ammonia formed without water, thus protecting its refrigeration characteristics) can be found as a colorless gas, a colorless liquid, or a white solid, depending on the temperature and pressure to which it is subjected. In all common refrigeration applications, it is in either the gaseous or liquid state. Ammonia (NH_3) is a simple compound composed of one atom of nitrogen and three atoms of hydrogen. As previously noted, it is also identified as refrigerant R-717.

1.14 Ammonia is available in several grades of purity depending on the use for which it is intended. The two most common uses are as fertilizer and as refrigerant, as presented in Table 1-3.

1.15 At standard (atmospheric) temperature and pressure conditions, ammonia gas (vapor) is less dense than air and the liquid is less dense than water. Both ammonia liquid and ammonia vapor in a closed container at atmospheric pressure (14.69 psia) have a saturated (equilibrium) temperature of -28°F (-33.3° C). Table 1-4 lists various important properties of ammonia, R-717.

1.16 Ammonia is classified as toxic, has an irritating odor, and is explosive within a limited range of mixtures with air. However, ammonia also has excellent thermal properties, the highest refrigeration effect per pound of any refrigerant, and suitable pressure-temperature relationships that match the requirements of the food and cold-storage industries. It is also environmentally friendly. Its pungent odor makes it self-alarming in the event of a leak, and it is extremely inexpensive (approximately $0.30/lb). Table 1-5 compares the refrigeration effect of ammonia with that of three other common refrigerants.

1.17 The large refrigeration effect of R-717 in comparison to the other refrigerants results in the fact that a much lower refrigerant flow rate is required to accomplish similar product cooling. This lower rate enables the use of smaller pipe sizes, smaller pumps, less liquid pumping horsepower, and, because ammonia is about half the weight of the halocarbon refrigerants, about half the refrigerant weight charge in the system. This is important because all refrigerants are purchased on a per-pound basis.

Table 1-3. Ammonia specifications

Constituent	Fertilizer	Refrigerant
Min. ammonia content	99.50%	99.98%
Max. water content	5000 ppm	150 ppm
Max. oil content	5 ppm	3 ppm
Max. noncondensables	N/A	0.2 ml/g

Table 1-4. Physical properties of ammonia

Property	Condition	Value
Molecular weight	—	17.03
Color	—	None
Physical state	68°F, 1 atm	Vapor
Physical state	-40°F, 1 atm	Liquid
Boiling point	1 atm	-28°F
Freezing point	1 atm	-108°F
Specific gravity	1 atm, 32°F vapor	0.596
Specific gravity	1 atm, 60°F liquid	0.62
Specific volume	1 atm, 32°F vapor	20.8 ft^3/lb
Odor	—	Pungent, irritating
Odor threshold	—	5–50 ppm
Flammability limits	Mixed with air	15–28%
Ignition temperature	No catalyst	1204°F

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Table 1-5. Refrigeration effect @ 5°F evap./86°F cond.

Refrigerant	Refrigeration effect (Btu/lb)	Refrigerant flow rate (lb/min)
R-12 (CFC)	50.0	4.00
R-22 (HCFC)	70.0	2.86
R-134a (HFC)	64.8	3.09
R-717	474.4	0.42

Hazardous Material Concerns

1.18 **Toxicity.** The pungent, disagreeable odor and toxicity of ammonia provide advantages along with the disadvantages. As mentioned, the odor provides a self-alarming feature that readily alerts personnel in the event of even the tiniest of leaks. The specific location of ammonia leaks can be quickly determined by the burning of a sulfur candle adjacent to the suspected leak. The smoke from the candle turns dense white in the presence of ammonia.

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1.19 The threshold level at which people can smell the presence of ammonia in the air is from 5 to 50 ppm (parts ammonia per million parts of air). A kitchen floor, freshly cleaned with an ammonia product, will temporarily exhibit an odor in the range of 30 to 50 ppm. Ammonia becomes irritating to the nose and throat at 400 ppm. Table 1-6 contains additional information on ammonia concentrations and their effects.

1.20 **Flammability.** Ammonia will burn in air if there is a sufficiently strong external flame introduced to support the burning. However, the ammonia will cease to burn upon removal of the external flame. There are some ammonia emergency release systems that rely on external flare techniques to burn the ammonia, resulting in harmless components, primarily nitrogen and water vapor.

1.21 The U.S. Department of Transportation has designated ammonia as nonflammable for shipping purposes. This results from the fact that ammonia does not support its own combustion, and that explosive mixtures are difficult to obtain in outdoor situations.

1.22 Ammonia is explosive in the range of 15 to 28% concentration with air. This concentration is many times beyond that in which any persons could exist without the aid of a self-contained breathing apparatus (SCBA). It is normally recommended that, if the concentration of ammonia in an enclosed space is suspected to approach the explosive range, all personnel be prevented from occupying the area.

Table 1-6. R-717 personnel concentration criteria

Concentration	Effect
5–50 ppm	Most people can smell ammonia at these levels.
100 ppm	Moderately strong odor, cause for concern but not alarm.
400 ppm	Irritation to nose and throat. Serious injury will not normally follow short exposure.
1700 ppm	Potentially fatal for exposures lasting longer than 30 minutes.
5000 ppm	Considered rapidly fatal.

1.23 Ammonia explosions are more correctly termed *deflagrations*, because the rate at which the combustion zone propagates is slower than the speed of sound. That is, ammonia explosions are less forceful in comparison to explosions of flammable fuel gases where the combustion velocity exceeds the speed of sound.

1.24 Some newer ammonia refrigeration machine rooms are being designed so that in the event of an ammonia deflagration, certain portions of the walls will collapse and harmlessly relieve the force of the explosion. Such design information is available from the National Fire Protection Association (NFPA), "Guide for Venting Deflagrations—NFPA 68, 1988."

1.25 **Hazardous material classification.** Ammonia has been categorized as a hazardous material under the Comprehensive Environmental Response, Compensation and Liability Act (CERCLA) of 1980. Since that time, in 1989 the Occupational Safety and Health Administration (OSHA) instituted the Hazardous Waste Operations and Emergency Response (HAZWOPER) Rule, 54 Fed. Reg. 9317. HAZWOPER requires that employers develop and implement procedures to protect the health and safety of employees involved in emergency response and cleanup of releases of hazardous materials. This rule applies to companies that have ammonia refrigeration systems.

1.26 In addition, OSHA in 1992 and the Environmental Protection Agency (EPA) in 1996 have both introduced mandatory regulations controlling the safe operation of ammonia refrigeration plants containing 10,000 lb or more of ammonia. The OSHA regulation targets safe working conditions for the employees within the plant and requires the establishment of a multistep process safety management (PSM) program. The EPA regulation targets the neighborhood and environment right-to-know and ammonia release minimization techniques through a similar multistep risk management program (RMP). These programs will be discussed later in this course.

The Programmed Exercises on the next page will tell you how well you understand the material you have just read. Before starting the exercises, remove the Reveal Key from the back of your book. Read the instructions printed on the Reveal Key. Follow these instructions as you work through the Programmed Exercises.

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1-1. As a refrigerant, ammonia is commonly referred to as ________.	1-1. R-717 Ref: 1.06
1-2. The basic elements of ammonia are ________ and ________.	1-2. HYDROGEN; NITROGEN Ref: 1.06
1-3. The ODP for ammonia is ________ and the GWP is ________.	1-3. 0.0; 0.0 Ref: 1.06, 1.12, Table 1-2
1-4. Ammonia gas is ________ dense than air, and ammonia liquid is ________ dense than water.	1-4. LESS; LESS Ref: 1.15
1-5. The refrigerant with by far the highest refrigeration effect per pound is ________.	1-5. AMMONIA Ref: 1.16, Table 1-5
1-6. The self-alarming feature of ammonia refrigerant is its ________.	1-6. ODOR Ref: 1.16, 1.18
1-7. Ammonia explosions are actually ________ because they occur at less than the speed of ________.	1-7. DEFLAGRATIONS; SOUND Ref: 1.23
1-8. OSHA and the EPA require special multistep safety programs for plants containing ________ lb or more of ammonia.	1-8. 10,000 Ref: 1.26

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Ammonia Temperature-Pressure Relationships

1.27 Water in an open container boils at 212°F (100°C) at a standard atmospheric condition of 14.69 psia. If the container is closed and pressure is controlled, the boiling temperature can be changed depending on the pressure in the closed vessel. Increasing the pressure increases the temperature at which the water boils, and lowering the pressure lowers the boiling temperature.

1.28 Refrigerants are fluids contained within a closed vessel, and the pressures in the vessel will determine the temperatures at which the refrigerant will boil, just as with water. Figure 1-1 indicates the boiling temperature vs. pressure for R-22, R-717, and water.

1.29 The temperature-pressure relationships indicate for these liquids the temperature at which boiling takes place. The curves of Fig. 1-1 are called *saturation curves*. The specific temperature for a particular refrigerant will always occur at the same specific pressure. The two are always linked in the same relationship. From these curves you can see that, at atmospheric pressure, the boiling temperature for R-22 is -40°F (-40°C), for R-717 is -28°F (-33.3°C), and for water is 212°F (100°C). Increasing or decreasing the pressure obviously changes the saturation temperature.

1.30 In a refrigeration system, the pressure in the evaporator is controlled so that the refrigerant in the evaporator will boil at the desired temperature. The pressure in the condenser is kept higher, typically by the prevailing atmospheric conditions. At the condenser pressure, it is not boiling that we are concerned with but rather the reverse process—condensing the refrigerant from a vapor to a liquid, which also occurs at the saturation condition.

1.31 For R-717 and evaporator temperatures in the range of -60 to 50°F (-51.1 to 10°C), evaporator pressures range from 18.6 in. of mercury vacuum (in. Hg vac) to 74.5 psig. Condenser pressures from 126 to 181 psig result in liquid ammonia temperatures of 75 to 95°F (23.9 to 35°C). Specific requirements of the refrigeration system determine the exact evaporator setpoints. The condenser pressure is determined by the physical size of the condenser and the weather conditions.

1.32 Good design condensing conditions are 90°F (32.2°C) and 166 psig, but operation at 200 psig or higher is common. Table 1-7 presents the temperature and pressure relationships for R-717 as well as other pertinent information including specific volume, density, enthalpy, and entropy. These terms are discussed in detail in Lesson Two and are included here only because you will use this table in later Lessons.

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Fig. 1-1. Pressure-temperature curves for R-22, R-717, and water

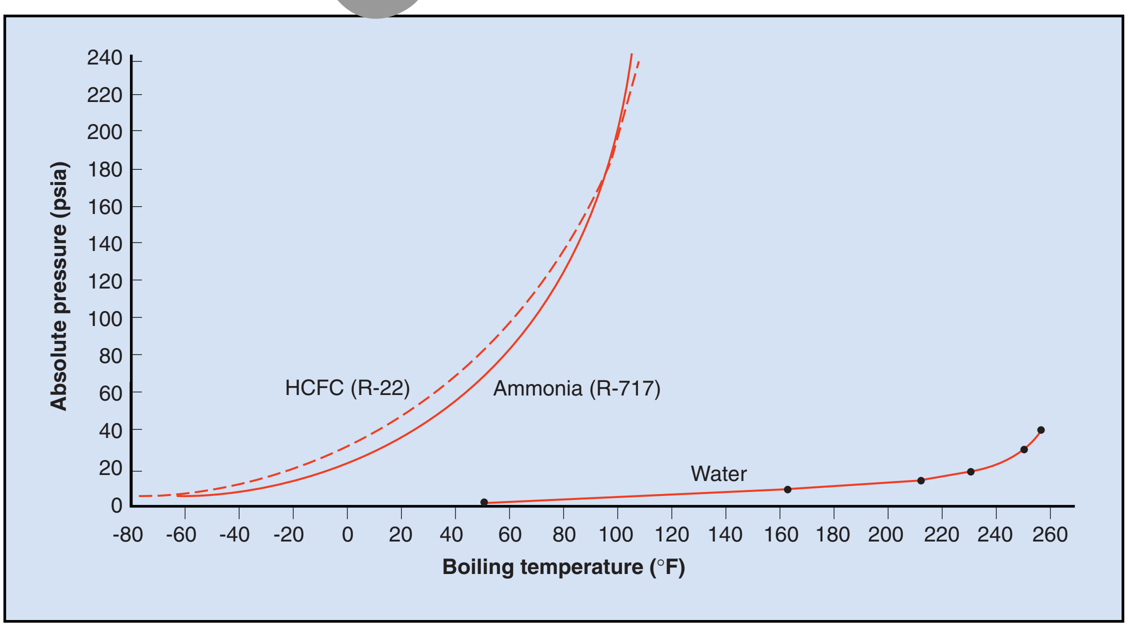

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Table 1-7. Thermodynamic properties of Refrigerant 717 (ammonia)

Temp. (°F)	Pressure (psi)		Volume (ft³/lb)		Density (lb/ft³)		Enthalpy (Btu/lb)			Entropy (Btu/lb) (°R)		Temp. (°F)
t	Absolute P	Gauge p	Liquid v_f	Vapor v_g	Liquid $1/v_f$	Vapor $1/v_g$	Liquid h_f	Latent h_{fg}	Vapor h_g	Liquid s_f	Vapor s_g	t
-60	5.55	18.6*	0.02278	44.73	43.91	0.02235	-21.2	610.8	589.6	-0.0517	1.4769	-60
-59	5.74	18.2*		43.37		.02306	-20.1	610.1	590.0	- .0490	1.4741	-59
-58	5.93	17.8*		42.05		.02378	-19.1	609.5	590.4	- .0464	1.4713	-58
-57	6.13	17.4*		40.79		.02452	-18.0	608.8	590.8	- .0438	1.4686	-57
-56	6.33	17.0*		39.56		.02528	-17.0	608.2	591.2	- .0412	1.4658	-56
-55	6.54	16.6*	0.02288	38.38	43.70	0.02605	-15.9	607.5	591.6	-0.0386	1.4631	-55
-54	6.75	16.2*		37.24		.02685	-14.8	606.9	592.1	- .0360	1.4604	-54
-53	6.97	15.7*		36.15		.02766	-13.8	606.2	592.4	- .0334	1.4577	-53
-52	7.20	15.3*		35.09		.02850	-12.7	605.6	592.9	- .0307	1.4551	-52
-51	7.43	14.8*		34.06		.02936	-11.7	604.9	593.2	- .0281	1.4524	-51
-50	7.67	14.3*	0.02299	33.08	43.49	0.03023	-10.6	604.3	593.7	-0.0256	1.4497	-50
-49	7.91	13.8*		32.12		.03113	-9.6	603.6	594.0	- .0230	1.4471	-49
-48	8.16	13.3*		31.20		.03205	-8.5	602.9	594.4	- .0204	1.4445	-48
-47	8.42	12.8*		30.31		.03299	-7.4	602.3	594.9	- .0179	1.4419	-47
-46	8.68	12.2*		29.45		.03395	-6.4	601.6	595.2	-0.0153	1.4393	-46
-45	8.95	11.7*	0.02310	28.62	43.28	0.03494	-5.3	600.9	[illegible]	-0.0127	1.4368	-45
-44	9.23	11.1*		27.82		.03595	-4.3	600.3	[illegible]	- .0102	1.4342	-44
-43	9.51	10.6*		27.04		.03698	-3.2	[illegible]	[illegible]	- .0076	1.4317	-43
-42	9.81	10.0*		26.29		.03804	-2.1	[illegible]	[illegible]	- .0051	1.4292	-42
-41	10.10	9.3*		25.56		.03912	[illegible]	[illegible]	[illegible]	- .0025	1.4267	-41
-40	10.41	8.7*	0.02322	24.86	43.07	[illegible]	[illegible]	597.6	597.6	0.0000	1.4242	-40
-39	10.72	8.1*		24.18		[illegible]	[illegible]	[illegible]	598.0	.0025	1.4217	-39
-38	11.04	7.4*		23.53		[illegible]	[illegible]	[illegible]	598.3	.0051	1.4193	-38
-37	11.37	6.8*		22.89		[illegible]	[illegible]	595.5	598.7	.0076	1.4169	-37
-36	11.71	6.1*		22.27		[illegible]	4.3	594.8	599.1	.0101	1.4144	-36
-35	12.05	5.4*	0.02333	[illegible]	[illegible]	[illegible]	5.3	594.2	599.5	0.0126	1.4120	-35
-34	12.41	4.7*		[illegible]		.04739	6.4	593.5	599.9	.0151	1.4096	-34
-33	12.77	3.9*		[illegible]		.04868	[illegible]	592.8	600.2	.0176	1.4072	-33
-32	13.14	3.2*		[illegible]		.04999	[illegible]	592.1	600.6	.0201	1.4048	-32
-31	13.52	2.4*		[illegible]		[illegible]	[illegible]	591.4	601.0	.0226	1.4025	-31
-30	13.90	1.6*	[illegible]	18.97	42.65	[illegible]	[illegible]	590.7	601.4	0.0250	1.4001	-30
-29	14.30	0.8*		18.48		[illegible]	11.7	590.0	601.7	.0275	1.3978	-29
-28	14.71	0.0		18.00		[illegible]	12.8	589.3	602.1	.0300	1.3955	-28
-27	15.12	0.4		[illegible]		[illegible]	13.9	588.6	602.5	.0325	1.3932	-27
-26	15.55	0.8		[illegible]		[illegible]	14.9	587.9	602.8	.0350	1.3909	-26
-25	15.98	1.3	0.02357	[illegible]	[illegible]	0.06003	16.0	587.2	603.2	0.0374	1.3886	-25
-24	16.42	1.7		[illegible]		.06158	17.1	586.5	603.6	.0399	1.3863	-24
-23	16.88	2.2		[illegible]		.06317	18.1	585.8	603.9	.0423	1.3840	-23
-22	17.34	2.6		15.43		.06479	19.2	585.1	604.3	.0448	1.3818	-22
-21	17.81	3.1		15.05		.06644	20.3	584.3	604.6	.0472	1.3796	-21
-20	18.30	3.6	0.02369	14.68	42.22	0.06813	21.4	583.6	605.0	0.0497	1.3774	-20
-19	18.79	4.1		14.32		.06985	22.4	582.9	605.3	.0521	1.3752	-19
-18	19.30	4.6		13.97		.07161	23.5	582.2	605.7	.0545	1.3729	-18
-17	19.81	5.1		13.62		.07340	24.6	581.5	606.1	.0570	1.3708	-17
-16	20.34	5.6		13.29		.07522	25.6	580.8	606.4	.0594	1.3686	-16
-15	20.88	6.2	0.02381	12.97	42.00	0.07709	26.7	580.0	606.7	0.0618	1.3664	-15
-14	21.43	6.7		12.66		.07898	27.8	579.3	607.1	.0642	1.3643	-14
-13	21.99	7.3		12.36		.08092	28.9	578.6	607.5	.0666	1.3621	-13
-12	22.56	7.9		12.06		.08289	30.0	577.8	607.8	.0690	1.3600	-12
-11	23.15	8.5		11.78		.08490	31.0	577.1	608.1	.0714	1.3579	-11
-10	23.74	9.0	0.02393	11.50	41.78	0.08695	32.1	576.4	608.5	0.0738	1.3558	-10
-9	24.35	9.7		11.23		.08904	33.2	575.6	608.8	.0762	1.3537	-9
-8	24.97	10.3		10.97		.09117	34.3	574.9	609.2	.0786	1.3516	-8
-7	25.61	10.9		10.71		.09334	35.4	574.1	609.5	.0809	1.3495	-7
-6	26.26	11.6		10.47		.09555	36.4	573.4	609.8	.0833	1.3474	-6
-5	26.92	12.2	0.02406	10.23	41.56	0.09780	37.5	572.6	610.1	0.0857	1.3454	-5
-4	27.59	12.9		9.991		.1001	38.6	571.9	610.5	.0880	1.3433	-4
-3	28.28	13.6		9.763		.1024	39.7	571.1	610.8	.0904	1.3413	-3
-2	28.98	14.3		9.541		.1048	40.7	570.4	611.1	.0928	1.3393	-2
-1	29.69	15.0		9.326		.1072	41.8	569.6	611.4	.0951	1.3372	-1

*Inches of mercury below one atmosphere

(Continued)

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Table 1-7. Thermodynamic properties of Refrigerant 717 (ammonia) (continued)

Temp. (°F)	Pressure (psi)		Volume (ft³/lb)		Density (lb/ft³)		Enthalpy (Btu/lb)			Entropy (Btu/lb) (°R)		Temp. (°F)
t	Absolute P	Gauge p	Liquid v_f	Vapor v_g	Liquid $1/v_f$	Vapor $1/v_g$	Liquid h_f	Latent h_{fg}	Vapor h_g	Liquid s_f	Vapor s_g	t
0	30.42	15.7	0.02419	9.116	41.34	0.1097	42.9	568.9	611.8	0.0975	1.3352	0
1	31.16	16.5		8.912		.1122	44.0	568.1	612.1	.0998	1.3332	1
2	31.92	17.2		8.714		.1148	45.1	567.3	612.4	.1022	1.3312	2
3	32.69	18.0		8.521		.1174	46.2	566.5	612.7	.1045	1.3292	3
4	33.47	18.8		8.333		.1200	47.2	565.8	613.0	.1069	1.3273	4
5	34.27	19.6	0.02432	8.150	41.11	0.1227	48.3	565.0	613.3	0.1092	1.3253	5
6	35.09	20.4		7.971		.1254	49.4	564.2	613.6	.1115	1.3234	6
7	35.92	21.2		7.798		.1282	50.5	563.4	613.9	.1138	1.3214	7
8	36.77	22.1		7.629		.1311	51.6	562.7	614.3	.1162	1.3195	8
9	37.63	22.9		7.464		.1340	52.7	561.9	614.6	.1185	1.3176	9
10	38.51	23.8	0.02446	7.304	40.89	0.1369	53.8	561.1	614.9	0.1208	1.3157	10
11	39.40	24.7		7.148		.1399	54.9	560.3	615.2	.1231	1.3137	11
12	40.31	25.6		6.996		.1429	56.0	559.5	615.5	.1254	1.3118	12
13	41.24	26.5		6.847		.1460	57.1	558.7	615.8	.1277	1.3099	13
14	42.18	27.5		6.703		.1492	58.2	557.9	616.1	.1300	1.3081	14
15	43.14	28.4	0.02460	6.562	40.66	0.1524	59.2	557.1	[illegible]	0.1323	1.3062	15
16	44.12	29.4		6.425		.1556	60.3	556.3	[illegible]	.1346	1.3043	16
17	45.12	30.4		6.291		.1590	61.4	[illegible]	[illegible]	.1369	1.3025	17
18	46.13	31.4		6.161		.1623	62.5	[illegible]	[illegible]	.1392	1.3006	18
19	47.16	32.5		6.034		.1657	[illegible]	[illegible]	[illegible]	0.1415	1.2988	19
20	48.21	33.5	0.02474	5.910	40.43	[illegible]	[illegible]	553.1	617.8	0.1437	1.2969	20
21	49.28	34.6		5.789		[illegible]	[illegible]	[illegible]	618.0	.1460	1.2951	21
22	50.36	35.7		5.671		[illegible]	[illegible]	[illegible]	618.3	.1483	1.2933	22
23	51.47	36.8		5.556		[illegible]	[illegible]	550.6	618.6	.1505	1.2915	23
24	52.59	37.9		5.443		[illegible]	[illegible]	549.8	618.9	.1528	1.2897	24
25	53.73	39.0	0.02488	[illegible]	[illegible]	0.1875	70.2	548.9	619.1	0.1551	1.2879	25
26	54.90	40.2		[illegible]		.1913	71.3	548.1	619.4	.1573	1.2861	26
27	56.08	41.4		[illegible]		.1952	[illegible]	547.3	619.7	.1596	1.2843	27
28	57.28	42.6		[illegible]		.1992	[illegible]	546.4	619.9	.1618	1.2825	28
29	58.50	43.8		[illegible]		.2032	[illegible]	545.6	620.2	.1641	1.2808	29
30	59.74	45.0	[illegible]	4.825	39.96	[illegible]	[illegible]	544.8	620.5	0.1663	1.2790	30
31	61.00	46.3		4.730		[illegible]	76.8	543.9	620.7	.1686	1.2773	31
32	62.29	47.6		4.637		[illegible]	77.9	543.1	621.0	.1708	1.2755	32
33	63.59	48.9		[illegible]		[illegible]	79.0	542.2	621.2	.1730	1.2738	33
34	64.91	50.2		[illegible]		[illegible]	80.1	541.4	621.5	.1753	1.2721	34
35	66.26	51.6	0.02518	[illegible]	[illegible]	0.2287	81.2	540.5	621.7	0.1775	1.2704	35
36	67.63	52.9		[illegible]		.2332	82.3	539.7	622.0	.1797	1.2686	36
37	69.02	54.3		[illegible]		.2377	83.4	538.8	622.2	.1819	1.2669	37
38	70.43	55.7		4.126		.2423	84.6	537.9	622.5	.1841	1.2652	38
39	71.87	57.2		4.048		.2470	85.7	537.0	622.7	.1863	1.2635	39
40	73.32	58.6	0.02533	3.971	39.49	0.2518	86.8	536.2	623.0	0.1885	1.2618	40
41	74.80	60.1		3.897		.2566	87.9	535.3	623.2	.1908	1.2602	41
42	76.31	61.6		3.823		.2616	89.0	534.4	623.4	.1930	1.2585	42
43	77.83	63.1		3.752		.2665	90.1	533.6	623.7	.1952	1.2568	43
44	79.38	64.7		3.682		.2716	91.2	532.7	623.9	.1974	1.2552	44
45	80.96	66.3	0.02548	3.614	39.24	0.2767	92.3	531.8	624.1	0.1996	1.2535	45
46	82.55	67.9		3.547		.2819	93.5	530.9	624.4	.2018	1.2519	46
47	84.18	69.5		3.481		.2872	94.6	530.0	624.6	.2040	1.2502	47
48	85.82	71.1		3.418		.2926	95.7	529.1	624.8	.2062	1.2486	48
49	87.49	72.8		3.355		.2981	96.8	528.2	625.0	.2083	1.2469	49
50	89.19	74.5	0.02564	3.294	39.00	0.3036	97.9	527.3	625.2	0.2105	1.2453	50
51	90.91	76.2		3.234		.3092	99.1	526.4	625.5	.2127	1.2437	51
52	92.66	78.0		3.176		.3149	100.2	525.5	625.7	.2149	1.2421	52
53	94.43	79.7		3.119		.3207	101.3	524.6	625.9	.2171	1.2405	53
54	96.23	81.5		3.063		.3265	102.4	523.7	626.1	.2192	1.2389	54
55	98.06	83.4	0.02581	3.008	38.75	0.3325	103.5	522.8	626.3	0.2214	1.2373	55
56	99.91	85.2		2.954		.3385	104.7	521.8	626.5	.2236	1.2357	56
57	101.8	87.1		2.902		.3446	105.8	520.9	626.7	.2257	1.2341	57
58	103.7	89.0		2.851		.3508	106.9	520.0	626.9	.2279	1.2325	58
59	105.6	90.9		2.800		.3571	108.1	519.0	627.1	.2301	1.2310	59

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Table 1-7. Thermodynamic properties of Refrigerant 717 (ammonia) (continued)

Temp. (°F)	Pressure (psi)		Volume (ft³/lb)		Density (lb/ft³)		Enthalpy (Btu/lb)			Entropy (Btu/lb) (°R)		Temp. (°F)
t	Absolute P	Gauge p	Liquid v_f	Vapor v_g	Liquid $1/v_f$	Vapor $1/v_g$	Liquid h_f	Latent h_{fg}	Vapor h_g	Liquid s_f	Vapor s_g	t
60	107.6	92.9	0.02597	2.751	38.50	0.3635	109.2	518.1	627.3	0.2322	1.2294	60
61	109.6	94.9		2.703		.3700	110.3	517.2	627.5	.2344	1.2278	61
62	111.6	96.9		2.656		.3765	111.5	516.2	627.7	.2365	1.2262	62
63	113.6	98.9		2.610		.3832	112.6	515.3	627.9	.2387	1.2247	63
64	115.7	101.0		2.565		.3899	113.7	514.3	628.0	.2408	1.2231	64
65	117.8	103.1	0.02614	2.520	38.25	0.3968	114.8	513.4	628.2	0.2430	1.2216	65
66	120.0	105.3		2.477		.4037	116.0	512.4	628.4	.2451	1.2201	66
67	122.1	107.4		2.435		.4108	117.1	511.5	628.6	.2473	1.2186	67
68	124.3	109.6		2.393		.4179	118.3	510.5	628.8	.2494	1.2170	68
69	126.5	111.8		2.352		.4251	119.4	509.5	628.9	.2515	1.2155	69
70	128.8	114.1	0.02632	2.312	38.00	0.4325	120.5	508.6	629.1	0.2537	1.2140	70
71	131.1	116.4		2.273		.4399	121.7	507.6	629.3	.2558	1.2125	71
72	133.4	118.7		2.235		.4474	122.8	506.6	629.4	.2579	1.2110	72
73	135.7	121.0		2.197		.4551	124.0	505.6	629.6	.2601	1.2095	73
74	138.1	123.4		2.161		.4628	125.1	504.7	629.8	.2622	1.2080	74
75	140.5	125.8	0.02650	2.125	37.74	0.4707	126.2	503.7	[illegible]	0.2643	1.2065	75
76	143.0	128.3		2.089		.4786	127.4	502.7	[illegible]	.2664	1.2050	76
77	145.4	130.7		2.055		.4867	128.5	501.7	[illegible]	.2685	1.2035	77
78	147.9	133.2		2.021		.4949	129.7	[illegible]	[illegible]	.2706	1.2020	78
79	150.5	135.8		1.988		.5031	130.8	[illegible]	[illegible]	0.2728	1.2006	79
80	153.0	138.3	0.02668	1.955	37.48	0.5115	[illegible]	[illegible]	630.7	0.2749	1.1991	80
81	155.6	140.9		1.923		[illegible]	[illegible]	497.7	630.8	.2769	1.1976	81
82	158.3	143.6		1.892		.5287	[illegible]	[illegible]	631.0	.2791	1.1962	82
83	161.0	146.3		1.861		[illegible]	[illegible]	495.7	631.1	.2812	1.1947	83
84	163.7	149.0		1.831		[illegible]	[illegible]	494.7	631.3	0.2833	1.1933	84
85	166.4	151.7	0.02687	[illegible]	[illegible]	0.5552	137.8	493.6	631.4	0.2854	1.1918	85
86	169.2	154.5		[illegible]		.5643	138.9	492.6	631.5	.2875	1.1904	86
87	172.0	157.3		[illegible]		.5735	140.1	491.6	631.7	.2895	1.1889	87
88	174.8	160.1		[illegible]		.5828	[illegible]	490.6	631.8	.2917	1.1875	88
89	177.7	163.0		[illegible]		.5923	[illegible]	489.5	631.9	.2937	1.1860	89
90	180.6	165.9	[illegible]	1.661	36.94	[illegible]	[illegible]	488.5	632.0	0.2958	1.1846	90
91	183.6	168.9		1.635		[illegible]	[illegible]	487.4	632.1	.2979	1.1832	91
92	186.6	171.9		1.609		[illegible]	145.8	486.4	632.2	.3000	1.1818	92
93	189.6	174.9		1.584		[illegible]	147.0	485.3	632.3	.3021	1.1804	93
94	192.7	178.0		[illegible]		[illegible]	148.2	484.3	632.5	.3041	1.1789	94
95	195.8	181.1	0.02727	[illegible]	[illegible]	0.6517	149.4	483.2	632.6	0.3062	1.1775	95
96	198.9	184.2		[illegible]		.6620	150.5	482.1	632.6	.3083	1.1761	96
97	202.1	187.4		[illegible]		.6725	151.7	481.1	632.8	.3104	1.1747	97
98	205.3	190.6		[illegible]		.6832	152.9	480.0	632.9	.3125	1.1733	98
99	208.6	193.9		1.441		.6939	154.0	478.9	632.9	.3145	1.1719	99
100	211.9	197.2	0.02748	1.419	36.40	0.7048	155.2	477.8	633.0	0.3166	1.1705	100
101	215.2	200.5		1.397		.7159	156.4	476.7	633.1	.3187	1.1691	101
102	218.6	203.9		1.375		.7270	157.6	475.6	633.2	.3207	1.1677	102
103	222.0	207.3		1.354		.7384	158.7	474.6	633.3	.3228	1.1663	103
104	225.4	210.7		1.334		.7498	159.9	473.5	633.4	.3248	1.1649	104
105	228.9	214.2	0.02769	1.313	36.12	0.7615	161.1	472.3	633.4	0.3269	1.1635	105
106	232.5	217.8		1.293		.7732	162.3	471.2	633.5	.3289	1.1621	106
107	236.0	221.3		1.274		.7852	163.5	470.1	633.6	.3310	1.1607	107
108	239.7	225.0		1.254		.7972	164.6	469.0	633.6	.3330	1.1593	108
109	243.3	228.6		1.235		.8095	165.8	467.9	633.7	.3351	1.1580	109
110	247.0	232.3	0.02790	1.217	35.84	0.8219	167.0	466.7	633.7	0.3372	1.1566	110
111	250.8	236.1		1.198		.8344	168.2	465.6	633.8	.3392	1.1552	111
112	254.5	239.8		1.180		.8471	169.4	464.4	633.8	.3413	1.1538	112
113	258.4	243.7		1.163		.8600	170.6	463.3	633.9	.3433	1.1524	113
114	262.2	247.5		1.145		.8730	171.8	462.1	633.9	.3453	1.1510	114
115	266.2	251.5	0.02813	1.128	35.55	0.8862	173.0	460.9	633.9	0.3474	1.1497	115
116	270.1	255.4		1.112		.8996	174.2	459.8	634.0	.3495	1.1483	116
117	274.1	259.4		1.095		.9132	175.4	458.6	634.0	.3515	1.1469	117
118	278.2	263.5		1.079		.9269	176.6	457.4	634.0	.3535	1.1455	118
119	282.3	267.6		1.063		.9408	177.8	456.2	634.0	.3556	1.1441	119
120	286.4	271.7	0.02836	1.047	35.26	0.9549	179.0	455.0	634.0	0.3576	1.1427	120

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Materials Compatibility

1.33 Ammonia reacts with a number of metals. Therefore, care must be taken in the materials used in an ammonia system. Ammonia reacts with copper and all copper alloys—for example, brass and bronze. Ammonia systems use steel piping and welded construction in place of the copper tubing and brazed construction of halocarbon systems. The welded steel construction provides a stronger, longer-lasting, and leak-tight piping system. Ammonia also reacts with mercury, cadmium, zinc, silver, gold, and their alloys.

1.34 Neoprene and buna-n are suitable rubber materials for gaskets and O-ring seals in ammonia systems. Teflon® is a suitable material for gaskets and valve seats.

Ammonia MSDS Criteria

1.35 Shipments of all potentially hazardous materials must be accompanied by government forms called *Material Safety Data Sheets*, or *MSDS*. The MSDS form has nine categories, which must be filled in by the supplier to provide adequate information for safe handling of the product. The categories are as follows:

- I Identification
- II Ingredients and Exposure Limits
- III Physical Data
- IV Fire and Explosion Hazard Data
- V Reactivity Data
- VI Spill or Leak Procedures
- VII Health Hazard Data
- VIII Special Protection Information
- IX Special Precautions.

Highlights of the information found on a typical ammonia MSDS form are provided in Table 1-8.

Ammonia Safety Cautions and First Aid

1.36 There are two primary standards documents that specify and control the safe design, construction, and installation of ammonia refrigeration equipment and systems. They are the following:

- ANSI/ASHRAE 15-1994: Safety Code for Mechanical Refrigeration
- ANSI/IIAR 2-1998: Equipment, Design, and Installation of Ammonia Mechanical Refrigeration Systems.

1.37 The ANSI/ASHRAE 15-1994 standard is a generalized code applicable to all mechanical refrigeration equipment, which includes all refrigerants, all sizes of equipment from residential air conditioning to gigantic industrial systems. It is the basic code written into most building codes in the United States. This code had its beginnings in 1919 as a tentative proposed code, finally was approved after much refinement, and became the American Standard B-9 Safety Code for Mechanical Refrigeration. It has been revised over the years and in 1978 was renamed ANSI/ASHRAE 15-1978.

1.38 The ANSI/ASHRAE 15-1994 standard deals with subjects that include refrigeration system occupancy classification—whether industrial, institutional, residential, and so on—and restrictions on refrigerant use within these classifications, as well as definitions of system classifications (for example, direct and indirect) and related restrictions. It also covers the following:

- installation restrictions and machinery room requirements
- system construction, piping, pressure vessels, and relief valves
- testing
- general requirements.

1.39 The ANSI/IIAR 2-1998 standard is written specifically for ammonia and in general is similar to ASHRAE 15-1994. In many cases, however, it provides a more limiting interpretation where required for the safe operation of ammonia equipment. It specifies the minimum design criteria for most ammonia refrigeration system components and the information required to be included on equipment nameplates by the manufacturer.

1.40 Ammonia is a hazardous material. It is a toxic gas, flammable when in a confined area at 15 to 28% concentration with air, extremely cold (-28°F [33.3°C] when liquid is vented to atmospheric pressure), and a general skin irritant at relatively low lev-

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Table 1-8. Highlights of ammonia MSDS data

I Identification:
- Product name – Anhydrous ammonia
- Common name – Ammonia
- DOT hazard class – Nonflammable gas
- Manufacturer – LaRoche Industries

II Ingredients and recommended exposure limits:
- Formula – NH_3
- CAS. no. – 7664-41-7
- % wt. – 99.995
- Exposure limit – TLV* = 25 ppm, STEL* = 35 ppm

III Physical data:
- Boiling point – -28.1°F
- Melting point – -107.9°F
- Vapor pressure – 94 psi @ 60°F
- Vapor density – 0.6 @ 32°F (air = 1)

IV Fire and explosion hazard data:
- Flammable limits – 16–25% in air
- Extinguishing media – Water fog or spray
- Fire-fighting procedures – Stop flow of gas. Stay clear of tank heads. Use water spray to control vapors. Do not put water on liquid ammonia. Personnel must be equipped with protective clothing and respiratory equipment.

V Reactivity data:
- Stability – Stable
- Incompatibility – Reacts violently with acids. Forms explosive compounds with halides, gold, silver, mercury.
- Decomposition – Forms hydrogen above 850°F.

VI Spill or leak procedures:
- Released material – Stop leak. Avoid breathing ammonia. Evacuate personnel. Use spray water or fog to absorb ammonia. **Do not put water on liquid ammonia.** Prevent ammonia from entering streams or sewage system.
- Waste disposal method – Recover ammonia if feasible. Let evaporate, dispose or dilute ammonia as fertilizer.

VII Health hazard data:
- Major exposure hazard – Inhalation, skin contact, eye contact.
- Emergency first aid – Remove from contact, apply copious amounts of water. For ingestion, **do not induce vomiting** – drink large quantities of water. In all cases, seek medical aid.

VIII Special protection information:
- Respiratory – Respiratory protection suitable for the magnitude of exposure must be used when exposure limits are exceeded.
- Skin – Rubber gloves and protective clothing should be worn to prevent skin contact. A face shield should be used for increased protection from liquid contact.
- Eye – Chemical splash goggles approved for ammonia must be worn to prevent eye contact with ammonia liquid and vapor. A face shield should be used over the goggles for additional protection.
- Ventilation – Positive pressure ventilation should be used to reduce ammonia vapor concentration in confined spaces.
- Other protective equipment – Emergency eyewash stations and deluge showers must be available in the work area. A list of emergency response contacts and phone numbers should be posted in the area.

IX Special precautions:
- Handling and storage – Refer to ANSI K16.1 for storage and handling. Protect containers from physical damage and temperatures above 120°F. Do not use zinc, copper, gold, silver, cadmium, or their alloys in ammonia systems because they can be rapidly corroded. Avoid hydrostatic rupture by adhering to proper filling procedures (80% maximum liquid fill).
- Other comments – Contact lenses must not be worn when working with ammonia.

*TLV = threshold limit valve; STEL = short-term exposure limit

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els of concentration (100 to 400 ppm). Systems must be designed so that the ammonia stays within the confines of the piping, equipment, and vessel network, where the positive attributes of ammonia—for example, excellent heat capacity, good heat transfer properties, and good system efficiency—can serve their beneficial purposes. Except for minimal servicing releases, there should be no ammonia present in the air or in the equipment rooms unless a leak or system failure occurs and demands attention.

1.41 There are four major concerns regarding bodily contact with ammonia vapor or liquid. These concerns are as follows:

- skin—vapor irritation, liquid freezing/burns
- eyes—vapor irritation, liquid freezing/burns
- aspiration (inhaling ammonia)—vapor irritation, liquid freezing/burns
- ingestion (swallowing ammonia)—liquid internal freezing/burns.

1.42 **Skin contact.** Ammonia vapor has a high attraction for water and will absorb moisture from the skin and body tissue, causing rashes of varying degrees. Liquid ammonia spilled on the skin will be at a temper-

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ature of -28°F (-33.3°C) or lower and has sufficient heat-withdrawal capacity to freeze the skin severely.

1.43 **First aid for skin contact.** Remove the victim from the ammonia area. Flush the skin area with large amounts of water to dilute and wash away the ammonia. In the case of liquid contact, do not attempt to remove clothing because it may be frozen to the skin. Flush with water, remove the victim to an emergency facility as soon as possible, and advise medical personnel that the burns are from ammonia to ensure that hospital treatment will avoid the use of ointments that may keep the ammonia within the wound.

1.44 **Eye contact.** Both ammonia vapor and ammonia liquid pose a major threat to eye safety. Moderate concentrations of vapor, 100 to 400 ppm, will cause tearing. As the concentration increases, the discomfort will force personnel to leave the area. Liquid ammonia splashed into the eyes is extremely dangerous, causing freezing and subsequent burns in the eye. Liquid contact generally results in permanent eye damage and blindness. Goggles and face shields are required when tasks involve the possibility of liquid contact.

1.45 **First aid for eye contact.** Remove the victim from the ammonia area, wash the eyes continually for at least 15 min in an eyewash bubbler to dilute and flood out the ammonia. Note that it may be necessary to hold the victim's eyes open and to keep them at the washing task. Remove to an emergency facility as soon as possible.

1.46 **Aspiration, lung contact.** Breathing ammonia vapor will result in drawing ammonia into the nasal passages and into the lungs. As the concentration increases, discomfort gives way to severe coughing as the delicate internal tissues become damaged. This, coupled with the eye tearing, force personnel to vacate the area. Severe coughing and excessive tearing often result in panic and disorientation, which further complicate escape. Liquid ammonia may be inhaled should a sudden, unexpected spurt of liquid be released next to the face. In this instance, some droplets of ammonia at -28°F (-33.3°C) or less may enter the lungs, where severe freeze and tissue burning may take place. In all cases where there is the possibility of liquid contact, goggles and a face shield must be the first line of facial protection from liquid contact.

1.47 **First aid for aspiration.** Remove the victim from the ammonia concentration source. Because aspiration of ammonia will certainly be associated with skin contact, treat with large amounts of water. Resuscitate if breathing has stopped. Transport as soon as possible to an emergency facility.

1.48 **Ingestion.** Although it seems far-fetched, liquid ammonia can be readily ingested. When the face is only an arm's length from a valve fitting, flange, or other component and an unexpected spurt of liquid is released, the natural reaction is to gasp, and in gasping, ammonia is ingested. The liquid will be at -28°F (-33.3°C) or less, and severe internal damage can result. Goggles and face shield are the prime protection for eye contact, lung aspiration, and ingestion of liquid refrigerant.

1.49 **First aid for ingestion.** Remove the victim from the ammonia source. Give generous amounts of water to drink. Transport as soon as possible to an emergency facility.

CAUTION

Do not induce vomiting.

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1-9. Increasing the pressure ________ the boiling or ________ temperature of ammonia.	1-9. INCREASES; SATURATION Ref: 1.27, Fig. 1-1
1-10. The boiling temperature for R-717 at atmospheric pressure is ________.	1-10. -28°F Ref: 1.29
1-11. Ammonia systems use piping made of ________, and neoprene, buna-n, and Teflon are used for ________.	1-11. STEEL; GASKETS Ref: 1.33, 1.34
1-12. Detailed information about handling ammonia is provided in nine categories on the ________.	1-12. MATERIAL SAFETY DATA SHEET (MSDS) Ref: 1.35
1-13. The four major concerns for bodily contact with ammonia are ________ and ________ contact, ________ and ________.	1-13. SKIN; EYE; ASPIRATION; INGESTION Ref: 1.41
1-14. The initial step in first aid for a victim of ammonia contact is ________.	1-14. REMOVAL FROM THE AREA Ref: 1.43, 1.45, 1.47, 1.49
1-15. When working with ammonia systems, you should wear protective clothing, ________, and a(n) ________.	1-15. GOGGLES; FACE SHIELD Ref: 1.44, 1.46, 1.48, Table 1-8
1-16. Should you induce vomiting in a victim of ammonia ingestion?	1-16. NO Ref: 1.49 CAUTION

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Answer the following questions by marking an "X" in the box next to the best answer.

1-1. About how much of the ammonia manufactured in North America is used as a refrigerant?

- ☐ a. 2%
- ☐ b. 10%
- ☐ c. 25%
- ☐ d. 65%

1-2. Which of the following refrigerants has no ozone depletion or global warming potential?

- ☐ a. R-12
- ☐ b. R-22
- ☐ c. R-134a
- ☐ d. R-717

1-3. In its liquid and vapor states, ammonia is ________ and has an equilibrium temperature of ________.

- ☐ a. colorless; -28°F
- ☐ b. light brown; 0°F
- ☐ c. milky white; 14.7°F
- ☐ d. yellow; 28°F

1-4. Ammonia vapor becomes irritating to the nose and throat at a concentration of ________ ppm.

- ☐ a. 50
- ☐ b. 100
- ☐ c. 200
- ☐ d. 400

1-5. Because of explosion hazards, personnel are prevented from occupying enclosed spaces with an ammonia concentration approaching ________%.

- ☐ a. 2
- ☐ b. 8
- ☐ c. 10
- ☐ d. 15

1-6. Ammonia refrigeration systems typically operate with evaporator temperatures of _____°F and condensing temperatures of _____°F.

- ☐ a. -60 to 10; 55 to 75
- ☐ b. -40 to 30; 75 to 95
- ☐ c. -20 to 50; 95 to 115
- ☐ d. 0 to 70; 115 to 135

1-7. Ammonia is compatible with which of the following construction metals?

- ☐ a. Copper
- ☐ b. Gold
- ☐ c. Steel
- ☐ d. Zinc

1-8. The main difference between ANSI/ASHRAE 15-1994 and ANSI/IIAR 2-1998 is that ANSI/IIAR 2-1998

- ☐ a. covers testing
- ☐ b. is less restrictive
- ☐ c. is written specifically for ammonia
- ☐ d. sets construction standards

1-9. Correct first aid procedures following contact with ammonia include

- ☐ a. inducing vomiting following ingestion
- ☐ b. removing clothing following skin contact
- ☐ c. removing contact lenses before starting eyewash
- ☐ d. seeking medical aid immediately

1-10. Liquid ammonia splashed into eyes

- ☐ a. causes minor irritation
- ☐ b. causes tearing
- ☐ c. is easily washed out with water
- ☐ d. usually causes permanent eye damage and blindness

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SUMMARY

Ammonia, known as R-717, is generated by cattle and people and produced commercially for fertilizers (80%) and many other uses. In North America, about 2% of manufactured ammonia is used as a refrigerant. Unlike the CFC, HCFC, and HFC refrigerants, ammonia has an ozone depletion potential (ODP) and global warming potential (GWP) of zero.

Ammonia (NH_3) is colorless as a vapor and liquid and has an equilibrium temperature of -28°F at one atmosphere. Ammonia is toxic and has a pungent, disagreeable odor, which provides a self-alarming feature. It also is very inexpensive, has excellent thermal properties, and has a much higher refrigeration effect per pound than any other refrigerant.

Ammonia burns in air only in the presence of a flame and is designated as nonflammable for shipping purposes. Personnel are prevented from occupying enclosed spaces with ammonia concentrations approaching 15%. Deflagrations are possible in concentrations of 15 to 28%. Because R-717 is classified as a hazardous material, plants with ammonia systems must establish a multistep process safety management (PSM) program and a risk management program (RMP).

Increasing the pressure in an enclosed container (including evaporators and condensers) increases the temperature of the refrigerant. Saturation curves show this relationship for refrigerants at a range of pressures and temperatures. Because ammonia reacts with certain metals, ammonia systems use steel piping and welded construction.

The Material Safety Data Sheet (MSDS) is a nine-category form providing safe handling information for hazardous materials. The two main standards documents are ANSI/ASHRAE 15-1994 and ANSI/IIAR 2-1998. The major safety concerns for ammonia systems are contact with the skin and eyes, aspiration, and ingestion. Protective clothing, goggles, and a face shield should be worn for prevention. In all cases of contact, the victim should be removed from the ammonia environment and medical aid should be sought immediately.

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Answers to Self-Check Quiz

1-1. a. 2%. Ref: 1.05

1-2. d. R-717. Ref: 1.06, 1.12, Table 1-2

1-3. a. Colorless; -28°F. Ref: 1.13, 1.15

1-4. d. 400. Ref: 1.19, Table 1-6

1-5. d. 15. Ref: 1.22

1-6. b. -40 to 30; 75 to 95. Ref: 1.31

1-7. c. Steel. Ref: 1.33

1-8. c. Is written specifically for ammonia. Ref: 1.39

1-9. d. Seeking medical aid immediately. Ref: 1.43, 1.45, 1.47, 1.49, Table 1-8

1-10. d. Usually causes permanent eye damage and blindness. Ref: 1.44

Contributions from the following source are appreciated:

Table 1-7. Air-Conditioning and Refrigeration Institute (ARI) and Vilter Manufacturing Corporation

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