

Refrigerating Engineers & Technicians Association

CARO STUDY GUIDE



Table of Contents

Introduction	2
Calculators	2
CARO Examination Content	2
<i>The following items will be available on-screen during the test in CARO References</i>	
Using CARO References On-Screen	3
Formulas	5
Refrigerant Characteristics	6
Theoretical Discharge Temperatures of Ammonia	6
Conditions of Ammonia at Various Operating Pressures	7
Ammonia Safety Data Sheet (SDS)	8
Ammonia Saturated Properties Table	22

Introduction to the CARO Study Guide

This CARO Examination Study Guide is designed to help you prepare to demonstrate your mastery of the content covered in this RETA certification test. You will be tested on concepts addressed in IR-1 and IR-4 (safety section only).

You will improve your chances of earning your CARO credential by treating this CARO Study Guide as you would the technical manuals in a refrigeration facility where you work. Your chances of earning the CARO credential improve if you are familiar with the details in the CARO Study Guide. Just as your job requires that you know what is in operating manuals and when to refer to them to understand or resolve a problem, the CARO test requires that you know what is in the References document and when to use it. ***You will not be told when to use the references for this test.***

Calculators

All calculations for the CARO examination can be completed with a simple calculator. Candidates should bring a simple, non-printing calculator. A scientific calculator is **NOT** required to perform well on this examination. You are permitted to bring a simple non-printing calculator to the test, but you will be required to clear the calculator memory before you may take any calculator into the testing room. Test centers are not required to provide a calculator to candidates during this test.

CARO Examination Content

CARO consists of 110 questions in English. Candidates have three hours to complete the test. The minimum passing score is 70. CARO also includes 10 questions that are being evaluated for use in future exams. Candidate scores are for just the 100 active questions in the test. These pilot questions are not counted in the candidate's test score.

The following content areas are in the CARO examination.

Refrigeration fundamentals	9 questions
Refrigeration cycle	8 questions
Properties of refrigerants and refrigerant tables	7 questions
Types of refrigerant compressors	6 questions
Operation and maintenance of compressors	14 questions
Lubrication	10 questions
Evaporators and cooling units	9 questions
Condensers and high-pressure receivers	12 questions
Purging	5 questions
Safety, hazards, and prevention	20 questions

The remaining pages in this Study Guide will appear on-screen during the test. The first two pages illustrate how to navigate these references. The remaining pages provide the content that is included in these References during the test.

Using Onscreen References during the CARO Examination

CARO examinations taken in a proctored test center display onscreen references that appear in a PDF next to test questions. This section provides a sample question and two sample screens to illustrate the tools available to find information in the onscreen references for the CARO examination.

The first screen a candidate sees at the start of a test is illustrated below. The CIRO EXAM REFERENCES Table of Contents appears on the right side of the sample screen below. CARO examinations use similar reference documents. The CARO Study Guide includes all of the references that appear onscreen during the full examination and in the CARO practice test.

The screenshot displays the CARO examination interface. On the left side, a question is presented: "1 of 1. Which of these becomes a risk from trying to control an ammonia fire with a CO₂ extinguisher?" with four multiple-choice options (A, B, C, D). Below the question is a checkbox labeled "Mark this item for later review." and three buttons: "Next >", "Review All", and "Submit Exam". On the right side, the "CIRO EXAM REFERENCES Table of Contents" is displayed, listing various references and their corresponding page numbers. The RETA logo is visible at the top of the right panel.

Time Remaining : 02:59:47

1 of 1. Which of these becomes a risk from trying to control an ammonia fire with a CO₂ extinguisher?

A. ☐ Carbon dioxide may displace oxygen.

B. ☐ Ammonia becomes more explosive in confined spaces.

C. ☐ Water spray increases the risk of injury from ammonia gas.

D. ☐ Ammonia gas usually ignites at vapor concentrations above 60%.

☐ Mark this item for later review.

Next > Review All Submit Exam

CIRO EXAM REFERENCES
Table of Contents

Using RETA References On-Screen	2
Formulas	4
Theoretical Discharge Chart – PSIG Scale	5
Theoretical Discharge Chart – PSIA Scale	6
Figures 3 and 4	7
Figures 5 and 7-14	8
Figure 17	9
Figure 18 Electrical Diagram	10
Figure 7-5 Electrical Diagram	11
Ammonia Safety Data Sheet (SDS)	12
CIRO Troubleshooting System Screens 1-24	26
Ammonia Saturated Properties Table	48

© November 2020 REFRIGERATING ENGINEERS & TECHNICIANS ASSOCIATION (RETA)

CIRO References Page 1 of 53

The following tools can help you use information in the CARO References file.

- Questions appear on the left side of the vertical line in the center of the screen.
- Time remaining appears in a countdown timer above the question.
- “Mark this item for later review” below the question lets the candidate flag the question to review later.
- Three buttons also appear below the question near the centerline:
 - Use the **Next** button to record the answer to a question and move to the next question on the test.
 - Use the **Review All** button to move to a screen that shows which questions the candidate has answered and identifies questions the candidate has marked for later review.
 - Use the **Submit Exam** button as the first of three steps required to end the test.

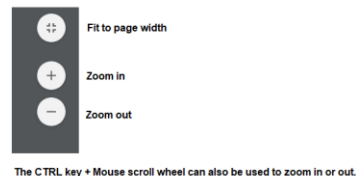
Candidates can move to each page in the onscreen references document by using one of these tools.

- Place the cursor on the icon in far right column at the top of the screen, then drag it to move to the page with the desired information. **OR**
- Use the mouse scroll wheel to move to the page with the desired information.

Candidates can expand the right side of the screen by moving the centerline to the left. This sample screen also shows the Fire Fighting Measures section of the Ammonia Safety Data Sheet (SDS) where the answer to the sample question appears. “Carbon dioxide can displace oxygen” parallels answer A in the sample question.

The screenshot displays the RE TA exam interface. On the left, a question is shown: "1 of 1. Which of these becomes a risk from trying to control an ammonia fire with a CO₂ extinguisher?" with four multiple-choice options: A. Carbon dioxide may displace oxygen, B. Ammonia becomes more explosive in confined spaces, C. Water spray increases the risk of injury from ammonia gas, and D. Ammonia gas usually ignites at vapor concentrations above 60%. Below the question is a "Mark this item for later review" link and three navigation buttons: "Next >", "Review All", and "Submit Exam". On the right, a reference document titled "5. Fire Fighting Measures" is displayed. It contains two sections: "Extinguishing" which lists "Use Water Spray or Water Fog, Carbon Dioxide, Polar or Alcohol Foam, Dry Chemical, Halon may decompose into toxic materials. Carbon dioxide can displace oxygen. Use caution when applying halon or carbon dioxide in confined spaces." and "Special Exposure Hazards" which states "Gas may ignite at vapor concentrations between 16% and 25% in air. However, ammonia-air mixtures are difficult to ignite and burn with little vigor. In the absence of oxygen enrichment, the risk of initiating an accidental fire or explosion is low. Do not allow ammonia vapors to accumulate in confined areas where ignition may occur. Intense heating particularly in contact with hot metallic surfaces may cause decomposition of ammonia generating hydrogen, a flammable gas."

Three navigation buttons appear on the far right side of the screen. The top button fits the image to the width of the window on the right side of the screen. The + and – icons zoom in or out. The CTRL key + Mouse scroll wheel also can be used to zoom in or out.



Formulas

Area of a rectangle: $A = side1 \bullet side2$

Area of a circle: $A = Radius \bullet Radius \bullet 3.1416$

Volume of a room $V = side1 \bullet side2 \bullet side3$

Volume of a cylinder $V = Length \bullet radius \bullet radius \bullet 3.1416$

One Horsepower (HP or BHP) = 2545 BTU / HR

To find kiloWatts of power (3 phase)

$$kW = \frac{Amps \bullet Volts \bullet PowerFactor \bullet 1.73}{1000}$$

To find Brake Horsepower used by a driven device (3 phase motor)

$$bhp = \frac{Amps \bullet Volts \bullet PowerFactor \bullet Efficiency \bullet 1.73}{746}$$

To find Power Cost in Dollars per Hour:

$$Cost(\$ / Hr) = (kiloWatt\ hour\ price \bullet kiloWatt\ hours) \div Hours$$

To find Power Cost in Dollars:

$$Cost(\$) = (kiloWatt\ hour\ price \bullet kiloWatt\ hours)$$

To find Brake Horsepower (used by a driven device) per TR (Ton of Refrigeration)

$$bhp\ per\ Ton = \frac{bhp}{TR}$$

To find kiloWatts per Ton of Refrigeration (TR)

$$kiloWatts\ per\ Ton = \frac{kW}{TR}$$

Heat Transfer Equations Where:

M = Mass or weight of object

C_p = Specific Heat of object

$(T1-T2)$ = Difference in temperature before and after process

hL = Latent Heat quantity in a pound of the object

Sensible Heat Transfer: $Q_{sensible} = M \bullet C_p \bullet (T1 - T2)$

Latent Heat Transfer: $Q_{latent} = M \bullet hL$

Compression Ratio Equation:

Ratio = Absolute Discharge Pressure / Absolute Suction Pressure

Vacuum Conversion: Use Saturation Tables

Refrigerant Characteristics							
10 °F Evaporator Temperature, 95 °F Condensing Temperature							
Refrigerant	Evaporator Pressure (psig)	Condensing Pressure (psig)	Theoretical Discharge Temperature (°F)	Refrigerating Effect (BTU/lb.)	Mass Flow Rate (lb./min/ton)	Specific volume Vapor (Cu. ft./lb.)	CFM/ton
R-507	46.2	226.4	107	45	4.44	.74	3.29
R-134-a	12	113.9	115	60	3.33	1.736	5.78
HCFC-22	32.8	181.8	145	67.74	2.9	1.129	3.33
R-404A	59.17	234.92	105	52	3.85	.7999	3.08
HCFC-502	41.1	199.7	100	43.51	4.60	.751	3.46
R-717	23.8	181.1	221	465.50	.43	7.304	3.14

A Comparison of Theoretical Discharge Temperatures of Reciprocating Compressors at Various Evaporator Temperatures						
Evaporator Temperature in °F	Condensing Temperature 95°F	Temperature Difference in °F (ΔT)	R-134a Discharge Temp. °F	HCFC-22 Discharge Temp. °F	R-717 Discharge Temp. °F	
30	95	65	100	133	190	
20	95	75	105	141	207	
10	95	85	110	145	221	
0	95	95	112	155	257	

Theoretical Discharge temperatures (°F) for Ammonia at various operating pressures																
		Suction Pressures and Corresponding Saturation Temperatures														
Condensing Press./Temp	Psig °F	0 -28	2.5 -22	5 -17	7.5 -12	10 -8	12.5 -4.6	15 0	17.5 2.4	20 5.5	22.5 8.5	25 11.3	27.5 14	30 16.6	32.5 21.4	35 25.8
105 psig / 65.9°F		240	225	210	200	189	183	172	167	160	154	149	142	138	131	123
115 psig / 70.4°F		253	238	223	213	202	195	184	179	172	165	160	154	149	141	132
125 psig / 74.7°F		265	251	234	225	214	206	195	190	183	176	171	165	160	151	142
135 psig / 78.7°F		277	262	246	236	225	217	205	200	193	186	181	175	170	161	152
145 psig / 82.6°F		288	273	256	246	235	227	214	209	203	196	191	184	179	170	161
155 psig / 86.2°F		298	283	266	256	245	237	224	219	212	205	200	193	188	179	170
165 psig / 89.7°F		308	293	276	266	254	246	233	228	221	214	209	202	197	188	179
175 psig / 93.1°F		318	303	286	275	263	255	242	237	230	223	217	210	205	196	187
185 psig / 96.2°F		328	312	295	284	272	264	251	246	238	231	225	218	213	204	195
195 psig / 99.4°F		336	321	304	292	280	272	259	254	246	239	233	226	221	212	203
205 psig / 102.3°F		345	329	312	300	288	280	267	262	254	247	241	234	228	219	210
215 psig / 105.2°F		354	337	320	308	295	288	274	269	261	254	248	241	235	226	217
225 psig / 108 0°F	361	345	328	316	303	295	281	276	268	261	255	247	242	233	224	



Safety Data Sheet

1. Product Identifier and Company Identification

Product name	: Anhydrous Ammonia	
HBCC SDS number	: CA10000	
Synonym	: Ammonia; NH ₃	
Product use and Restrictions	: Refer to label or call	
Manufacturer	: Corporate Headquarters	Corporate Safety & Compliance
Contact Address	Hill Brothers Chemical Company 1675 North Main Street Orange, California 92867 714-998-8800 800-821-7234	Hill Brothers Chemical Company 7121 West Bell Road, Suite 250 Glendale, Arizona 85308 623-535-9955 - Office 623-535-9944 - Fax
Emergency telephone Number (Chemtrec)	: 800-424-9300	
Website	: http://hillbrothers.com	

2. Hazard Identification

Classification	: Flammable Gases – Category 2 Gases Under Pressure – Compressed Gas Acute Toxicity: Inhalation – Category 3 Skin Corrosion/Irritation – Category 1B Serious Eye Damage/Eye Irritation – Category 1 Aquatic Toxicity (Chronic) – Category 1
----------------	---

Signal Word : DANGER

Pictogram(s) :



Hazard Statements	: Flammable Gas. Contains gas under pressure; may explode if heated. Toxic if inhaled. Causes severe skin burns and eye damage. Very toxic to aquatic life with long lasting effects.
-------------------	--

Precautionary Statements

- Response** : IF INHALED: Remove victim to fresh air and keep at rest in a position comfortable for breathing. Immediately call a POISON CENTER or doctor.
IF SWALLOWED: Rinse mouth. Immediately call a POISON CENTER or physician. Do NOT induce vomiting.
IF ON SKIN (or hair): Take off immediately all contaminated clothing. Rinse skin with water or shower. Wash contaminated clothing before reuse. Immediately call a POISON CENTER or doctor.
IF IN EYES: Rinse cautiously with water for several minutes. Remove contact lenses, if present and easy to do. Continue rinsing. Immediately call a POISON CENTER or doctor.
- Prevention** : Wear protective gloves, protective clothing, eye protection and face protection.
Keep away from heat, hot surfaces, sparks, open flames and other ignition sources. – No Smoking.
Use only outdoors or in a well-ventilated area.
Avoid release to the environment.
Do NOT breathe gas or vapors.
Wash hands thoroughly after handling. Collect spillage.
Leaking gas fire: Do not extinguish, unless can leak be stopped safely.
In case of leakage, eliminate all ignition sources.
- Storage** : Store locked up.
Protect from sunlight.
Store in a well-ventilated place. Keep container tightly closed.
- Disposal** : Dispose of contents and container in accordance with all local, regional, national and international regulations.

3. Composition/Information on Ingredients

CAS Number	Ingredient Name	Weight %
7664-41-7	Anhydrous Ammonia (NH ₃)	99.8 – 99.999% wt.
7732-18-5	Water	0.2% -.001% wt.

4. First Aid Measures

Ingestion	: If this gas is swallowed in liquid form, keep victim warm and OBTAIN IMMEDIATE MEDICAL ATTENTION. If signs of respiratory obstruction develop, immediately transport to medical facility. Do not induce vomiting. <u>Never give fluids or induce vomiting if patient is unconscious or having convulsions.</u>
Inhalation	: Remove victim to fresh air. Give oxygen if breathing is difficult. If breathing has stopped, start artificial respiration. OBTAIN IMMEDIATE MEDICAL ATTENTION.
Skin	: Apply water immediately to exposed areas of skin and continue for at least 30 minutes. Remove contaminated clothing, shoes, and constrictive clothing while continuing to apply water, being careful not to tear the skin. If skin surface is damaged, apply a clean dressing. If skin surface is not damaged, cleanse the affected area(s) thoroughly with mild soap and water. Do not apply salves or ointments to affected areas. OBTAIN IMMEDIATE MEDICAL ATTENTION.
Eyes	: Remove victim to fresh air. Immediately flush with plenty of water for at least 30 minutes with the eyelids held apart. OBTAIN IMMEDIATE MEDICAL ATTENTION.
Medical Conditions	: Ammonia is a respiratory irritant. Persons with impaired pulmonary function may be at an increased risk from exposure. Also pre-existing skin disorders may be aggravated by exposure.
Effects of Overexposure	: N/A
<u>Summary of Acute Health Hazards</u>	: N/A
Ingestion	: This material is a gas under normal atmospheric conditions and ingestion is unlikely. Ingestion of liquid ammonia may result in severe irritation or ulceration of the mouth, throat and digestive tract which may be displayed by nausea, vomiting, diarrhea and, in severe cases, collapse, shock and death.

Inhalation

: Irritation to the mucous membranes of the nose, throat and lungs is noticeable at 100 ppm. Concentrations above 400 ppm will cause throat irritation and may destroy mucous surfaces upon prolonged contact. High concentrations can cause pulmonary edema. Breathing air containing concentrations greater than 5,000 ppm may cause sudden death from spasm or inflammation of the larynx.

Skin

: Liquid Ammonia produces severe skin burns on contact. Ammonia gas may cause skin irritation, especially if skin is moist. The liquid can cause skin damage resulting from combined freezing and corrosive action on the skin. Atmospheric concentrations above 30,000 ppm will burn and blister skin after a few seconds of exposure.

Eyes

: Exposure to high gas concentrations may cause temporary blindness and severe eye damage. Direct contact of the eyes with liquid ammonia will produce serious eye burns.

Note to Physicians

: N/A

Summary of Chronic Health

: N/A

5. Fire Fighting Measures

Extinguishing

- : Use Water Spray or Water Fog, Carbon Dioxide, Polar or Alcohol Foam, Dry Chemical. Halon may decompose into toxic materials. Carbon dioxide can displace oxygen. Use caution when applying halon or carbon dioxide in confined spaces.

Special Exposure Hazards

- : Gas may ignite at vapor concentrations between 16% and 25% in air. However, ammonia-air mixtures are difficult to ignite and burn with little vigor. In the absence of oxygen enrichment, the risk of initiating an accidental fire or explosion is low. Do not allow ammonia vapors to accumulate in confined areas where ignition may occur. Intense heating particularly in contact with hot metallic surfaces may cause decomposition of ammonia generating hydrogen, a flammable gas.

Special Protective Firefighters Equipment

- : Stop flow of gas. Use water fog to keep fire-exposed containers cool and to protect personnel effecting the shut-off. Wear self-contained breathing apparatus (SCBA) and encapsulating chemical protective clothing. Approach fire upwind and evacuate area downwind. Emergency responders in the danger area should wear bunker gear and self-contained breathing apparatus for fires beyond the incipient stage (29CFR 1910.156). In addition, wear other appropriate protective equipment as conditions warrant (See Section VIII). Isolate damage area, keep unauthorized personnel out. Stop spill/release if it can be done with minimal risk. If this cannot be done, allow fire to burn. Move undamaged containers from danger area if it can be done with minimal risk. Stay away from ends of container. Water spray may be useful in minimizing or dispersing vapors. Cool equipment exposed to fire with water, if it can be done with minimal risk.

Fire Fighting Procedures

- : Dry Chemical or carbon dioxide are recommended extinguishing media. Stop flow of gas before extinguishing fire. Use water spray to keep fire exposed containers cool. Extinguish fire using agent suitable for surrounding fire.

Combustible. Wear goggles, self-contained breathing apparatus, and rubber over clothing (including gloves). Stop flow of gas, or liquid if possible. Let fire burn.

If material involved in fire: Cool all affected containers with flooding quantities of water. Apply water from as far distance as possible. Use water spray to knock-down vapors. Solid streams of water may spread fire. Do not use water on material itself. Do not apply water to point of leak in tank car or container.

NFPA Rating

: Health - 3
Flammability - 1
Instability - 0



0=Insignificant 1=Slight 2=Moderate 3=High 4=Extreme

Uniform Fire Code Rating

: According to the (UFC) Uniform Fire Code Standard 79-3 (2000), the degree of Hazard is 3-3-0 in a confined space.

Additional Description Requirement

: Inhalation Hazard

6. Accidental Release Measures

Personal Precautions

: Note that although ammonia gas is lighter than air, sudden release may generate an aerosol of liquefied ammonia which may cling to the ground for long distances. May ignite in the presence of open flames and sparks. Narrow lower to upper combustion range (16-25%) makes ignition difficult. Keep all sources of ignition away from spill/release. Do not apply water onto leaking tank. Stop the flow of gas or liquid. Use water to protect personnel effecting the shut-off. Approach from upwind. Evacuate the area immediately. Eliminate all open flames in vicinity of indoor spills or released vapor. Water fog can be used to cleanse atmosphere of ammonia vapor. Downwind areas can be protected by water fog nozzles positioned downwind.

Emergency Procedures

: Do not enter a visible cloud of ammonia. Isolate and evacuate the leak or spill area immediately for at least 150 feet in all directions. For larger spills, isolate at least 300 feet in all directions and then evacuate area downwind at least 0.4 miles in width and at least 0.8 miles in length. Keep area isolated until gas has dispersed.

Methods of Containment And Clean-Up

: Dike liquid spills to contain liquid.

7. Handling and Storage

Safe Handling

: Contents are under pressure. The use of explosion-proof equipment is recommended and may be required (see appropriate fire codes). Do not enter confined spaces such as tanks or pits without following proper entry procedures such as ASTM D-4276. Protect against physical damage.

Storage

: Outside shaded area or detached storage is preferred. Inside storage should be in a cool, dry, well ventilated, noncombustible location, away from all possible sources of ignition.

Work/Hygienic Practices

: Avoid contact with skin and avoid breathing vapors. Do not eat, drink, or smoke in work area. Wash hands before eating, drinking, or using restroom. Do NOT place food, coffee or other drinks in the area where dusting or splashing of solutions is possible.

Ventilation

: Local exhaust is essential. Spark-proof fans desirable with mechanical ventilation. Ducts should be located at ceiling level and lead upwards to the outside. Eyewash and safety shower should be available in work area.

8. Exposure Controls/Personal Protection

Occupational Exposure Limits : CAL-OSHA: 25 ppm, 18 mg/m³ Oregon-OSHA: 25 ppm, 18 mg/m³; STEL: 35 ppm, 27 mg/m³

Chemical Name: Anhydrous Ammonia				
Exposure Limits (TWAs) in Air				
CAS Number	IDLH	ACGIH TLV	OSHA PEL	STEL
7664-41-7	300 ppm	25 ppm, 18 mg/m ³	50 ppm, 35 mg/m ³	35 ppm, 27 mg/m ³

Protective Equipment : Rubber or synthetic chemical gloves and boots should be worn as well as cotton clothing and underwear. Rubber or synthetic chemical coats or aprons should be available, an encapsulating chemical protective clothing garment is desirable for heavy exposures. The use of long sleeved clothing closed at the neck is advised. Change if clothing becomes contaminated.

Eye Protection : Chemical splash goggles should be worn when handling Anhydrous Ammonia to protect from liquids or mists.

A face shield can be worn over chemical splash goggles as additional protection. Do not wear contact lenses when handling Anhydrous Ammonia.

A full-face air-purifying respirator (APR) or supplied-air respirator (SAR) should be worn to protect from chemical vapors.

Respiratory Protection : Unless ventilation is adequate to keep concentration below permissible exposure limit (PEL), wear NIOSH approved ammonia chemical cartridge or canister full facepiece chin-style respirators with an air-purification factor (APF=50). In emergency or planned entry into unknown concentrations, use self-contained breathing apparatus (SCBA) or any supplied-air full facepiece chin-style respirators.

9. Physical and Chemical Properties

Appearance: Compressed Liquid Gas, clear, colorless	Odor: Sharp, penetrating
Odor Threshold: 5 ppm	pH: 11.6 for 1% NH ₃ solution
Melting Point/Freezing Point: -107.9°F; -78°C	Initial Boiling Point/Range: -28°F; -33.4°C
Flash Point: N/A	Evaporation Rate (BuAc=1): N/A
Flammability: 16 – 25% in air	Lower/Upper Explosive Limit: 25% by Volume/16% by Volume
Vapor Pressure (mmHg): 110 PSIG at 68°F (20°C)	Vapor Density (Air=1): 0.0549 lb./ft ³ at -28°F at 1 atm
Relative Density: 42.57 lbs./cu.ft @ -28°F and 1 atm	Solubility in Water: 33.10%
Partition Coefficient: N/A	Autoignition Temperature: 650°C; 1204°F
Decomposition Temperature: N/A	Viscosity: N/A
% Volatiles: 100%	Specific Gravity (Water=1): 0.6189 of liquid at -28°F and 1 atm
Molecular Weight: 17.032	VOC: N/A

10. Stability and Reactivity

Reactivity	: Reacts violently and explosively with oxidizing gases such as chlorine, bromine, and other halogens. Reacts explosively with hypochlorites such as bleach. Reacts vigorously with acids. Highly reactive with reducing agents. Hazardous polymerization will not occur.
Chemical Stability	: Stable
Possibility of Hazardous Reactions or Polymerizations	: Avoid contact with oxidizing gases, chlorine, bromine, mineral hypochlorite, iodine, halogens, calcium, and strong acids. Avoid contact with copper, silver, zinc, and alloys of same. Mercury, silver oxide can form explosive compounds.
Conditions to Avoid	: Avoid all possible sources of ignition. Heat will increase pressure in the storage tank.
Incompatible Materials	: Avoid contact with strong acids, use of metals containing copper or zinc.
Hazardous Decomposition Products	: Combustion will generate oxides of nitrogen. Intense heating of the gas, particularly in contact with hot metallic surfaces, may cause decomposition of ammonia to hydrogen and nitrogen.

11. Toxicological Information

Acute and Chronic Effects : Can cause irritation and burns of the skin and mucous membranes, and headache, salivation, nausea, and vomiting. Difficult or labored breathing and cough with bloody mucous discharge. Can cause bronchitis, laryngitis, hemoptysis, and pulmonary edema or pneumonitis. Death may result. Can cause ulceration of the conjunctiva and cornea, and corneal and lenticular opacities. Damage to the eyes may be permanent.

Routes of Exposure

Ingestion : Yes
Inhalation : Yes
Skin : Yes
Eyes : Yes

Symptoms related to Physical, Chemical & Toxicological Characteristics : Can cause burning of the eyes, conjunctivitis, skin irritation, swelling of the eyelids and lips, dry red mouth and tongue, burning in the throat, and coughing, and in more severe cases of exposure, difficulty in breathing, signs and symptoms of lung congestion, and, ultimately, death from respiratory failure due to pulmonary edema may occur.

Numerical Measures of Toxicity :

Oral LD50	350 mg/kg	Rat	ATSDR 1991
	96 mg/kg	Mouse	EPA 1989

Inhalation LC50	19,770 ppm	F Rat	EPA 1989
	14,140 ppm	M Rat	EPA 1989
	17,401 ppm	Rat	ATSDR 1991

Chronic Toxicity : N/A

Carcinogenicity :

Product Name: Anhydrous Ammonia					
ACGI H	IARC	EPA	NIOS H	NTP	OSH A
No	No	No	No	No	No

Target Organs : N/A

12. Ecological Information

Ecotoxicity : Even at extremely low concentrations aquatic life will be harmed by liquid ammonia.

Persistence and Degradability : N/A

Bioaccumulative Potential :

Product/Ingredient	Log _{Pow}	BCF	Potential
-	-	-	-

Mobility in Soil : When anhydrous ammonia is applied in the soil, ammonia reacts with organic matter, and it dissolves in water. Anhydrous Ammonia reacts with water to form ammonium. The initial reactions with water, organic matter and clays limit the mobility of ammonia.

13. Disposal Considerations

Disposal of Container : Because of the toxicity of ammonia to aquatic organisms, NEVER dispose of or allow any ammonia or ammonia contaminated water to flow into any surface water bodies. Surface water bodies include drainage ditches, storm water and sanitary sewers, wetlands, ponds, lakes and streams. Diking will contain the liquid and allow it to stabilize. Keep unprotected personnel away from area until it is free of ammonia. Do not apply water directly to ammonia liquid as this will cause boiling and splattering. Soil contaminated with ammonia or aqua ammonia may need to be excavated and properly disposed of according to local and state regulations.

Consult Federal, State, or Local Authorities for additional proper disposal procedures.

14. Transport Information

UN# : UN1005
 Proper Shipping Name : Anhydrous Ammonia
 Hazard Class/Division : 2.2 [Domestic]; 2.3, (8) [International]
 Packing Group : N/A
 Marine Pollutant : Yes
 Special Provisions : 13, T50
 Emergency Response : 2012 ERG, Guide 125, pages 188-189

Guidebook

Placard Advisory :



15. Regulatory Information

SARA 302 Extremely Hazardous Substances (EHS) : This product contains the following Extremely Hazardous Substance(s) (EHS) under Section 302 of EPCRA, subject to the reporting requirements of Sections 311 and 312 (Tier I/Tier II reporting) at quantities greater than or equal to 500 pounds or in excess of the substance's EHS Threshold Planning Quantity (TPQ), whichever is lower. A Safety Data Sheet (SDS) must be provided to the SERC, LEPC, and local fire department.
 Ammonia, CAS #7664-41-7 Sec. 302 EHS TPQ = 500 lbs. (226.8 kg.)

SARA 304 Extremely and Hazardous Substances (EHS) Release Notification : EPCRA Section 304 requires a facility to notify the SERC and LEPC in the event of a release of an EHS at or exceeding the substance's RQ under Section 302 of EPCRA, or its CERCLA RQ, if applicable, whichever is lower. This product contains the following Extremely Hazardous Substance(s) (EHS) subject to the reporting requirements of Section 304.
 Ammonia, CAS #7664-41-7 Sec. 304 RQ = 100 lbs. (45.4 kg.)

SARA 311/312 Hazards :

SARA 311/312 Hazards				
Acute	Chronic	Flammability	Pressure	Reactivity
Yes	No	Yes	Yes	No

- SARA 313 Reportable Chemicals** : This product contains the following chemical(s) subject to annual emissions, transfers, and/or waste management reporting under the Community-Right-to-Know provisions of EPCRA Section 313, also known as the Toxic Release Inventory (TRI) Report or Form R: Ammonia, CAS #7664-41-7
- CERCLA Hazardous Substances** : This product contains the following CERCLA hazardous substance(s) subject to the National Response Center (NRC) reporting requirements if released to the environment in quantities greater than or equal to the substance's CERCLA Reportable Quantity (RQ).
Ammonia, CAS #7664-41-7 CERCLA RQ = 100 lbs. (45.4 kg.)
- Clean Air Act (CAA) Section 112(r) Air Pollutants** : This product contains the following air pollutant(s) under the U.S. Clean Air Act (CAA), Section 112(r) [40 CFR 61], which, if accidentally released to the atmosphere in quantities at or above the CAA 112(r) Threshold Quantity (TQ), is reportable.
Ammonia, CAS #7664-41-7 CAA 112(r) TQ = 10,000 lbs. (4436 kg.)
- California Prop 65 Chemicals** : This product does not contain any chemicals known to the state of California to cause cancer, birth defects or other reproductive harm.
- Hazard Label Warning** : This product requires the following hazard label warning:
Domestic: Non-Flammable Gas (Class 2.2)
International: Poisonous Gas Inhalation (Class 2.3); Corrosive (Class 8)

ACRONYMS:

CAS # – Chemical Abstract Services Registry Number

CFR – Code of Federal Regulations

CERCLA – Comprehensive Environmental Response, Compensation, and Liability Act

EPCRA – Emergency Planning and Community Right-to-Know Act

LEPC – Local Emergency Planning Committee

SERC – State Emergency Response Commission



Maximum use level for Anhydrous Ammonia under NSF/ANSI Standard 60

Maximum Use

5 mg/l

16.	Other Information
-----	-------------------

Revision date : 05/14/2015
Supersedes : 05/20/2014
First Issue : 12/01/1985

Chemical Family/Type : Hydride, (Alkaline Gas), Inorganic Base

Section(s) changed since last revision : MSDS to First Issue SDS Conversion

IMPORTANT! Read this SDS before use or disposal of this product. Pass along the information to employees and any other persons who could be exposed to the product to be sure that they are aware of the information before use or other exposure. This SDS has been prepared in accordance with the Globally Harmonized System of Chemical and Labeling of Chemicals (GHS) Fifth Edition and the OSHA Hazard Communication Standard [29 CFR 1910.1200]. The SDS information is based on sources believed to be reliable. Available data, safety standards, and government regulations are subject to change and the conditions of handling and use, or misuse are beyond our control; Hill Brothers Chemical Company makes no warranty, either expressed or implied, with respect to the completeness or continuing accuracy of the information contained herein and disclaims all liability for reliance thereon. Additional information may be necessary or helpful for specific conditions and circumstances of use. It is the user's responsibility to determine the suitability of this product and to evaluate risks and exercise appropriate precautions for protection of employees and others prior to use.

Refrigerant R717 (Ammonia)						
Temp in Degrees Fahrenheit	Gauge Pressure	Absolute Pressure	Specific Volume liquid	Specific Volume Vapor	Density Liquid	Density Vapor
(°f)	psig *	psia	ft³/lb.	ft³/lb.	lbs./ ft³	lbs./ ft³
-65	20.4" hg	4.69	0.0227	52.5619	44.15	0.0190
-64	20.0" hg	4.84	0.0227	50.8815	44.11	0.0197
-63	19.7" hg	5.02	0.0227	49.3229	44.07	0.0203
-62	19.4" hg	5.18	0.0227	47.7644	44.03	0.0209
-61	19.0" hg	5.37	0.0227	46.3175	43.99	0.0216
-60	18.6" hg	5.53	0.0228	44.8709	43.95	0.0223
-59	18.2" hg	5.72	0.0228	43.5023	43.90	0.0230
-58	17.8" hg	5.91	0.0228	42.1830	43.86	0.0237
-57	17.4" hg	6.11	0.0228	40.9108	43.82	0.0244
-56	17.0" hg	6.31	0.0228	39.6840	43.78	0.0252
-55	16.6" hg	6.52	0.0229	38.5006	43.74	0.0260
-54	16.2" hg	6.73	0.0229	37.3589	43.69	0.0268
-53	15.7" hg	6.95	0.0229	36.2572	43.65	0.0276
-52	15.3" hg	7.18	0.0229	35.1939	43.61	0.0284
-51	14.8" hg	7.41	0.0230	34.1675	43.57	0.0293
-50	14.3" hg	7.64	0.0230	33.1765	43.53	0.0301
-49	13.8" hg	7.89	0.0230	32.2196	43.48	0.0310
-48	13.3" hg	8.14	0.0230	31.2953	43.44	0.0320
-47	12.8" hg	8.39	0.0230	30.4025	43.40	0.0329
-46	12.2" hg	8.66	0.0230	29.5398	43.46	0.0339
-45	11.7" hg	8.92	0.0231	28.7062	43.32	0.0348
-44	11.1" hg	9.20	0.0231	27.9004	43.27	0.0358
-43	10.6" hg	9.48	0.0231	27.1216	43.23	0.0369
-42	10.0" hg	9.77	0.0232	26.3685	43.19	0.0379
-41	9.3" hg	10.07	0.0232	25.6402	43.15	0.0390
-40	8.7" hg	10.38	0.0232	24.9359	43.10	0.0401
-39	8.1" hg	10.69	0.0232	24.2545	43.06	0.0412
-38	7.4" hg	11.01	0.0232	23.5953	43.02	0.0424
-37	6.8" hg	11.34	0.0233	22.9574	42.97	0.0436
-36	6.1" hg	11.67	0.0233	22.3400	42.93	0.0448
-35	5.4" hg	12.01	0.0233	21.7423	42.89	0.0460
-34	4.7" hg	12.37	0.0233	21.1637	42.85	0.0473
-33	3.9" hg	12.73	0.0234	20.6035	42.80	0.0485
-32	3.2" hg	13.10	0.0234	20.0609	42.76	0.0498

Refrigerant R717 (Ammonia)						
Temp in Degrees Fahrenheit (°f)	Gauge Pressure psig *	Absolute Pressure psia	Specific Volume liquid ft³/lb.	Specific Volume Vapor ft³/lb.	Density Liquid lbs./ ft³	Density Vapor lbs./ ft³
-31	2.4" hg	13.47	0.0234	19.5353	42.72	0.0512
-30	1.6" hg	13.86	0.0234	19.0262	42.67	0.0526
-29	.8" hg	14.25	0.0235	18.5328	42.63	0.0540
-28	0 psig	14.66	0.0235	18.0548	42.59	0.0554
-27	0.37	15.07	0.0235	17.5914	42.55	0.0568
-26	0.79	15.49	0.0235	17.1422	42.50	0.0583
-25	1.23	15.93	0.0236	16.7068	42.46	0.0599
-24	1.67	16.37	0.0236	16.2845	42.42	0.0614
-23	2.12	16.82	0.0236	15.8750	42.37	0.0630
-22	2.58	17.28	0.0236	15.4778	42.33	0.0646
-21	3.05	17.75	0.0236	15.0925	42.29	0.0663
-20	3.54	18.24	0.0237	14.7187	42.24	0.0679
-19	4.03	18.73	0.0237	14.3559	42.20	0.0697
-18	4.53	19.23	0.0237	14.0038	42.16	0.0714
-17	5.05	19.75	0.0237	13.6621	42.11	0.0732
-16	5.57	20.27	0.0238	13.3303	42.07	0.0750

Refrigerant R717 (Ammonia)						
Temp in Degrees Fahrenheit (°f)	Gauge Pressure psig *	Absolute Pressure psia	Specific Volume liquid ft³/lb.	Specific Volume Vapor ft³/lb.	Density Liquid lbs./ ft³	Density Vapor lbs./ ft³
-15	6.11	20.81	0.0238	13.0082	42.02	0.0769
-14	6.66	21.36	0.0238	12.6954	41.98	0.0788
-13	7.22	21.92	0.0238	12.3917	41.94	0.0807
-12	7.79	22.49	0.0239	12.0966	41.89	0.0827
-11	8.37	23.07	0.0239	11.8100	41.85	0.0847
-10	8.96	23.66	0.0239	11.5315	41.81	0.0867
-9	9.57	24.27	0.0239	11.2608	41.76	0.0888
-8	10.19	24.89	0.0240	10.9978	41.72	0.0909
-7	10.82	25.52	0.0240	10.7422	41.67	0.0931
-6	11.47	26.17	0.0240	10.4937	41.63	0.0953
-5	12.13	26.83	0.0240	10.2521	41.59	0.0975
-4	12.80	27.50	0.0241	10.0172	41.54	0.0998
-3	13.48	28.18	0.0241	9.7887	41.50	0.1022
-2	14.18	28.88	0.0241	9.5665	41.45	0.1045
-1	14.89	29.59	0.0241	9.3503	41.41	0.1069
0	15.62	30.32	0.0242	9.1401	41.36	0.1094
1	16.36	31.06	0.0242	8.9355	41.32	0.1119
2	17.11	31.81	0.0242	8.7364	41.27	0.1145
3	17.88	32.58	0.0243	8.5426	41.23	0.1171
4	18.66	33.36	0.0243	8.3540	41.19	0.1197
5	19.46	34.16	0.0243	8.1704	41.14	0.1224
6	20.28	34.98	0.0243	7.9917	41.10	0.1251
7	21.10	35.80	0.0244	7.8177	41.05	0.1279
8	21.95	36.65	0.0244	7.6482	41.01	0.1307
9	22.81	37.51	0.0244	7.4831	40.96	0.1336
10	23.68	38.38	0.0244	7.3224	40.92	0.1366

Refrigerant R717 (Ammonia)						
Temp in Degrees Fahrenheit (°f)	Gauge Pressure psig *	Absolute Pressure psia	Specific Volume liquid ft³/lb.	Specific Volume Vapor ft³/lb.	Density Liquid lbs./ ft³	Density Vapor lbs./ ft³
11	24.58	39.28	0.0245	7.1657	40.87	0.1396
12	25.48	40.18	0.0245	7.0132	40.82	0.1426
13	26.41	41.11	0.0245	6.8645	40.78	0.1457
14	27.35	42.05	0.0246	6.7196	40.73	0.1488
15	28.31	43.01	0.0246	6.5784	40.69	0.1520
16	29.28	43.98	0.0246	6.4408	40.64	0.1553
17	30.28	44.98	0.0246	6.3066	40.60	0.1586
18	31.29	45.99	0.0247	6.1758	40.55	0.1619
19	32.32	47.02	0.0247	6.0483	40.51	0.1653
20	33.36	48.06	0.0247	5.9240	40.46	0.1688
21	34.43	49.13	0.0247	5.8027	40.41	0.1723
22	35.51	50.21	0.0248	5.6844	40.37	0.1759
23	36.61	51.31	0.0248	5.5690	40.32	0.1796
24	37.73	52.43	0.0248	5.4564	40.27	0.1833
25	38.87	53.57	0.0249	5.3466	40.23	0.1870
26	40.03	54.73	0.0249	5.2395	40.18	0.1909
27	41.21	55.91	0.0249	5.1349	40.14	0.1947
28	42.41	57.11	0.0249	5.0328	40.09	0.1987
29	43.62	58.32	0.0250	4.9332	40.04	0.2027
30	44.86	59.56	0.0250	4.8360	40.00	0.2068
31	46.12	60.82	0.0250	4.7410	39.95	0.2109
32	47.40	62.10	0.0251	4.6483	39.90	0.2151
33	48.70	63.40	0.0251	4.5678	39.85	0.2189
34	50.02	64.72	0.0251	4.4695	39.81	0.2237
35	51.37	66.07	0.0252	4.3831	39.76	0.2281

Refrigerant R717 (Ammonia)						
Temp in Degrees Fahrenheit (°f)	Gauge Pressure psig *	Absolute Pressure psia	Specific Volume liquid ft³/lb.	Specific Volume Vapor ft³/lb.	Density Liquid lbs./ ft³	Density Vapor lbs./ ft³
36	52.73	67.43	0.0252	4.2988	39.71	0.2326
37	54.12	68.82	0.0252	4.2165	39.67	0.2372
38	55.53	70.23	0.0252	4.1360	39.62	0.2418
39	56.96	71.66	0.0253	4.0574	39.57	0.2465
40	58.41	73.11	0.0253	3.9806	39.52	0.2512
41	59.89	74.59	0.0253	3.9055	39.47	0.2560
42	61.39	76.09	0.0254	3.8321	39.43	0.2610
43	62.91	77.61	0.0254	3.7604	39.38	0.2659
44	64.46	79.16	0.0254	3.6903	39.33	0.2710
45	67.03	81.73	0.0255	3.6218	39.28	0.2761
46	67.63	82.33	0.0255	3.5548	39.23	0.2813
47	69.25	83.95	0.0255	3.4893	39.18	0.2866
48	70.89	85.59	0.0255	3.4253	39.14	0.2919
49	72.56	87.26	0.0256	3.3626	39.09	0.2974
50	74.25	88.95	0.0256	3.3014	39.04	0.3029
51	75.97	90.67	0.0256	3.2415	38.99	0.3085
52	77.71	92.41	0.0257	3.1828	38.94	0.3142
53	79.48	94.18	0.0257	3.1255	38.89	0.3199
54	81.28	95.98	0.0257	3.0694	38.84	0.3258
55	83.10	97.80	0.0258	3.0145	38.79	0.3317
56	84.95	99.65	0.0258	2.9608	38.74	0.3377
57	86.83	101.53	0.0258	2.9082	38.69	0.3439
58	88.73	103.43	0.0259	2.8568	38.64	0.3500
59	90.66	105.36	0.0259	2.8064	38.59	0.3563
60	92.62	107.32	0.0259	2.7571	38.54	0.3627

Refrigerant R717 (Ammonia)						
Temp in Degrees Fahrenheit (°f)	Gauge Pressure psig *	Absolute Pressure psia	Specific Volume liquid ft³/lb.	Specific Volume Vapor ft³/lb.	Density Liquid lbs./ ft³	Density Vapor lbs./ ft³
61	94.60	109.30	0.0260	2.7089	38.49	0.3692
62	96.62	111.32	0.0260	2.6616	38.44	0.3757
63	98.66	113.36	0.0260	2.6154	38.39	0.3824
64	100.73	115.43	0.0261	2.5701	38.34	0.3891
65	102.83	117.53	0.0261	2.5257	38.29	0.3959
66	104.96	119.66	0.0262	2.4823	38.24	0.4029
67	107.12	121.82	0.0262	2.4397	38.19	0.4099
68	109.31	124.01	0.0262	2.3981	38.14	0.4170
69	111.53	126.23	0.0263	2.3572	38.09	0.4242
70	113.78	128.48	0.0263	2.3173	38.04	0.4315
71	116.06	130.76	0.0263	2.2781	37.99	0.4390
72	118.37	133.07	0.0264	2.2397	37.93	0.4465
73	120.71	135.41	0.0264	2.2021	37.88	0.4541
74	123.08	137.78	0.0264	2.1652	37.83	0.4619
75	125.48	140.18	0.0265	2.1291	37.78	0.4697
76	127.92	142.62	0.0265	2.0936	37.73	0.4776
77	130.39	145.09	0.0265	2.0589	37.67	0.4857
78	132.89	147.59	0.0266	2.0249	37.62	0.4939
79	135.42	150.12	0.0266	1.9915	37.57	0.5021
80	137.99	152.69	0.0267	1.9588	37.52	0.5105
81	140.59	155.29	0.0267	1.9268	37.46	0.5190
82	143.22	157.92	0.0267	1.8953	37.41	0.5276
83	145.89	160.59	0.0268	1.8645	37.36	0.5363
84	148.59	163.29	0.0268	1.8342	37.31	0.5452
85	151.33	166.03	0.0268	1.8046	37.25	0.5541

Refrigerant R717 (Ammonia)						
Temp in Degrees Fahrenheit (°f)	Gauge Pressure psig *	Absolute Pressure psia	Specific Volume liquid ft³/lb.	Specific Volume Vapor ft³/lb.	Density Liquid lbs./ ft³	Density Vapor lbs./ ft³
86	154.10	168.80	0.0269	1.7755	37.20	0.5632
87	156.90	171.60	0.0269	1.7470	37.14	0.5724
88	159.75	174.45	0.0270	1.7190	37.09	0.5817
89	162.62	177.32	0.0270	1.6915	37.04	0.5912
90	165.54	180.24	0.0270	1.6646	36.98	0.6007
91	168.48	183.18	0.0271	1.6381	36.93	0.6105
92	171.47	186.17	0.0271	1.6122	36.87	0.6203
93	174.49	189.19	0.0272	1.5867	36.82	0.6302
94	177.55	192.25	0.0272	1.5617	36.77	0.6403
95	180.65	195.35	0.0272	1.5372	36.71	0.6505
96	183.78	198.48	0.0273	1.5131	36.66	0.6609
97	186.95	201.65	0.0273	1.4895	36.60	0.6714
98	190.16	204.86	0.0274	1.4663	36.55	0.6820
99	193.41	208.11	0.0274	1.4436	36.49	0.6927
100	196.70	211.40	0.0274	1.4212	36.43	0.7036
101	200.02	214.72	0.0275	1.3993	36.38	0.7146
102	203.39	218.09	0.0275	1.3777	36.32	0.7258
103	206.80	221.50	0.0276	1.3565	36.27	0.7372
104	210.24	224.94	0.0276	1.3358	36.21	0.7486
105	213.73	228.43	0.0277	1.3153	36.15	0.7603
106	217.25	231.95	0.0277	1.2953	36.10	0.7720
107	220.82	235.52	0.0277	1.2756	36.04	0.7839
108	224.43	239.13	0.0278	1.2563	35.98	0.7960
109	228.08	242.78	0.0278	1.2373	35.93	0.8082
110	231.77	246.47	0.0279	1.2186	35.87	0.8206

Refrigerant R717 (Ammonia)						
Temp in Degrees Fahrenheit (°f)	Gauge Pressure psig *	Absolute Pressure psia	Specific Volume liquid ft³/lb.	Specific Volume Vapor ft³/lb.	Density Liquid lbs./ ft³	Density Vapor lbs./ ft³
111	235.50	250.20	0.0279	1.2003	35.81	0.8331
112	239.28	253.98	0.0280	1.1822	35.75	0.8459
113	243.10	257.80	0.0280	1.1645	35.70	0.8587
114	246.96	261.66	0.0281	1.1471	35.64	0.8718
115	250.87	265.57	0.0281	1.1300	35.58	0.8850
116	255.40	269.52	0.0282	1.1132	35.52	0.8983
117	259.40	273.51	0.0282	1.0967	35.46	0.9118
118	263.50	277.55	0.0282	1.0805	35.41	0.9255
119	267.60	281.63	0.0283	1.0645	35.35	0.9394
120	271.70	285.76	0.0283	1.0488	35.29	0.9535
121	275.90	289.93	0.0284	1.0334	35.23	0.9677
122	280.10	294.15	0.0284	1.0183	35.17	0.9820
123	284.40	298.41	0.0285	1.0033	35.11	0.9967
124	288.70	302.72	0.0285	0.9887	35.05	1.0114
125	293.10	307.08	0.0286	0.9743	34.99	1.0264