Ammonia & Ammonia Solution

STORAGE, HANDLING

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Anhydrous Ammonia

Ammonia Solution

Introduction

Ammonia Molecular Weight: 17.03

Ammonia Formula: NH_3

Anydrous Ammonia

Anhydrous ammonia is a chemical compound of nitrogen and hydrogen. At atmospheric pressure it is a gas with a density just over half that of air. It liquefies at modest pressures.

Terra supplies anhydrous ammonia in three grades; commercial, refrigeration and metallurgical (see Table 1, below). Commercial grade anhydrous ammonia is the most commonly used and is suitable for most applications. Refrigeration and metallurgical grades are products manufactured for applications requiring higher purity. All grades are available from Terra. Ammonia can be delivered as liquid by pipeline, tank truck, railcar or barge, depending on the facility at which it is manufactured. Ammonia production facilities are located in Courtright, Ontario; Port Neal, Iowa; Woodward and Verdigris, Oklahoma; Yazoo City, Mississippi; and Trinidad & Tobago.

If you use anhydrous ammonia in bulk, consult your Terra sales representative for technical advice on the product and its safe storage, handling and use. Terra offers you help with ammonia handling practices such as system design and installation, operational procedures, employee training, and environmental, health and safety requirements, including emergency response procedures.

Table 1: Anhydrous Ammonia Specifications

	Commercial	**Refrigeration**	**Metallurgical**
Water content	<5,000 ppm	75 ppm maximum	33 ppm maximum
Oil content	<5 ppm	4 ppm maximum	2 ppm maximum

Applications

Anhydrous ammonia has a wide range of industrial applications. It is used:

- To manufacture nitrogen fertilizers.
- To remove nitrogen oxides from flue gases.
- To manufacture explosives.
- To manufacture dyes and man-made fibers.
- As a chemical reagent, for example, to form amines and ammonium compounds.
- To nitride special steels.
- To prevent flue-duct, economizer and air heater corrosion in oil refineries.
- To prevent acid smut emission from oil-fired boilers.
- To neutralize acid effluents.
- As a preservative in rubber latex.
- As a non-ionizing solvent for many chemical compounds.
- As a refrigerant.

Properties

Physical Properties

Anhydrous ammonia is a colorless gas with a very pungent odor. It is lighter than air at ambient temperature (68°F). Anhydrous ammonia can be liquefied at ambient temperature under moderate pressure (approximately 8.5 atm.) and is typically stored and transported as a liquid. Table 2 (Pages 4-7) gives the physical properties of saturated ammonia vapor and liquid in the temperature range - 60°F to +30°F and Table 3 (Pages 8-9) shows the properties of superheated ammonia.

Table 2. Properties of Saturated Ammonia

		DENSITY		ENTHALPY		ENTROPY
Temp. °F	Pressure PSIA	Vapor Lbs./Ft.^{3}	Liquid Lbs./Ft.^{3}	Vapor Btu/Lb.	Liquid Btu/Lb.	Vapor Btu/Lb.-F
-60	5.549	0.022354	43.907	589.607	-21.189	1.476907
-58	5.929	0.023779	43.825	590.425	-19.077	1.471339
-56	6.330	0.025276	43.742	591.238	-16.963	1.465842
-54	6.752	0.026849	43.659	592.047	-14.848	1.460413
-52	7.198	0.028501	43.576	592.852	-12.732	1.455052
-50	7.668	0.030233	43.493	593.651	-10.614	1.449756
-48	8.162	0.032050	43.410	594.446	-8.494	1.444525
-46	8.683	0.033955	43.326	595.235	-6.373	1.439358
-44	9.230	0.035949	43.242	596.020	-4.251	1.434252
-42	9.805	0.038037	43.158	596.799	-2.127	1.429206
-40	10.410	0.040222	43.074	597.573	0.000	1.424220
-38	11.044	0.042507	42.990	598.342	2.127	1.419292
-36	11.710	0.044894	42.905	599.105	4.256	1.414421
-34	12.407	0.047389	42.820	599.862	6.388	1.409605
-32	13.139	0.049993	42.735	600.614	8.521	1.404844
-30	13.905	0.052711	42.649	601.359	10.655	1.400136
-28	14.706	0.055546	42.563	602.099	12.792	1.395481
-26	15.545	0.058502	42.478	602.832	14.931	1.390877
-24	16.422	0.061582	42.391	603.560	17.072	1.386323
-22	17.339	0.064790	42.305	604.280	19.214	1.381818
-20	18.296	0.068130	42.218	604.995	21.359	1.377361
-18	19.296	0.071607	42.131	605.702	23.508	1.372951
-16	20.339	0.075223	42.044	606.403	25.654	1.368587
-14	21.427	0.078983	41.957	607.098	27.805	1.364269
-12	22.562	0.082892	41.869	607.785	29.958	1.359994

		DENSITY		ENTHALPY		ENTROPY
Temp. °F	Pressure PSIA	Vapor Lbs./Ft.^{3}	Liquid Lbs./Ft.^{3}	Vapor Btu/Lb.	Liquid Btu/Lb.	Vapor Btu/Lb.-F
-10	23.743	0.086953	41.781	608.465	32.113	1.355763
-8	24.974	0.091170	41.693	609.139	34.270	1.351575
-6	26.256	0.095548	41.604	609.805	36.429	1.347428
-4	27.589	0.100092	41.515	610.464	38.591	1.343322
-2	28.976	0.104805	41.426	611.115	40.755	1.339256
0	30.418	0.109693	41.337	611.759	42.921	1.335228
2	31.917	0.114760	41.247	612.395	45.089	1.331240
4	33.473	0.120010	41.157	613.024	47.260	1.327289
6	35.090	0.125449	41.067	613.645	49.432	1.323374
8	36.767	0.131081	40.976	614.259	51.608	1.319496
10	38.508	0.136911	40.866	614.864	53.786	1.315654
12	40.312	0.142945	40.794	615.462	55.966	1.311846
14	42.184	0.149187	40.703	616.052	58.149	1.308072
16	44.123	0.155643	40.611	618.633	60.334	1.304332
18	46.131	0.162318	40.519	617.207	62.522	1.300624
20	48.211	0.169217	40.427	617.772	64.713	1.296949
22	50.364	0.176346	40.334	618.329	66.906	1.293305
24	52.591	0.183710	40.241	618.878	69.102	1.289692
26	54.896	0.191316	40.147	619.418	71.301	1.286110
28	57.278	0.199168	40.053	619.950	73.503	1.282558
30	59.741	0.027273	39.959	620.474	75.708	1.279035
32	62.286	0.215636	39.865	620.989	77.916	1.275541
34	64.914	0.224265	39.770	621.496	80.127	1.272075
36	67.629	0.233164	39.675	621.994	82.341	1.268637
38	70.431	0.242340	39.579	622.484	84.559	1.265226

Table 2. Properties of Saturated Ammonia (continued)

		DENSITY		ENTHALPY		ENTROPY
Temp. °F	Pressure PSIA	Vapor Lbs./Ft.^{3}	Liquid Lbs./Ft.^{3}	Vapor Btu/Lb.	Liquid Btu/Lb.	Vapor Btu/Lb.-F
40	73.332	0.251800	39.483	622.964	88.779	1.261842
42	76.305	0.261550	39.387	623.436	89.004	1.258484
44	79.381	0.271597	39.290	623.900	91.231	1.255153
46	82.553	0.281947	39.193	624.354	93.463	1.251846
48	85.822	0.292608	39.096	624.800	95.697	1.248565
50	89.191	0.303586	38.998	625.237	97.936	1.245308
52	92.661	0.314888	38.899	625.665	1..0178	1.242075
54	96.234	0.326522	38.801	626.084	102.424	1.238866
56	99.912	0.338496	38.702	626.494	104.674	1.235681
58	103.698	0.350816	38.602	626.895	106.928	1.232517
60	107.594	0.363490	38.502	627.287	109.186	1.229377
62	111.602	0.378527	38.402	627.669	111.448	1.226258
64	115.723	0.389935	38.301	628.043	113.714	1.223160
66	119.960	0.403720	38.199	628.407	115.984	1.220084
68	124.315	0.417892	38.098	628.761	118.258	1.217028
70	128.790	0.432460	37.995	629.106	120.536	1.213992
72	133.388	0.447432	37.893	629.442	122.819	1.210976
74	138.110	0.462816	37.789	629.768	125.105	1.207978
76	142.959	0.478622	37.686	630.084	127.396	1.205000
78	147.937	0.494859	37.581	630.390	129.692	1.202039
80	153.047	0.511537	37.477	630.686	131.991	1.199096
82	158.290	0.528665	37.371	630.971	134.294	1.196170
84	163.668	0.546254	37.265	631.246	136.602	1.193260
86	169.185	0.564312	37.159	631.510	138.914	1.190366
88	174.842	0.582851	37.052	631.764	141.231	1.187487

		DENSITY		ENTHALPY		ENTROPY
Temp. °F	Pressure PSIA	Vapor Lbs./Ft.^{3}	Liquid Lbs./Ft.^{3}	Vapor Btu/Lb.	Liquid Btu/Lb.	Vapor Btu/Lb.-F
90	180.642	0.601882	36.945	632.006	143.551	1.184622
92	186.587	0.621415	36.837	632.237	145.876	1.181771
94	192.680	0.641463	36.728	632.456	148.205	1.178933
96	198.992	0.662035	36.619	632.662	150.539	1.176107
98	205.316	0.683146	36.509	632.856	152.877	1.173291
100	211.865	.0704807	36.399	633.038	155.220	1.170486
102	218.571	0.727032	36.288	633.205	157.568	1.167690
104	225.436	0.749834	36.176	633.359	159.921	1.164902
106	232.463	0.773227	36.063	633.498	162.279	1.162121
108	239.655	0.797227	35.950	633.662	164.643	1.159346
110	247.013	0.821850	35.837	633.731	167.013	1.156575
112	254.541	0.847112	35.722	633.822	169.390	1.153807
114	262.240	0.873030	35.607	633.896	141.775	1.151040
116	270.114	0.899625	35.491	633.952	174.167	1.148274
118	278.165	0.926915	35.375	633.989	176.570	1.145505
120	286.395	0.954924	35.257	634.005	178.982	1.142733
122	294.807	0.983675	35.139	634.000	181.407	1.139955
124	303.404	1.013193	35.020	633.972	183.846	1.137170
126	312.188	1.043506	34.901	633.921	186.300	1.134374
128	321.163	1.074646	34.780	633.843	188.772	1.131567
130	330.329	1.106646	34.659	633.739	191.265	1.128744
132	339.692	1.139544	34.536	633.606	193.781	1.125904
134	349.252	1.173381	34.413	633.443	196.325	1.123044
136	359.013	1.208204	34.289	633.246	198.900	1.120160
138	368.977	1.244065	34.164	633.016	201.510	1.117250

Table 3. Properties of Superheated Ammonia

			SUPERHEAT TEMPERATURE DEGREES F			
Pressure		**Sat.**	**-50**	**0**	**50**	**100**
5	v_g	49.309	51.048	57.554	63.963	70.331
PSIA	h_g	588.33	595.16	620.43	645.45	670.22
-63.11 F	s_g	1.48570	1.50265	1.56088	1.61258	1.65985
10	v_g	25.812	—	28.584	31.847	35.066
PSIA	h_g	597.05	—	618.86	644.47	669.97
-41.35 F	s_g	1.42757	—	1.47731	1.53011	1.57793
15	v_g	17.674	—	18.924	21.139	23.309
PSIA	h_g	602.36	—	617.22	643.37	669.21
-27.29 F	s_g	1.39384	—	1.42719	1.48120	1.52959
25	v_g	10.958	—	11.187	12.571	13.902
PSIA	h_g	609.15	—	613.75	641.20	667.68
-7.96 F	s_g	1.35149	—	1.36158	1.41831	1.46789
35	v_g	7.991	—	—	8.895	9.896
PSIA	h_g	613.61	—	—	638.94	666.12
5.89 F	s_g	1.32359	—	—	1.37562	1.42649
50	v_g	5.710	—	—	6.135	6.843
PSIA	h_g	618.24	—	—	635.40	663.71
21.67 F	s_g	1.29391	—	—	1.32858	1.38160
75	v_g	3.887	—	—	3.982	4.485
PSIA	h_g	623.23	—	—	629.07	659.56
41.13 F	s_g	1.25994	—	—	1.27150	1.32861
100	v_g	2.952	—	—	—	3.304
PSIA	h_g	626.50	—	—	—	655.21
56.05	s_g	1.23561	—	—	—	1.28907
150	v_g	1.994	—	—	—	2.118
PSIA	h_g	630.51	—	—	—	645.90
78.81 F	s_g	1.20084	—	—	—	1.22888
200	v_g	1.502	—	—	—	1.520
PSIA	h_g	632.70	—	—	—	635.66
96.34 F	s_g	1.17563	—	—	—	1.18091
250	v_g	1.202	—	—	—	—
PSIA	h_g	633.77	—	—	—	—
110.80 F	s_g	1.15547	—	—	—	—
300	v_g	0.999	—	—	—	—
PSIA	h_g	633.99	—	—	—	—
123.21 F	s_g	1.13827	—	—	—	—

SUPERHEAT TEMPERATURE DEGREES F					
150	**200**	**250**	**300**	**350**	**400**
76.679	83.014	89.340	95.661	101.979	108.293
696.41	722.61	749.38	776.76	804.77	833.43
1.70382	1.74513	1.78425	1.82152	1.85723	1.89158
38.262	41.446	44.622	47.792	50.958	54.121
695.83	722.16	749.01	776.45	804.50	833.20
1.62220	1.66370	1.70294	1.74030	1.77607	1.81046
25.456	27.590	29.715	31.835	33.950	36.063
695.26	721.70	748.64	776.14	804.24	832.98
1.57416	1.61585	1.65521	1.69266	1.72848	1.76292
15.210	16.503	17.788	19.068	20.343	21.616
664.10	720.78	747.89	775.52	803.72	832.53
1.51310	1.55517	1.59479	1.63241	1.66836	1.70288
10.817	11.751	12.676	13.595	14.510	15.422
692.92	719.86	747.15	774.90	803.20	832.08
1.47238	1.51485	1.55472	1.59251	1.62859	1.66320
7.521	8.185	8.840	9.489	10.134	10.776
691.14	718.47	746.02	773.97	802.41	831.40
1.42855	1.47164	1.51190	1.54996	1.58621	1.62096
4.956	5.410	5.855	6.294	6.728	7.160
688.11	716.12	744.13	772.41	801.09	830.28
1.37750	1.42167	1.46260	1.50111	1.53768	1.57265
3.672	4.021	4.361	4.695	5.024	5.351
685.01	713.75	742.23	770.85	799.78	829.15
1.34011	1.38542	1.42705	1.46602	1.50290	1.53810
2.385	2.631	2.866	3.095	3.319	3.540
678.57	708.90	738.39	767.69	797.13	826.89
1.28485	1.33268	1.37578	1.41569	1.45322	1.48888
1.740	1.935	2.118	2.295	2.466	2.635
671.80	703.92	734.49	764.52	794.48	824.62
1.24288	1.29354	1.33823	1.37912	1.41732	1.45345
1.352	1.518	1.670	1.815	1.955	2.093
664.62	698.79	730.53	761.31	791.80	822.35
1.20784	1.26174	1.30814	1.35007	1.38894	1.42555
1.091	1.239	1.372	1.496	1.616	1.732
656.88	693.47	726.49	758.08	789.12	820.06

V is specific volume, Ft^3/Lb.

H is enthalpy, Btu/Lb.

S is entropy, Btu/Lb.-°F

Chemical Properties

Ammonia gas is highly soluble in water with a heat of solution of 900 Btu/lb. Liquid ammonia is completely miscible in water with a heat of dilution of 340 Btu/lb. Removal of the heat of solution by means of a cooling surface (such as a shell and tube heat exchanger) permits up to a 25% ammonia/water solution by weight to be made at atmospheric pressure.

Ammonia is flammable in air at concentrations of between 15.5 and 27 percent by volume; increases in pressure or temperature expand this range slightly. Explosions can occur with flammable mixtures confined in vessels or enclosed spaces.

Ammonia is a moderately strong alkali, which reacts with strong acids and acid gases to form ammonium salts. Given the heat of neutralization (about 1,300 Btu/lb.) the reaction is particularly vigorous with concentrated strong acids.

Rubber-based compounds and some plastics are susceptible to attack and degradation by liquid and gaseous ammonia. Teflon and EPDM (ethylene-propylene resin) materials are recommended for ammonia storage, transportation and application equipment.

Physio-logical Properties

Ammonia is an alkali with a strong affinity for water and prolonged exposure will result in irritation of the eyes, skin and mucus membrane linings of the nasal passages, airways and lungs.

Ammonia concentrations less than 25 ppm in air are not harmful, but may result in some of the irritant effects described. Exposure to high concentrations may result in bronchitis or permanent damage to the lungs and mucus membranes. Toxicity effects are not cumulative.

Ammonia can be detected by smell at concentrations of less that 10ppm.

Occupational Exposure Limits for ammonia have been established by NIOSH (the National Institute of Occupational Safety and Health), ACGIA (the American Conference of Government Industrial Hygienists), and OSHA (the Occupational Safety and Health Administration). They are:

- NIOSH recommended exposure limit (REL) (8 hour TWA reference period) - 25 ppm.
- ACGIH short term exposure limit (STEL) (15 minute TWA reference period) - 35 ppm.
- OSHA permissible exposure limit (PEL) (8 hour TWA reference period) - 50 ppm.

In addition, NIOSH has set the IDLH (immediately dangerous to life and health) concentration for ammonia at 300 ppm. This very conservative limit includes a significant safety factor and is intended to be protective of the most sensitive populations.

Concentrations between 150 and 400 ppm will cause irritation and discomfort of the mucus membranes and the eyes, but usually with no lasting consequences. Exposure to concentrations above 1,500 ppm will damage or destroy tissue, and exposure to 2,500 ppm and higher increases the risk of fatality (see Table 4, Page 11).

Table 4. Exposure Limits and Effects of Ammonia Vapor at Increasing Concentrations in Air

Vapor Concentration (ppm)	Limit or General Effect	Exposure Period
5	Odor detectable by most persons	Unlimited
25	NIOSH REL	8 hour TWA
35	ACGIH STEL	15 minute TWA
50	OSHA PEL	8 hour TWA
300	NIOSH IDLH	
400-700	Immediate nose and throat irritation	30 minutes to 1 hour exposure causes serious effect
1,700	Severe coughing; severe eye, nose and throat irritation	Could be fatal after 30 minutes
2,000-5,000	Severe coughing; severe eye, nose and throat irritation	Could be fatal after 15 minutes
5,000-10,000	Respiratory spasm; rapid asphyxias	Fatal within minutes

Storage Installations

Liquid ammonia has a dew point temperature, at atmospheric pressure, below - 28°F and if splashed on the skin will cause burns. The severity of burning will depend on the amount of liquid involved. One or two drops will have only local freezing effect lasting for a minute or two. Flooding will cause first-degree burns and almost certainly remove the exposed skin. Even the smallest liquid splash in the eyes can result in permanent injury.

The following guidelines constitute the minimum siting standards and are in no way intended to override more stringent requirements of federal, state or local regulations.

Ammonia storage installations must be sited within a secure boundary. The immediate surroundings of the tank must be off limits to all unauthorized persons, and a physical barrier is required. Installations are best sited outdoors, away from occupied buildings and workspaces. Siting of ammonia tanks indoors is not recommended. However, if tanks are sited indoors they must be totally isolated from any occupied building or workspace; the tank house must be provided with separate high level ventilation and any vents from the installation must lead to the open air. Delivery tanker off-loading should be carried out in the open air, in a space away from normal traffic and where occupied buildings are not affected.

Ammonia storage installations and unloading areas must be a reasonable distance from dwellings and places of public assembly. Emergency response and fire services should be informed of the location and expected date of equipment commissioning.

Safe System Design

System layout should protect the tank and all prime valves from accidental damage. Crash barriers or similar protective devices may be necessary. Ease of access by delivery or emergency response vehicles, regardless of wind direction, should be considered. The design should also provide adequate space for maintenance and worker egress from the area during emergencies. Self-contained breathing apparatuses and a safety shower with an eye wash station should be readily available.

An adequate water supply must be provided for use in emergencies and as a precaution during off-loading. Fixed spray systems (fire monitors) with hoses equipped with spray/jet nozzles are recommended. Ammonia vapor concentrations between 15.5 and 27 percent in air are considered flammable.

Ammonia will not normally attack steel, but in the presence of oxygen can result in stress corrosion cracking. This risk can be minimized by selecting suitable steels for constructing vessels and pipes, thermally stress relieving these metals during fabrication and purging ammonia systems of air prior to commissioning.

The most commonly used construction material in ammonia installations is carbon steel. Adequate low temperature ductility and an acceptable resistance to stress corrosion cracking can be obtained by selecting steels containing less than 0.25% carbon and with an actual ultimate tensile strength less than 72,000 psi.

At elevated temperatures (>750°F) vessel nitriding is a problem with all carbon steels and the only suitable materials are nickel chrome alloys. Copper and its alloys, and galvanized, zinc and cadmium plating are readily attacked and must not be used in ammonia systems.

As a minimum requirement, pressure vessels must be designed to ANSI K61.1[1]. Vessels must be subjected to 100% radiography of the main seams and must be thermally stress relieved when welding is completed. All piping should conform to ANSI/ASME B31.3.

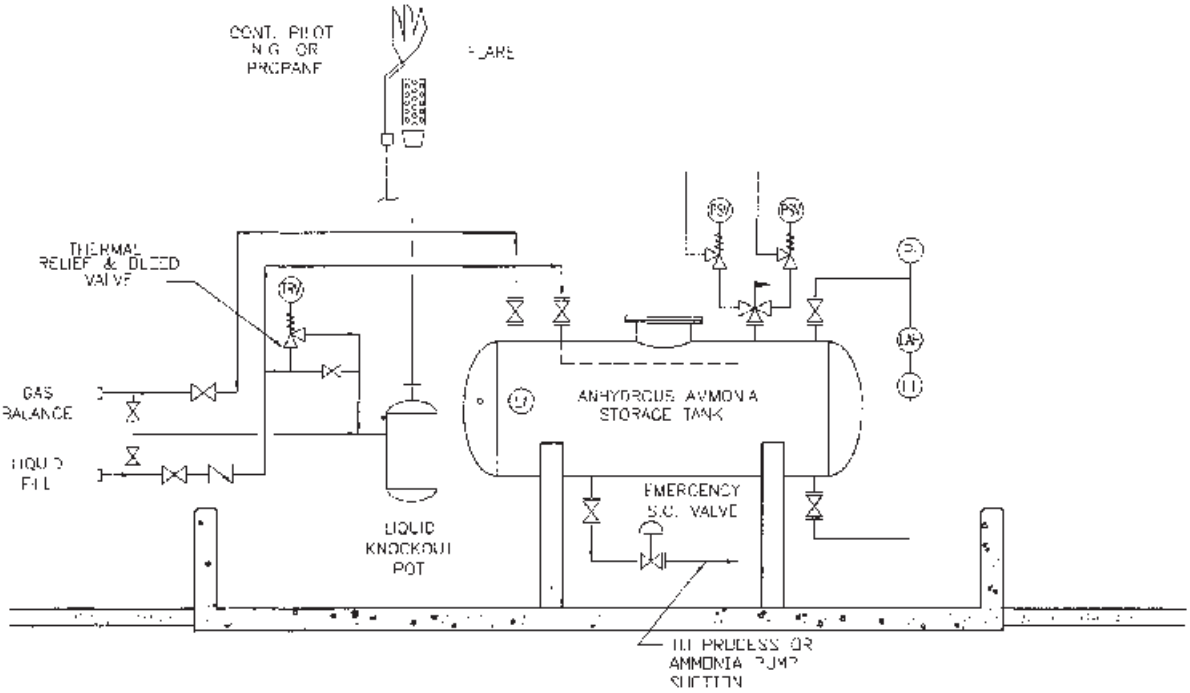
The number of openings into the pressure vessel should be kept to a minimum. The manhole should be located on top of the vessel. A line diagram of a typical ammonia pressure storage vessel is given in Figure 1, Page 13.

All ammonia tanks must be fitted with at lease one serviceable level indicator or contents gauge. “Sightglass” gauges, where the glass is exposed to ammonia, are not recommended.

Ammonia distribution systems should be kept outdoors, away from areas where accidental damage is likely,

[1] American national Standard Safety Requirements for the Storage and Handling of Anhydrous Ammonia.

Figure 1. A Typical Pressure Storage Installaion



System Maintenance

but accessible for maintenance. Where a factory roadway has to be crossed, a pipebridge is preferable to a duct. The ammonia transfer piping should conform to ASME B31.3.

Ammonia feeds to reaction vessels or mixing chambers must allow for a safe and controlled rate of transfer, which prevents directional changes in flow. Given the high solubility of ammonia vapors into water, the vacuum collapse of vessels is possible. Safety relief valves should be provided to prevent the overpressure to piping systems caused by thermal expansion.

A comprehensive external inspection of the ammonia installation and distribution system should be completed annually. Particular attention to corrosion, minor gland or joint leaks, the completeness of the system, and its associated safety and emergency equipment is required. The minimum inspection requirements are specified in ANSI K61.1.

Terra recommends an internal tank inspection be performed within three years of commissioning to establish a baseline for future inspections. Subsequent inspections should be conducted at intervals within 5 years and in no case longer than 10 years. A wet florescent magnetic particle examination should be carried out covering 100% of the main internal welded seams, including “T” junctions and internal nozzle welds. Ultrasonic thickness testing of shell plating and branches is recommended if external corrosion is detected. Routine replacement of gland packings, joint rings, flange bolts, etc. should be undertaken to ensure the inspection covers the complete installation.

Pressure relief valves are usually set in the range of 230-250 psig. Terra recommends that vessel relief valves be tested by a certified repair shop every 4 years.

Hazards

All maintenance operations carried out on an ammonia installation must be subject to some form of “safe work permit” system. This must take into account the nature of the work and the potential hazard. Burning or welding operations constitute an explosion hazard in piping and vessels if they have not been completely and properly purged. Hazards arise from the uncontrolled mixing of anhydrous ammonia with mutually reactive materials or from leaks of ammonia gas or liquid to the atmosphere. Such occurrences are usually the result of improper operation or the failure of some part of an installation; they can be avoided by rigidly adhering to a comprehensive operating and maintenance plan. With a soundly designed and correctly maintained and operated system, there is virtually no possibility of a major leak occurring except as a result of external accident. A leak is more likely to occur during maintenance operations or when an ammonia delivery is taking place. (See also Safe Operation, right, and Emergency Procedures, Page 15.)

Maximum safety is achieved by adequately training all operators and strictly adhering to standard operating and maintenance procedures. Procedures for clearing and purging equipment and piping systems are especially important. To achieve the optimum response to an unforeseen emergency, training should aim to familiarize operators with the product, plant and process.

Safety Equipment

A HAZMAT team of specially selected and trained employees should be available to respond to any emergency. Procedures should include the use of audible and visual alarms, local emergency services and community notification systems. These should all be included in a detailed emergency response plan. Adequate high-level ventilation must be provided when ammonia is piped through an enclosed area. There must be two unimpeded points of egress from these workspaces with appropriate Personal Protective Equipment (PPE) available. When and where practical, ammonia distribution systems should avoid enclosed workspaces.

Terra reserves the right to refuse product delivery to facilities not meeting applicable standards.

Emergency Procedures

If there is a risk that ammonia may be released, during maintenance work, for example, proper PPE must be used. The equipment required will vary from splash goggles and gloves to full protective closing and Self Contained Breathing Apparatuses (SCBA). Employee training in the proper use of this equipment is essential to maintain a safe and productive operation.

Fire hydrants or an adequate water supply should be located no more than 100 feet from ammonia storage tanks. Safety showers and eye wash stations must be provided at all bulk ammonia installations and close to the unloading area. Eyewash stations using bottles should be checked regularly and the solution changed at specified intervals. Appropriate fire extinguishers should be installed around the storage tank.

First Aid

Emergency situations occur when the unexpected happens. Employee development and full understanding of the site emergency response plan is critical to successfully managing any chemical event. A trained, active and involved HAZMAT team is key to effectively handling emergency situations.

Refer to Terra's Material Safety Data Sheet, available on our web site at www.terraindustries.com.

Ref 2: Chemical Engineers' Handbook, B.H. Perry & C.H. Chilton, McGraw Hill Ltd. (ISBN 0,07,049478,9)

Ref 3: Bureau of Standards Circular No. 142, Tables of Thermodynamic Properties of Ammonia, 1st Edition, April 16, 1923

Introduction

Certified to
NSF / ANSI 61

Ammonia Solution (Aqua Ammonia)

Terra ammonia solution (also called aqueous ammonia or ammonium hydroxide) is a solution of ammonia in pure water.

Terra supplies ammonia solution in bulk by tanker truck or railcar.

Terra's aqueous ammonia products are of the highest quality, made with ammonia and demineralized water or equivalent at six world-class production facilities located throughout North America. Reliability of supply goes hand-in-hand with seasoned technical know-how founded on over 35 years' of progressive, ammonia manufacturing and distribution experience. These attributes allow Terra to offer our customers a wide range of services including but not limited to, equipment design and installation, employee HAZMAT training, environmental and process safety reviews, equipment maintenance and inspection programs and development of operating and emergency response procedures.

Terra can supply aqueous ammonia certified to NSF Standard 60. If your application calls for this grade of product, contact your Terra Sales representative to discuss supply options.

Table 1A. Ammonia Solution Specifications

	Commercial Grade	Agricultural Grade
Ammonia as NH_3	19-29% (+/- 0.5%)	24.3-25.3%
Chlorides (Cl)	< 1.0 ppm	N/A
Carbonate as CO_2	<1.0 ppm	N/A
Appearance	Clear	Clear
Nitrogen content	15.6-24%	20.0-20.8%

Applications

Terra ammonia solution has a wide range of industrial uses, including:

- As a chemical intermediate for the manufacture of ammonia salts, amines, pharmaceuticals, explosives and catalysts.
- As a reducing agent in SCR/SNCR processes.
- As a solvent for copper in the etching of printed circuits.
- As a nutrient for fermentation processes.
- As a nutrient for effluent treatment.
- As a neutralizing agent and for pH control.
- As a water softener for textile finishing.
- As a developer in some reprographic processes.

Terra provides full technical service support, including advice on safe handling, to our customers.

Product Specifications

There are two grades of Terra aqua ammonia available, commercial and agricultural.

Slight variations from the specified strength may occur (+/- 0.5% w/w) depending on ambient temperature and storage conditions at time of delivery.

Properties

Terra aqua ammonia is typically available in concentrations not less than 10% and not more than 35% ammonia, with specific gravities ranging from 0.0957 to 0.880 at 60°F. Aqua ammonia concentrations as high as 50% (specific gravity of 0.825 at 60°F) may be provided for certain applications. Terra aqua ammonia is a solution of ammonia in water. It is a clear, colorless liquid with the characteristic pungent odor of ammonia.

Ammonia vapor may evolve from ammonia solution and is a colorless gas with a density just over half of that of air. The rate of vaporization depends on, and increases with, temperature and solution concentration (see Figure 1A, Page 19). Ammonia vapor is flammable at concentrations between 15.5% and 27% by volume in air. Care must be taken during design, maintenance and operations to ensure flammable mixtures cannot and do not form in confined spaces.

Physical Properties

Specific gravities of ammonia solutions are provided in Table 2A (Page 18) with standard testing methodologies furnished in Table 3A (Page 19). Freezing point and boiling point variations according to concentration are shown in Figures 2A and 3A (Page 20).

Aqua ammonia is a moderately strong alkali, which will react with acids or acid gases to form ammonium salts. There is a considerable heat of neutralization (about 430 Btu/lb. of 35% solution) and therefore a violent reaction with concentrated strong acids can be

expected with some ammonia vaporization probable.

Aqua ammonia dissolves many metallic oxides and hydroxides, as well as many water insoluble salts and will react with many organic and inorganic compounds. These properties should be considered when determining storage and transportation arrangements
(continued on Page 21)

Table 2A. Specific Gravity of Aqueous Solutions of Ammonia
This table applies to ammonia Solutions at 60°F (15.5°C)

Specific Gravity	% NH_3 w/w	G NH_3 per 100 ml.
0.876	36.55	32.02
0.878	35.88	31.50
0.880	35.20	30.98
0.882	34.53	30.45
0.884	33.86	29.93
0.886	33.19	29.41
0.888	32.52	28.88
0.890	31.85	28.34
0.892	31.18	27.82
0.894	30.51	27.28
0.896	29.84	26.74
0.898	29.17	26.19
0.900	28.50	25.65
0.902	27.83	25.10
0.904	27.16	24.55
0.906	26.49	24.00
0.908	25.82	23.44
0.910	25.15	22.89
0.912	24.48	22.32
0.914	23.82	21.77
0.916	23.16	21.21
0.918	22.50	20.65
0.920	21.85	20.10
0.922	21.21	19.55
0.924	20.57	19.01
0.926	19.94	18.46
0.928	19.31	17.92
0.930	18.69	19.38
0.932	18.07	16.87
0.934	17.46	16.31
0.936	16.85	15.68
0.938	16.25	15.24
0.940	15.65	14.71
0.942	15.06	14.14
0.944	14.47	13.66
0.946	13.89	13.14
0.948	13.31	12.62
0.950	12.74	12.10
0.952	12.17	11.58
0.954	11.61	11.08
0.956	11.05	10.56
0.958	10.50	10.07
0.960	9.95	9.55
0.962	9.40	9.04
0.964	8.86	8.54
0.966	8.32	8.04
0.968	7.79	7.54
0.970	7.27	7.05
0.972	6.75	6.56
0.974	6.24	6.08
0.976	5.73	5.59
0.978	5.23	5.11
0.980	4.73	4.64
0.982	4.24	4.16
0.984	3.75	3.69
0.986	3.27	3.22
0.988	2.79	2.76
0.990	2.31	2.29
0.992	1.84	1.82
0.994	1.37	1.36
0.996	0.91	0.90
0.998	0.45	0.45

Table 3A. Correction for a Measured Specific Gravity - for Sample Temperature

1 Measure the specific gravity and temperature of the sample.
2 Find the temperature difference, above or below, 60°F.
3 Multiply the temperature difference by the correction factor appropriate to the measured specific gravity listed in Table 3A.
4 If the temperature of the sample is higher than 60°F, add the product (from Step 3) to the measured specific gravity. If the sample temperature is below 60°F, subtract the product from the measured specific gravity.

Specific Gravity	Correction Factor
0.880	0.00065
0.890	0.00060
0.900	0.00060
0.910	0.00050
0.920	0.00040
0.930	0.00040
0.940	0.00033
0.950	0.00025

Figure 1A. Total Vapor Pressure of Ammonia Solutions (% NH_3 W/W)

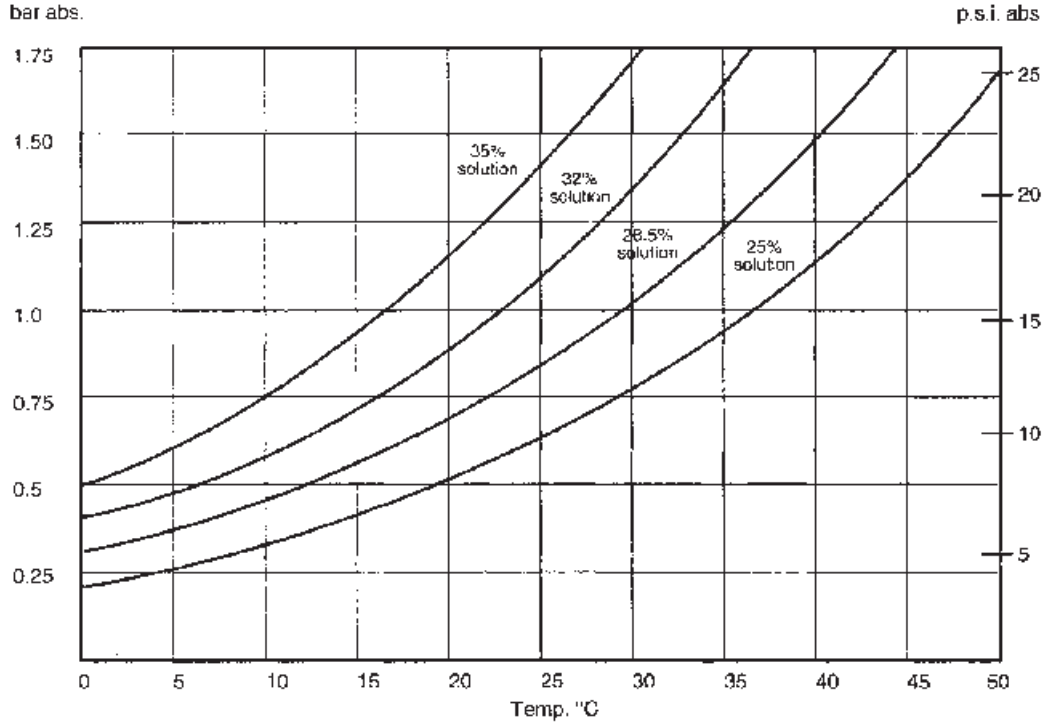


Figure 2A. Freezing Point of Aqueous Ammonia Solutions

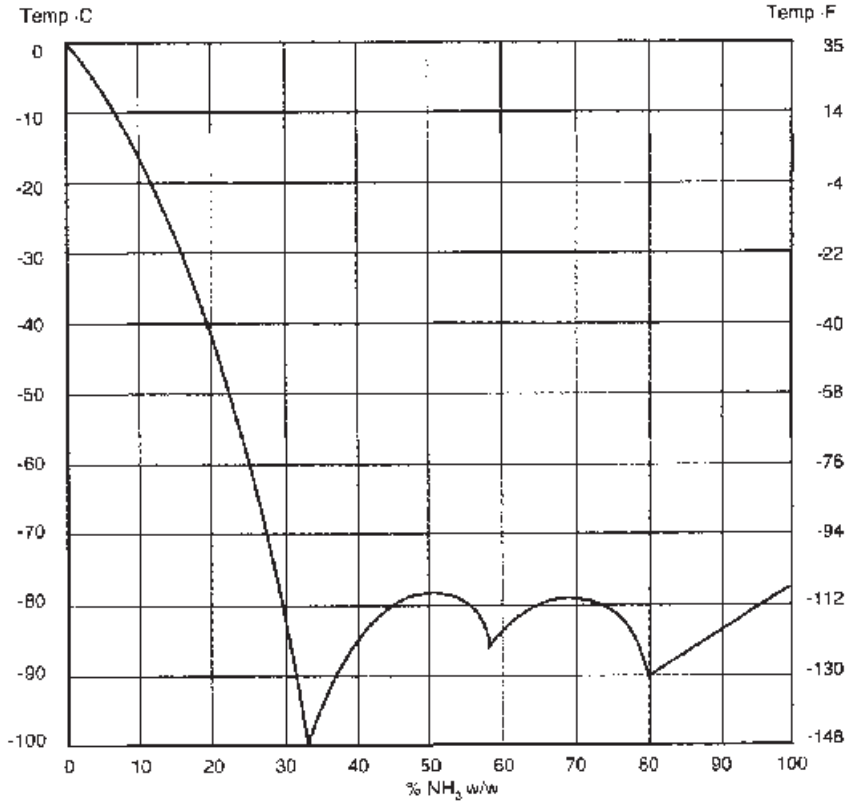
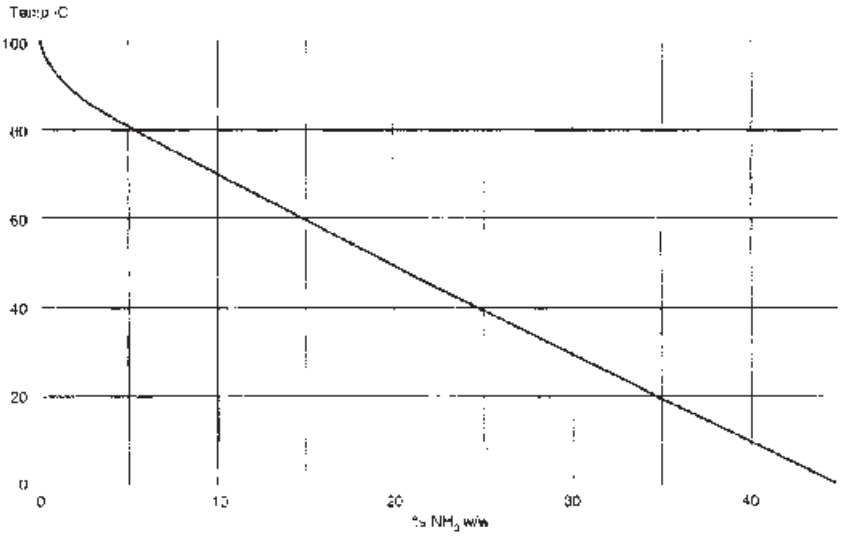


Figure 3A. Atmospheric Boiling Point for Aqueous Ammonia Solutions

Total vapor pressue 1.013 bar absolute



Bulk Deliveries

Physio-logical Properties

Copper, zinc, cadmium and all of their alloys are readily attacked by ammonia solution. Reaction with halogens, hypochlorites, mercury, nitric acid and some organic compounds may form unstable or explosive compounds. Certain metallic oxides, notably silver, mercury and cadmium, can form unstable nitrides or azides, which are explosive upon drying. Ammonia is an alkali with a strong affinity for water. It is an irritant to eyes, skin and mucus membranes such as the linings of the nasal passages, airways and lungs (refer to Table 4, Page 11 for exposure limits and effects).

Terra aqua ammonia is available in concentrations up to 35.0% ammonia and can be diluted by customers with demineralized water or equivalent.

A dilution calculation appears in Table 4A, below.

Table 4A. Calculation of Dilution Water for Storage at Lower Strength than Received.

Calculation:

P = pounds of dilution water required

G = gallons of dilution water required

P = [(% Delivered/ % Desired)-1] x (Pounds Delivered)= Pounds of Dilution Water

G = pounds of Dilution Water/8.33

Bulk deliveries are made in general purpose tank trucks or railcars. Tank trucks have stainless steel tanks protected with relief valves and are equipped with pumps. Unloading is accomplished through a tank bottom connection and a length of flexible hose, usually 20 feet long.

Tankers vary in physical dimensions, but will be within the following general specifications:

- Gross weight: 40 tons
- Capacity: 25 tons
- Length: 42 feet
- Width: 8 feet
- Turning circle: 180 feet
- Overhead clearance: 13 feet

Receiving locations should be sited outdoors with adequate road access for trucks. The unloading line should be a 3” or 4” pipe terminating with a block valve and OPW fitting for connection to the truck. This line should be capped when not in use as an added safety precaution in preventing storage tank back siphoning.

Tankers are off-loaded by the driver in coordination with the customer’s staff. A customer employee familiar with site equipment installations and related unloading and safety procedures must be present to supervise the off-loading activity.

Terra reserves the right to refuse deliveries into sites that do not meet agreed upon standards.

Bulk Storage

Tank Siting

The unloading procedures will depend on the strength of the delivered aqua solution and the design of the customer's installation. Terra will assist in customer installation design and unloading procedures.

Bulk storage installations and unloading areas for aqua ammonia should be sited outdoors and away from enclosed spaces. If an installation is indoors the tank vent, overflow, and delivery connections should be piped to the outside and the room isolated and equipped with high-level ventilation. Tank containment equal to 100% tank volume is required, regardless of tank location

Construc-tion Materials

Carbon, steel, aluminum or stainless steel may be used for storing and handling aqua ammonia. If high purity is a requirement, these materials should be restricted to stainless steel and aluminum, or as an alternative, lined tanks. Carbon steel is the most commonly used material for aqua ammonia storage. Due to mill scale and rust found on carbon steel, initial passivation of carbon steel tanks is recommended.

Storage Tank Design

Aqua ammonia solutions stronger than 19% should be stored in closed tanks to prevent loss of ammonia to the atmosphere and to prevent the absorption of atmospheric carbon dioxide. These tanks are typically low pressure bullets designed to ASME Section 8, Division 1 Code for working pressures of 30 psig or greater. The recommended construction material is usually carbon steel. Unloading facilities for pressure storage should include vapor return piping to carry ammonia vapor displaced during the off-loading operation back to the tank truck. Since stronger ammonia solutions are capable of developing modest positive vapor pressures during warm weather, pressure bullets must be equipped with suitable relief valves set in accordance with the design pressure of the vessel. A vacuum relief valve should also be provided since the vapor pressure can fluctuate below atmospheric pressure depending on ambient temperature. Product transfer from the tanker to the pressure storage bullet should use either tanker or customer's off-loading pump.

Storage tanks for concentrations up to 19% by weight can be atmospheric tanks fabricated to API-650 Code. There will be low level ammonia emissions from atmospheric tanks during tanker unloading.

Pumps

Centrifugal pumps with mechanical seals having all wetted parts made from iron, carbon steel or stainless steel are recommended. Pumps in critical service should be heavy duty, industrial service pumps intended for continuous operation. Reliable seal-less magnetic drive pumps are also available for this service. Piping layouts should ensure sufficient NPSH to avoid pump cavitations and product flashing.

Safe Handling

Proper facility design and installation coupled with adequate maintenance and operating procedures are essential for safe, reliable and productive operations. Employee training must ensure familiarity with the product, plant and process. HAZMAT team training and complete emergency response procedures will provide the required competency to manage these products safely. Please contact the Terra sales department or refer to the product MSDS for further information.

Figure 4A. Typical Aqua Ammonia Pressure Storage Installation

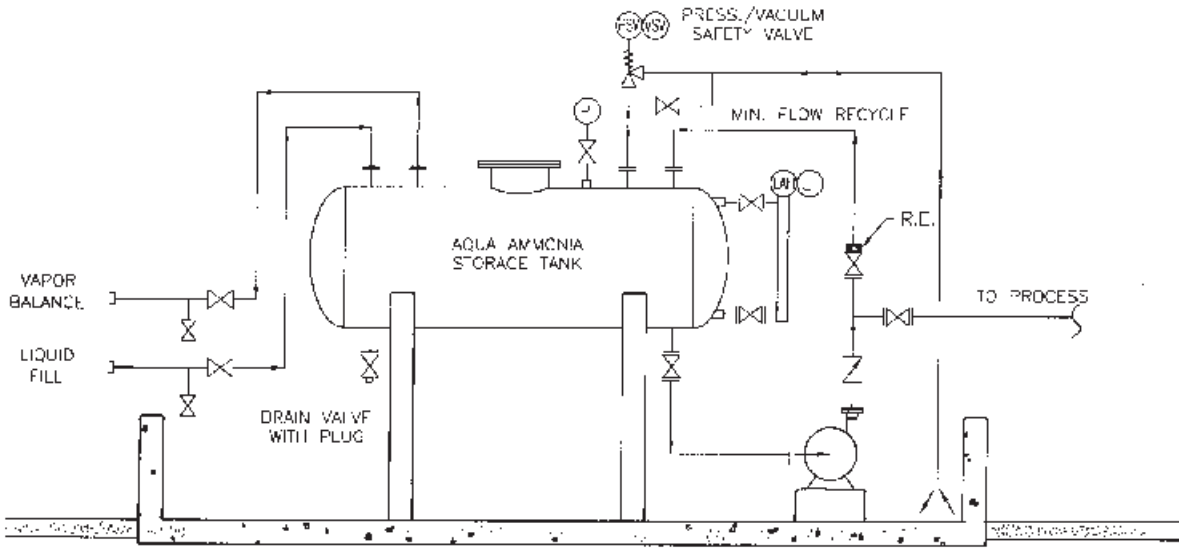


Figure 5A. Typical Atmospheric Pressure Installation