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AEA MARITIME WEBINAR - MARINE AMMONIA ENGINE SAFETY

16.5.2023

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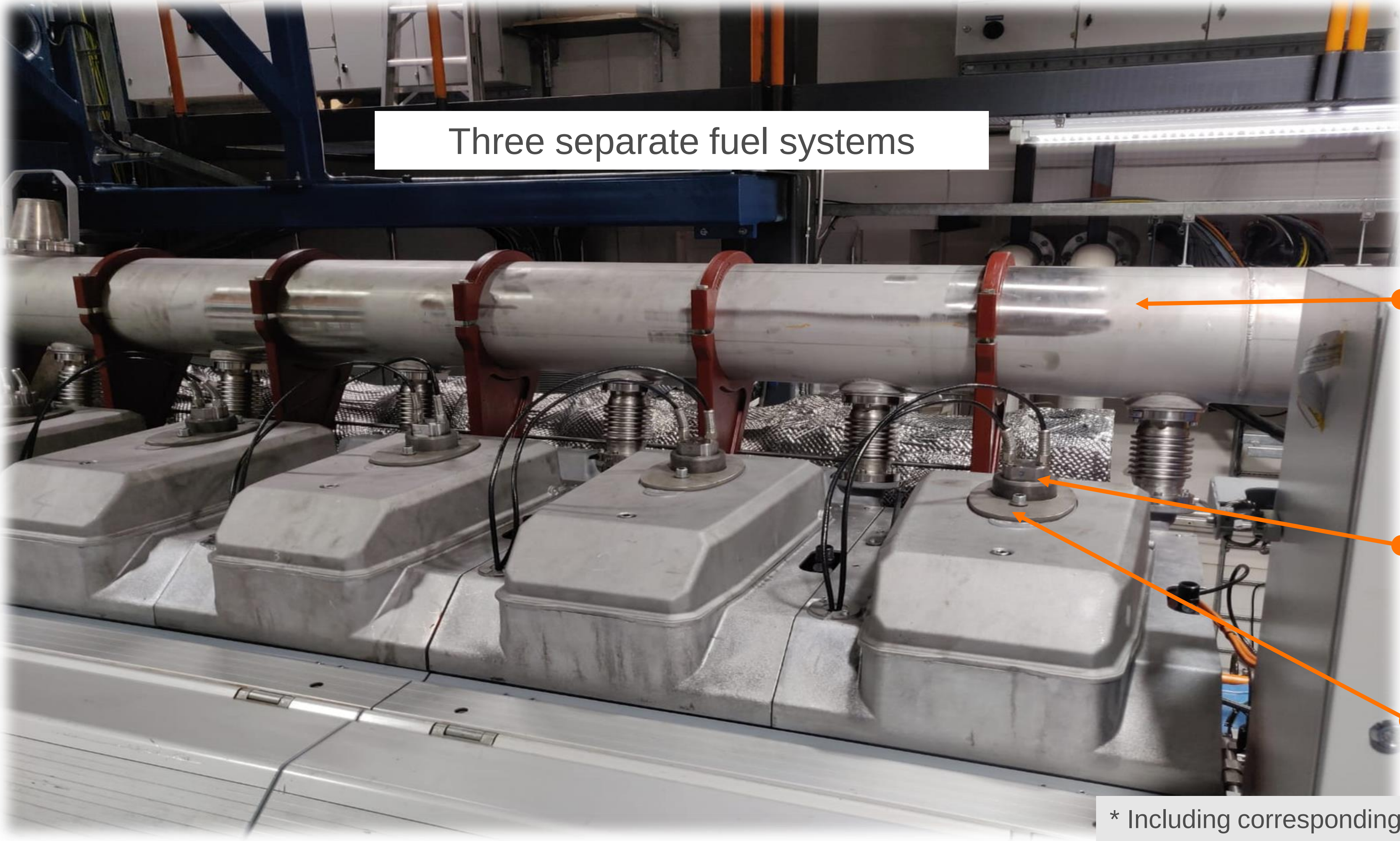
The multifuel engine



Gaseous fuels*
- LNG
- LPG
- **Ammonia**
- Hydrogen

Liquid fuels*
- HFO
- MDO
- LPG
- **Ammonia**
- Methanol
- Ethanol

Pilot fuel*
- MDO

* Including corresponding bio and synthetic fuel

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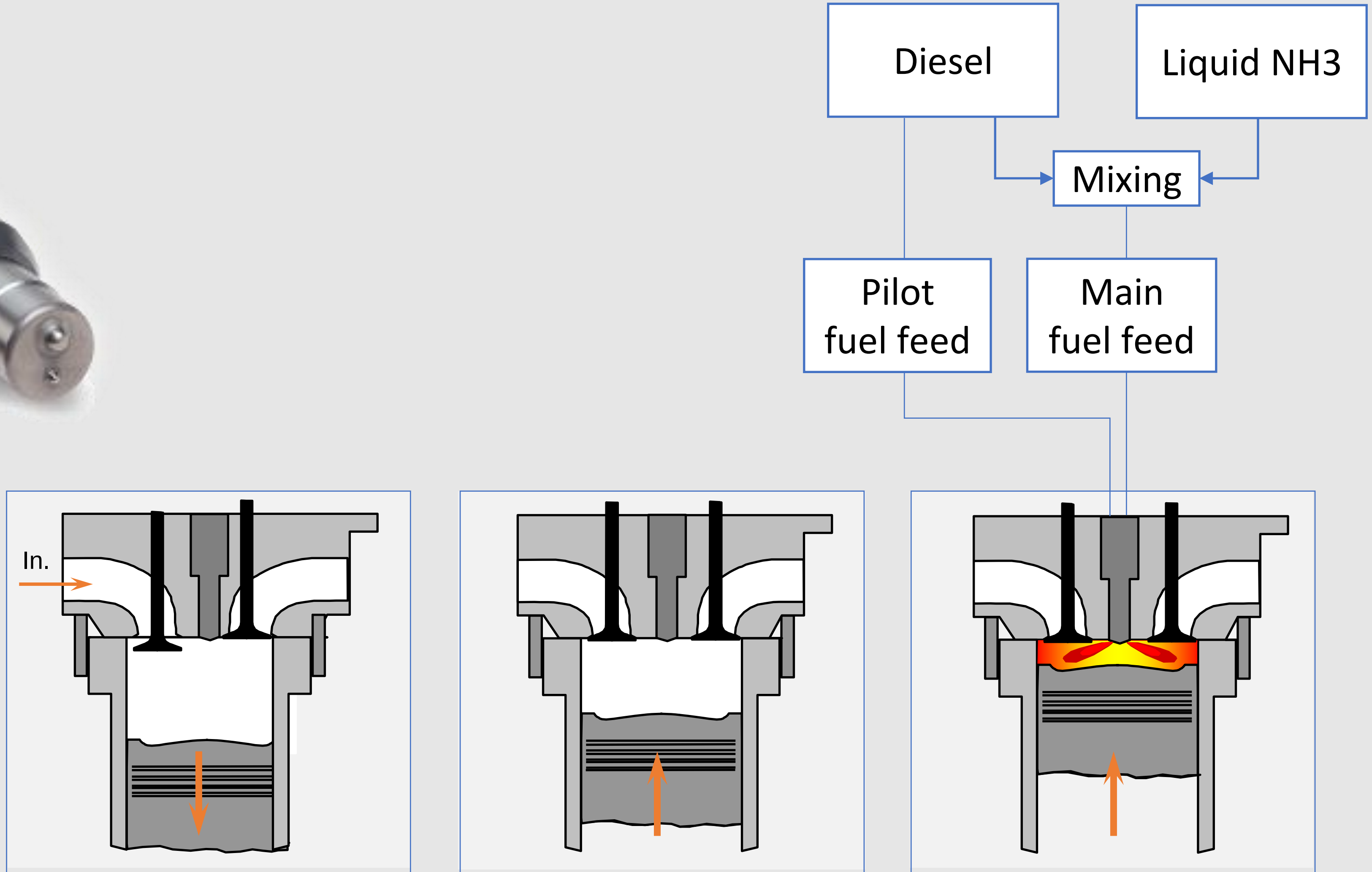

Intake of air

Compression of air

Ignition by pilot diesel
Injection of diesel fuel share

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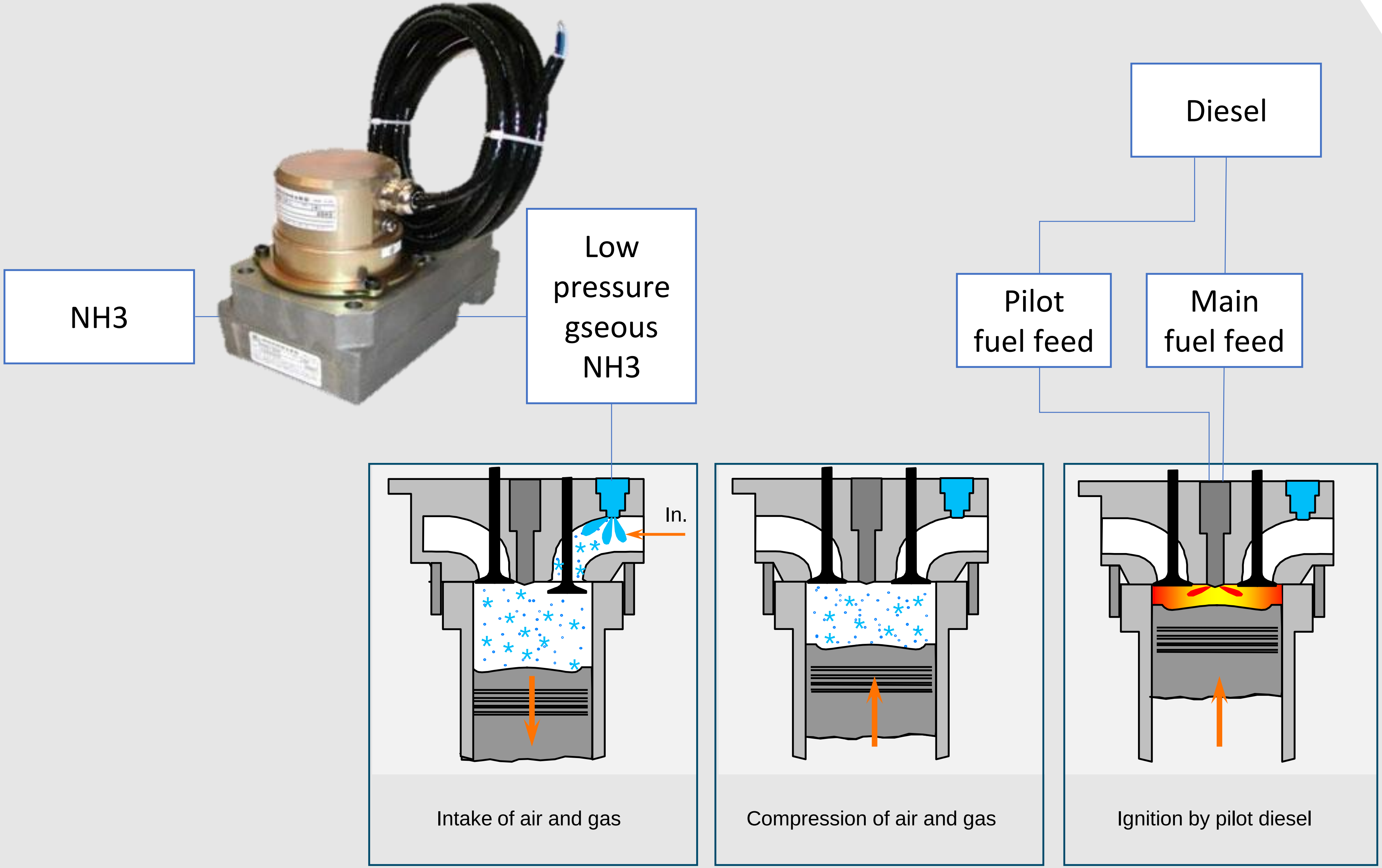
GASEOUS NH_3 OPERATION CONCEPT



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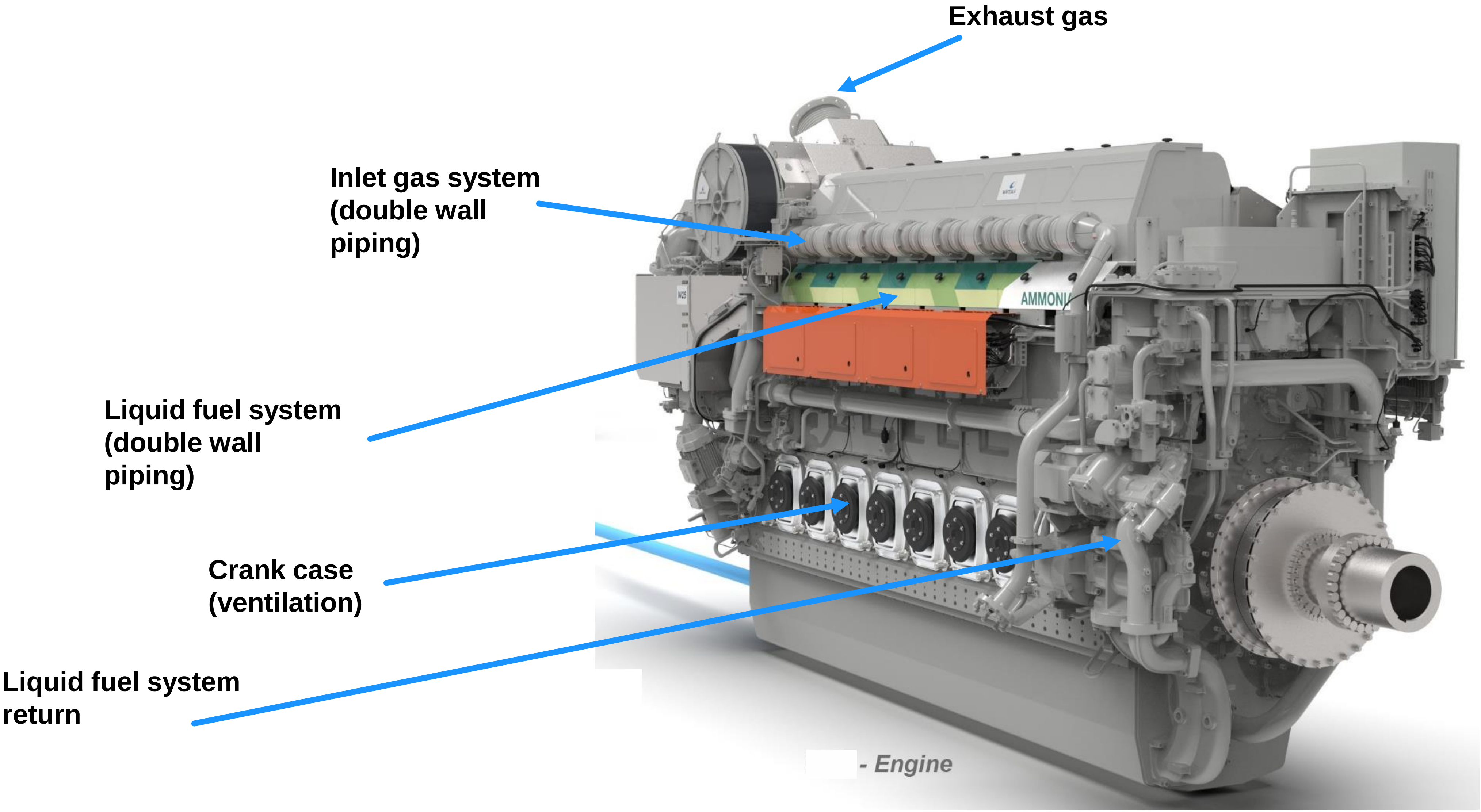
Possible locations for Ammonia outlet/leakage



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KEY LEARNINGS AMMONIA ENGINE TESTING

- Wärtsilä started first ammonia engine testing in research laboratory in Vaasa Finland summer 2021.

- Ammonia is widely used and well known chemical as fertilizer, refrigerating agent and in manufacturing processes.
  - Using ammonia as fuel in engines is in research phase.

- During normal operation ammonia engine room is gas safe space similarly to LNG engine room.

- Ammonia calibrated detectors are added in addition to gas detectors into the engine room.

- By utilizing high level of automation the need to enter ammonia gas containing space in case of ammonia leakage can be removed.

Ammonia fuel container

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KEY LEARNINGS AMMONIA ENGINE TESTING

- Running the engine as premixed otto combustion mode will led to ammonia gas concentration to go up in the crankcase. Because of this engine operators can not go to the engine room straight after engine stop to open crankcase doors.

- When running ammonia engine with gaseous ammonia, ammonia odour can remain in the engine until the next day. It was measured proximately 10ppm of ammonia near the engine. Such small concentration of NH_3 are not dangerous.

- It was observed that ammonia can enter the lube oil through ammonia filled crankcase space. Changes in oil properties were not observed in more detailed laboratory tests. About 100 ppm of ammonia was measured to evaporate from the hot lubricating oil.

- When running the engine with liquid ammonia, the ammonia odour disappeared quickly.

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KEY LEARNINGS AMMONIA ENGINE TESTING

- To operate ammonia engine and perform maintenance personnel must have good level of ammonia training.
- When performing maintenance work on ammonia engine or systems suitable ammonia PPE should be used due to the toxicity of ammonia.
- During the testing of the ammonia engine no major ammonia leakages has occurred. Some small ammonia leakages have been observed.






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Maritime Ammonia

Ammonia Fundamentals

Cargo in Gas Carriers

Fuel in Atmospheric Pressure Fuel Tanks below deck

Fuel in Low Pressure Fuel Tanks above deck

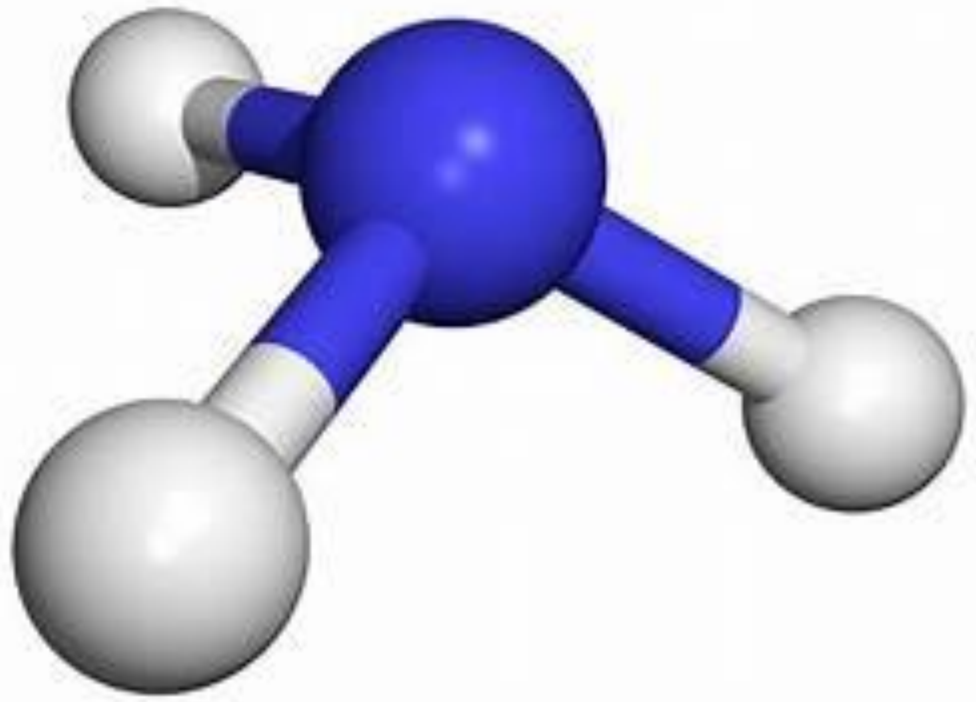
Risk & Hazard profile depends on type and size of release

Accidental Ammonia Spills into bodies of water

ASTI Training Program and Literature

Emergency Response and PPE

Design Issues



Fundamentals

Naturally Occurring, background levels in air, water, soil

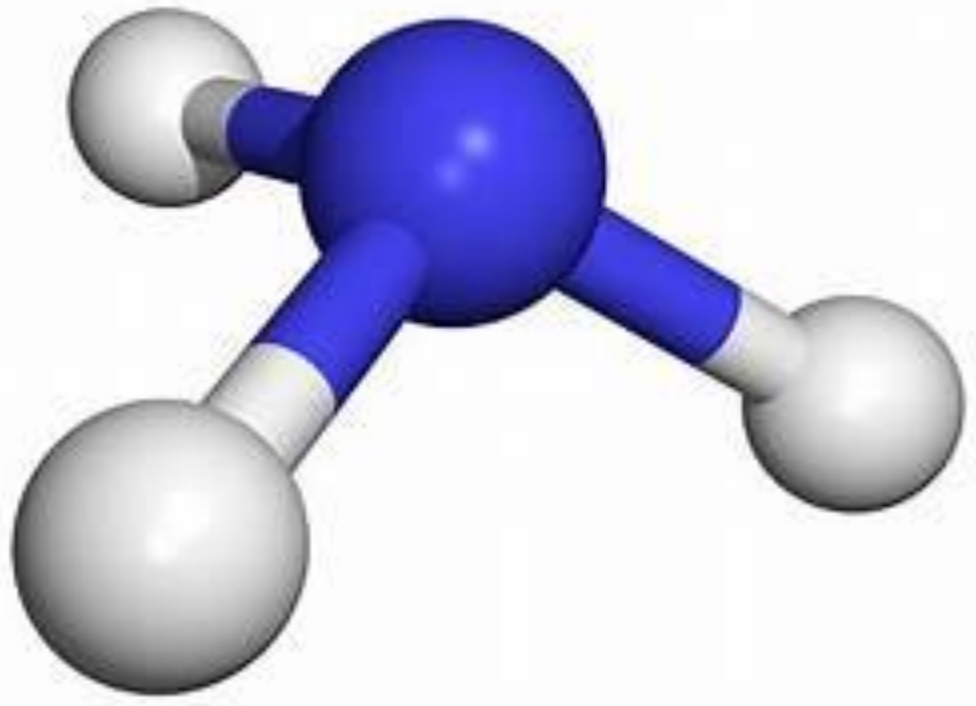
Molecular weight 17

Colourless

Water and Ammonia are hugely attracted to each other

Putting water and ammonia together creates a huge reaction

Ammonia is self alarming with a very pungent odour which will drive you out of the space at a concentration of one tenth of that which can harm you



Ammonia is produced in the human body primarily from the breakdown of amino acids. Your body removes ammonia through the liver by forming urea and it is then eliminated via the kidneys in your urine.

States – Liquid, aerosol stream, aerosol cloud, vapour, gas, solid (-77C)

Boiling Point -33C at atmospheric pressure

pH 11.6 to 13.8 for NH4 OH Strong Alkaline

Lower Flammability Limit 15% in air (LPG is 2.1% in air)

Upper Flammability Limit 28% in air

Ignition Temperature +651C

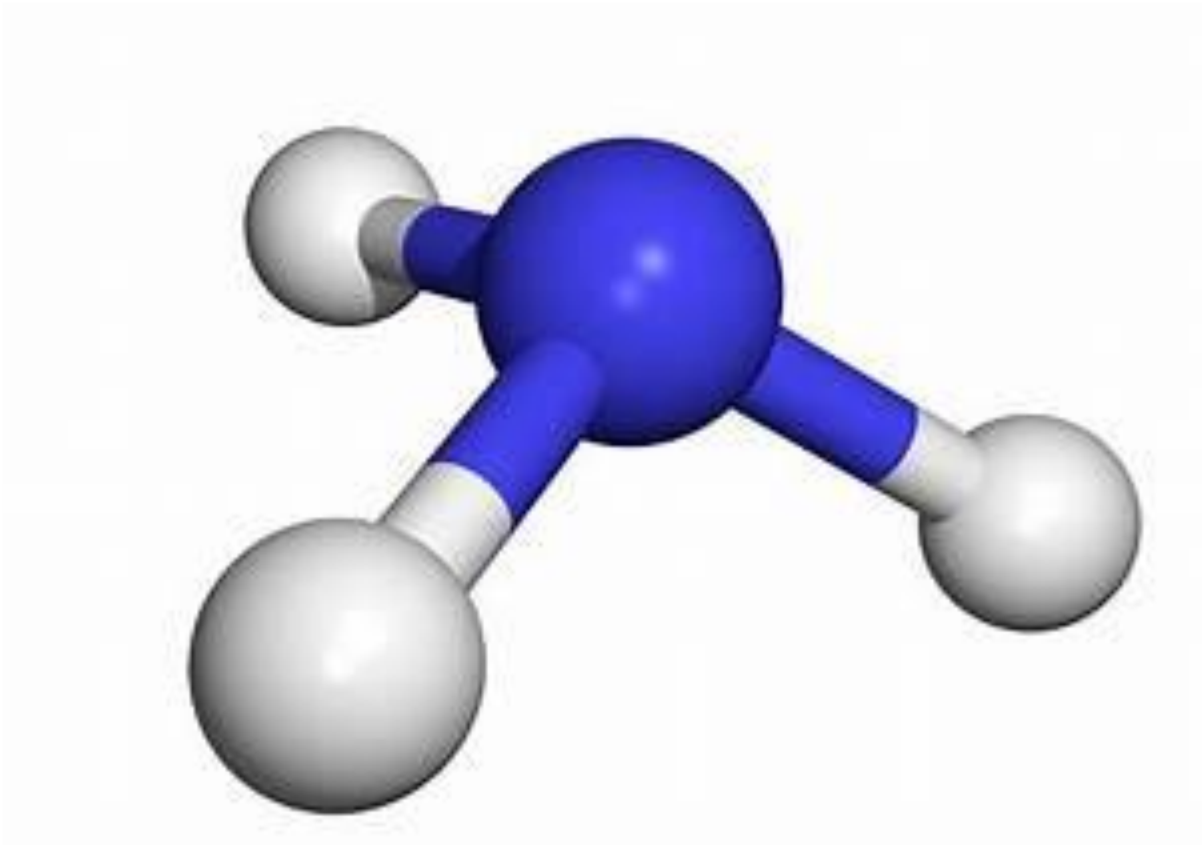
Odour Threshold 5 Parts Per Million in air

Threshold Limit Value 25 ppm in air (8 hour per day allowable exposure value)

IDLH is 300 ppm

Gas density 60% of air (Much lighter than air)

Liquid density 68% of water (Lighter than water)



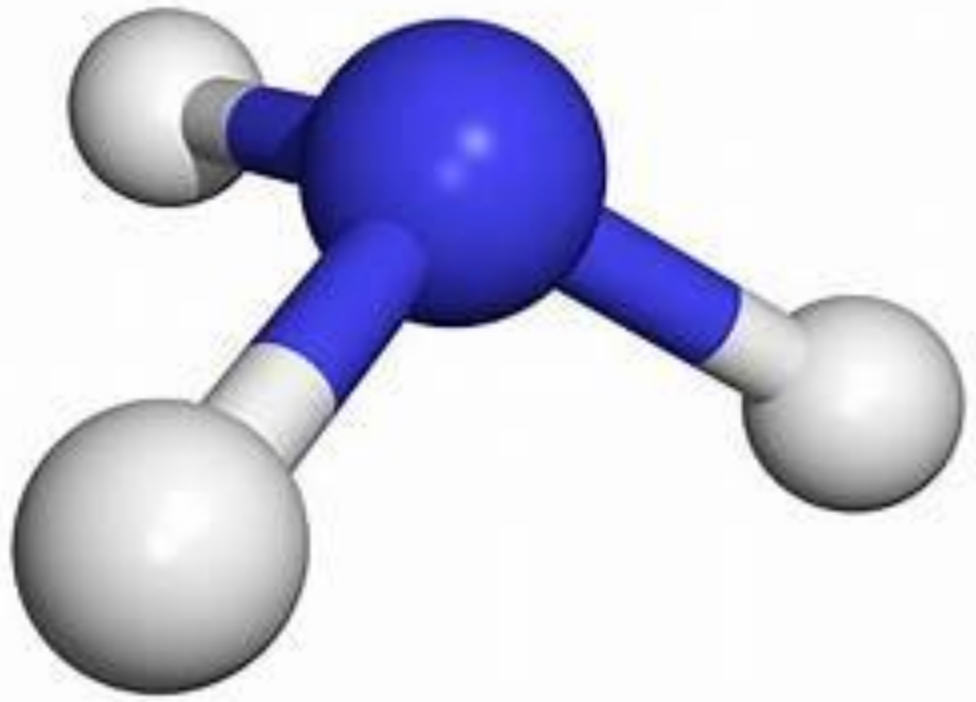
Acute Exposure Guideline Levels

	10 min	30 min	60 min	4 hr	8 hr
AEGL 1	30	30	30	30	30
AEGL 2	220	220	160	110	110
AEGL 3	2,700	1,600	1,100	550	390

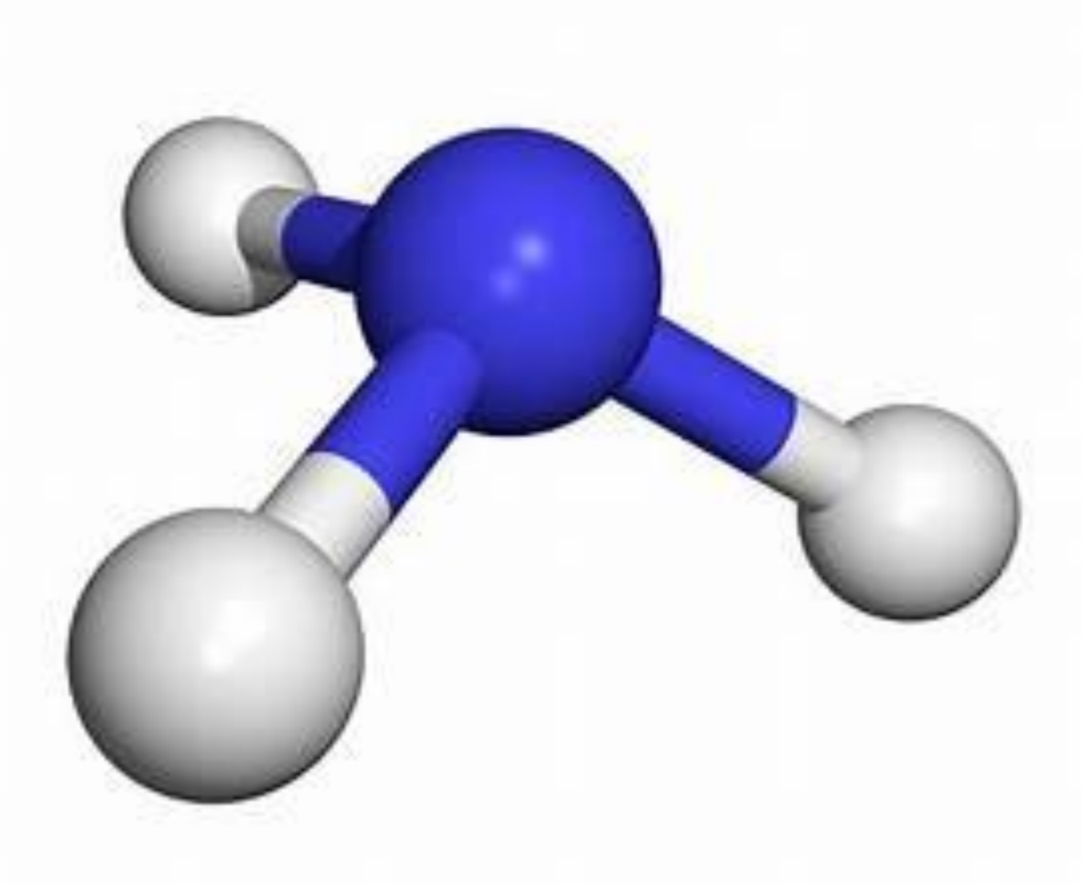
AEGL 1 Minor Exposure Low Exposure

AEGL 2 Moderate Exposure

AEGL 3 Acute Exposure



Fully Refrigerated (FR) Gas Carriers transport ammonia liquid at -33C in insulated hold tanks at a low pressure slightly above atmospheric pressure



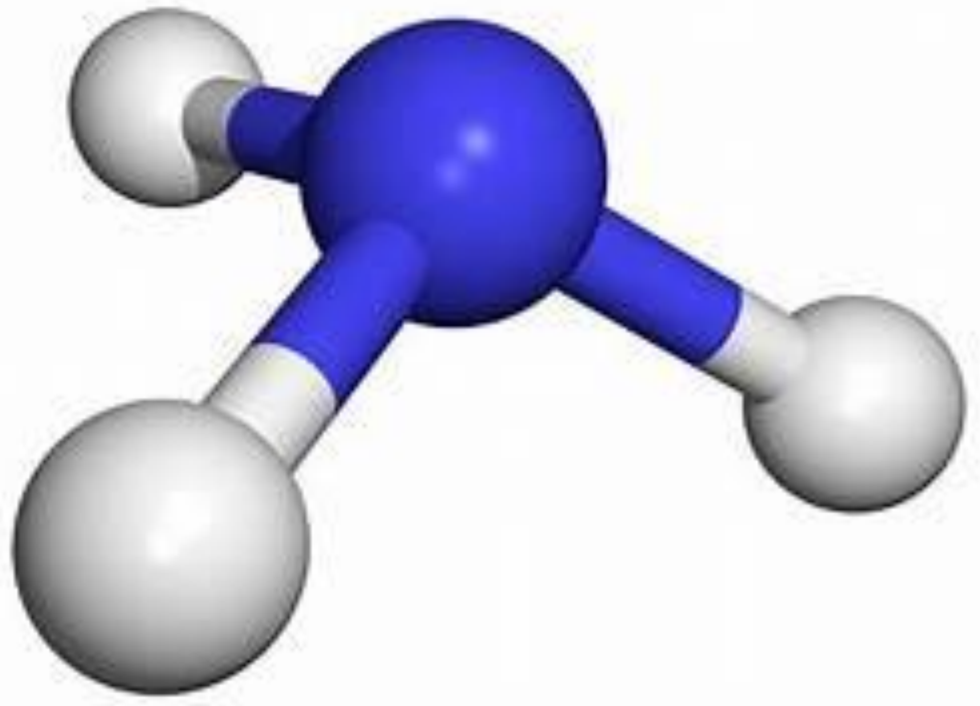
The temperature of the ammonia cargo in these Gas Carriers must be carefully controlled to ensure it is at the right temperature ready for unloading at the destination.

Below Deck

Container Ships, where above deck space is at a premium, can likely use insulated, below deck, FR liquid ammonia insulated bunker fuel tanks to make optimum use of the available hold space given the ammonia fuel tanks will be significantly bigger than HFO tanks to achieve equivalent range. These tanks will operate at slightly above atmospheric pressure.

Ammonia fuel will be pumped from the tanks to the engine room via the pressurised fuel piping system

The vast majority of the ammonia fuel will be contained in the fuel tanks at slightly above atmospheric pressure and -33C, whereas a tiny fraction of the ammonia fuel will be within the fuel management system under pressure.



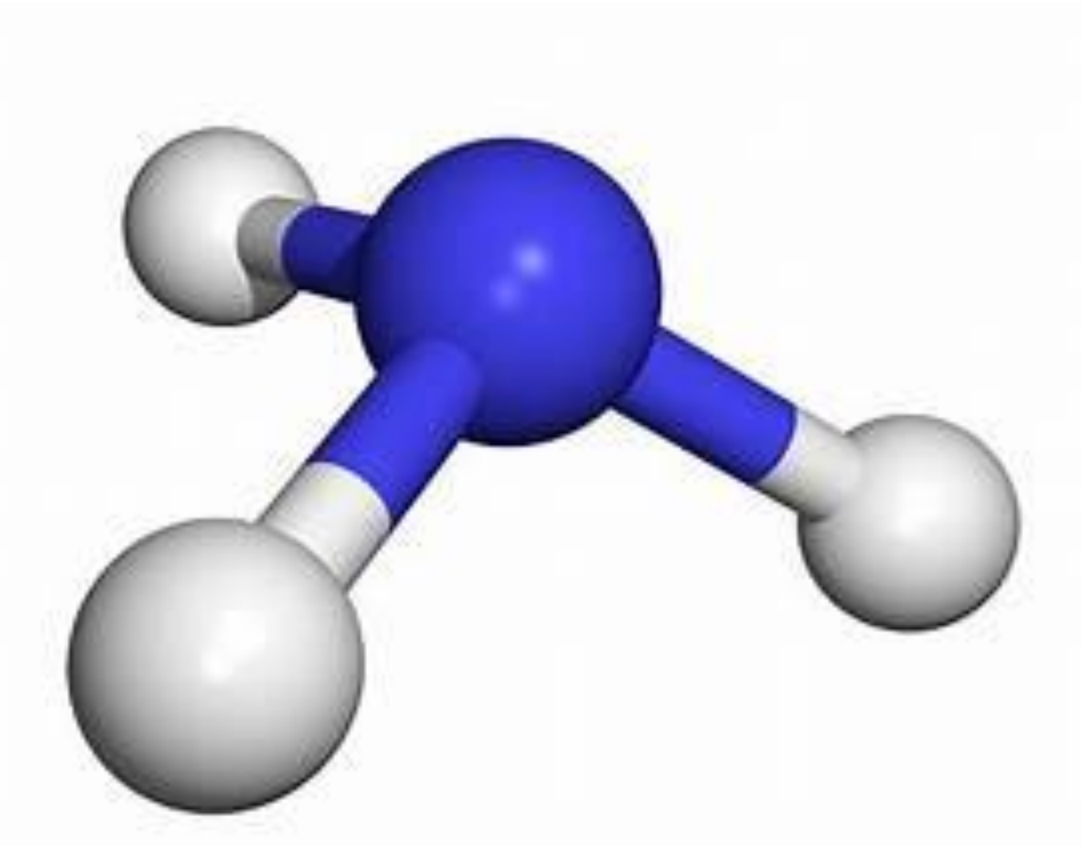
Automatic shut off valves will be available to activate and close the ammonia fuel supply in the event that an accidental release is detected.

Above Deck

Bulk Carrier and similar ships, where above deck space is available, could possibly use insulated, low pressure, non-refrigerated ammonia bunker fuel tanks located on the deck. These thanks would typically be horizontal, cylindrical steel pressure vessels, with design pressure of up to 5 barg. They would be bunkered using -33C liquid ammonia with a saturated pressure slightly above atmospheric, which would allow them to undertake a voyage of up to one or two months duration before the pressure builds up in fuel tanks due to heat ingress through the insulation.

Ammonia fuel will be pumped from the tanks to the engine room via the pressurised fuel piping system

The majority of the ammonia fuel will be contained in the fuel tanks at up to about 4 barg , and a tiny fraction of the ammonia fuel will be within the fuel management system at a much higher pressure.



Automatic shut off valves will be available to activate and close the ammonia fuel supply in the event that an accidental release is detected.

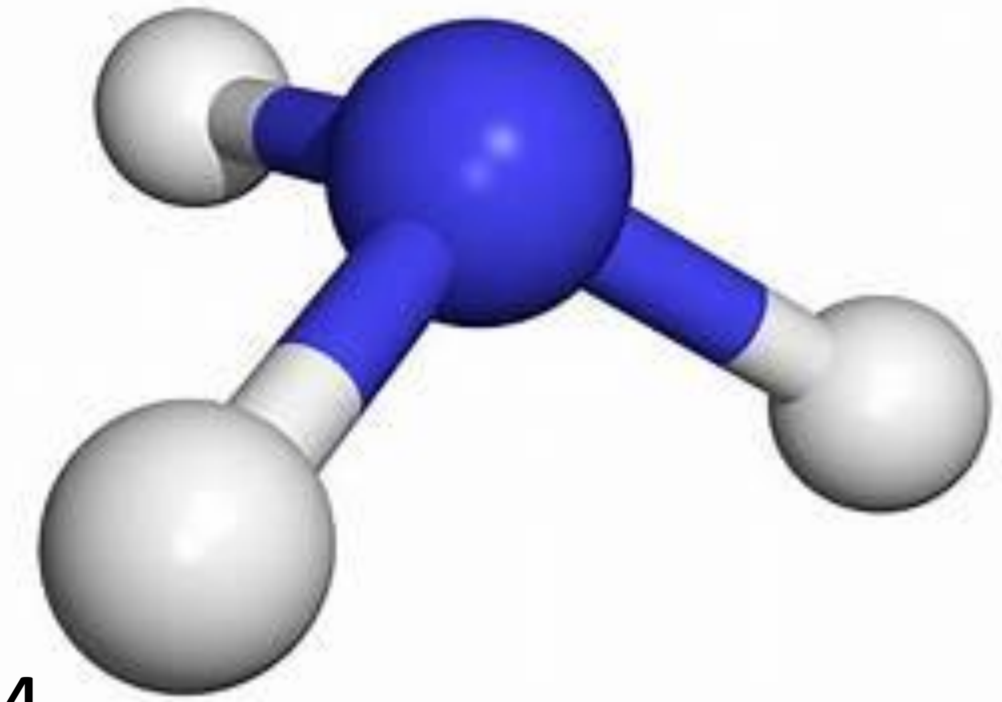
Release of saturated liquid under pressure

Release under pressure results in an aerosol and potentially a dense gas cloud which is usually heavier than air

The example shown involves a pressure reduction at the point of release vertically down the line from 5 to 4 arriving at atmospheric pressure and a dryness fraction of 0.22

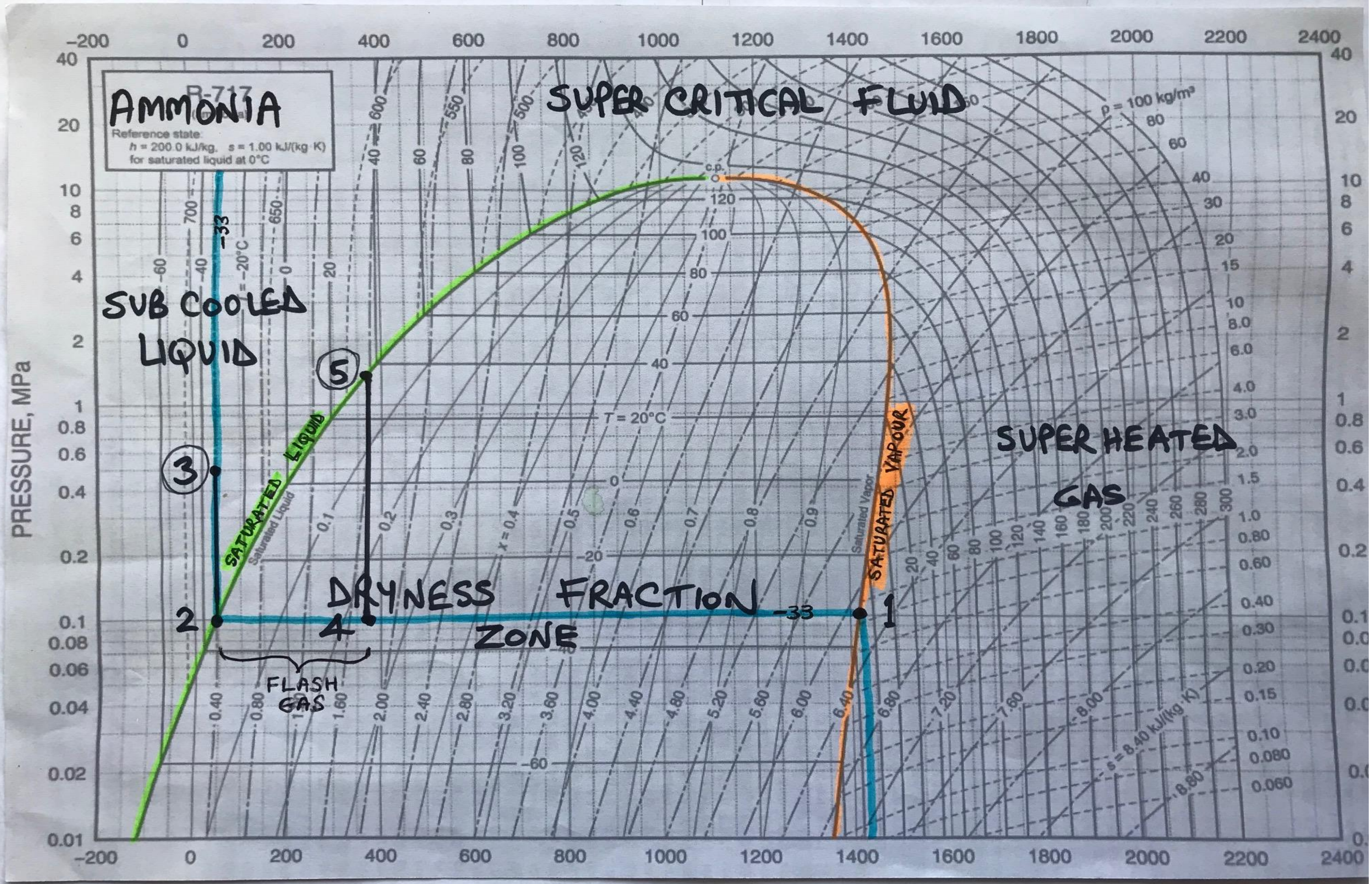
We can therefore estimate that 22% of the mass flow of the release will instantaneously turn to flash gas at the breach

The volume ratio of gas to liquid at atmospheric pressure and -33C is a factor of 766



For example 1 litre/sec of liquid releasing will generate 168 litre/sec of flash gas which will violently propel an aerosol and then become a dense gas cloud which will be heavier than air.

This kind of release poses the highest risk.



AMMONIA
R-717
Reference state:
h = 200.0 kJ/kg, s = 1.00 kJ/(kg·K)
for saturated liquid at 0°C
SUPER CRITICAL FLUID
SUB COOLED LIQUID
SATURATED LIQUID
Saturated Liquid
SATURATED VAPOUR
Saturated Vapor
SUPER HEATED GAS
DRYNESS FRACTION ZONE
FLASH GAS
c.p.
T = 20°C
ρ = 100 kg/m³
s = 8.40 kJ/(kg·K)
PRESSURE, MPa
-33
1
2
3
4
5

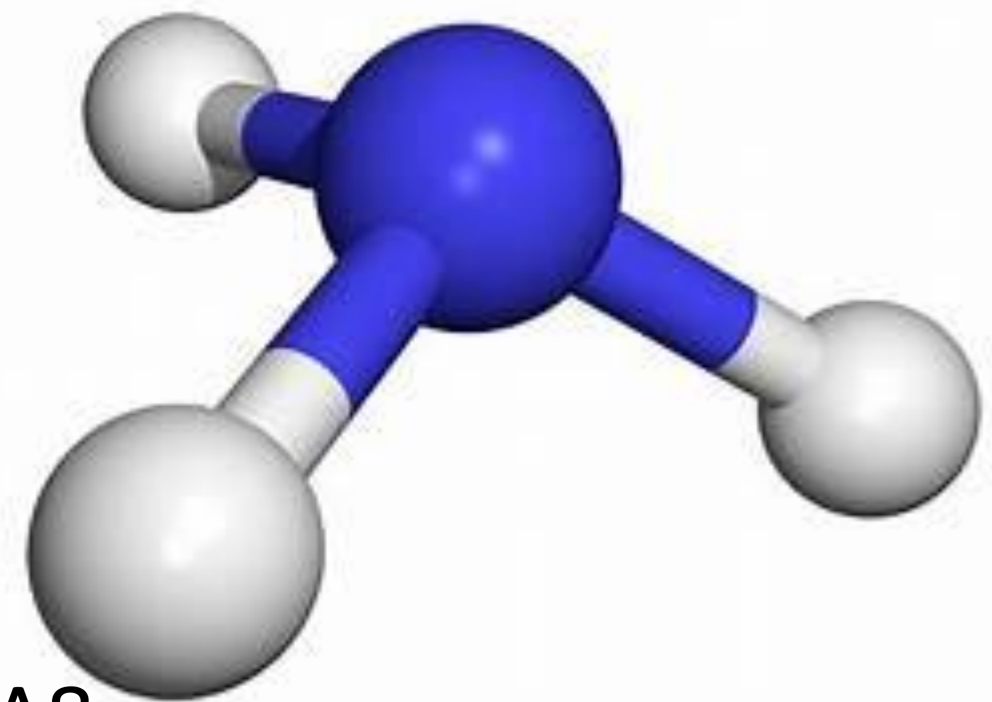
Release of saturated liquid at atmospheric pressure

Release from storage at atmospheric pressure (point 2)

The majority of the gas evaporating from the pool will be invisible pure gas which is about 60% of the density of air and will quickly rise into the atmosphere. There will be no aerosol or dense gas cloud and therefore the risk is low.

A little bit of water vapour may be visible whisping from the surface of the pool

Spraying water onto the pool will increase the evaporation rate and even cause a gas cloud which may be heavier than air so this should never be done.



The amount of gas evaporating from the surface will be a function of the quantity of heat entering the pool from the surface below and the air above. Ammonia has a very high latent heat of evaporation , so the rate at which the ammonia evaporates will be very low.

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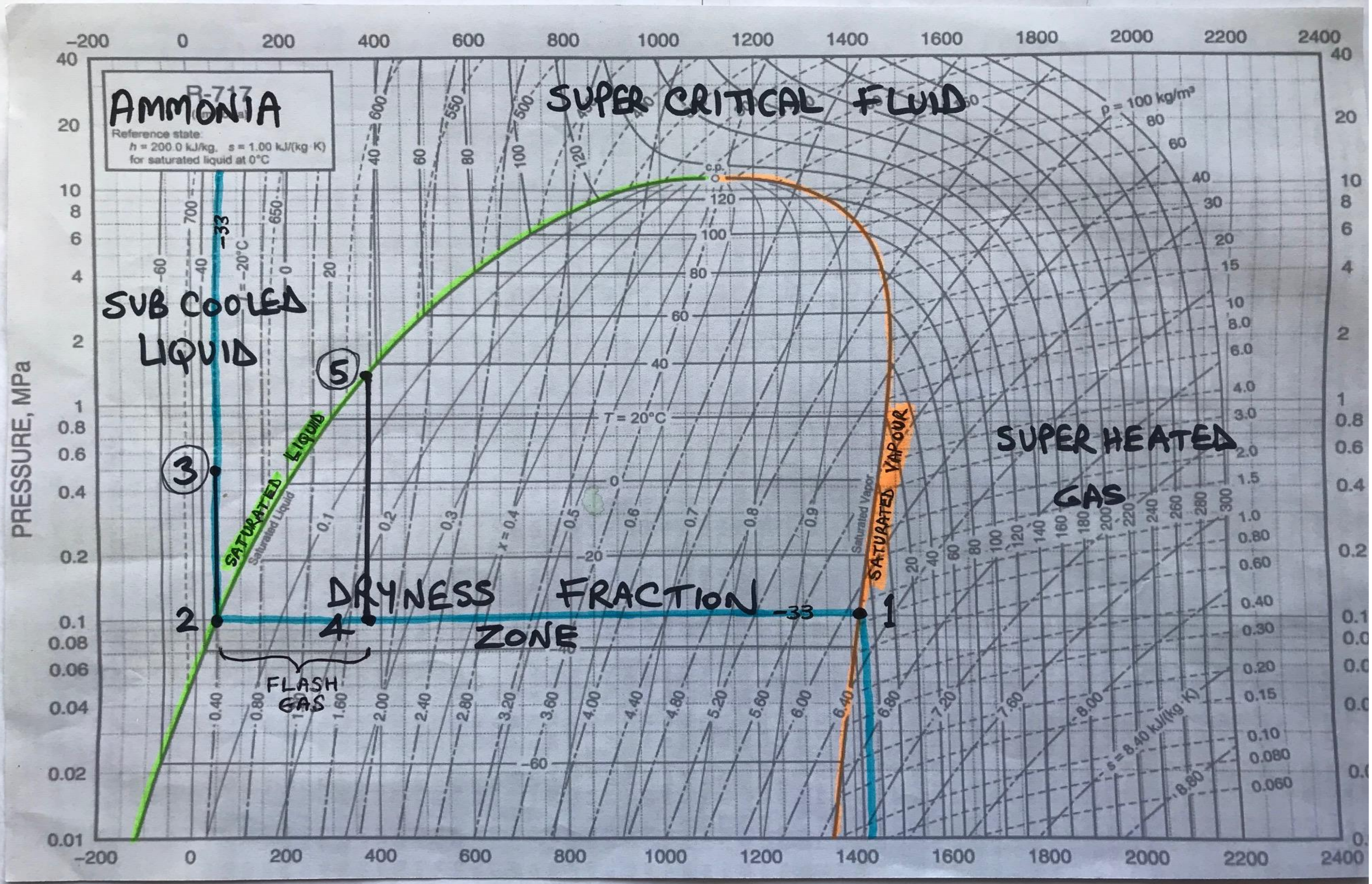
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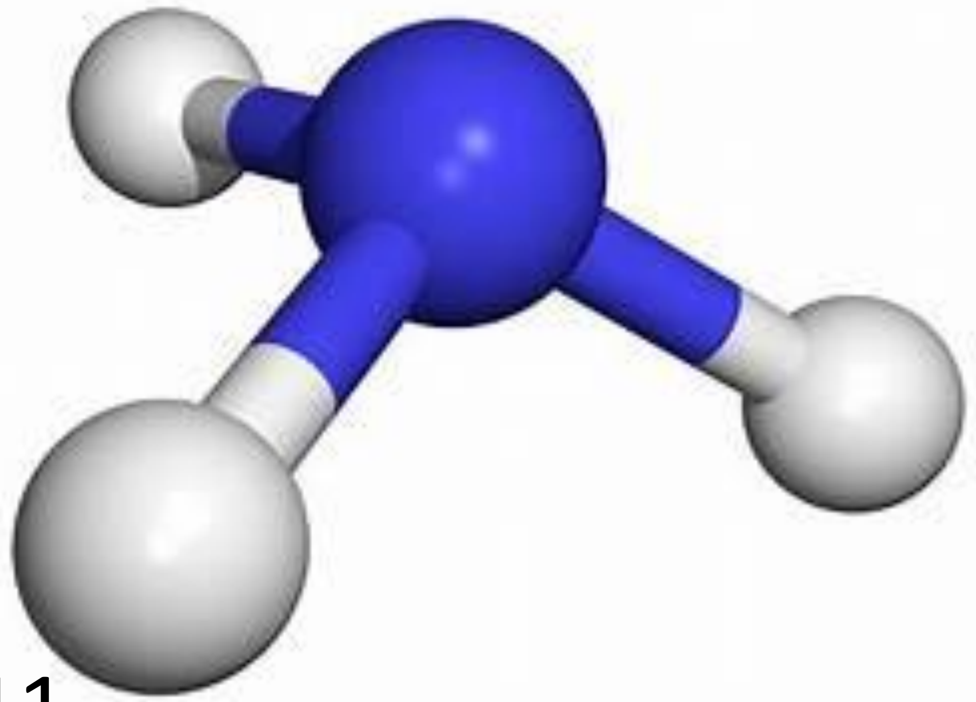
Saturated Vapor
SUPER HEATED GAS
PRESSURE, MPa
c.p.
T = 20°C
ρ = 100 kg/m³
s = 8.40 kJ/(kg·K)
x = 0.4
-33
1
2
3
4
5

Summary

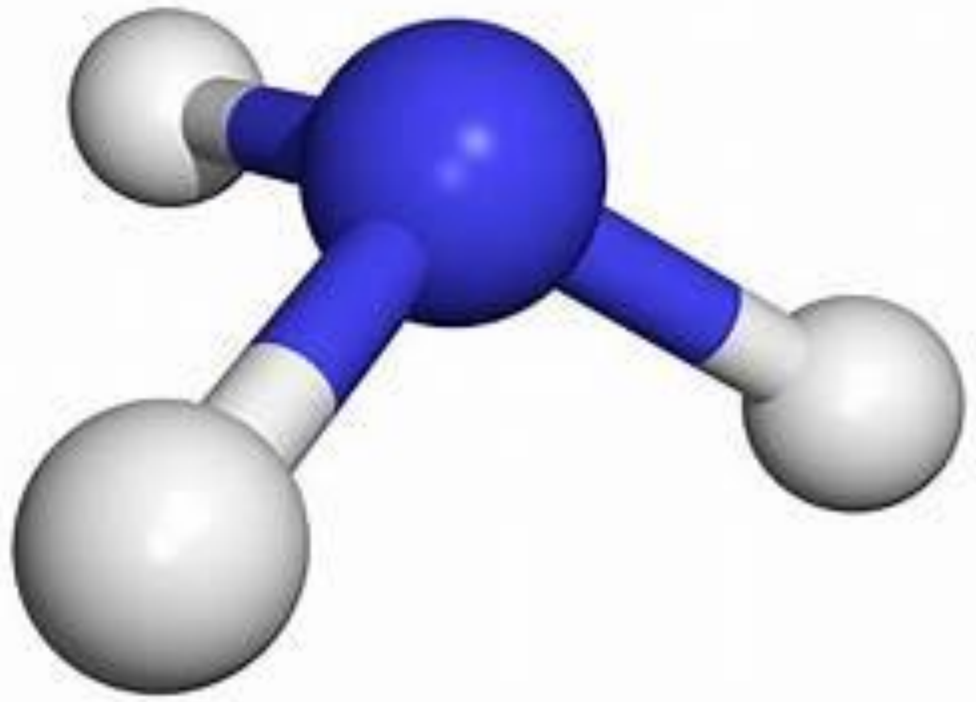
The highest risk and hazard profile will be from a pressurized saturated ammonia liquid release in an enclosed space

The lowest risk and hazard profile will be from an atmospheric pressure storage of saturated liquid ammonia in an outdoor area



Case Study 1

Minot North Dakota 2002 Five rail tankers ruptured spilling ammonia

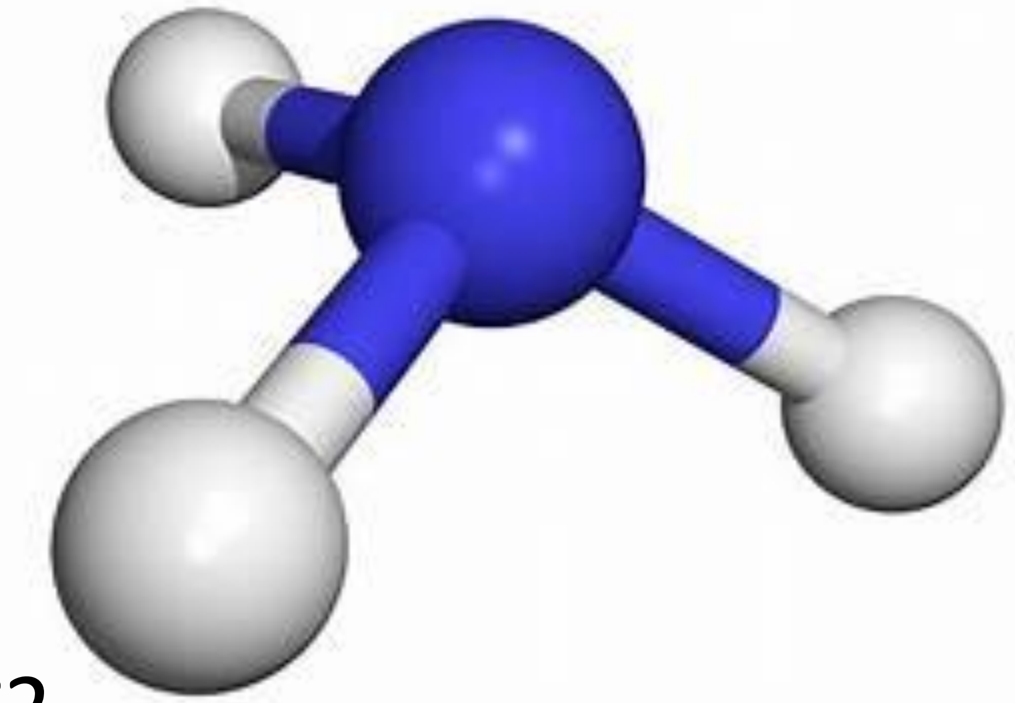


250 Tons were released. A cloud of ammonia lay over the city for several hours.

Dispatchers told residents to stay inside, close doors and windows, and cover their faces with wet cloths to counteract the ammonia.

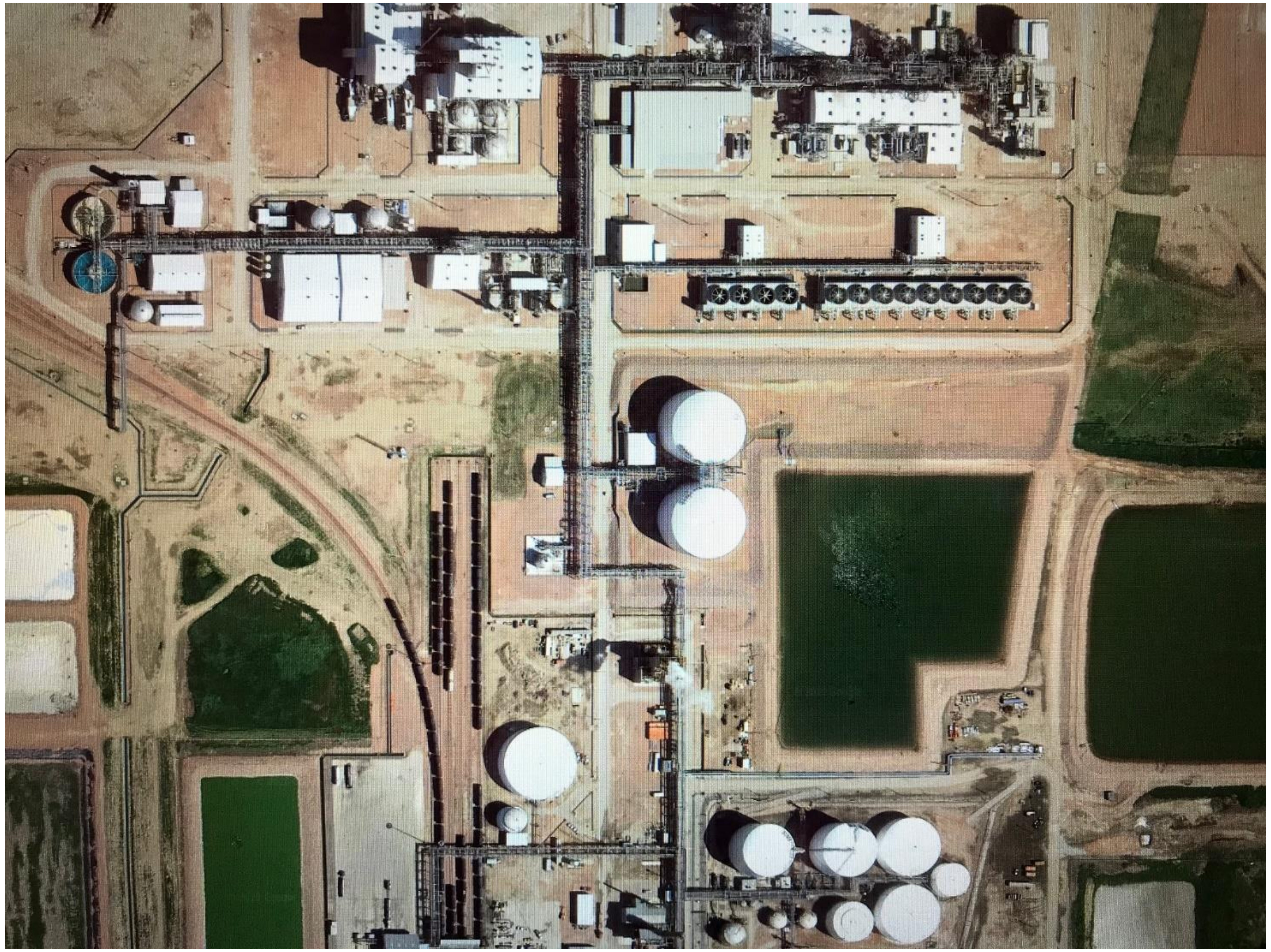
Residents were also instructed to go into their bathroom and turn on the shower if the ammonia smell became too strong. The ammonia is absorbed into the shower water and carried down the drain which reduces the ammonia concentration.

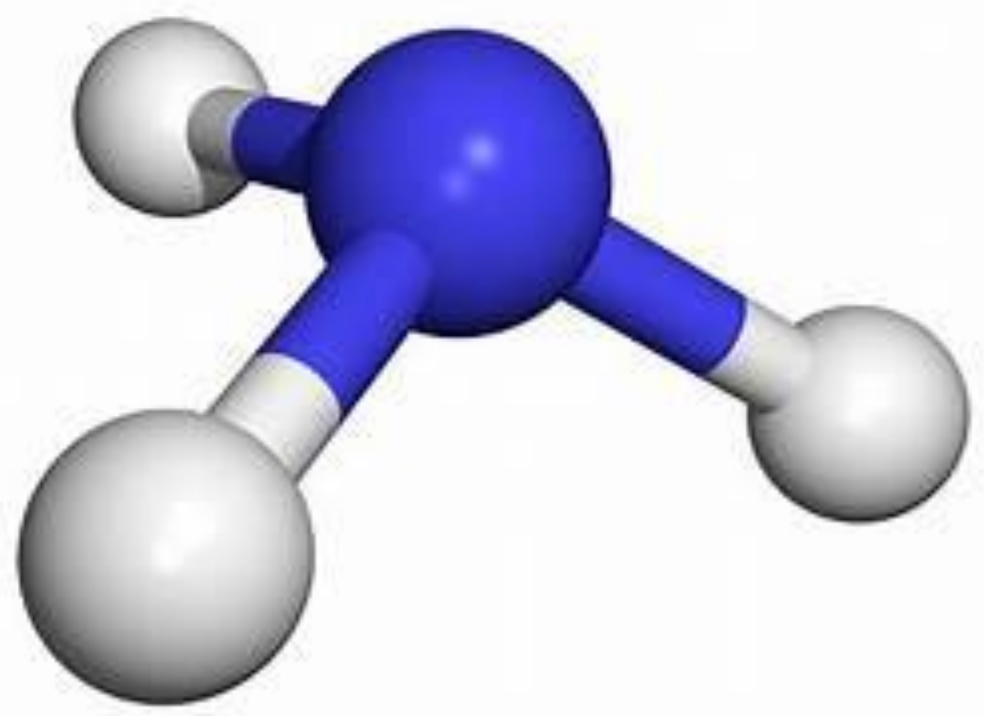
This was one of the largest outdoor, pressurized ammonia releases in recent history, which tragically resulted in one death and fourteen serious injuries.



Case Study 2

In December 1994 there was an explosion in the Port Neal Iowa ammonium nitrate plant which ruptured nearby atmospheric pressure ammonia storage tanks allowing 5700 tons of liquid to escape into the bunded area. This was the largest ammonia release in US history.





1700 residents were evacuated from the surrounding area however there were no deaths or injuries as a result of the ammonia release.

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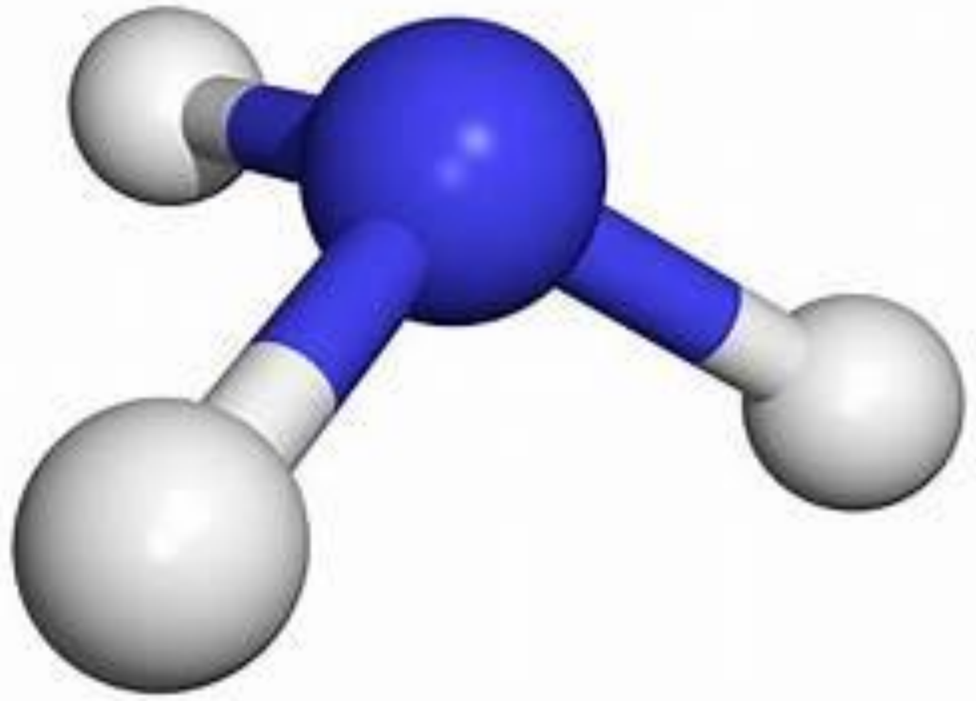


ASTI Education and Training Overview

Safety Days   Run regularly on three continents

Table Top Events

Live Release Training

Joint Training Exercises - Tripod

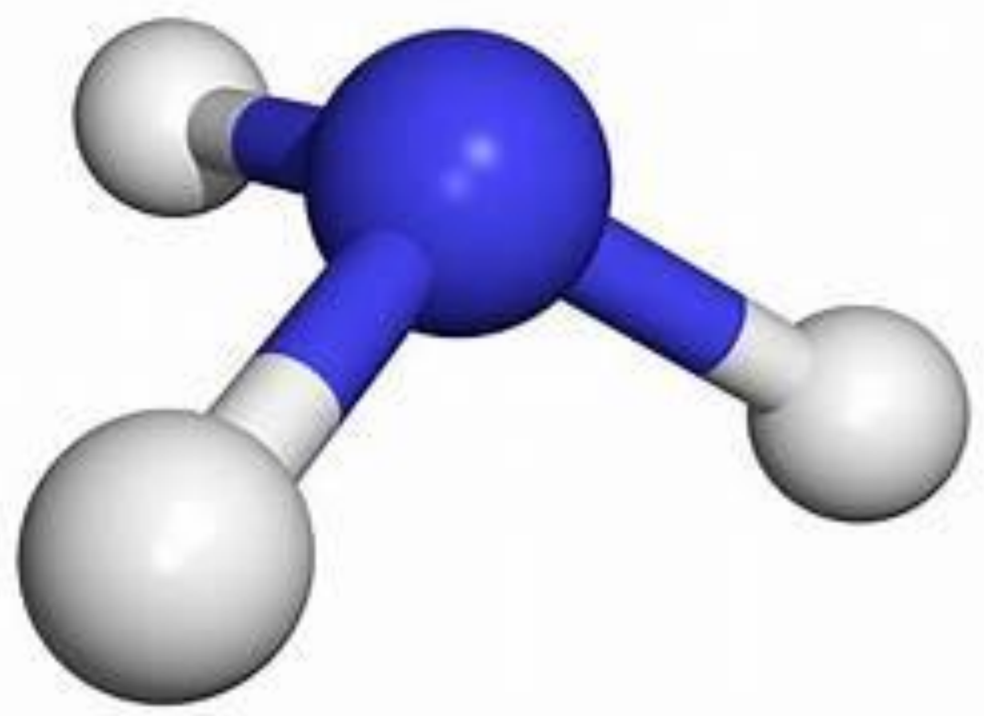
Site Specific Emergency Response Plans

Site Specific Technical and PPE Reviews

Statutory code of practice development

Dispersion Modelling

Literature for the General Public



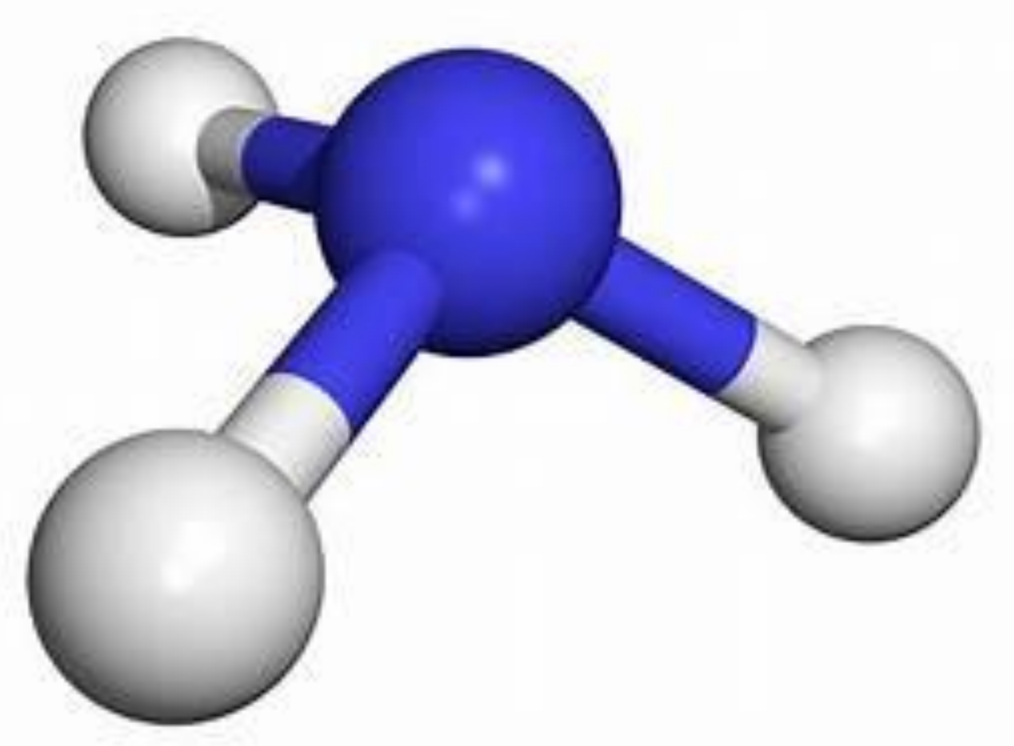
Ammonia 300 Also known as the 32 hour ammonia responder course.

The 32 hour courses are usually held in North America and they involve significant live ammonia releases. The ammonia 300 live release training provides essential knowledge and hands-on experience in:

Various types of releases including Saturated liquid under pressure, sub cooled liquid under pressure and gas under pressure.

Tarp and cover methods to knock down an aerosol release. - Shelter in place effectiveness - Handling aqua-ammonia solutions - appropriate use of fogging nozzles or water curtains.

Use of level A, B and C PPE ensembles in live ammonia conditions.



Demonstration of the interactions between ammonia and water - Spills of liquid ammonia into water.

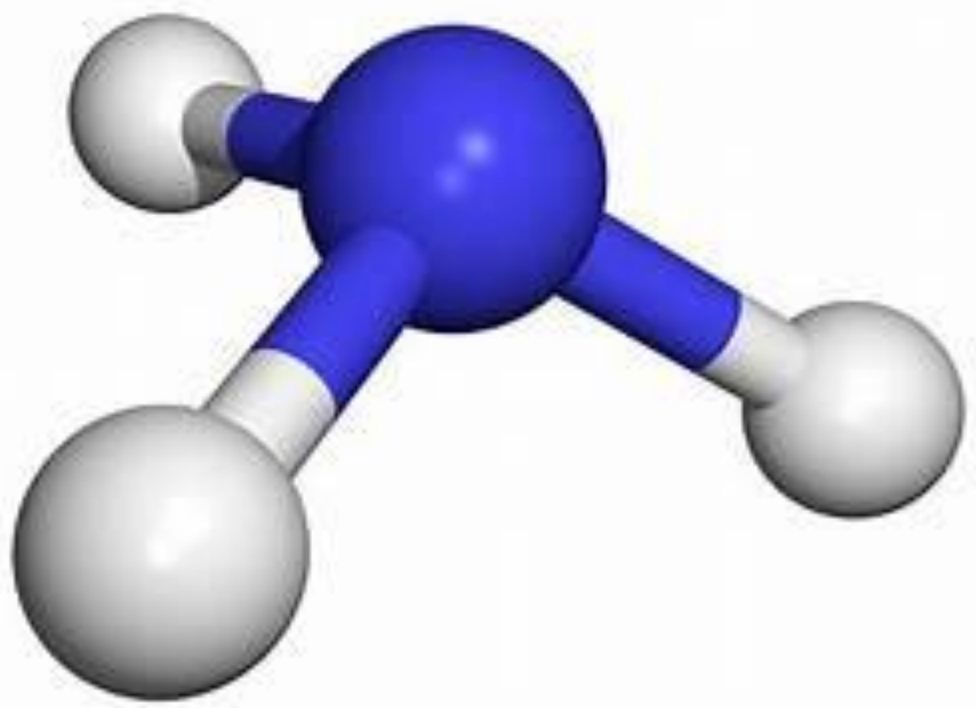
Ammonia 100 On-Line   Based on the Safety Day program

Ammonia 100 is a series of three online sessions which provide an introduction to ammonia safety including modules relating to large scale storage and transport, fuel, energy and as a hydrogen carrier

101 Introduction to Ammonia Safety

102 Risk Profile, Emergency Response, PPE, case studies and scenarios.

103 Ammonia Safety - Maritime Bunker Fuel, case studies and scenarios.



Ammonia 200 On-Line Based on the Tabletop Events program

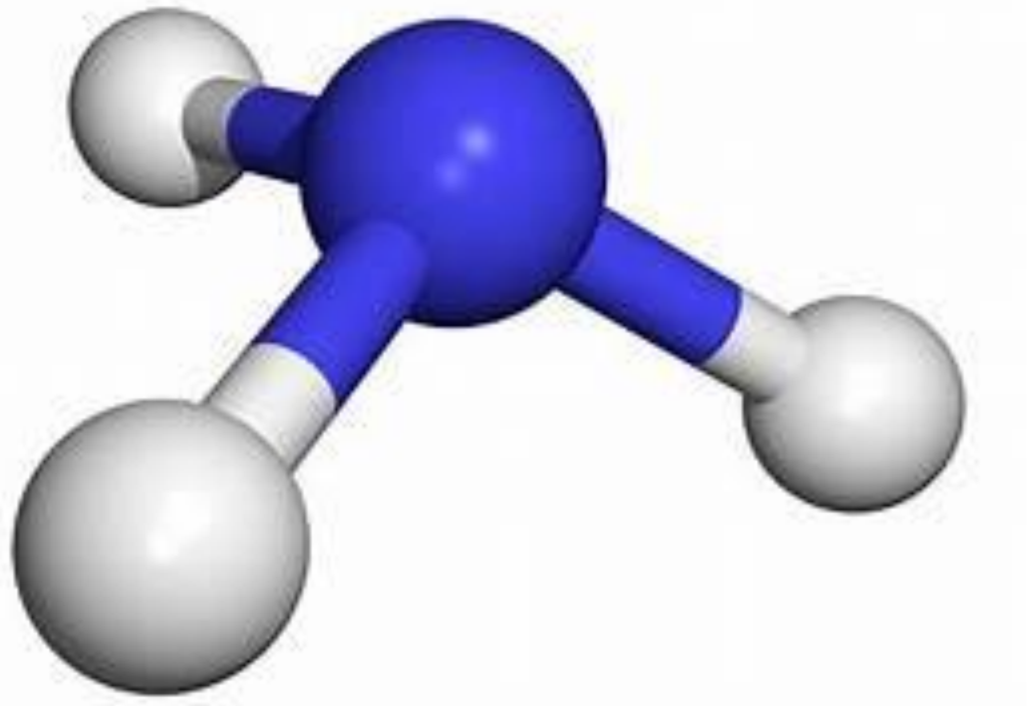
These modules involve a deeper dive into the following:

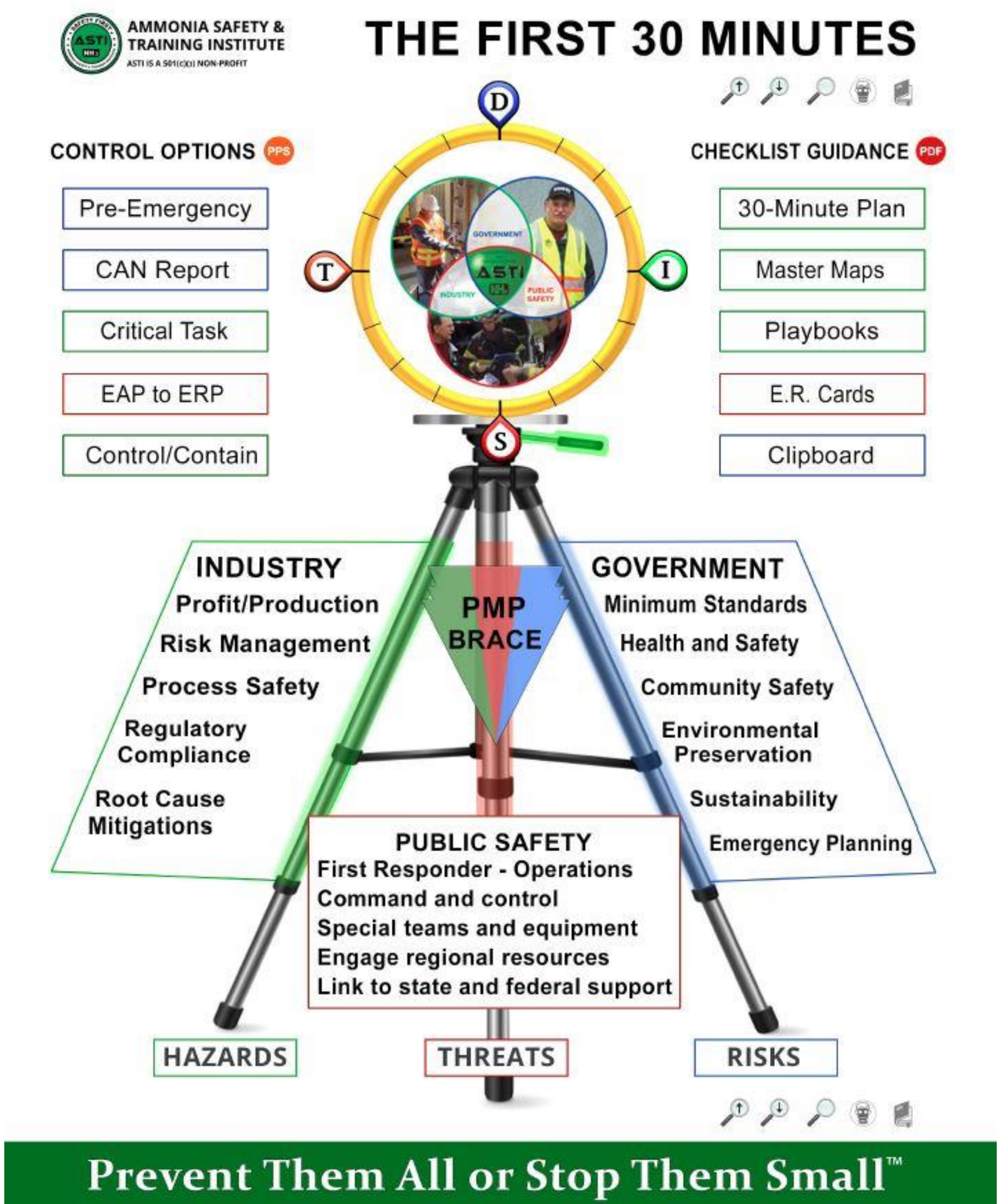
201 Ammonia Properties, Toxicity, Hazards, Risks, AEGL's, Medical responses and management, case studies and scenarios.

202 Emergency Response Planning for an accidental release, ICS system, OnePlan, case studies and scenarios.

203 First Responders, HAZMAT, PPE, Public Safety, Offsite consequences, Plume dispersion modelling, case studies and scenarios.

204 Government regulators, Standards, Codes, Regulatory Requirements, Social Licence, ammonia in the community, case studies and scenarios.

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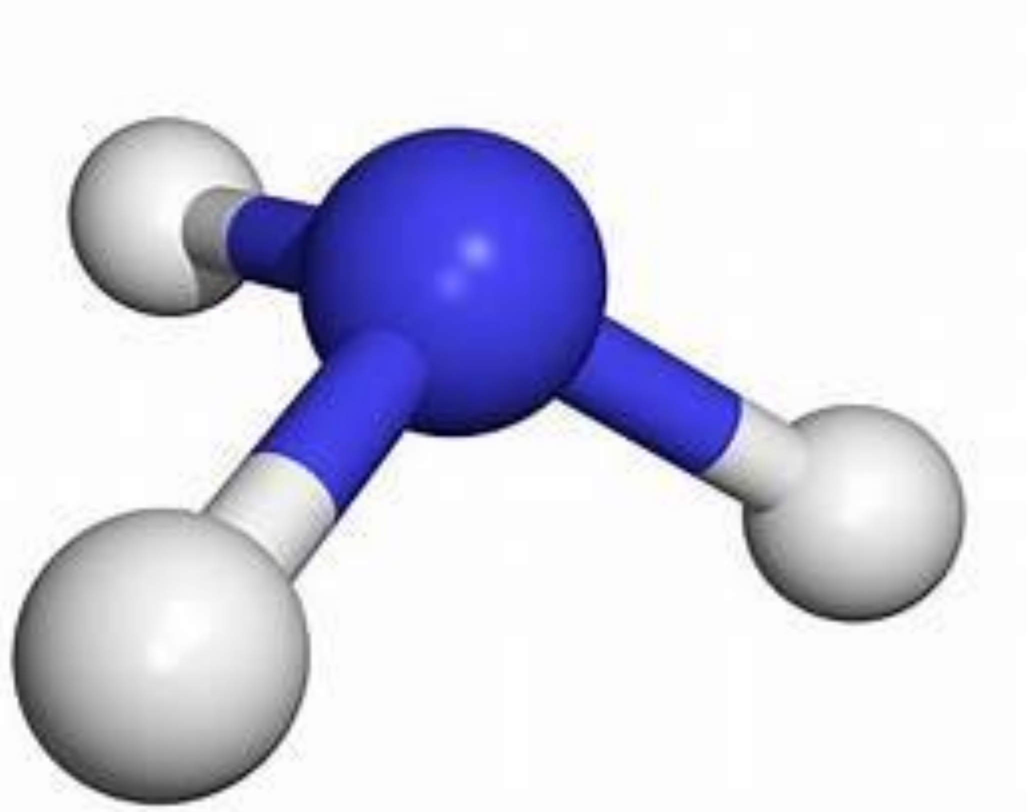
THE FIRST 30 MINUTES
CONTROL OPTIONS
Pre-Emergency
CAN Report
Critical Task
EAP to ERP
Control/Contain
CHECKLIST GUIDANCE
30-Minute Plan
Master Maps
Playbooks
E.R. Cards
Clipboard
D
T
I
S
INDUSTRY
Profit/Production
Risk Management
Process Safety
Regulatory Compliance
Root Cause Mitigations
PMP BRACE
GOVERNMENT
Minimum Standards
Health and Safety
Community Safety
Environmental Preservation
Sustainability
Emergency Planning
PUBLIC SAFETY
First Responder - Operations
Command and control
Special teams and equipment
Engage regional resources
Link to state and federal support
HAZARDS
THREATS
RISKS
Prevent Them All or Stop Them Small™



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30-MINUTE PLAN EMERGENCY CONTROL GUIDE

PHASE 1 DISCOVERY - LANCE

Life Safety: Clear the Isolation Zone (NH3 = 100 ft. to 1,000 ft.)
- ☐ Clear the Isolation Zone and escape laterally and upwind or SIP
- ☐ Set up for rapid entry rescue, decontamination, and medical care

Alert: Record Size-Up on Alert Form
- ☐ Who? (your name)
- ☐ What? (casualties, rescue, medical, fire, or chemical release)
- ☐ Where? (specific location)

Notification: Coordinate Checklist Notifications with IC
- ☐ 9-1-1; give response route and on-site meeting location
- ☐ LEPC: (___)__________ SERC: (___)__________
- ☐ NRC: (800) 424-8802 OSHA: (___)__________
- ☐ Contractor: (___)__________ CORP: (___)__________

Command and Control

Action: Identify Hazard Zone, Level of Concern, size of Isolation Zone, and location of the Incident Command Post (ICP)

Plan: Engage the Command Team; set the Life Safety Objective

Hazards (chemical/physical), **Risks** (life and environmental), **Threats** (fire, pressure, reactivity, slip/fall, structural integrity)

Level of Concern: 1-Controlled and contained
2-Controlled or contained
3-Uncontrolled and uncontained

Isolation and Protective Action Distance (PAD) for ammonia:

Small 100 ft.	PAD: 550 ft. (day and night)
Large 500 ft.	PAD: Day = .5 miles; Night = 1.3 miles
Catastrophic 1,000 ft.	PAD: Track plume beyond 1.3 miles

Acute Exposure Guideline Levels (AEGL):

10 Minutes: AEGL 2 = 220 PPM	AEGL 3 = 2,700 PPM
30 Minutes: AEGL 2 = 220 PPM	AEGL 3 = 1,600 PPM

Flammability of confined NH_3 vapor with a 1,204°F ignition source: Caution at 15,000 and high risk at 40,000 PPM

Evacuation to Safe Refuge or SIP
- ☐ Movement Plan–move laterally and upwind to safe refuge
- ☐ Secure the safe refuge locations
- ☐ Setup Access Controls to and from the Plant
- ☐ Personnel accountability–check in/check out

PHASE 2 INITIAL RESPONSE - SIMPLE

Size-up: CAN report Conditions-Actions-Needs

Conditions: Hazard Zone Location? Status of emergency; Level 1, 2, or 3? Life Safety status? Controlled? Not Controlled? Contained?

Actions: Incident Commander and Command Post location? Evacuation status and rescue in progress? Size of Isolation Zone? Status of emergency Shut-down?

Needs: Rescue? Medical? Decon? Shut-down? Ventilation support? Downwind/downstream receptor management?

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Sources of ignition and fire suppression controls
- ☐ Control utilities, ventilation, and sources of ignition
- ☐ Access to hydrants and FDCs for fire sprinkler system
- ☐ Firewall integrity, containment of fire, exposure protection

Isolate the source of the leak and pump down the liquid
- ☐ Identify upstream and downstream control points
- ☐ Avoid hydraulic shock caused by slamming a valve
- ☐ Avoid trapping liquid between valves with no relief valve
- ☐ Isolate the liquid flow to the leak site, and control defrost cycle
- ☐ Containment: tarp, and/or close doors
- ☐ Move liquid to safe location upstream or downstream of leak

Manage energy flow to the high and low sides
- ☐ Release: High or low side? Status of emergency relief system?
- ☐ Manage liquid flow and system pressure
- ☐ Reduce incoming heat–disable evaporators and defrost
- ☐ Use diffuser and/or pressure equalizer

Pressurized ventilation using system or portable fans
- ☐ Plan air flow–entry (upwind) and exhaust (downwind)
- ☐ Use fan to dilute or redirect vapor
- ☐ Engage portable fan to support rescue

Life Safety and Engage Incident Action Plan
- ☐ Set up Control Zone Layout (see diagram below)
- ☐ Public Safety coordination of downwind receptors in the Protective Action Area
- ☐ Eye-level wind movement: CAUTION for wind changes, eddies, backflow, and turbulence
- ☐ Consider site access control and air monitoring
- ☐ Assure containment of downstream environmental threat

PHASE 3 SUSTAINED RESPONSE

Sustained Response: Integrate and/or Unify Command

Actions: Assure personnel accountability and conduct a pre-entry site evaluation.

Plan: Write an IAP and Safety Plan (see back of 30-Minute Plan)

Hazmat Tech Team Engagement
- ☐ IC to review a Situation Status Report
- ☐ IC to integrate Command with Plant Liaison
- ☐ Safety Officer to update Site Safety and Control Plan (ICS 208)
- ☐ Conduct and IAP Command Team briefing
- ☐ Plans Section Chief updates situation status and proposes future IAP objectives
- ☐ Hazard assessment updates at least every 30 minutes and prior to engaging the next IAP
- ☐ Consider opening a Joint Information Center
- ☐ Consider opening an Emergency Command Center and assign a Public Information Officer and Plans Section Chief

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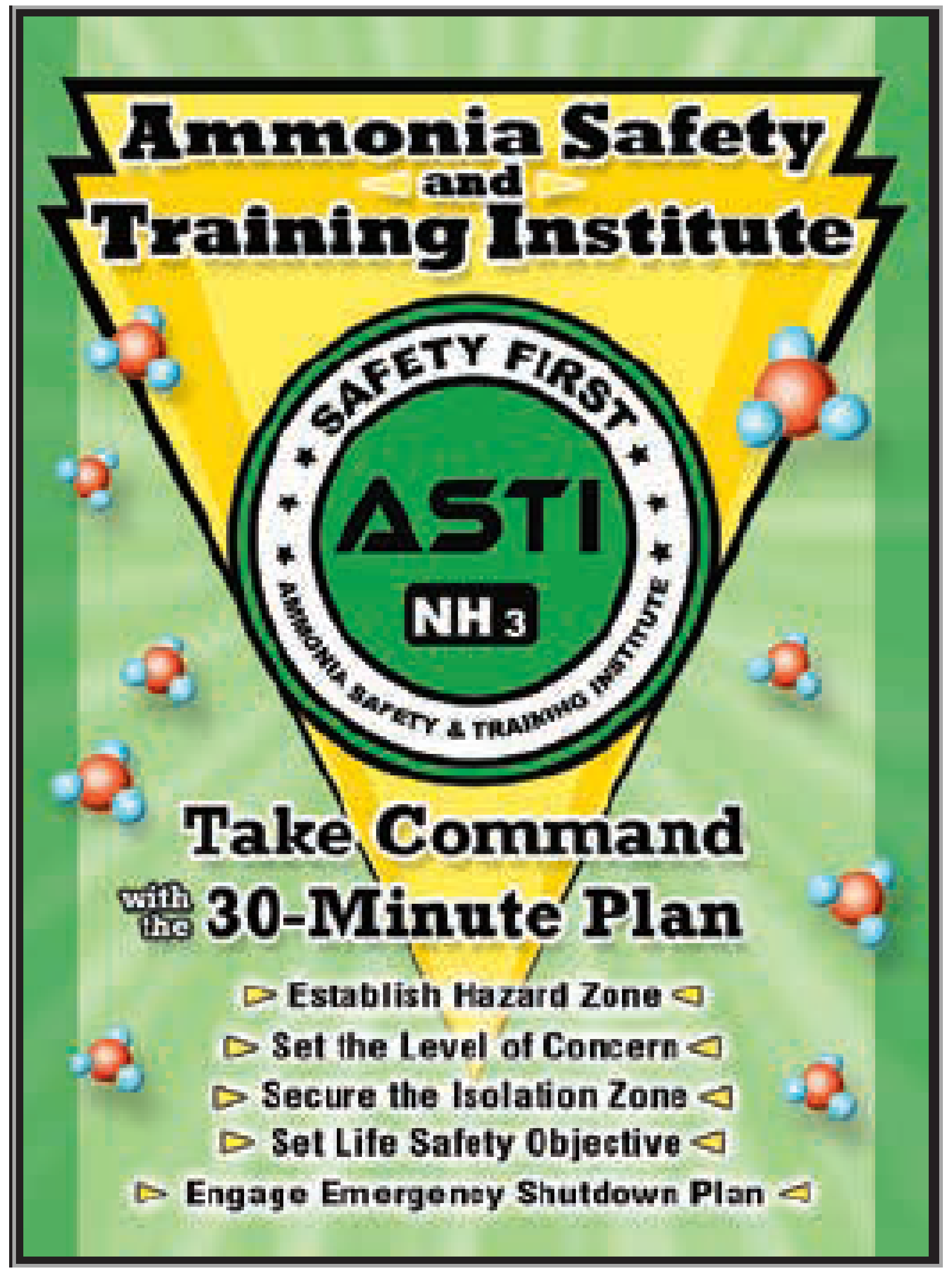
Safety Plan: Pre-entry to Hot Zone
- ☐ Review the IAP objective(s) and task assignments
- ☐ Assure safety, rehab, decon, and medical evaluation
- ☐ Position hose line, ventilation and back-up team
- ☐ NO entry into IDLH without IC approval and a back-up
- ☐ Do a pre-entry review: use back-ups, proper PPE, entry/exit times, communications, and emergency alert signals
- ☐ Respirator < IDLH (300 PPM) and SCBA > IDLH (300 PPM)
- ☐ Vapor protection: Level B < 5,000 PPM to 10,000 PPM and Level A > 10,000 PPM
- ☐ Flammability = No entry > 15,000 PPM without mitigations (for sources of ignition) and flash protection
- ☐ Aerosol Stream/Dense Gas: Level A with flashfire and cold temperature protection (avoid using water to absorb liquid or aerosol)
- ☐ Chemical monitoring (fixed and/or handheld) for monitoring control zones and for entry team

PHASE 4 TERMINATION

Termination of the Emergency

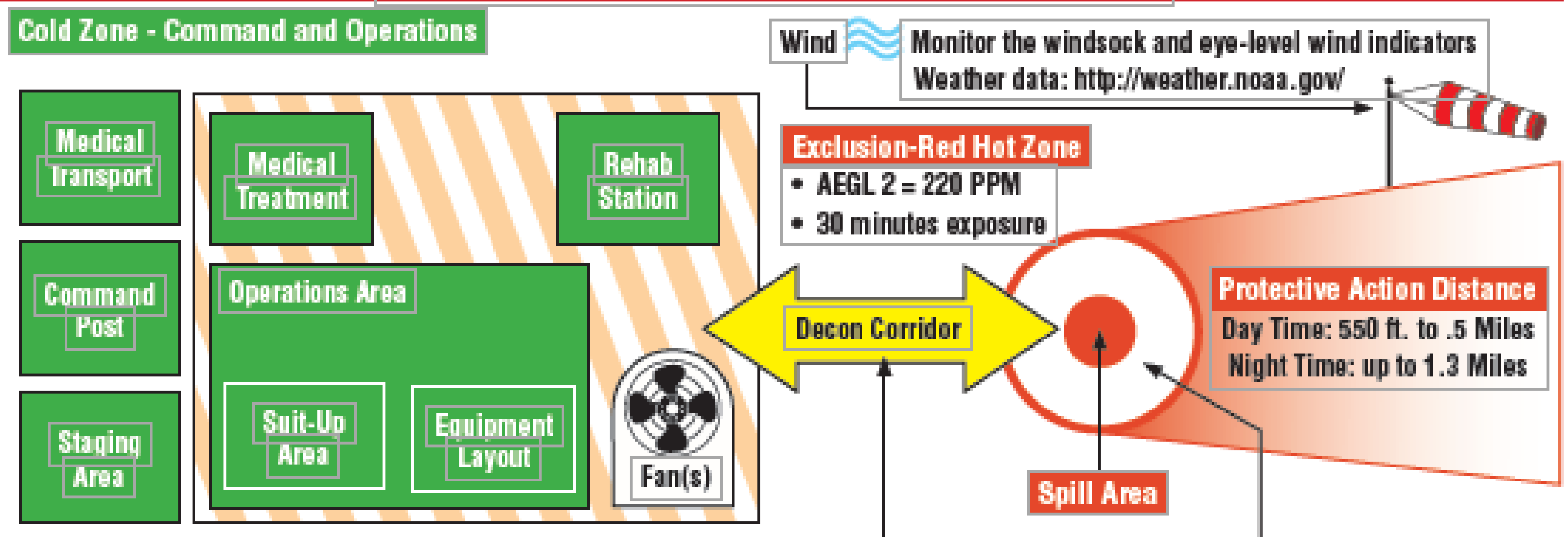
Actions: Hazard/threat mitigations completed and IC sign-off of Termination Proclamation

Plan: Communicate termination order to Command Team, shelter locations, regulators, and media
- ☐ Plant IC engages Recovery, Restart, and Business Continuation IAP; maintain pre-emergency status (PPE and Command Team)
- ☐ Debrief and identify prevention and mitigation and preparedness improvements



Save yourself, engage the team, and help others. Act decisively to stop problems when they are small.

CONTROL ZONE LAYOUT—AMMONIA RELEASE



Command Team
- Establish personnel accountability
- Secure a site safety and control plan (ICS 208)
- Situation status and pre-entry hazard analysis
- Written Incident Action Plan

Contamination Reduction - Yellow Zone
- Minimum of 100 ft. to 150 ft. between Red and Green Zones
- Drop equipment at the entry
- Decon with water for gross contamination (liquid)
- Decon with a fan for vapor exposure

Initial Isolation Zone
- 100' small leak < 100#s
- 500' large leak (aerosol cloud)
- Use buddy system
- Support with a fan and hose line

Quick Guides and Playbooks

Blue Playbook

Green Playbook

Red Playbook

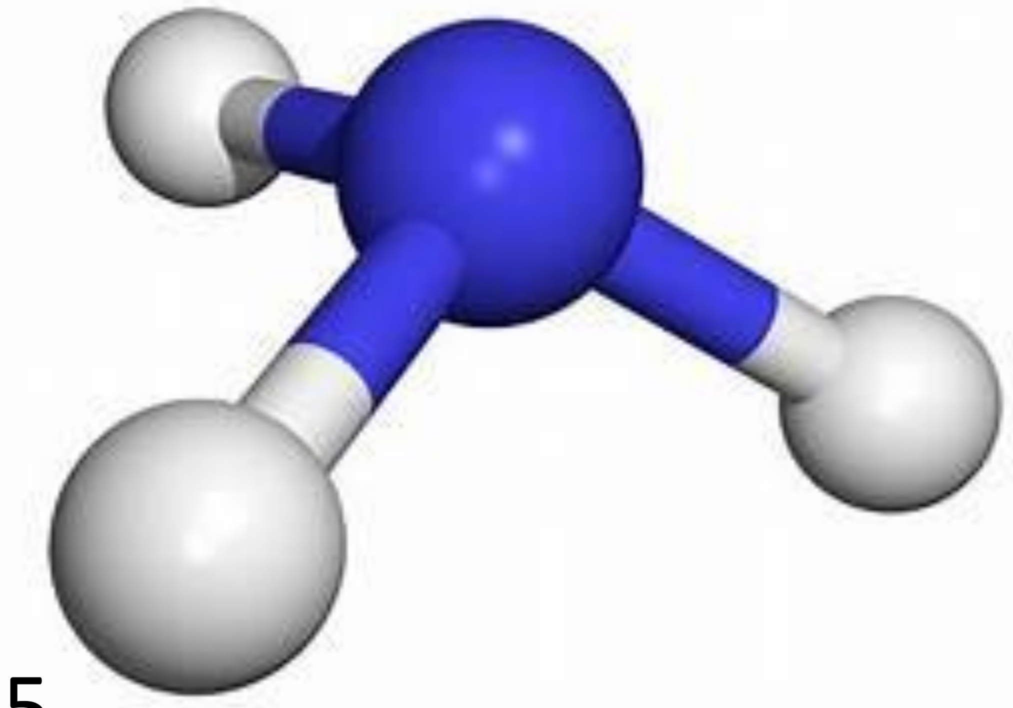
Orange Playbook

Hazard Analysis Quick Guide

Release Estimator Guide

30 Minute Plan

56 page Emergency Response Plan Training Manual



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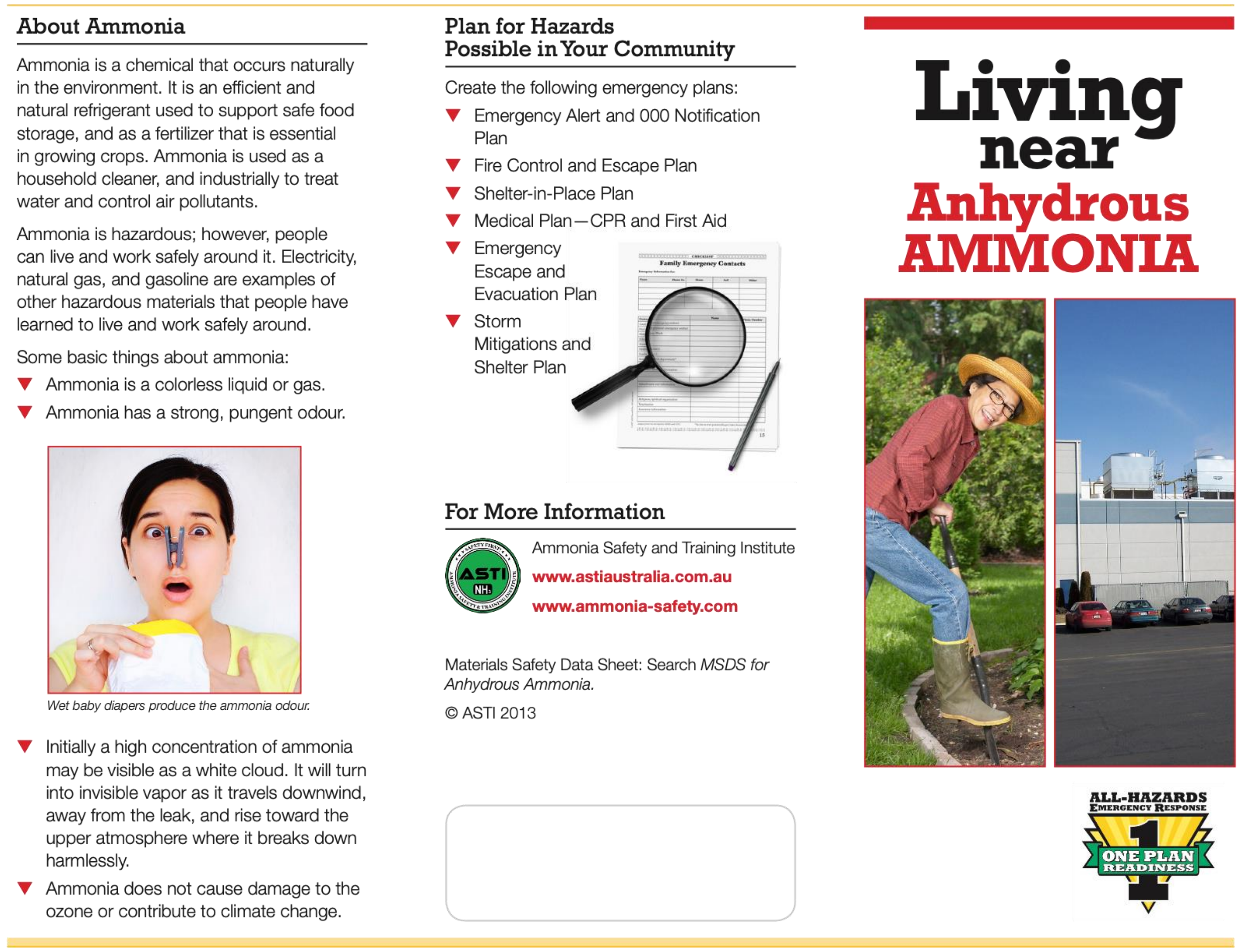
Tri-fold brochures



About Ammonia

Ammonia is a chemical that occurs naturally in the environment. It is an efficient and natural refrigerant used to support safe food storage, and as a fertilizer that is essential in growing crops. Ammonia is used as a household cleaner, and industrially to treat water and control air pollutants.

Ammonia is hazardous; however, people can live and work safely around it. Electricity, natural gas, and gasoline are examples of other hazardous materials that people have learned to live and work safely around.

Some basic things about ammonia:

- Ammonia is a colorless liquid or gas.
- Ammonia has a strong, pungent odour.

Wet baby diapers produce the ammonia odour.

- Initially a high concentration of ammonia may be visible as a white cloud. It will turn into invisible vapor as it travels downwind, away from the leak, and rise toward the upper atmosphere where it breaks down harmlessly.
- Ammonia does not cause damage to the ozone or contribute to climate change.

Plan for Hazards Possible in Your Community

Create the following emergency plans:

- Emergency Alert and 000 Notification Plan
- Fire Control and Escape Plan
- Shelter-in-Place Plan
- Medical Plan—CPR and First Aid
- Emergency Escape and Evacuation Plan
- Storm Mitigations and Shelter Plan

For More Information

Ammonia Safety and Training Institute
www.astiaustralia.com.au
www.ammonia-safety.com

Materials Safety Data Sheet: Search *MSDS for Anhydrous Ammonia.*

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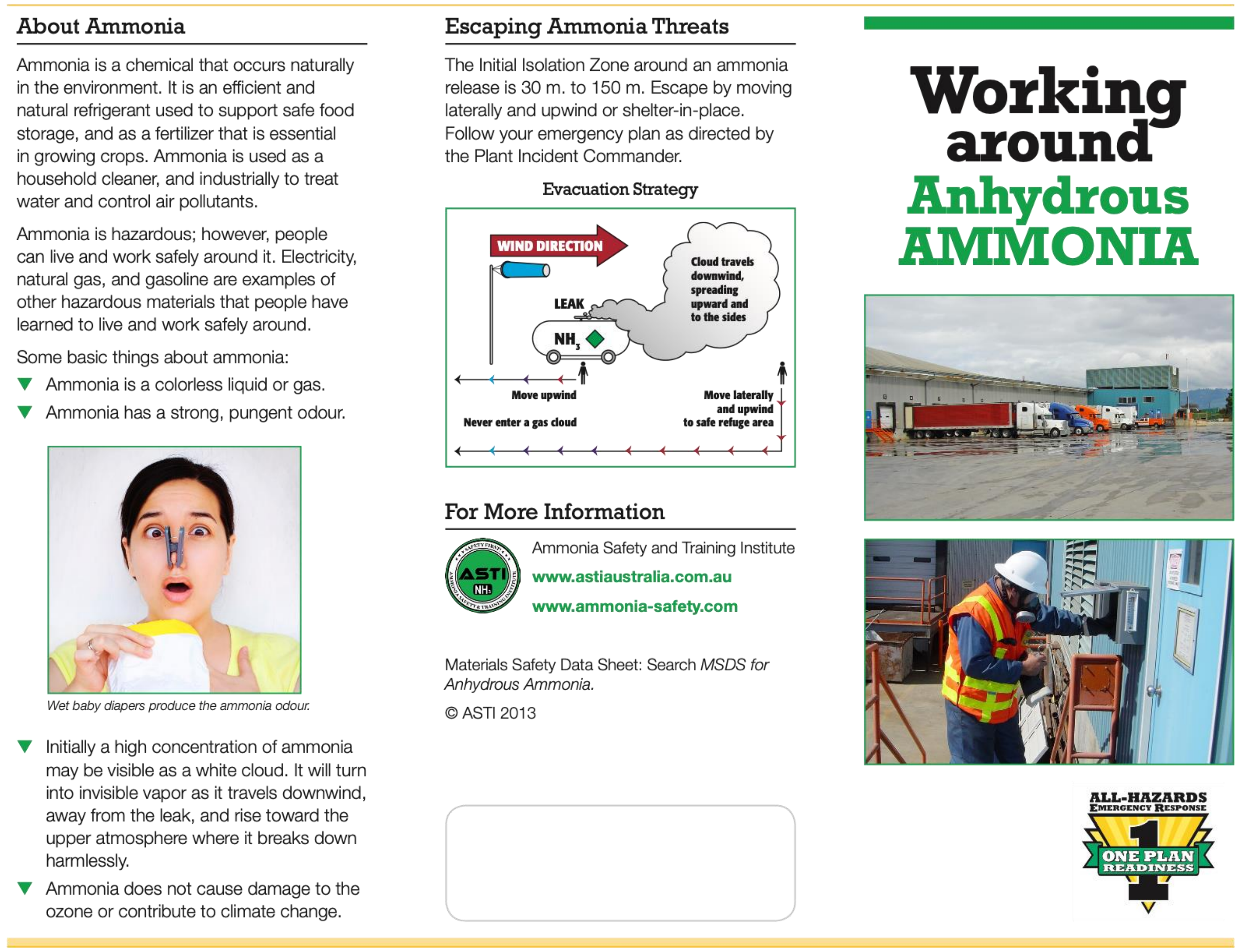
Living near Anhydrous AMMONIA

ALL-HAZARDS EMERGENCY RESPONSE
1 ONE PLAN READINESS



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Escaping Ammonia Threats

The Initial Isolation Zone around an ammonia release is 30 m. to 150 m. Escape by moving laterally and upwind or shelter-in-place. Follow your emergency plan as directed by the Plant Incident Commander.

Evacuation Strategy

For More Information

Ammonia Safety and Training Institute
www.astiaustralia.com.au
www.ammonia-safety.com

Materials Safety Data Sheet: Search *MSDS for Anhydrous Ammonia.*

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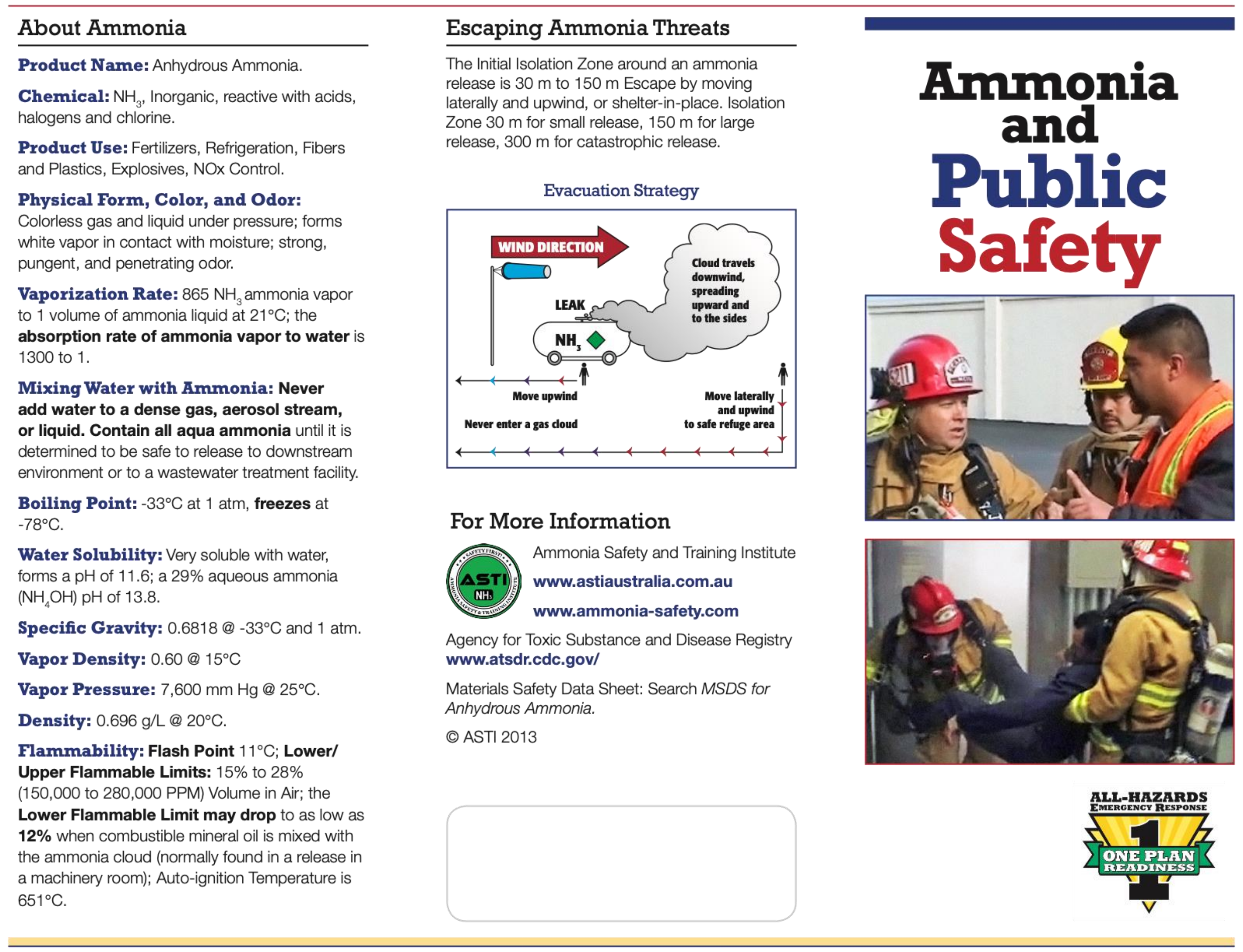
Working around Anhydrous AMMONIA

ALL-HAZARDS EMERGENCY RESPONSE
1 ONE PLAN READINESS



About Ammonia

Product Name: Anhydrous Ammonia.

Chemical: NH_3, Inorganic, reactive with acids, halogens and chlorine.

Product Use: Fertilizers, Refrigeration, Fibers and Plastics, Explosives, NOx Control.

Physical Form, Color, and Odor: Colorless gas and liquid under pressure; forms white vapor in contact with moisture; strong, pungent, and penetrating odor.

Vaporization Rate: 865 NH_3 ammonia vapor to 1 volume of ammonia liquid at 21°C; the **absorption rate of ammonia vapor to water** is 1300 to 1.

Mixing Water with Ammonia: Never add water to a dense gas, aerosol stream, or liquid. Contain all aqua ammonia until it is determined to be safe to release to downstream environment or to a wastewater treatment facility.

Boiling Point: -33°C at 1 atm, **freezes** at -78°C.

Water Solubility: Very soluble with water, forms a pH of 11.6; a 29% aqueous ammonia (NH_4OH) pH of 13.8.

Specific Gravity: 0.6818 @ -33°C and 1 atm.

Vapor Density: 0.60 @ 15°C

Vapor Pressure: 7,600 mm Hg @ 25°C.

Density: 0.696 g/L @ 20°C.

Flammability: Flash Point 11°C; **Lower/Upper Flammable Limits:** 15% to 28% (150,000 to 280,000 PPM) Volume in Air; the **Lower Flammable Limit may drop** to as low as **12%** when combustible mineral oil is mixed with the ammonia cloud (normally found in a release in a machinery room); Auto-ignition Temperature is 651°C.

Escaping Ammonia Threats

The Initial Isolation Zone around an ammonia release is 30 m to 150 m Escape by moving laterally and upwind, or shelter-in-place. Isolation Zone 30 m for small release, 150 m for large release, 300 m for catastrophic release.

Evacuation Strategy

For More Information

Ammonia Safety and Training Institute
www.astiaustralia.com.au
www.ammonia-safety.com

Agency for Toxic Substance and Disease Registry
www.atsdr.cdc.gov/

Materials Safety Data Sheet: Search *MSDS for Anhydrous Ammonia.*

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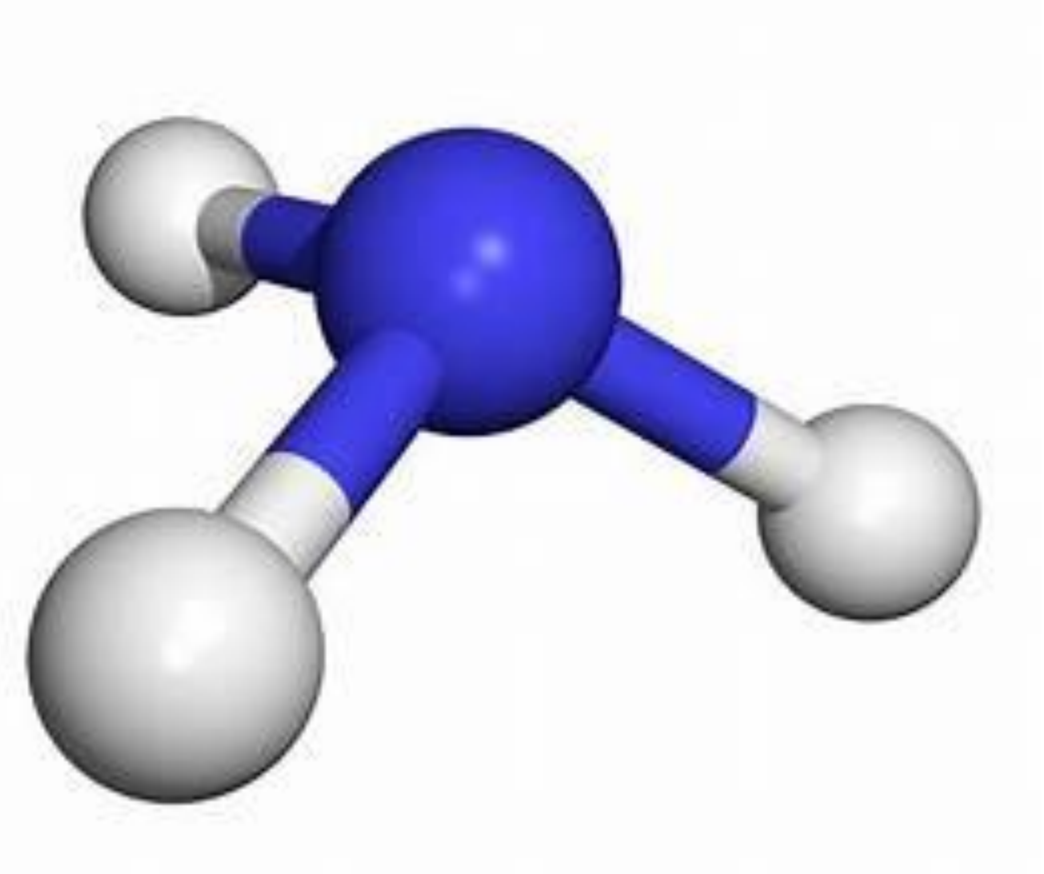
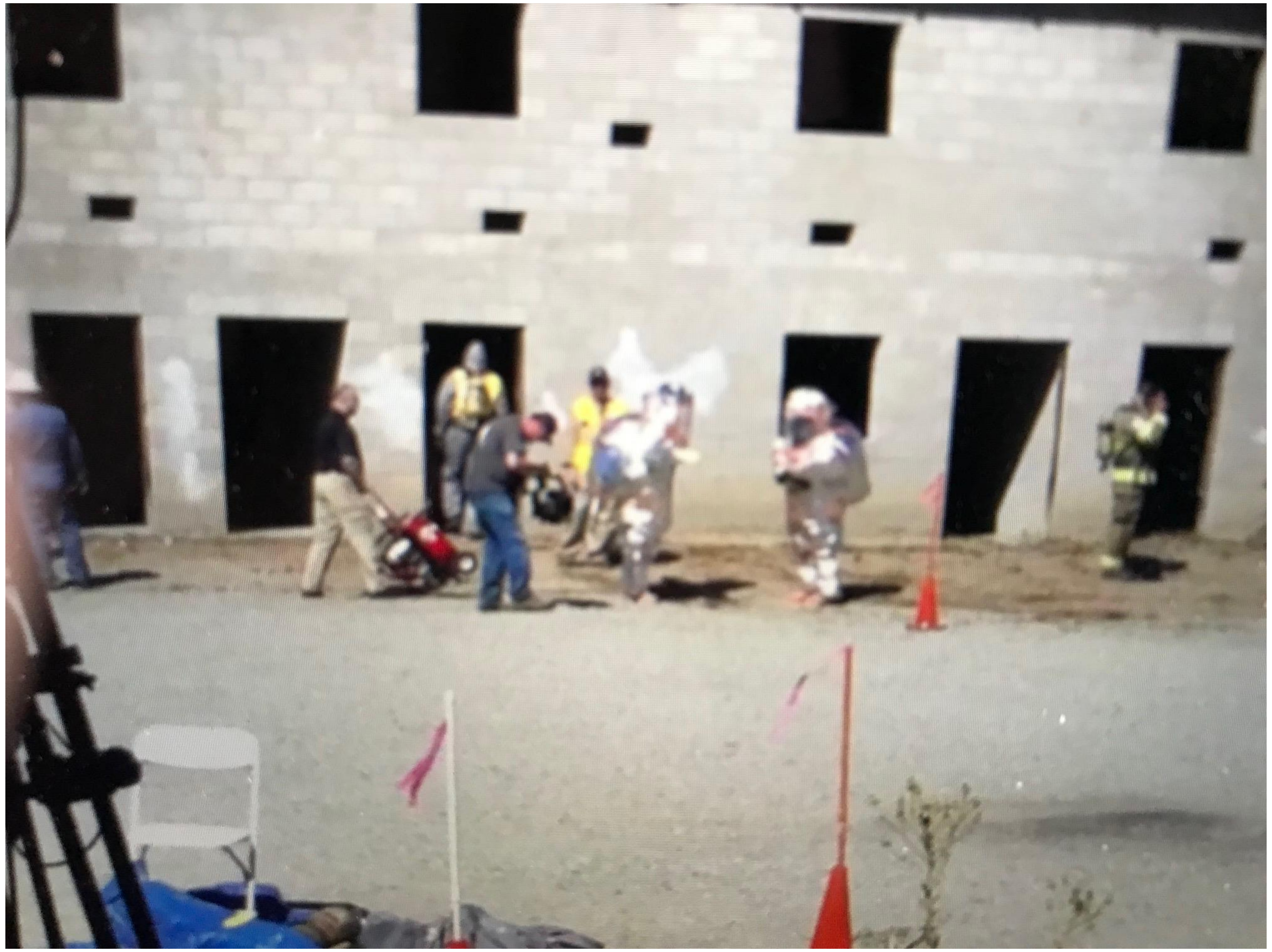
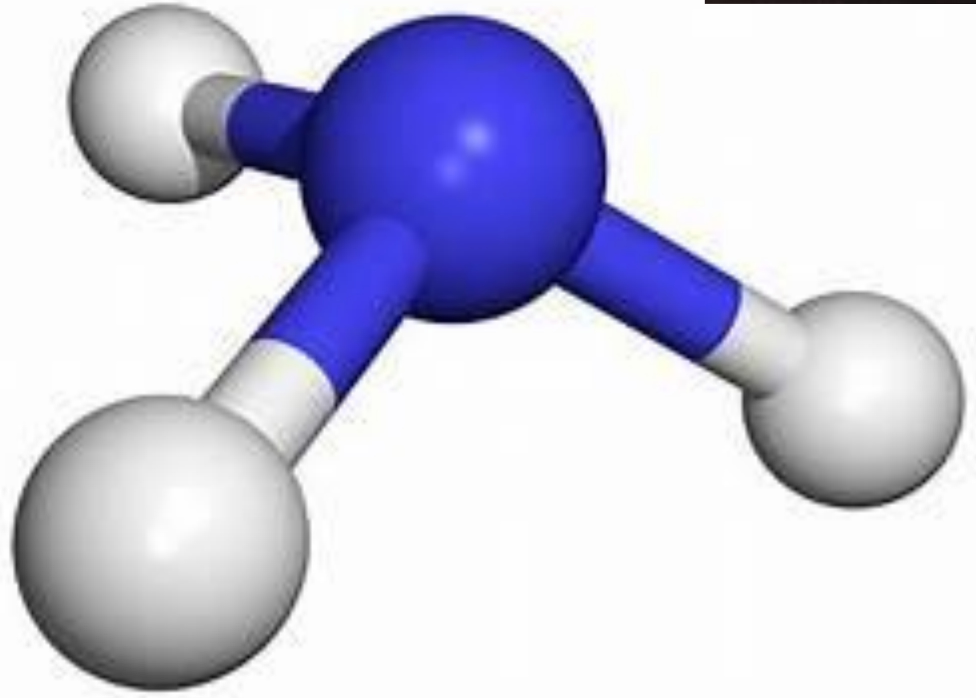
Ammonia and Public Safety

ALL-HAZARDS EMERGENCY RESPONSE
1 ONE PLAN READINESS



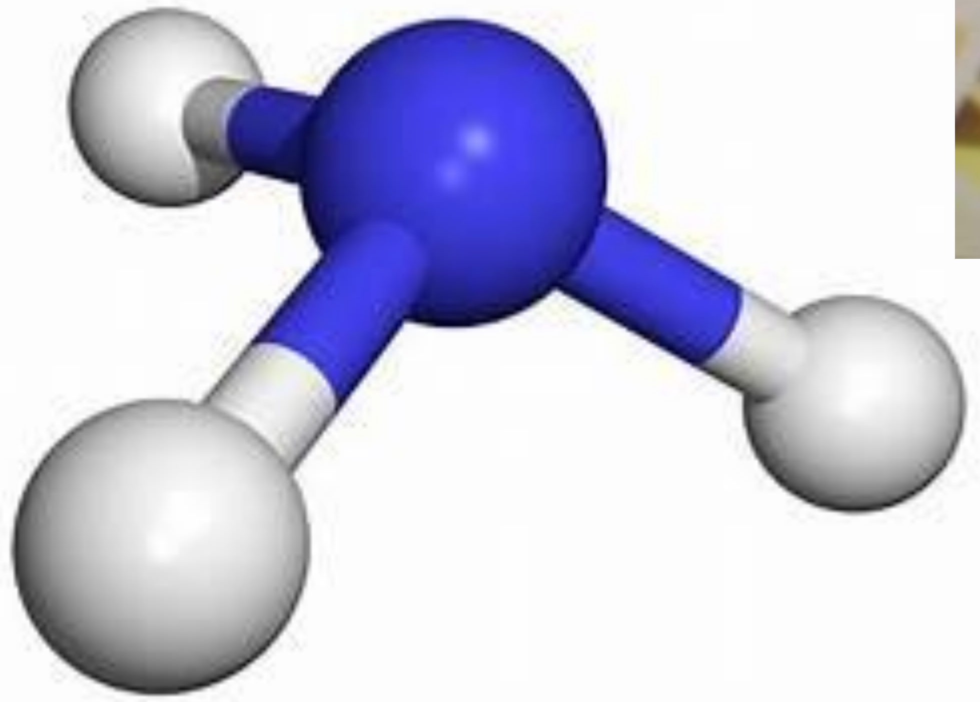
Level A   Using gas tight suit over SCBA





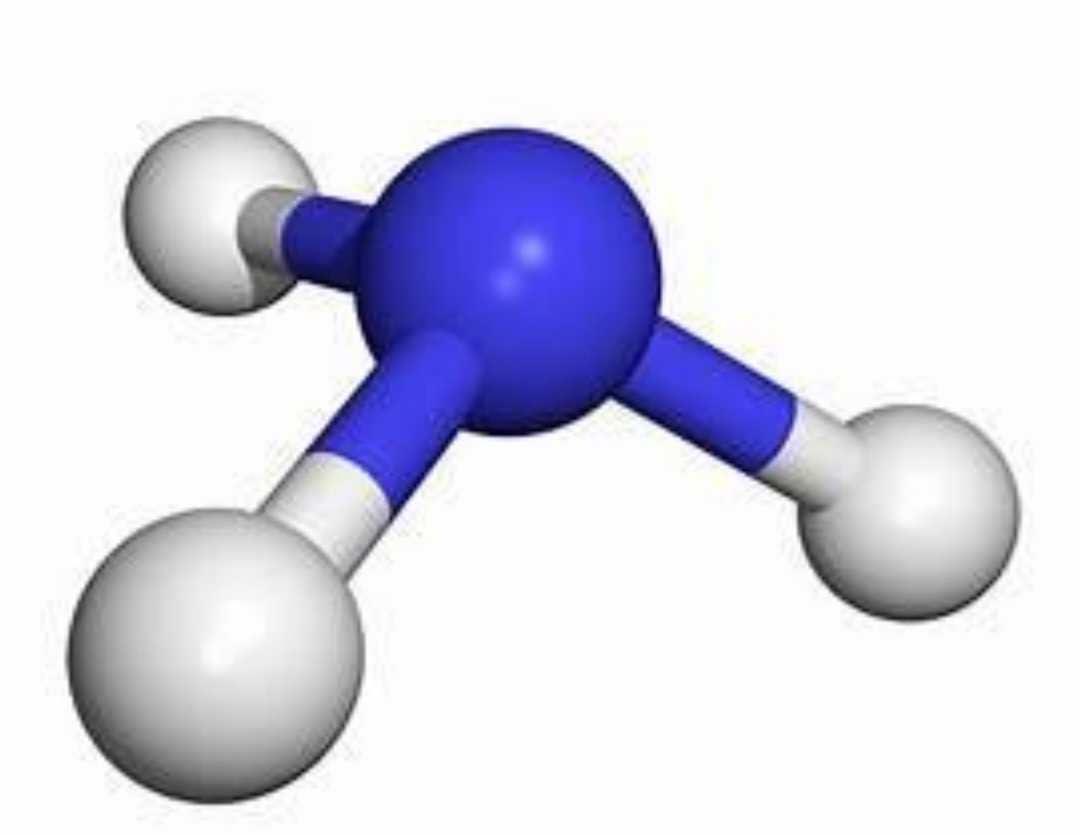
Recommended for concentrations above 5000 ppm and temperatures down to -40

Level B   Disposable suit under SCBA



Recommended for 300 – 5000 ppm

Level C. ASTI Vest



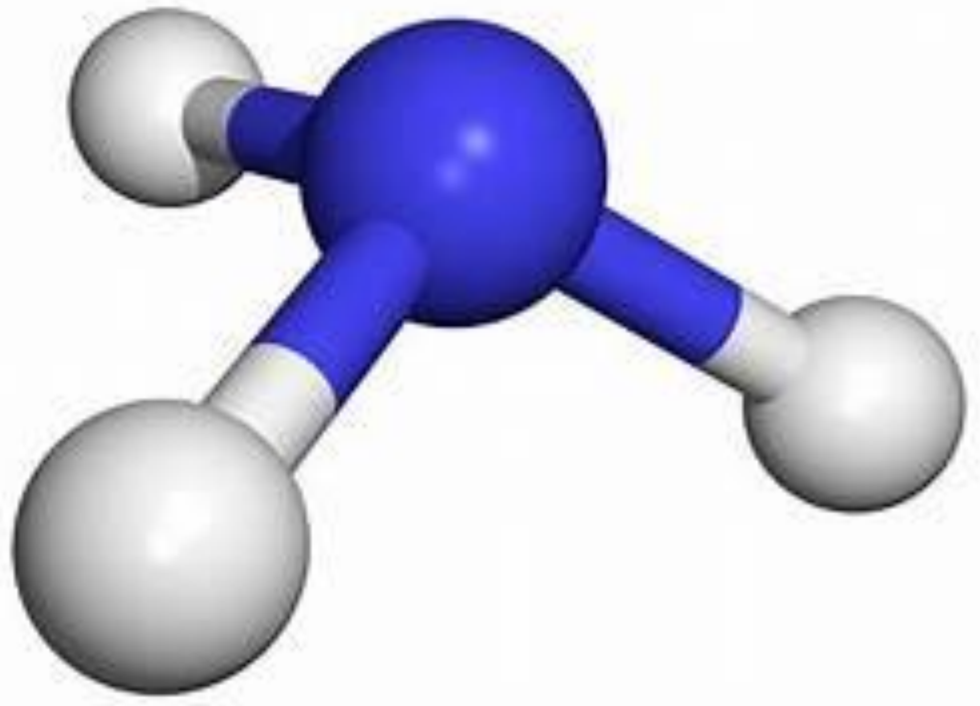
ASTI high visibility vest
Lapel mounted personal ammonia detector
Negative pressure, full face compact mask with replaceable K2 filter
White LED right angle flashlight
Ultravision anti fog goggles with forehead seal
Elbow length chemical safety gloves
Chemical break open eyewash
Anti-fogging agent to use on mask & goggles
ASTI 30 Minute Plan (*A3 folded*)

Ammonia Engine Room Design

Ventilation Forced ventilation of 6 - 10 air changes per hour should be sufficient to ensure the concentration during an accidental ammonia release never approaches the LFL.

Detection. An ammonia detection system will enable automatic isolating valves to be closed and ventilation systems to be started in the event of an accidental release in the engine room. The detection system can also be used to shunt trip all electrical circuits in the engine room to eliminate potential ignition sources if the concentration exceeds one fifth of LFL.

Explosion Vents Some Regulators and insurance companies require ammonia engine rooms to be fitted with explosion vents in case there is an ammonia deflagration to prevent damage due to a pressure wave.



Fire Suppression Water Sprinklers are usually advised against in ammonia engine rooms. Carbon Dioxide suppression systems should work provided it is known that when ammonia gas and CO2 gas mix together they form a white solid, ammonium carbamate, so it appears to be snowing inside.

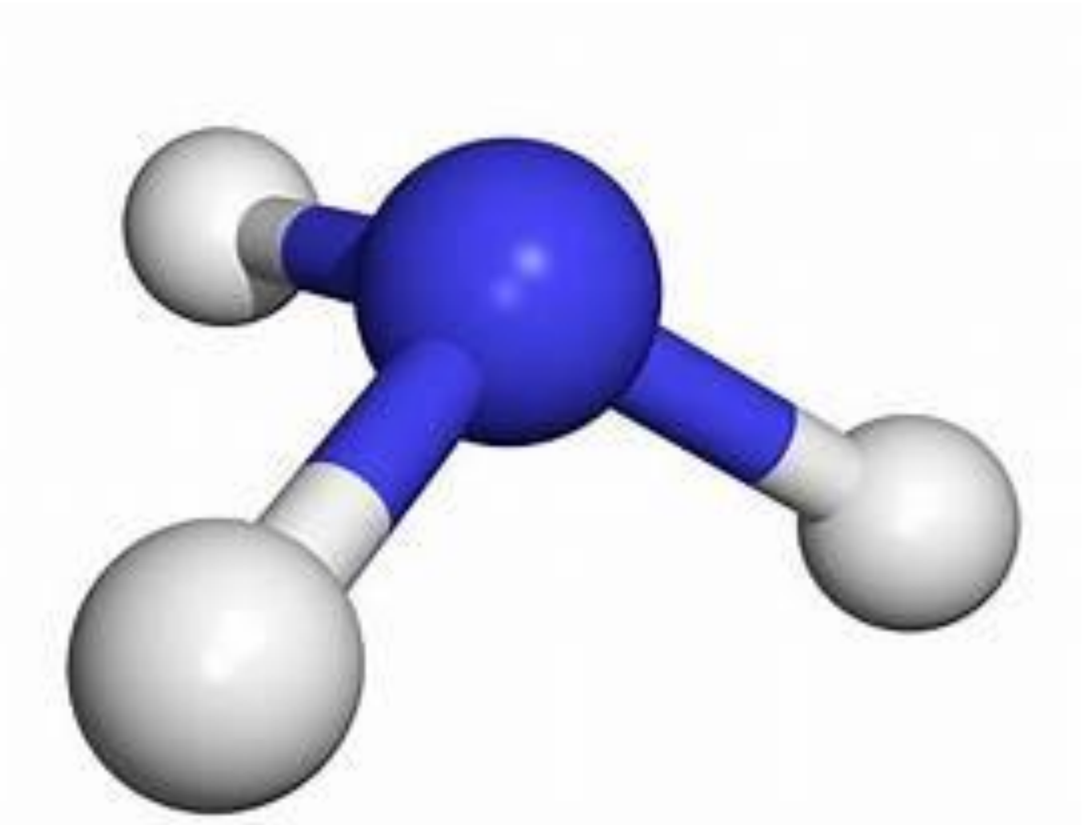
SAFETY FIRST

ASTI

NH_3

AMMONIA SAFETY & TRAINING INSTITUTE

Fully Refrigerated (FR) Gas Carriers transport ammonia liquid at -33C in insulated hold tanks at a low pressure slightly above atmospheric pressure



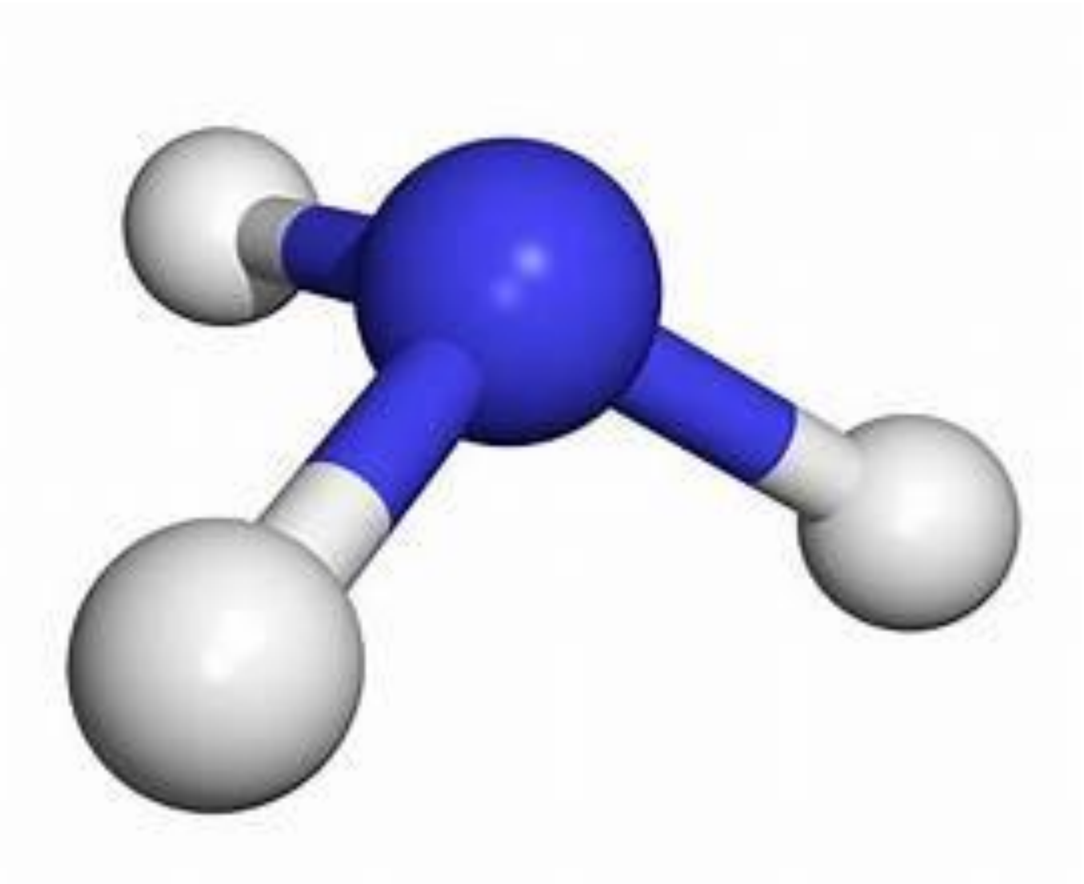
The temperature of the ammonia cargo in these Gas Carriers must be carefully controlled to ensure it is at the right temperature ready for unloading at the destination.

Below Deck

Container Ships, where above deck space is at a premium, can likely use insulated, below deck, FR liquid ammonia insulated bunker fuel tanks to make optimum use of the available hold space given the ammonia fuel tanks will be significantly bigger than HFO tanks to achieve equivalent range. These tanks will operate at slightly above atmospheric pressure.

Ammonia fuel will be pumped from the tanks to the engine room via the pressurised fuel piping system

The vast majority of the ammonia fuel will be contained in the fuel tanks at slightly above atmospheric pressure and -33C, whereas a tiny fraction of the ammonia fuel will be within the fuel management system under pressure.



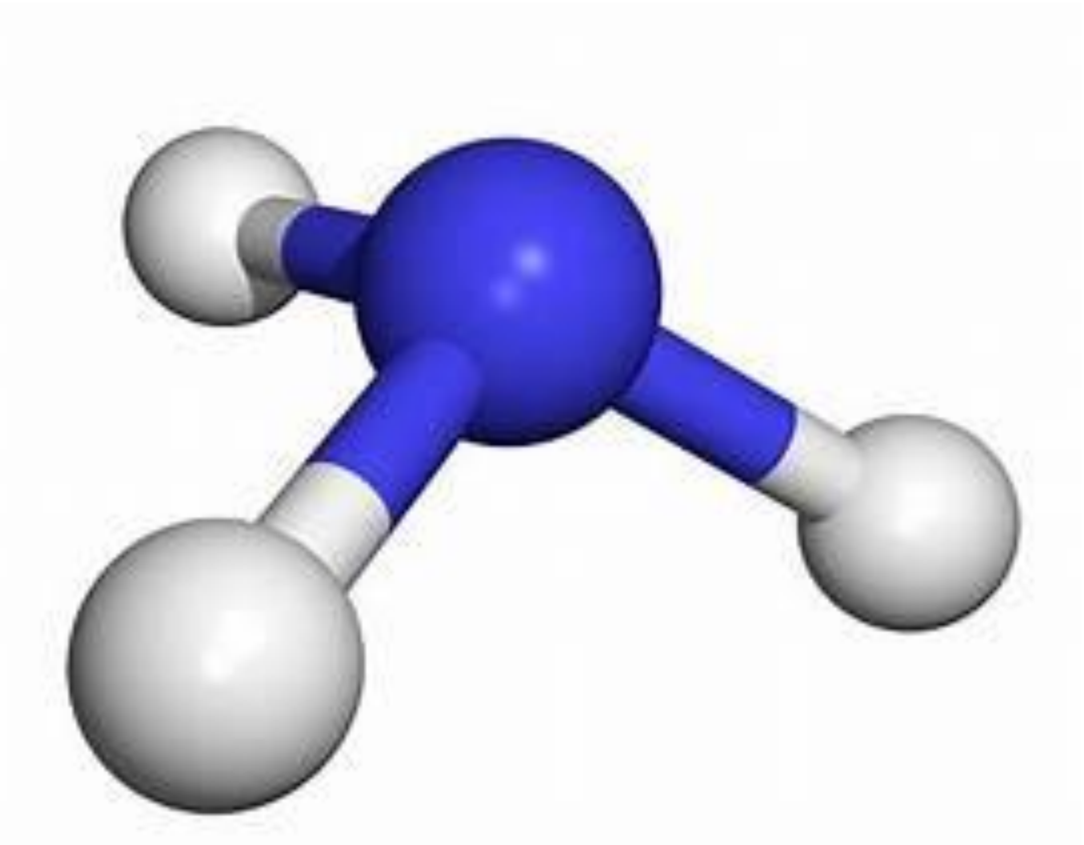
Automatic shut off valves will be available to activate and close the ammonia fuel supply in the event that an accidental release is detected.

Above Deck

Bulk Carrier and similar ships, where above deck space is available, could possibly use insulated, low pressure, non-refrigerated ammonia bunker fuel tanks located on the deck. These thanks would typically be horizontal, cylindrical steel pressure vessels, with design pressure of up to 5 barg. They would be bunkered using -33C liquid ammonia with a saturated pressure slightly above atmospheric, which would allow them to undertake a voyage of up to one or two months duration before the pressure builds up in fuel tanks due to heat ingress through the insulation.

Ammonia fuel will be pumped from the tanks to the engine room via the pressurised fuel piping system

The majority of the ammonia fuel will be contained in the fuel tanks at up to about 4 barg , and a tiny fraction of the ammonia fuel will be within the fuel management system at a much higher pressure.



Automatic shut off valves will be available to activate and close the ammonia fuel supply in the event that an accidental release is detected.

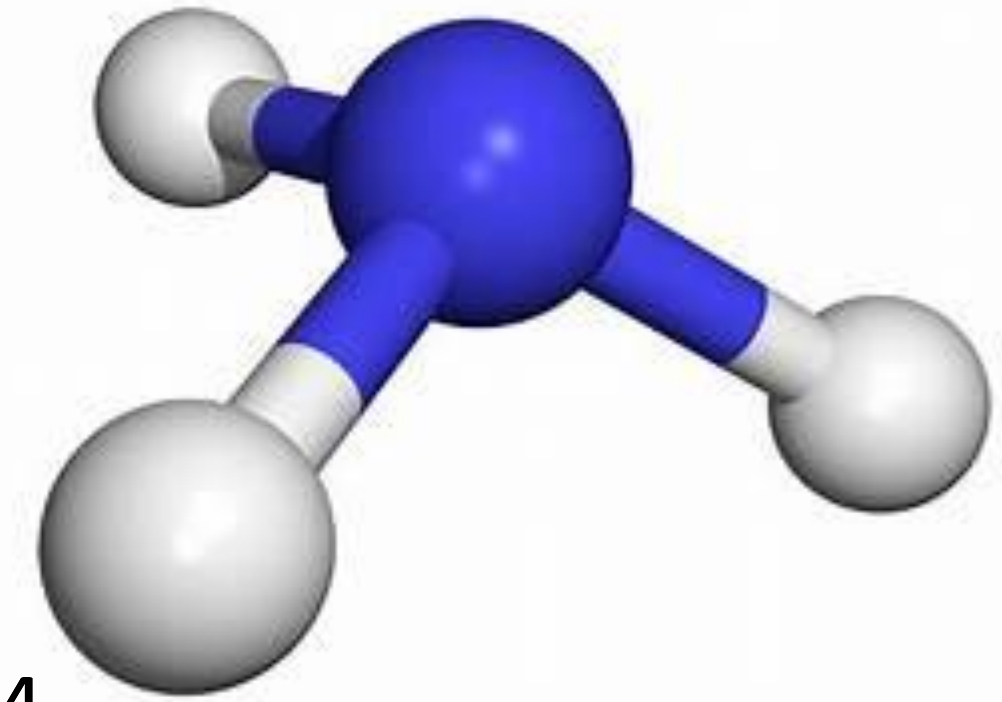
Release of saturated liquid under pressure

Release under pressure results in an aerosol and potentially a dense gas cloud which is usually heavier than air

The example shown involves a pressure reduction at the point of release vertically down the line from 5 to 4 arriving at atmospheric pressure and a dryness fraction of 0.22

We can therefore estimate that 22% of the mass flow of the release will instantaneously turn to flash gas at the breach

The volume ratio of gas to liquid at atmospheric pressure and -33C is a factor of 766



For example 1 litre/sec of liquid releasing will generate 168 litre/sec of flash gas which will violently propel an aerosol and then become a dense gas cloud which will be heavier than air.

This kind of release poses the highest risk.

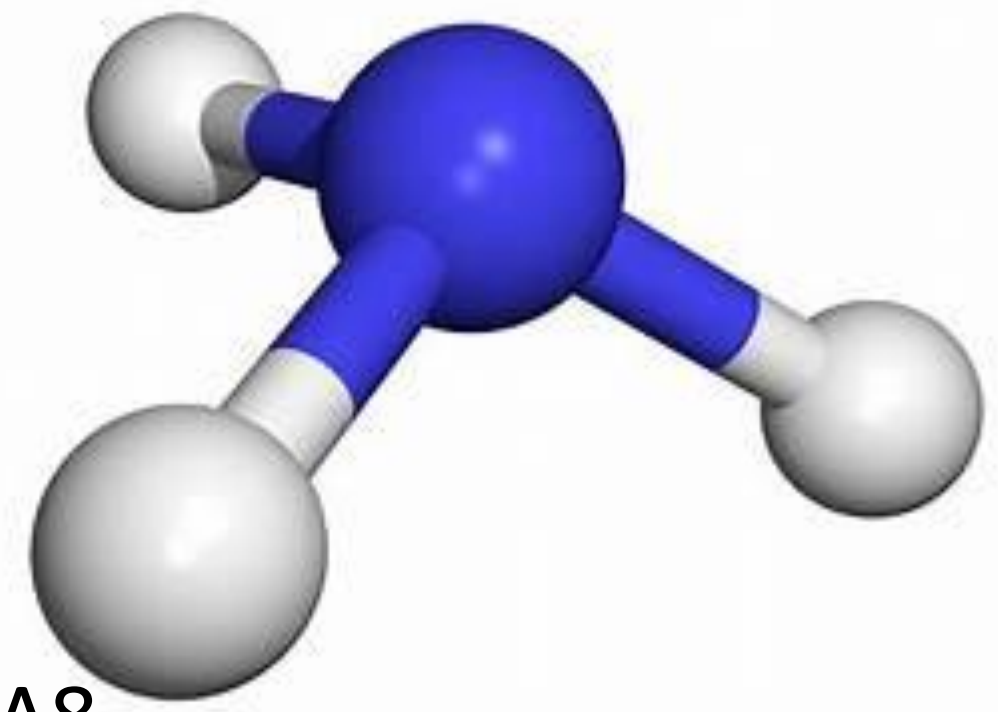
Release of saturated liquid at atmospheric pressure

Release from storage at atmospheric pressure (point 2)

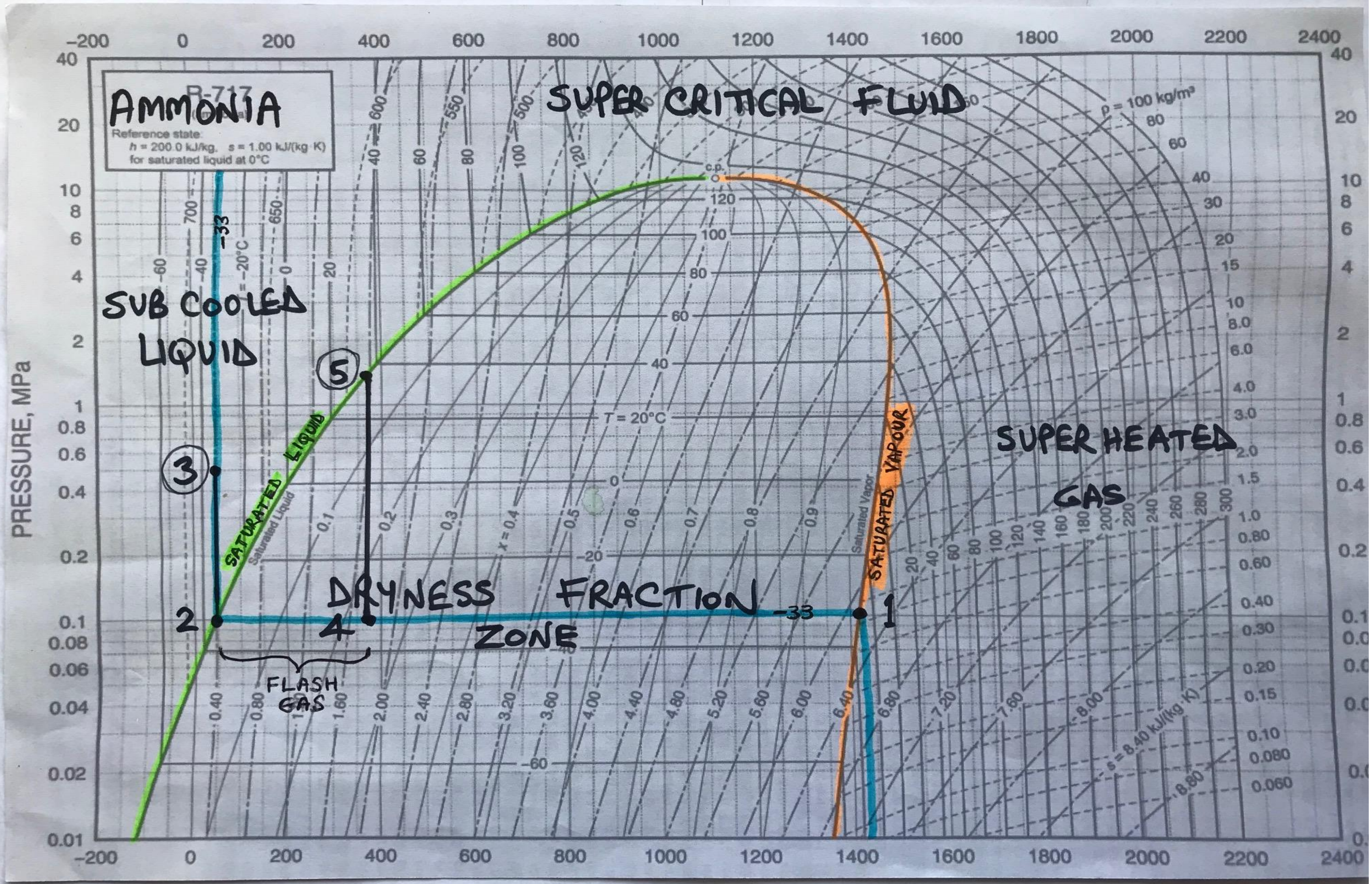
The majority of the gas evaporating from the pool will be invisible pure gas which is about 60% of the density of air and will quickly rise into the atmosphere. There will be no aerosol or dense gas cloud and therefore the risk is low.

A little bit of water vapour may be visible whisping from the surface of the pool

Spraying water onto the pool will increase the evaporation rate and even cause a gas cloud which may be heavier than air so this should never be done.



The amount of gas evaporating from the surface will be a function of the quantity of heat entering the pool from the surface below and the air above. Ammonia has a very high latent heat of evaporation , so the rate at which the ammonia evaporates will be very low.


AMMONIA
R-717
Reference state:
h = 200.0 kJ/kg, s = 1.00 kJ/(kg·K)
for saturated liquid at 0°C
SUPER CRITICAL FLUID
SUB COOLED LIQUID
SATURATED LIQUID
Saturated Liquid
SATURATED VAPOUR
Saturated Vapor
SUPER HEATED GAS
DRYNESS FRACTION ZONE
FLASH GAS
1
2
3
4
5
-33
c.p.
T = 20°C
ρ = 100 kg/m³
s = 8.40 kJ/(kg·K)
PRESSURE, MPa

Ammonia Engine Room Design

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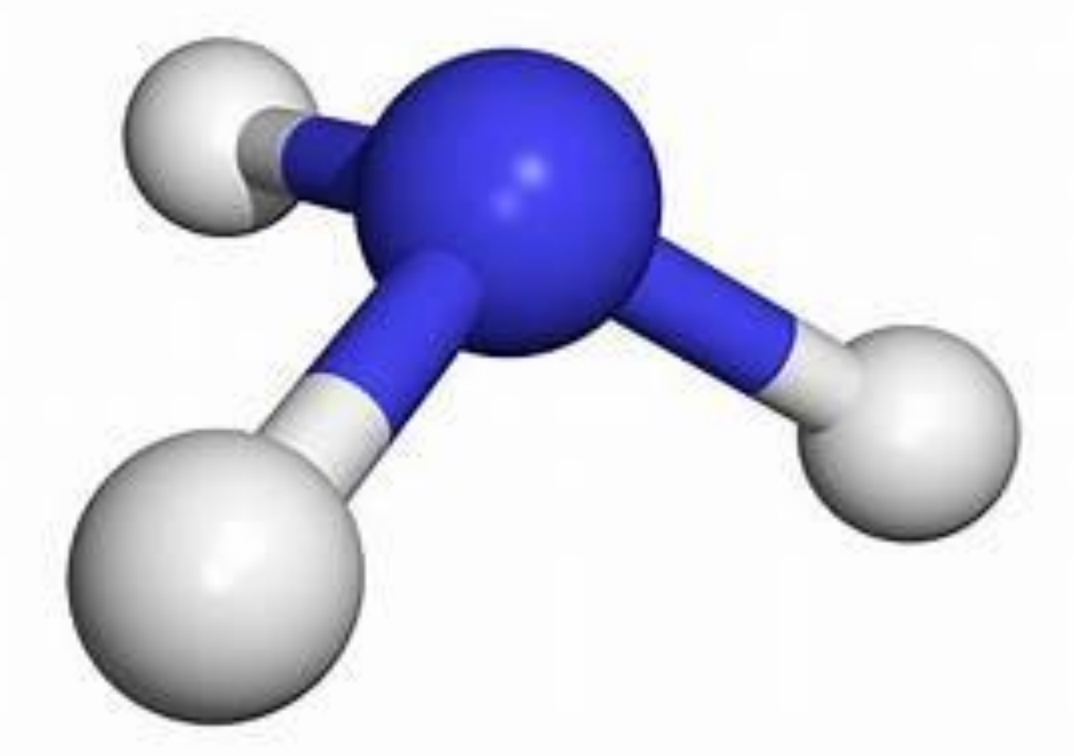

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