Ammonia safety issues

Workshop Ammonia as Energy Carrier
October 24th, 2025

Towards fertilisation leadership and the industry of the future

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Ammonia safety issues

Transformación sostenible hacia una cultura de "pérdidas cero" en Grupo Fertiberia

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- Hazards
- Physical and chemical properties
- Health Hazards of Ammonia
- Handling and storage
- Personal and enviromental precautions
- Accident examples

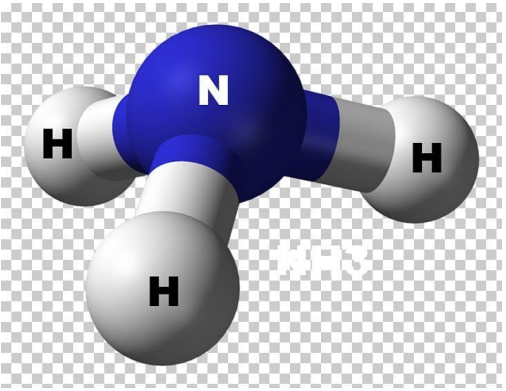
HAZARDS

H221 Flammable gas.
H280 Contains gas under pressure; may explode if heated.
H331 Toxic if inhaled.
H314 Causes severe skin burns and eye damage.
H410 Very toxic to aquatic life with long lasting effects.

Very important as well as to understand its reactivity and compatibility with materials of construction.

CHEMICAL AND PHYSICAL PROPERTIES OF AMMONIA

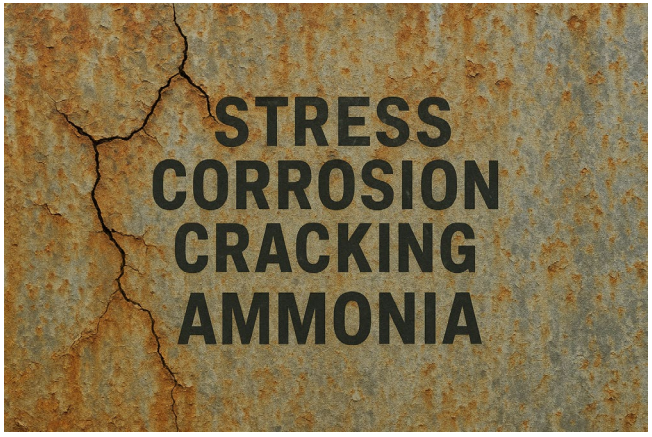
GENERAL PROPERTIES OF AMMONIA	
Chemical formula	NH_3
Chemical name	Ammonia, Anhydrous Ammonia
Molecular weight	17.03
Boiling point	-33.3°C



- Ammonia is an alkaline colourless gas with a penetrating pungent and suffocating odour.
- Ammonia gas is very soluble in water.
- The gas is strongly irritant/corrosive to the skin, eyes and respiratory tract and has toxic properties.
- Ammonia condenses into a colourless liquid when cooled and compress.
- The liquid can cause severe cold burns in contact with the skin.
- Although ammonia is capable of forming flammable mixtures with air, it is difficult to burn.

CHEMICAL AND PHYSICAL PROPERTIES OF AMMONIA

CHEMICAL PROPERTIES	
pH 1% aqueous	11.7
Contact with: Hg, Cl_2, I_2, Br_2, Ca, Ag_2O, hypochlorite, …	Explosive compounds
Gas with NOx and strong acids	Violent reaction
Very corrosive to materials	Copper and its alloys
Ammonia in presence of Oxigen.	Can cause stress corrosion in Steel vessels: ***CONTROL OF OXIGEN CONTENT AND ADDITION OF WATER UP TO 0.2%***



CHEMICAL AND PHYSICAL PROPERTIES OF AMMONIA

FLAMMABLE PROPERTIES

Ammonia is combustible	Difficult to ignite and in open air the flame is not stable (Flash point: 132°C, auto ignition T: 651°C)
Ammonia gas from liquid pool	Does not burn, nor does the pool ignite.
Ammonia-air mixture in open air	Generally outside flammability limits
Ammonia-air mixture in confined spaces	Risk of explosion and fire
Ammonia aqueous solutions (e.g. 26%)	Vapor pressure can be within the flammability limit

In EU and UN legislation ammonia is not classified as a flammable gas

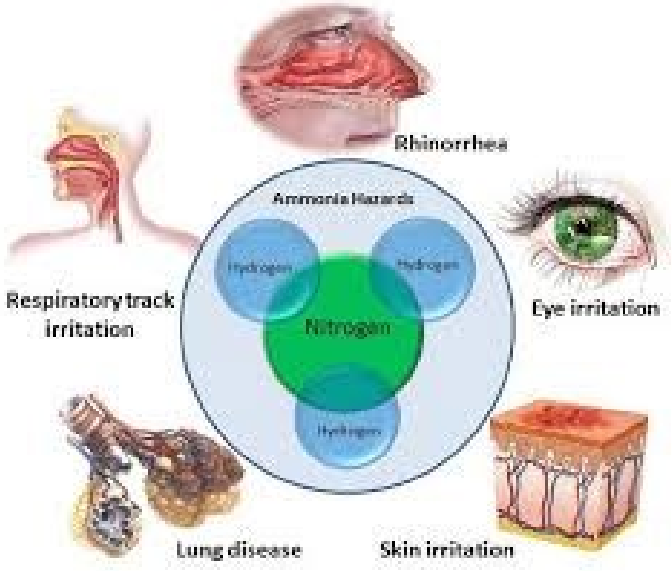
FLAMMABILITY LIMITS FOR AMMONIA AT ATMOSPHERIC PRESSURE

Flammability Limits	**Approximate Volume % Ammonia**	
	In Air	**In Pure Oxygen**
At ambient temperature	16 to 26	13 to 82
At 300°C	13 to 34	
At 400°C	11 to 37	

HEALTH HAZARDS OF AMMONIA

HAZARD PROPERTIES

Ammonia is a potentially hazardous substance.	It can produce acute effects on humans and animals.
Strong alkaline and hygroscopic properties.	They cause a primary irritation or corrosion to damp tissue surfaces, such as the eyes, respiratory system and skin.
It has a pungent odour with a threshold in the region of 5 ppm	Concentrations between 20-50 ppm in air are detectable by most people. This provides an adequate warning of its presence well below the hazardous concentration levels.
Gaseous ammonia affects the mucous membranes and the respiratory tract and severely irritates the eyes	Inhaling high concentrations may cause pulmonary oedema. High gas concentrations in the air may cause blisters and chemical burns to the skin.
Liquid ammonia in direct contact with the skin.	It freezes tissues and causes chemical burns.



Threshold Limit Values in the EU.

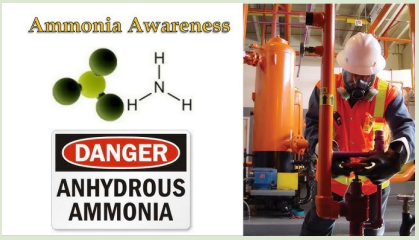
TLV/15 min TWA: 50 ppm = 36 mg/m^3

TLV/8 hr TWA: 20 ppm = 14 mg/m^3

Exposure to 300 ppm can cause serious health issues.

HANDLING AND STORAGE OF AMMONIA

SAFE HANDLING PROCEDURE

General Precautions 	• Only trained personnel should handle ammonia. • Work in well-ventilated areas or under fume hoods. • Avoid inhalation and direct contact with liquid or gas. • Never mix with acids, halogens, or oxidizers (forms toxic chloramines or explosive compounds).
Personal Protective Equipment (PPE) 	• **Chemical-resistant gloves:** Butyl rubber, neoprene, or nitrile. • **Eye/face protection:** Goggles and face shield. • **Protective clothing:** Long sleeves, ammonia-resistant apron or coveralls. • **Respiratory protection:** Full-face respirator with ammonia cartridges or supplied-air respirator for high concentrations.
Leak Detection 	• Ammonia has a strong odor even at 5 ppm, serving as an early warning. • Use **ammonia detectors** or **litmus paper (turns blue)** for verification.

HANDLING AND STORAGE OF AMMONIA

STORAGE REQUIREMENTS

Containers	• Store in steel pressure vessels rated for ammonia service (per ASME standards).
	• Avoid materials such as copper, brass, bronze, and galvanized metals.
	• Use valves and fittings made of steel, stainless steel, or certain plastics (Teflon, PVC).
	• Different types of tanks depending on pressure and capacity:
	  • Pressurized Storage: gas compressed into liquid form (10-15 bar, ambient temperature)
	  • Refrigerated storage: liquid (atmospheric pressure and temperature < -33ºC)

Conditions	• **Temperature:** Keep below 40 °C (ideally below ambient).
	• **Pressure**: Must be maintained within design limits of the vessel (usually 10–15 bar).
	• **Location**:
	  • Outdoor or well-ventilated area.
	  • Away from heat sources, open flames, and sunlight.
	  • Minimum 15 m from buildings, combustible materials, and oxygen/acetylene cylinders.
	  • Use secondary containment or dikes in large storage systems.

Labeling and Signage	Cylinders and tanks must display: "**Ammonia – Poison Gas**" Hazard class (Toxic Gas, Corrosive). UN No. 1005 (anhydrous) or UN No. 2672 (aqueous).

STORAGE OF AMMONIA. TYPES OF AMMONIA TANKS

- Ammonia has been stored as a liquid since ammonia production on an industrial scale began about 100 years ago.
- Ammonia was initially stored in pressurized systems, such as bullets and Horton spheres. Typically, spheres were used to store up to 2,000 tonnes.
- Today, atmospheric ammonia storage tanks are used to store up to 50,000 tonnes of ammonia at plant sites and distribution terminals.

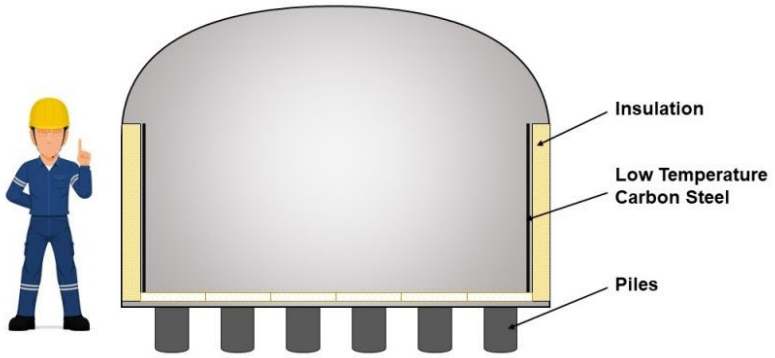
- Low-pressure ammonia storage has been widely accepted for two reasons:
  - It requires much less capital per unit volume.
  - It is safer than sphere storage that uses pressures higher than atmospheric.
- With the large-scale industrial production of ammonia, it has become common to store ammonia at atmospheric pressure and at -33°C.

STORAGE OF AMMONIA. ATMOSPHERIC AMMONIA TANKS

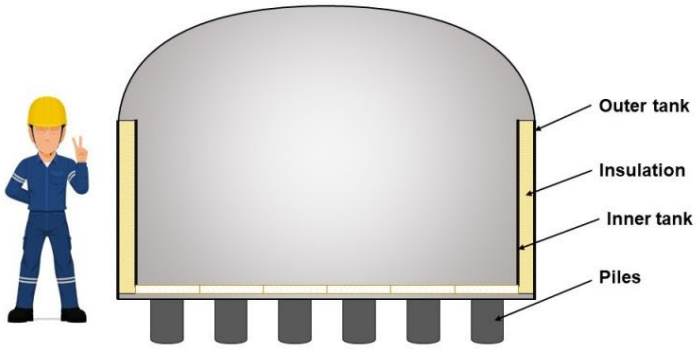
The main types of atmospheric tanks operating at -33°C are:

- Single-wall steel tanks with external insulation. Some of these tanks have concrete bunds surrounding the tank to contain the entire contents of the tank.

- Steel tanks with double walls and perlite insulation in between the walls are known as double-wall tanks or double containment tanks.



Single-wall Tank



Double-wall Tank (Double Containment)

There are two types of double-wall, double-integrity (DWDI) tanks: those with insulation in annular space and those with insulation on the outer tank

PERSONAL AND ENVIROMENTAL PRECAUTIONS

EMERGENCY EQUIPMENT

Loading/unloading area 	• A positive pressure breathing air supply to the control building in the direct vicinity of the loading/unloading station. • An ammonia gas detection system around the perimeter of the container. • A flow monitoring and shutdown system to detect excessive 'flow' caused by pipe or connection failure. • Dry drainage ditches and/or retaining tanks/bunds to contain spillages. • Fire hydrants at various locations in the area so that a water supply will always be available, irrespective of the wind direction.
Operator Training 	• General requirements for the carriage of dangerous goods, • Special requirements from RID for class 2 substances related to ammonia, • The properties of ammonia and the behaviour of the liquefied gas, • The consequences of improper handling of equipment and the hazards that may result from a leakage of either liquid or gaseous ammonia, • The action to be taken in the event of a spillage of ammonia, • The recognition of defects on a container, • The correct labelling of container transporting liquid ammonia, • The correct use of protective equipment, fire extinguishers and breathing equipment.

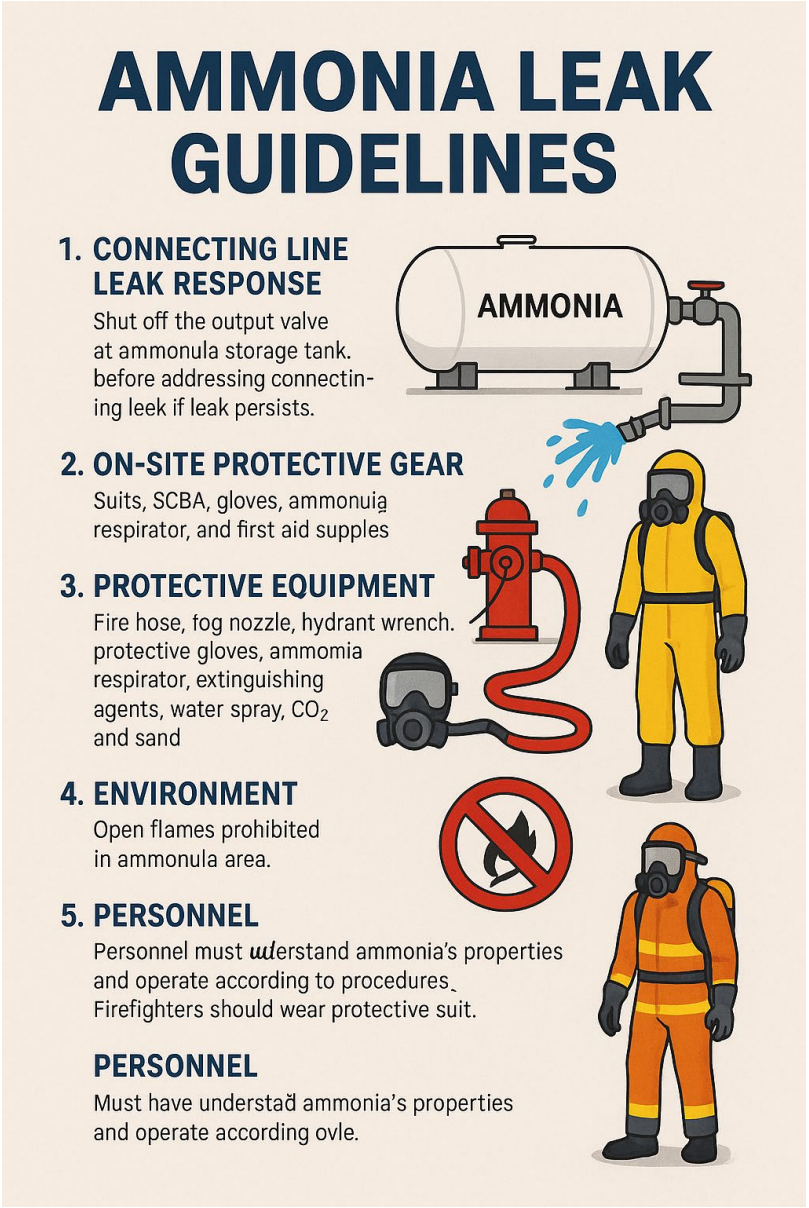
PERSONAL AND ENVIROMENTAL PRECAUTIONS

EMERGENCY EQUIPMENT

- A full chemical-resistant suit,
- Positive-pressure self-contained breathing apparatus (SCBA),
- Chemical-resistant gloves, and chemical-resistant boots.

For lower risk scenarios:

- A full-face respirator with an ammonia-specific cartridge.
- Never wear contact lenses, as they can trap the gas and cause severe eye damage.



PERSONAL AND ENVIROMENTAL PRECAUTIONS

EMERGENCY PROCEDURES

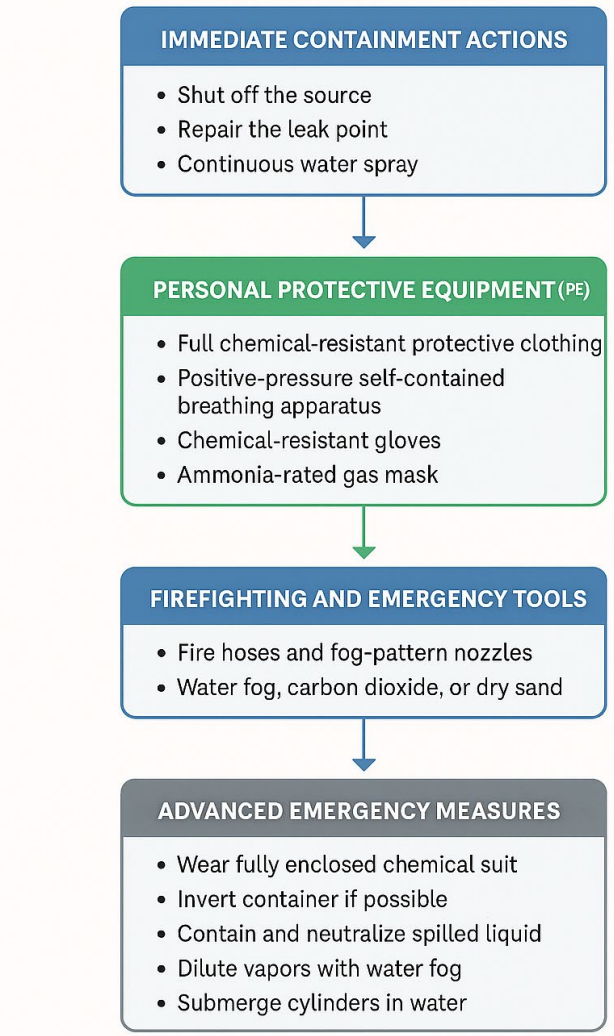
Spill or Leak
 
	• Evacuate and isolate area.
	• Wear SCBA (self-contained breathing apparatus).
	• Use water spray to absorb vapor— but not direct water jets on leaks.
	• Contain liquid to prevent environmental release (it is toxic to aquatic life).
	• Consideration to the evacuation of the population living downwind of the incident.
	• Warn population in the danger zone and advise to stay inside, close doors, windows and ventilations and to use wet towels to cover openings under doors and windows.
	• Limit the release by:
	  • Closing the leak opening with provisional measures,
	  • Repairing the leaking valve/flange connection,
	  • Transferring the ammonia to another container.

Fire 	• Use dry chemical (foams), CO_2 or water spray to cool containers (not to extinguish ammonia directly). • Use water sprays to cool fire-exposed containers and structures, to disperse vapours and to protect personnel. • Wear self-contained breathing apparatus and full protective clothing. • If safe, shut off supply; otherwise, allow controlled burning under supervision.

PERSONAL AND ENVIROMENTAL PRECAUTIONS

ENVIRONMENTAL AND WASTE CONSIDERATIONS

- Prevent ammonia discharge into drains or natural waters.
- Contain the spillage if possible.
- Remove any ignition sources.
- Consider covering the liquid pool with foam to reduce evaporation.
- Use water sprays to combat gas clouds. Do not apply water directly into large ammonia spills.
- Neutralize small quantities with dilute acid (sulfuric or phosphoric) before disposal.
- Follow local environmental regulations (e.g., EPA, OSHA, ISO 45001).



ACCIDENT EXAMPLES

1.-ACCIDENT INVOLVING AMMONIA OCCURRED IN DAKAR, 1992

- On Mar. 24, 1992, Senegal in Western Africa experienced its worst industrial accident at a peanut oil processing facility near the Dakar port.
- Anhydrous ammonia, which was used to detoxify the product made at the facility, was stored in a portable tank commissioned in 1983 and repaired via welding in 1991.
- The weld repairs were made on cracks detected on the tank's surface.
- An overpressure inside the tank led to its catastrophic failure, releasing 22 t of pressurized ammonia.
- The debris from the tank explosion pierced process equipment containing liquid ammonia under pressure.
- A two-phase flow of ammonia fluid (vapor plus liquid as a fine aerosol) formed a dense vapor cloud and spread over a significant distance, resulting in injuries and fatalities.
- 41 people died immediately, and many others were hospitalised.
- Ultimately, the incident caused 129 fatalities and 1,150 injuries.
- Most of the injuries and fatalities resulted from inhalation of ammonia at concentrations that caused respiratory lesions, edema in the lungs, and skin/eye irritation.
- Near the release location, many fatalities resulted from direct skin exposure, cold burns and inhalation of high concentrations of ammonia.

ACCIDENT EXAMPLES

1.-ACCIDENT INVOLVING AMMONIA OCCURRED IN DAKAR, 1992

- A root cause analysis of the Dakar accident shows that multiple causal factors (related to design, operation, hazards management, etc.) were behind the incident.
- One primary cause (**overfilling**) is apparent and has resulted in and continues to cause numerous incidents worldwide.
- Overfilling of high-pressure compressed (or liquified) gases can result in overpressure and loss of containment.

$$Filling\ Ratio = (8.5\times10^{-4})\, d_g\, P_h \qquad (1)$$

where dg is the gas density (at 15°C and 1 bar) in kg/m3 and Ph is the minimum test pressure in bar

Table 1. Ammonia receptacles should not exceed maximum filling ratios *(12)*.

Receptacles	Maximum Allowable Working Pressure, bar	Minimum Test Pressure, bar	Maximum Filling Ratio
Cylinders, drums	---	29	0.54
Portable tanks	20–29	---	0.53
Tanks	---	26–29	0.53

ACCIDENT EXAMPLES

1.-ACCIDENT INVOLVING AMMONIA OCCURRED IN DAKAR, 1992

The main learnings from the Dakar accident highlight the need to:

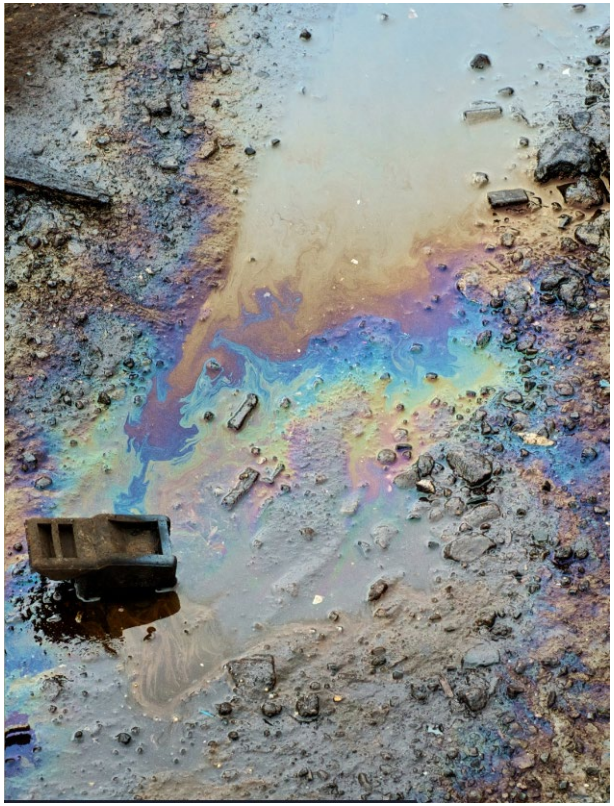
- ensure an understanding of the hazards of anhydrous ammonia under pressure,
- properly design fail-safe equipment and their appropriate utilization in production, transportation and handling,
- train operators and emergency responders on possible abnormal situations
- conduct frequent hazard reviews, audits, and assessments aimed at minimizing process risk.



ACCIDENT EXAMPLES

2.-ILLINOIS CRASH INVOLVING TRUCK CARRYING AMMONIA, 2023

- At about 9:25 p.m. local time, authorities were notified about a crash on the highway involving multiple vehicles, including a semi-truck that was leaking anhydrous ammonia.
- Five people died and parts of an Illinois neighbourhood were evacuated due to the crash.
- The truck was carrying about 7,500 gallons (28.4 m^3) of ammonia at the time of the wreck and more than half of that – about 4,000 gallons (15 m^3) – were released.
- Firefighters, police and other emergency responders tried to contain the cloud of ammonia leaking from the overturned tanker.



Many Thanks

QUESTIONS?

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