Training Course
Ammonia Refrigeration
R717/NH_3

Citation

- Ammonia is found on earth exactly like water in a natural form. Whereas water is generally praised for it's purity and essential properties, Ammonia with it's conspicuous and unpleasant odour is generally connected with rottenness and decay....

Anders Lindborg
Executive Safety Senior
Refrigeration Expert of Frigoscandia AB

Ammonia

putrid smell like rot and dung

Overview: Modules and Sections

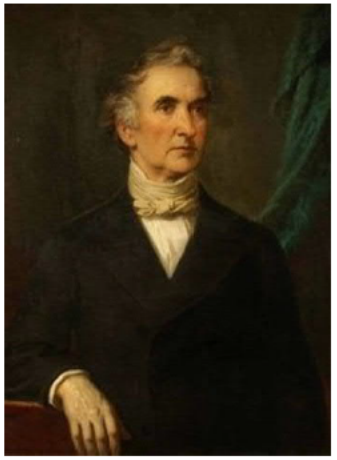
- History and importance of Ammonia
- Ammonia refrigerant issues
- European standards and regulations
- Ammonia application potential
- Design, Construction, PPM
- Safety issues
- First Aid
- Review of tools and equipment
- Commissioning and maintenance
- Mechanical integrity

History and importance of Ammonia

Ammonium chloride (NH_4Cl), a salt of ammonia, was already used in ancient Egypt.

In 1774 pure ammonia was produced for the first time by Joseph Priestley (English theologian, dissenting clergyman, natural philosopher, chemist, educational scientist…).

In 1840 the German chemist Justus von Liebig recognized the importance of mineral fertilizers, leading to ammonia becoming the base material for most fertilizers.

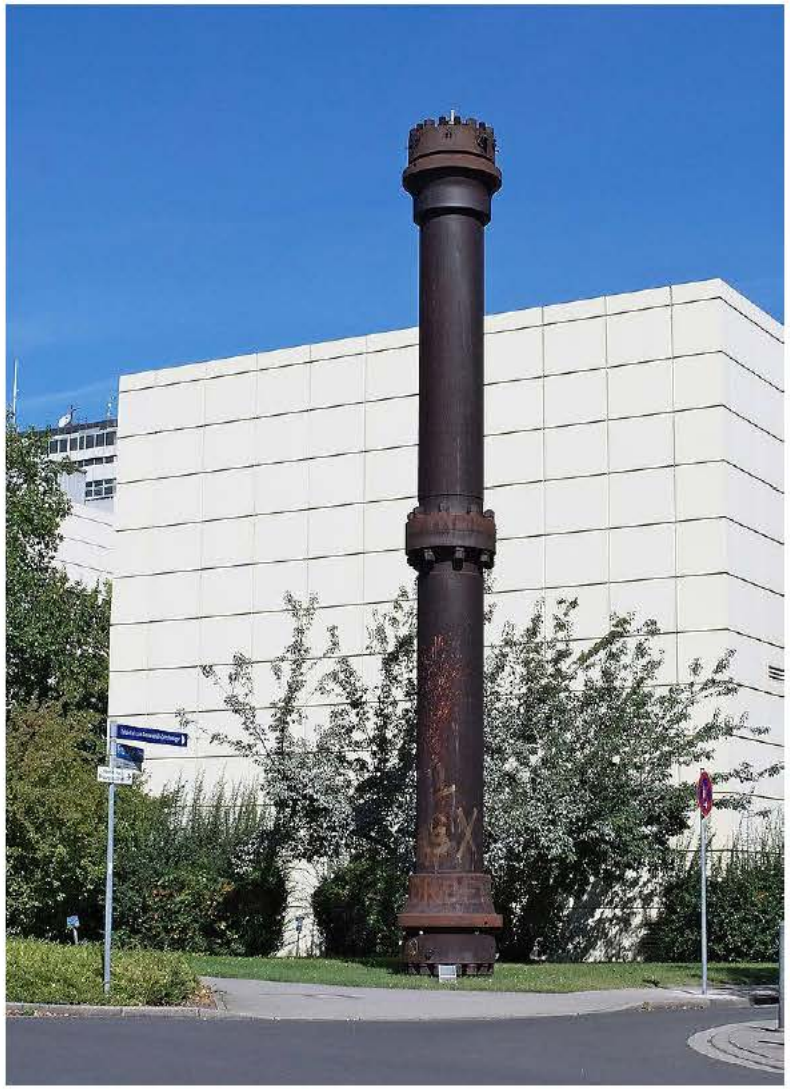


History and importance of Ammonia

In 1913 Fritz Haber and Carl Bosch succeeded in the first large-scale synthesis of ammonia from the elements.

Fritz Haber

Carl Bosch



High-pressure reactor (1921, BASF Ludwigshafen)
Re-erected at the University of Karlsruhe KIT, Germany

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History and importance of Ammonia

Agriculture

- As mineral fertilizer

Industry

- Ammonia is used as raw material for protective gas during gas-phase nitration of metal surfaces

Environmental protection

- Ammonia is used for denitrification or desulfurisation of exhaust fumes

Refrigeration technology

- Ammonia is used as natural refrigerant

Ammonia-fertilizer
(calcium ammonium nitrate)

Ammonia refrigerant cylinders

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http://www.uniongas-limited.com

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Ammonia refrigerant issues

The ammonia as refrigerant. Advantages and performance. Brief introduction.

- Ammonia is a common element, which exists naturally in the atmosphere.
- The refrigeration by ammonia is the most economic and energetically efficient method. It has got superior thermodynamic properties, that is the reason why the refrigeration by ammonia system has got a lower electrical energy consumption.
- It is environmentally friendly. It does not contribute neither to depletion of the ozone layer nor to the greenhouse effect.
- The characteristic scent of the ammonia is its greater safety quality. Leaks are detected easy and quickly. The sharp scent motivates the workers to leave the area, where a leak appears, before a dangerous concentration is accumulated.
- The cost of the ammonia is much lower that any other synthetic refrigerant. In general, its cost is 10 to 20% less in installation. Since ammonia is a natural product, it does not have any limit date to be used or to be produced unlike others synthetic refrigerants, whose use or production is limited to a certain amount of years.

Ammonia refrigerant issues

RAC Refrigerant purity grade

	NH_3, liquid, technically pure (weight %)	NH_3, liquid particularly cleaned (weight %)
NH_3 - content	≈ 99.1	≈ 99.98
H_2O - content	≈ 0.1	≈ 0.01
Residue of ignition	< 0.0001	< 0.0001
Oil - content	< 0.0005	n. n.
CL - content	< 0.0001	< 0.0001
S - content	< 0.0001	< 0.0001
Fe - content	< 0.0001	< 0.00005
Inert gas content	< 0.05	< 0.0014

(based on gaseous NH_3)

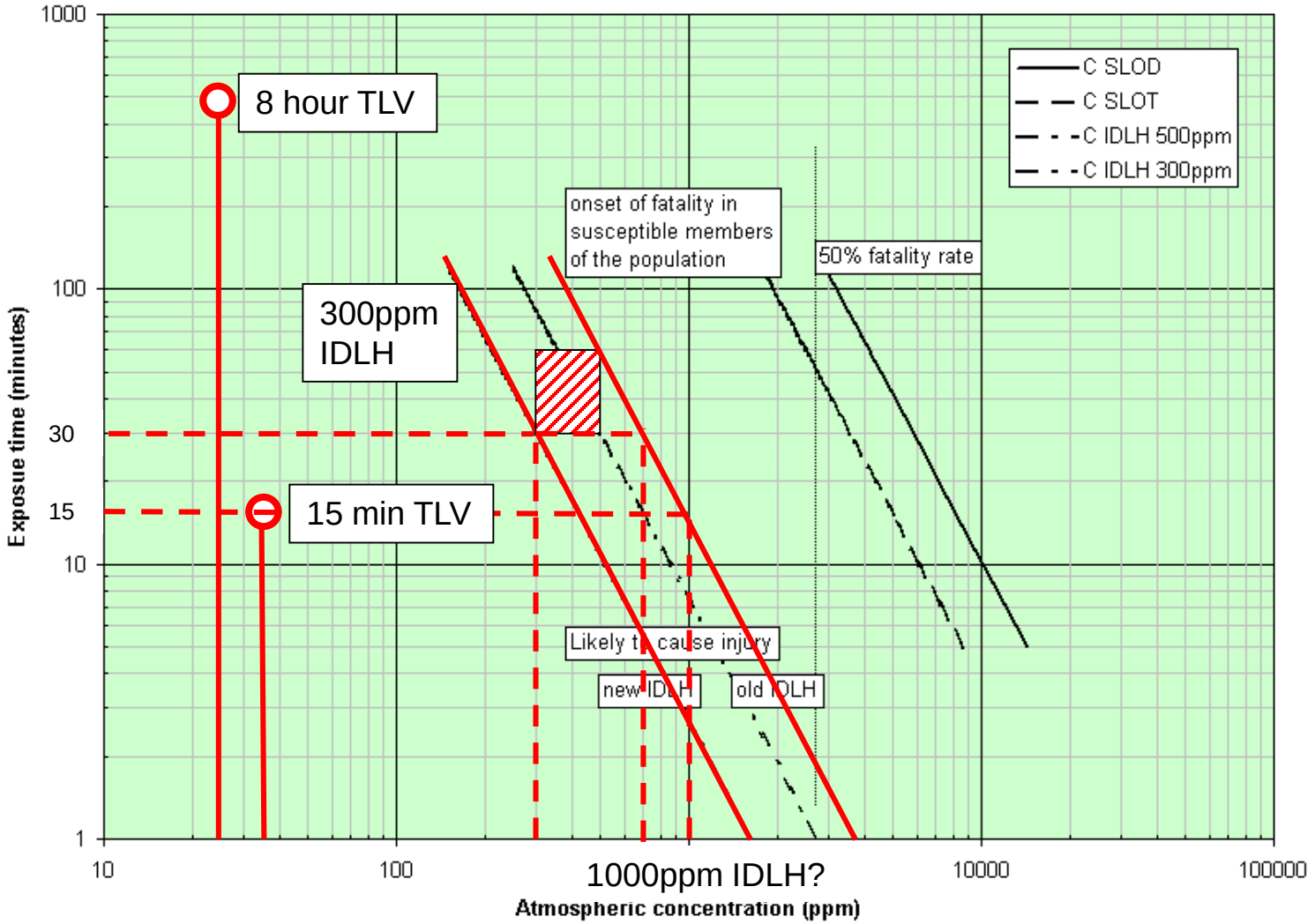
http://www.uniongas-limited.com

Ammonia refrigerant issues

Physiological properties NH_3

noticable limit	- 5 ppm
max. working place concentration	- 50 ppm
annoyance limit	- 250 ppm
hardly bearable limit	- 500-1000 ppm
poisoning appearance	- 2500 ppm
deadly concentration	- 5000 ppm
long term effect	- non carcinogenic, - non genotype harmful
content in human blood	- 0,8- 1,7 ppm
daily human production	- 17g= 1 mol

Ammonia refrigerant issues



* Henderson and Haggard (1943) cited in AIHA "Hygienic Guide Series" (1971)

General refrigerant classification

	Lower (chronic) toxicity		Higher (chronic) toxicity	
No flame propagation	**A1**	R22 R744 R134a R4010A R404	**B1**	R123 R245fa
Lower flammability	**A2L**	R32 R143a R1234yf R1234ze R444A/B	**B2L**	R717
Flammable	**A2**	R152a R142b R405A R411A R439A	**B2**	R30
Higher flammability	**A3**	R290 R600a R1270 R443A E170	**B3**	R1140

More onerous requirements

More onerous requirements

EN378-1 Annex E
AHRI 700
ISO817

Flammability and toxicity classification

- Refrigerants are classified according to their flammability and toxicity. "A" classification indicates low toxicity ("B" is high toxicity). The numbers 1,2 or 3 following the A or B indicate the degree of flammability.

- The safety classifications below are defined in ISO 817 used in ISO5149, AHRI700 and EN 378-1 Annex E (release 2017).

Flammability and toxicity classification

Note: In contrast to the previous version of EN378:2008/2012, **A2L** safety classification is included with the revisions of EN378:2015 (release in 2017), ISO817 and ISO5149.

Flammability and toxicity classification

Safety classification	Lower flammability level, % in air by volume	Heat of combustion J/kg	Flame propagation
A1	No flame propagation when tested at 60°C and 1013 mbar (101.3 kPa)		
A2 lower flammability	> 3.5	< 19,000	Exhibit flame propagation when tested at 60°C and 1013 mbar (101.3 kPa)
A2L lower flammability	> 3.5	< 19,000	Exhibit flame propagation when tested at 60°C and 1013 mbar (101.3 kPa) and have a maximum burning velocity of ≤ 10 cm/s when tested at 23°C and 1013 mbar
A3 higher flammability	≤ 3.5	≥ 19,000	Exhibit flame propagation when tested at 60°C and 1013 mbar

General natural refrigerants characteristics

Lower Flammability & Toxic → Very high pressure → Higher Flammability

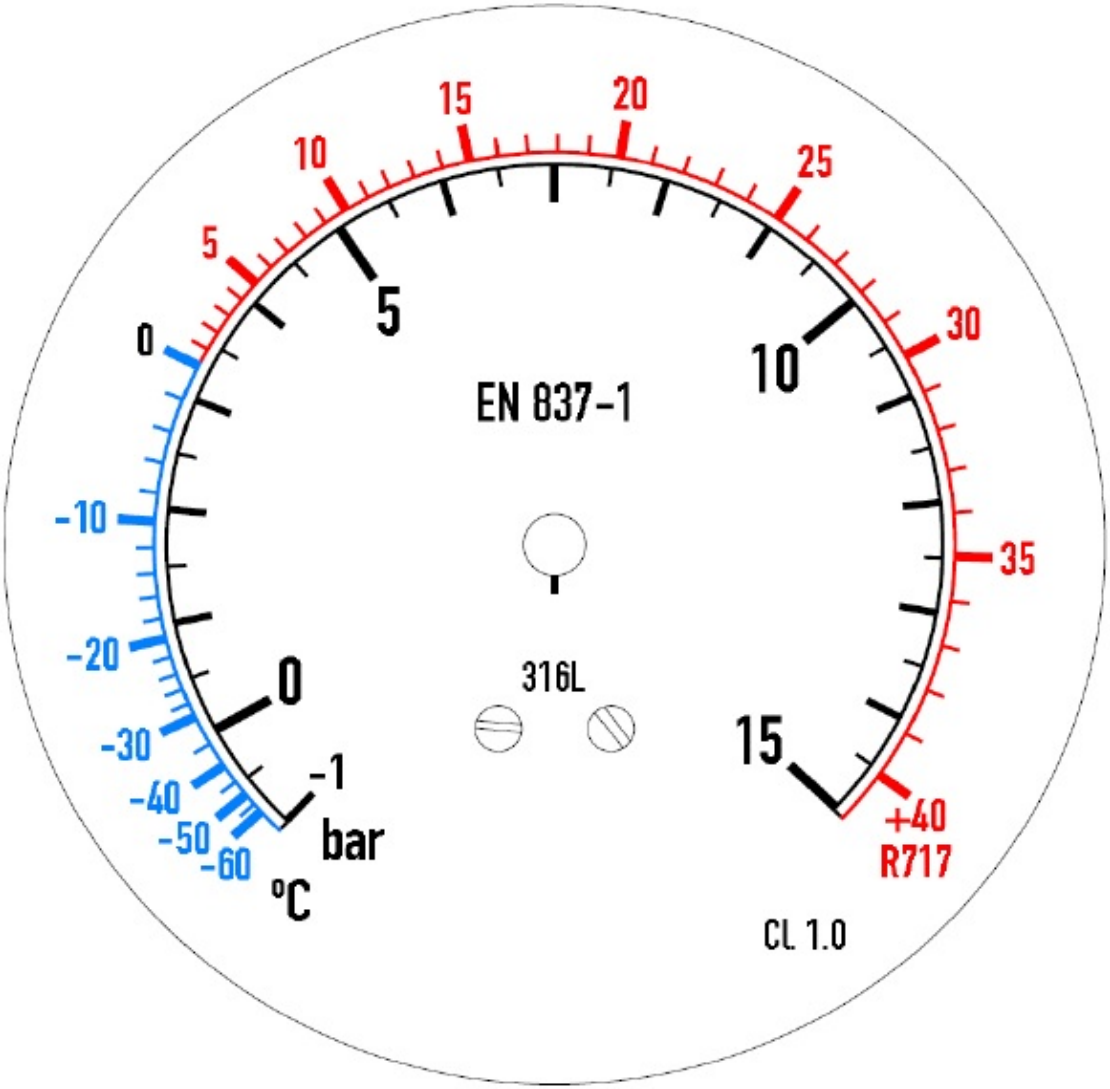
REFRIGERANT	REFRIGERANT NUMBER	CHEMICAL FORMULA	GWP (100 YEARS)	ODP	NORMAL BOILING POINT (°C)	CRITICAL TEMPERATURE (°C)	CRITICAL PRESSURE (BAR)	SAFETY GROUP	MOLECULAR WEIGHT (G/MOL)
Ammonia	R717	NH_3	0	0	-33.3	132.4	114.2	B2L	17.03
Carbon dioxide	R744	CO_2	1	0	-78	31.4	73.8	A1	44.0
Propane	R290	C_3H_8	3.3	0	-42.1	96.7	42.5	A3	44.10
Isobutane	R600a	C_4H_{10}	4	0	-11.8	134.7	36.48	A3	58.12
Propylene	R1270	C_3H_6	1.8	0	-48	91	46.1	A3	42.08
Water	R718	H_2O	0	0	100	373.9	217.7	A1	18.0
Air	R729	-	0	0	-192.97	-	-	-	28.97

Ammonia refrigerant issues

Refrigeration properties NH_3

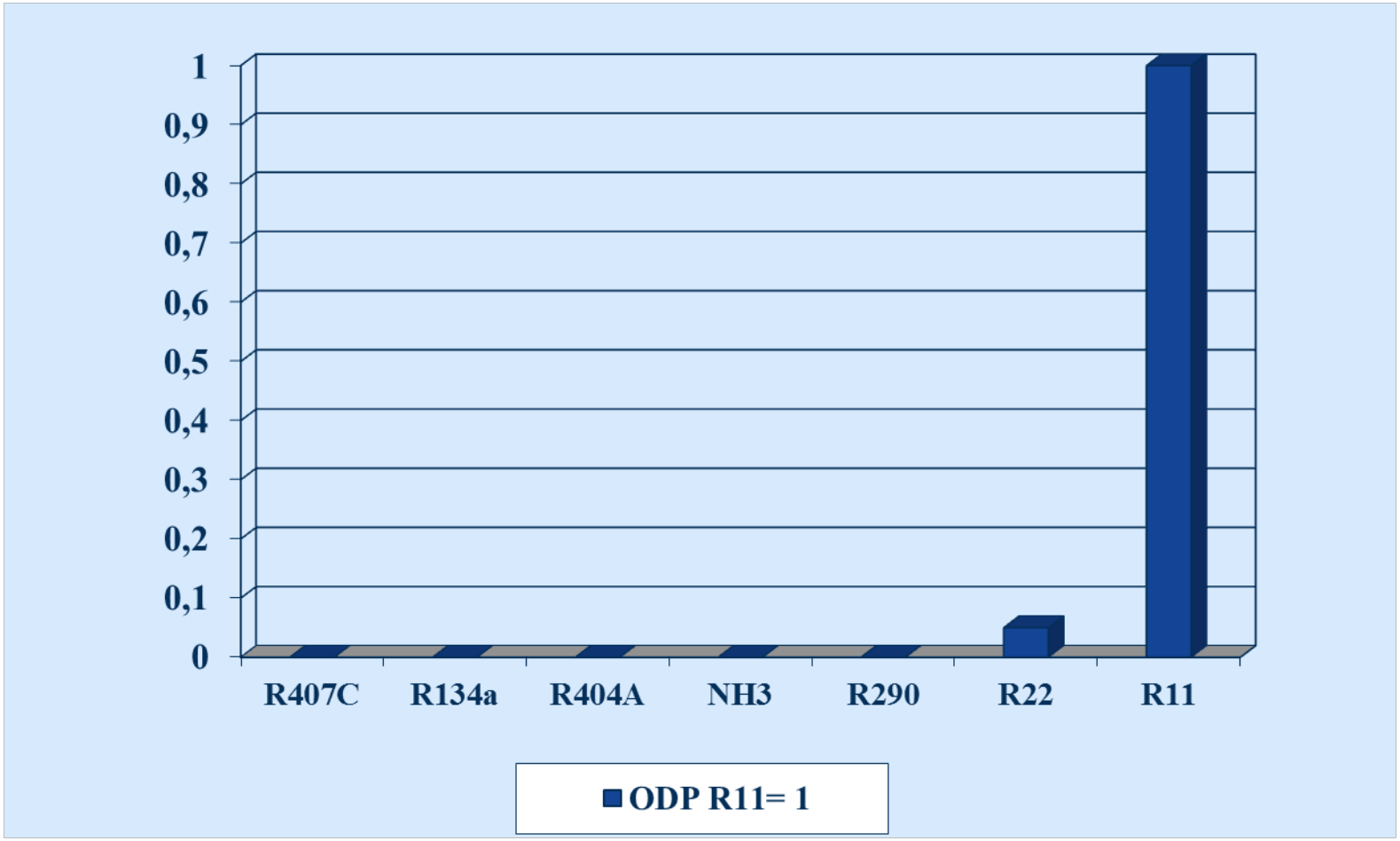
evaporation enthalpy 0 °C	1262 KJ/KG
pressure at 0 °C	4,9 bar
pressure ratio 0/35 °C	3,15
volumetric refrigerating capacity	3800 KJ/m^3
c.o.p isentrop 0/35 °C	6,77
dischargetemperature isentrop 0/35°C	81 °C
volumetric refrigerating capacity of R134a	2000 kJ/m^3

Gauge pressure values



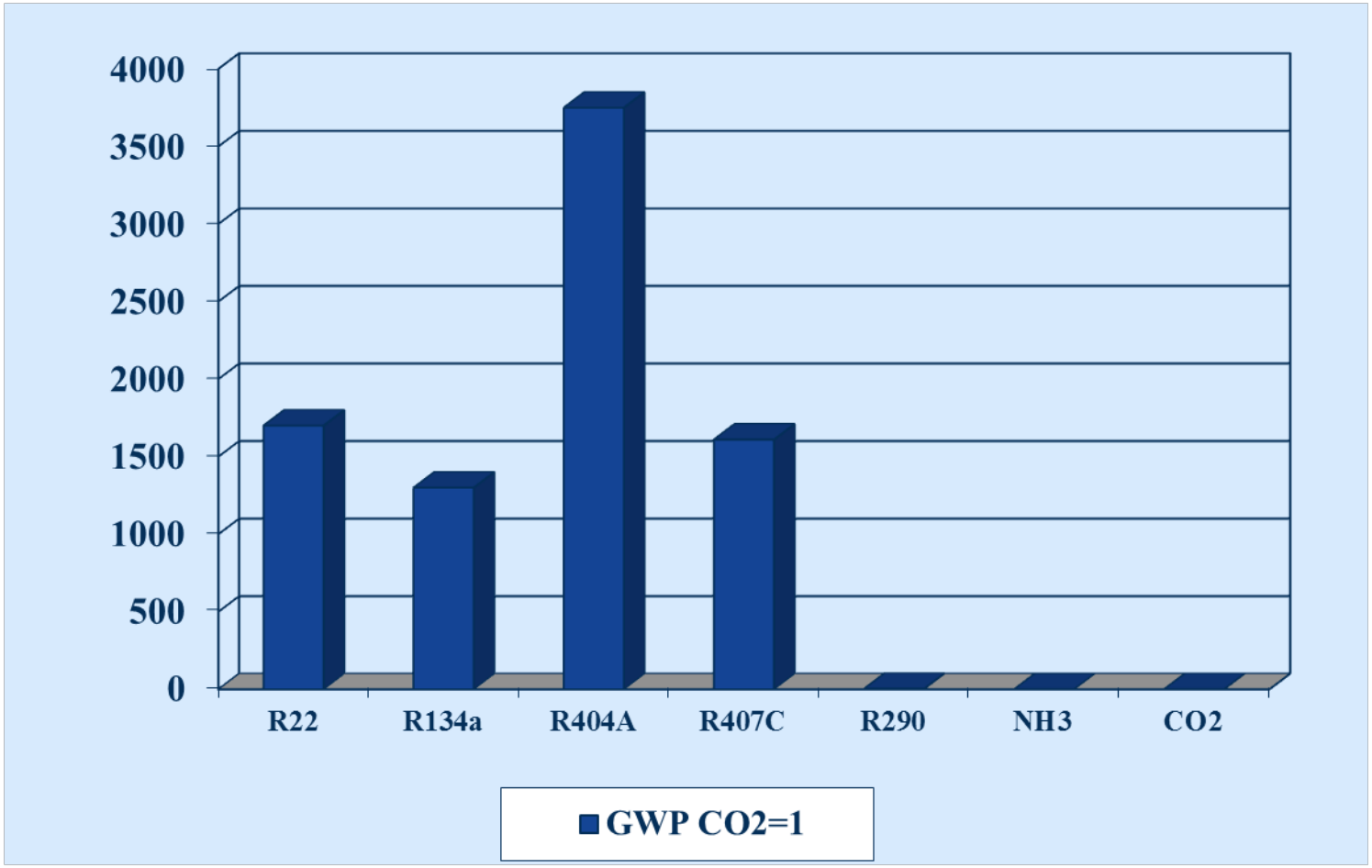
Ammonia refrigerant issues

Ozone Depletion Potential

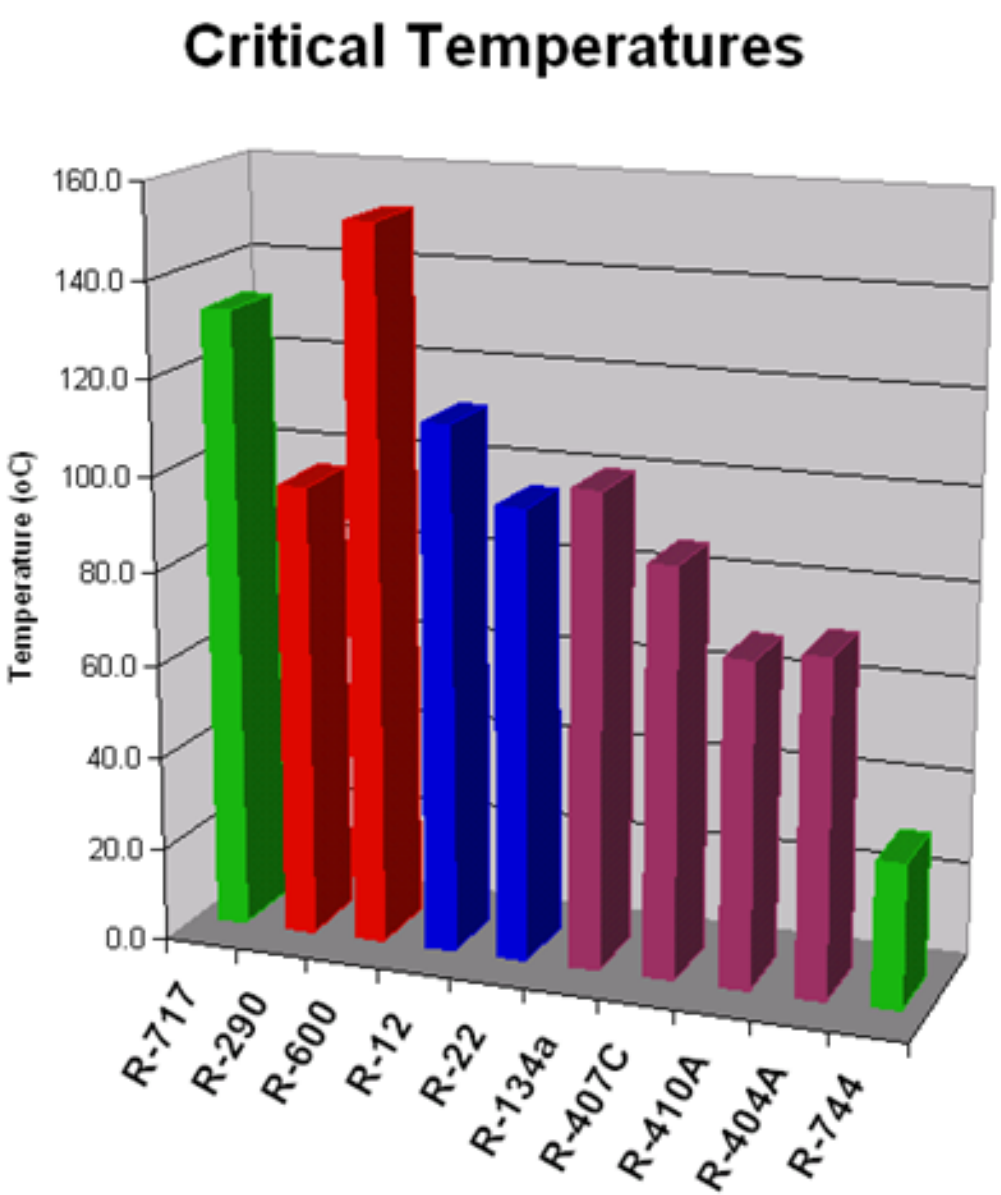


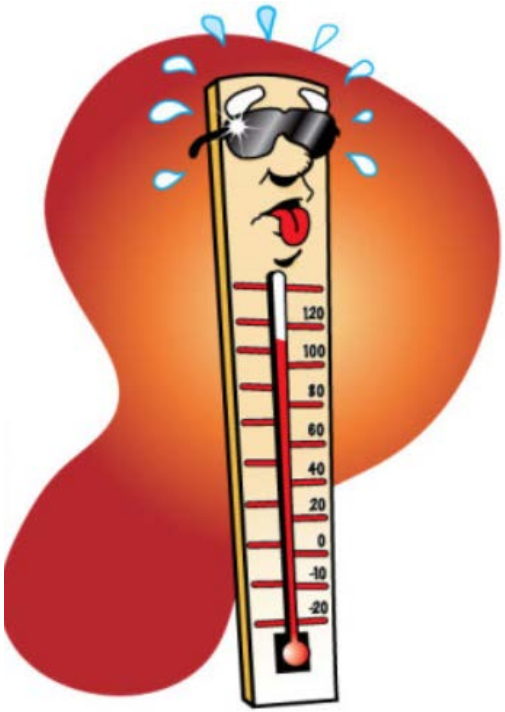
Ammonia refrigerant issues

Global Warming Potential



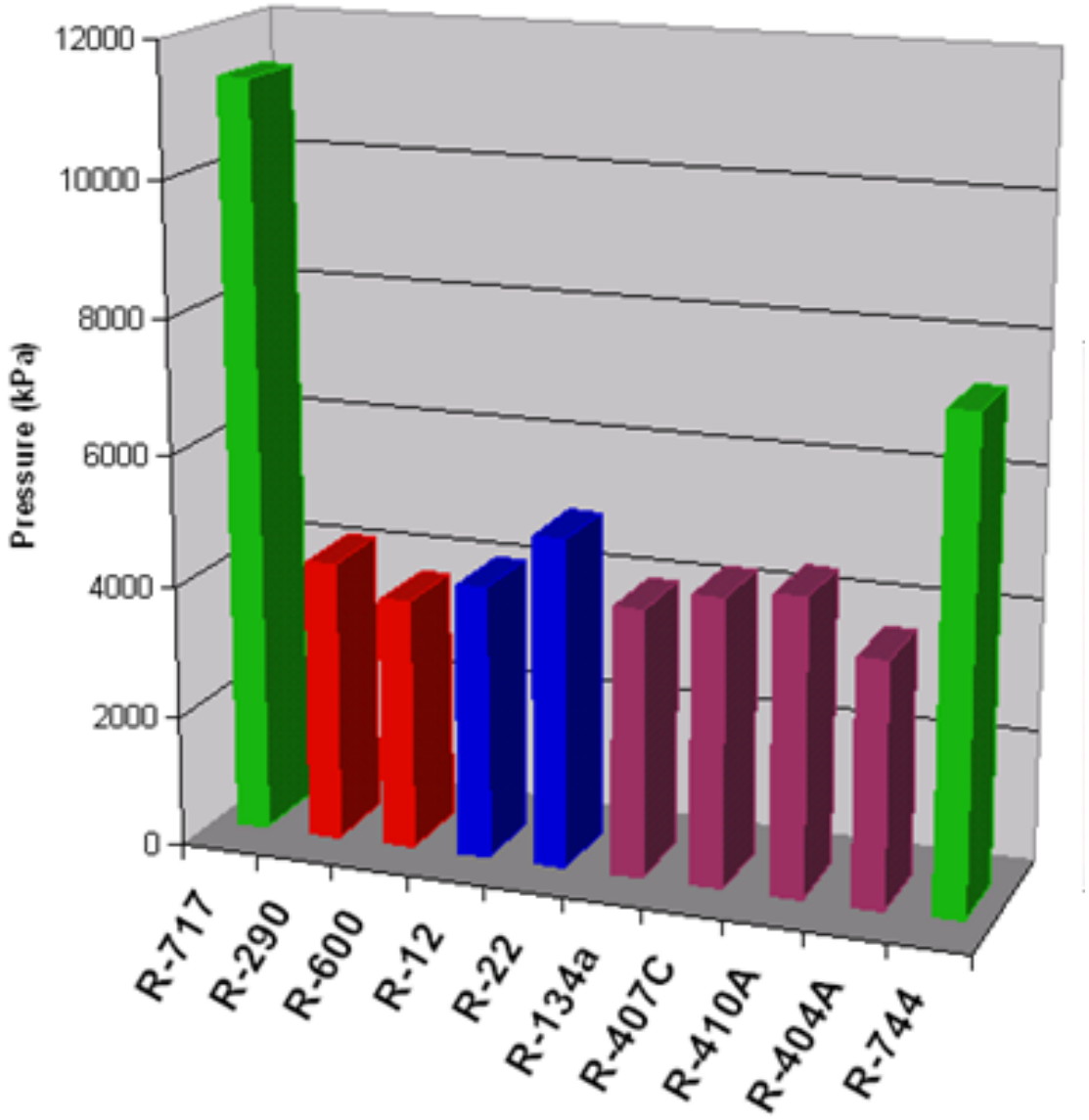
Ammonia refrigerant issues





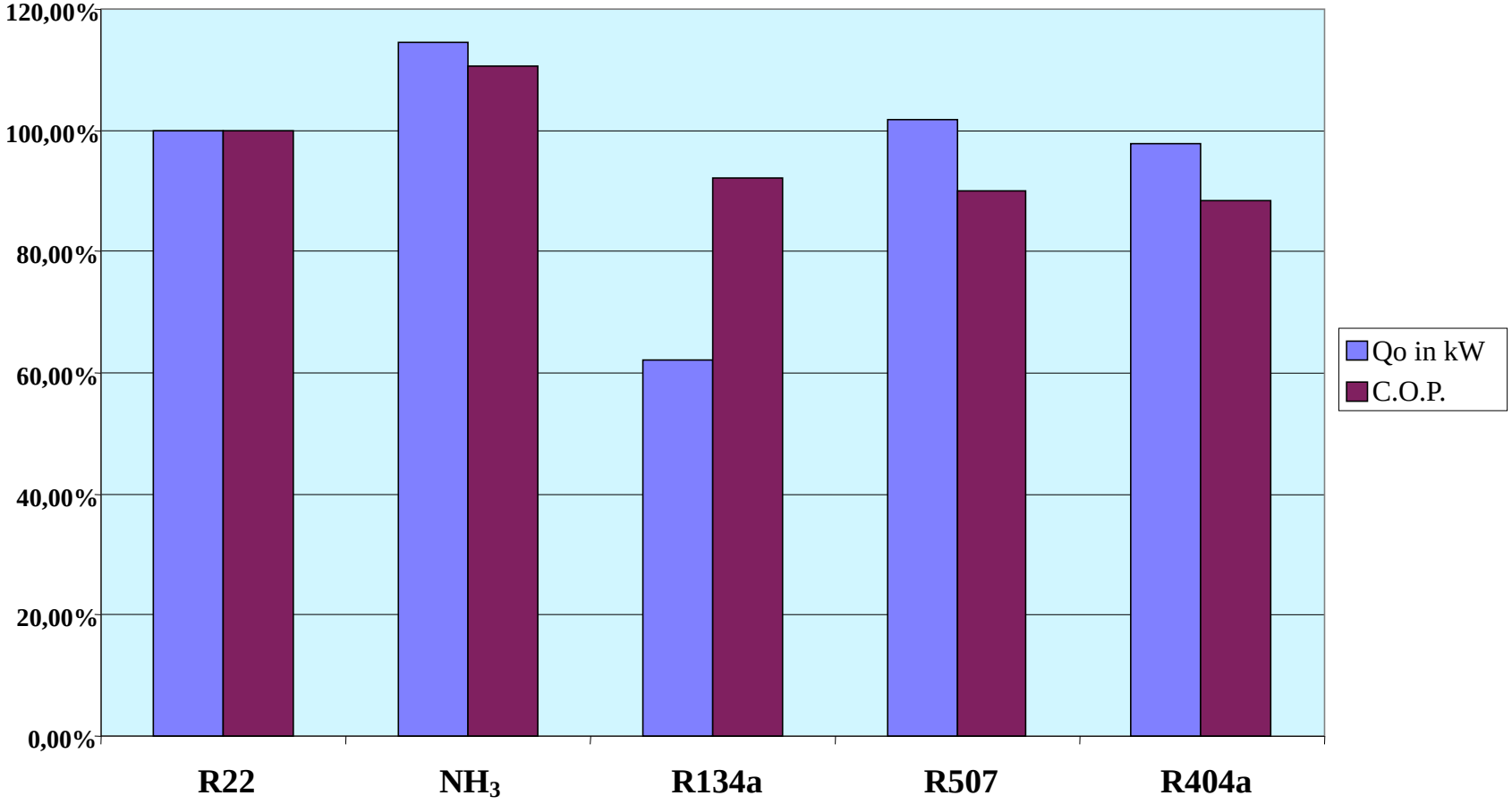
Ammonia refrigerant issues

Critical Pressure



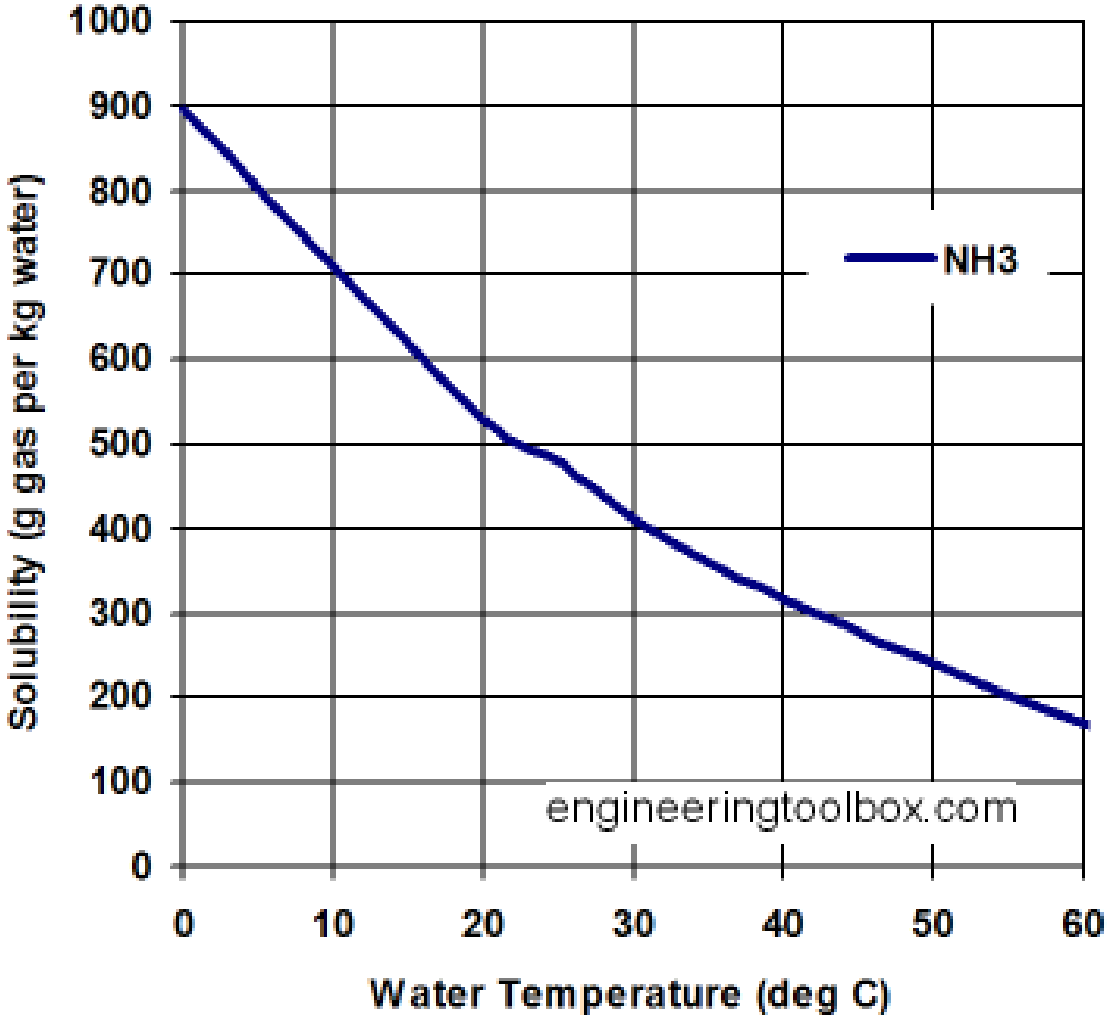
Capacity and Performance

Comparison of refrigerants with a Grasso screw compressor Grasso type S (Vth=1290m³/h)
Operating conditions To=0 °C, Tc=40 °C

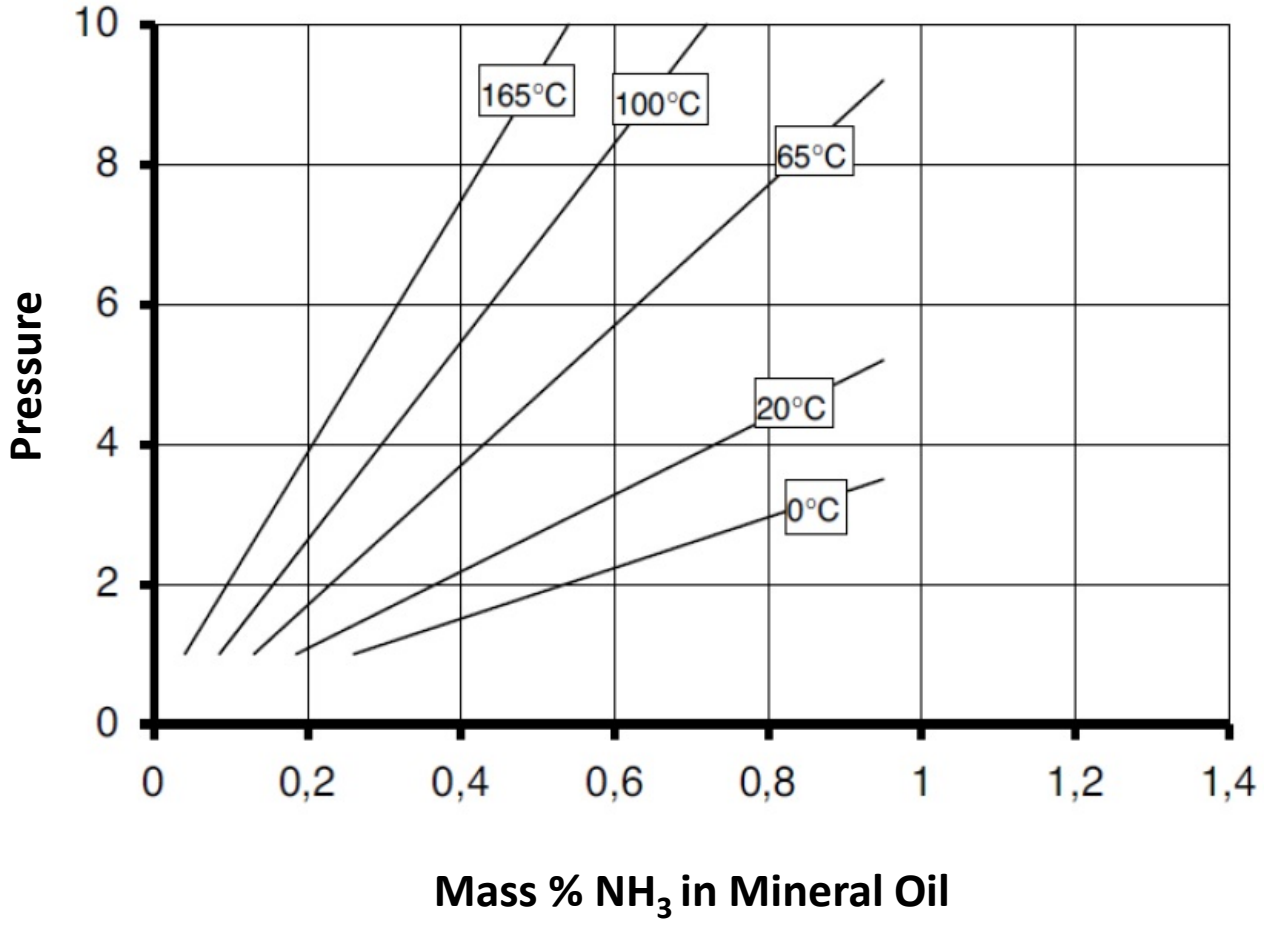


Ammonia refrigerant issues

Solubility of NH_3 in H_2O



Solubility of NH_3 in Mineral oil



Ammonia refrigerant issues

Ammonia R 717 > Conclusions

Ammonia is safe if it is used correctly

It is easy to use, and reliable in operation

It offers exceptionally good efficiency

The two key drivers for increased adoption are:

- Reduced charge systems
- Enlightened regulation

Incentive will come from:

- Training and familiarity
- Technical Development
- Economies of Scale

Ammonia R 717 > Conclusions

- Group B2L lower flammable 16% to 25%.
- Excellent thermodynamic properties.
- High latent heat-content. The highest C.O.P.
- Lighter that the air.(1,7 times).
- Easily absorbent in the water. (520 ltr of NH3 in 1000 ltr water at 20ºC.).
- Easy location of leaks. (it is detected in concentrations of 5 p.p.m).
- Reduced cost price.
- Environmentally friendly. (ODP=0, GWP=0, minimum TEWI).
- Biodegradable (Life in atmosphere 7-14 days).
- 120 years of experience. Very few accidents.

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European Standards and Regulations

Important Rules, Regulations, Laws

- DGUV rule 100-500 > prevention of accidents
- PED European pressure equipment directive
- BlmSCHG protection against emissions
- WHG - Water household law
- DIN 2405 Pipelines in refrigerating systems and cooling equipment - MarkingEN 378 Part 1 to 4 (new release early 2017)
- (old) DIN 8975 safety regulations replaced by EN378 (part 2&3)

European Standards and Regulations

Design Considerations: Recommendations

Purchaser:

- Specify EN378 as minimum design
- Mandate detectors and alarms in unoccupied areas
- Prohibit automatic plant room ventilation

Designer/Installer:

- Ensure compliance with EN378 parts 2 and 3
- Design for minimum charge
- Design for lifetime operation and efficiency

Operator:

- Ensure that the plant is designed for maintenance
- Conduct a HAZOP before the design is finished (hazard and operability study)

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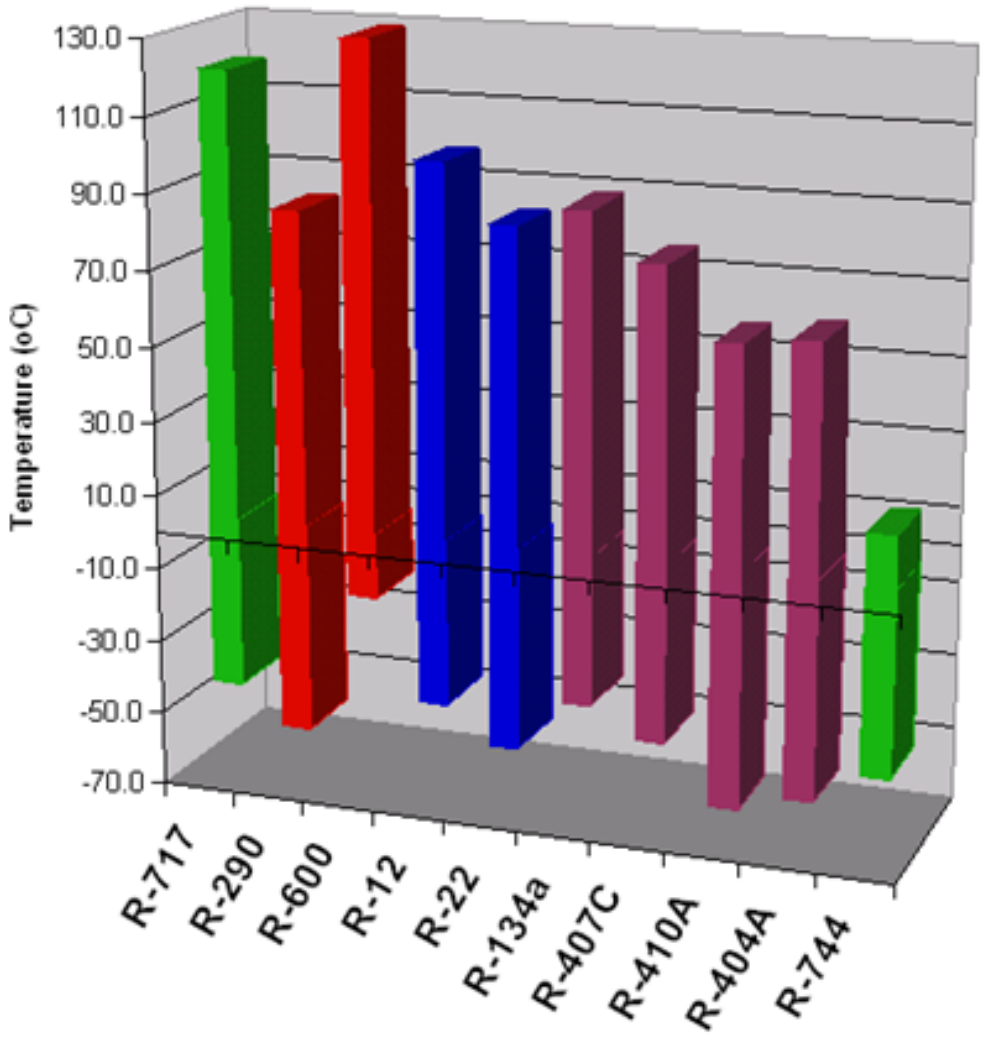
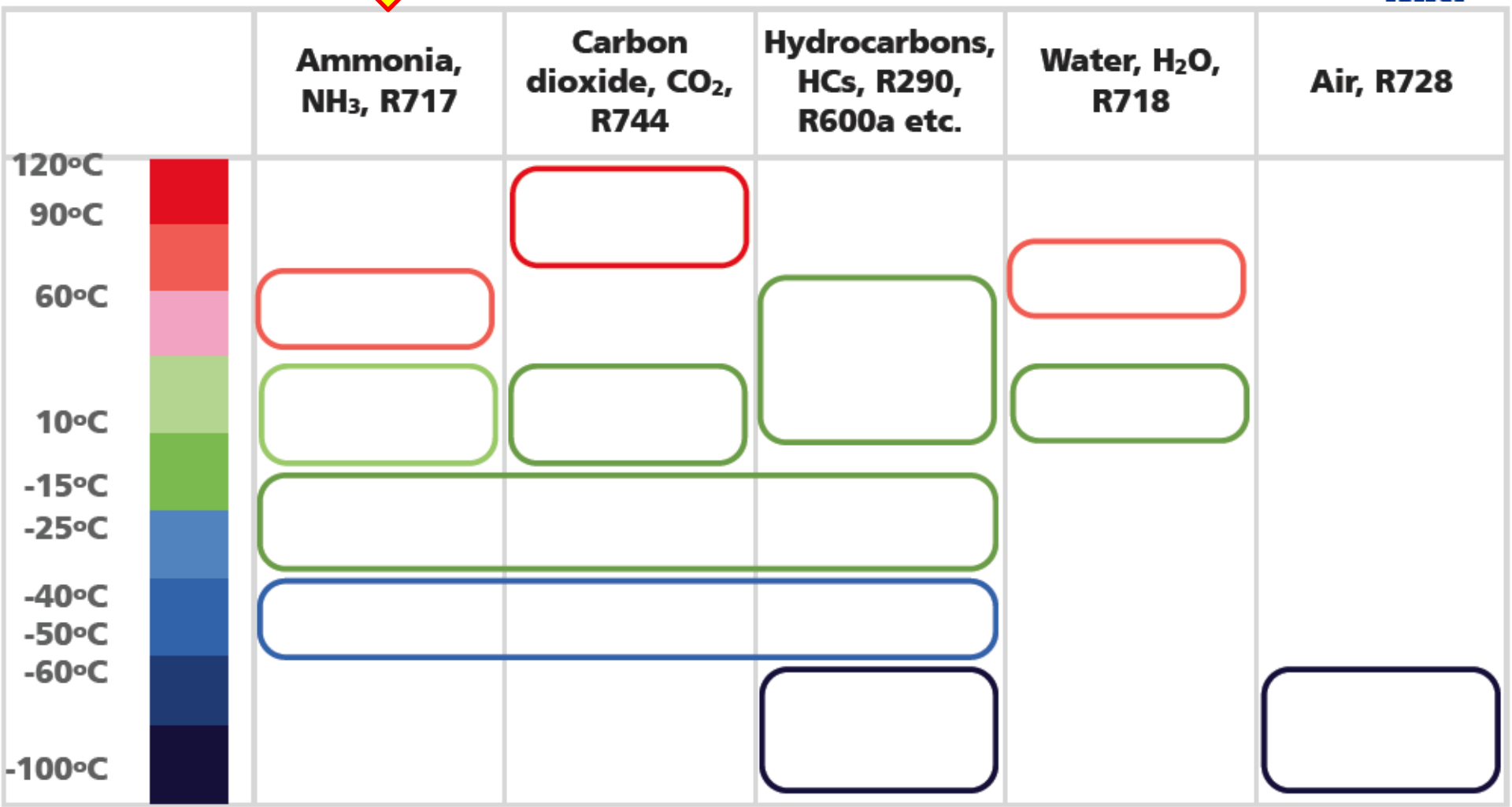
Ammonia Application Potential



- High Temp Heat Pump
- District Heating
- Process Heating
- Air cooled chiller
- Water cooled chiller
- Process chiller
- Ice rink
- Cold Store
- Air Blast Freezer
- Spiral Freezer

Potentials of Natural Refrigerants RHPAC Applic.



RHPAC = Refrigeration, Heat Pumps, Air- Conditioning

Source: adapted from Mayekawa, 2012

Ammonia Application Potential

First commercial use in mid- 1850s. Today, 90% of NH_3 use is in developed countries, 40% of NH_3 in developing countries

- Industrial food processing, storage and chemical processes
- Cascade systems for supermarkets (NH_3/CO_2)
- Chillers for air- conditioning (chilled water)
- Marine refrigeration
- Indoor ski-loops and ice-skating areas
- Deep mining AC systems

Ammonia Chiller AC Installation / Basement Public Building

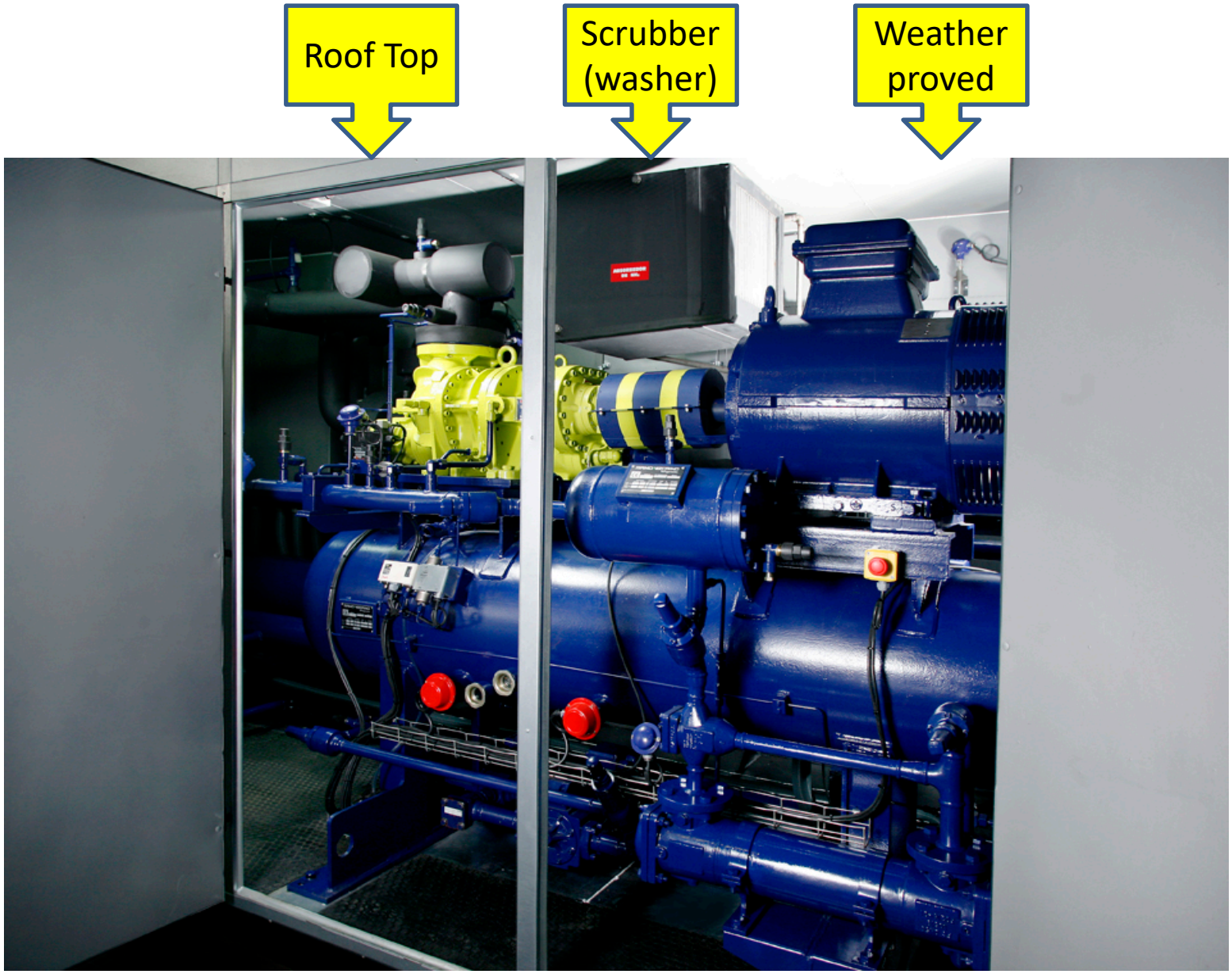
Ammonia Application Potential

Ammonia as chiller fluid

- Factory tested
- Guaranteed performance
- Plug and play
- Good turndown
- Compact Design
- Low charge
- Low noise levels
- Efficient fans
- Long-life package

Ammonia Application Potential

Ammonia Application Potential



Ammonia Application Potential

Training NH_3 Cascade

with CO_2

MT / LT Cold Stores

CO_2 Transcritical

Ammonia machine room design example

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Design – Construction - PPM

Provisions & protection equipment. Extractors, detectors, showers, etc.

The safety regulations for refrigerating plants and installations in force, is the EN 378.

This standard states that:

- The machine room will be used exclusively to store the components of the refrigerating installation.
- Outside the machine room and near the front door, must be installed an emergency switch that allows stopping the refrigerating system.
- Inside each machine room, two portable ABC polyvalent powder extinguishers must be placed as minimum. One of them should be placed at the entrance of the room and the other one at the end.

Design – Construction - PPM

- It is necessary to place sign boards, forbidding non-authorized personnel the manipulation of the system.
- The doors of the machine room must be fitted with a quick opening system (anti-panic) and they must open towards outside.
- The doors have to be tight.
- Compressed air supply and generators and heating systems are not allowed to be exposed to refrigerant.
- Due to the high ammonia steams absorption capacity of the water, inside each machine room should have a water supply connection.
- The ammonia machine room must be fitted with a mechanical ventilation system, that has to be explosion proof if it keeps operating during a an ammonia leakage.

Design – Construction - PPM

- It is necessary to install a leak detector that activates the alarm and the forced ventilation at 500 ppm. The air with ammonia will be either led to a an air duct with an outlet far enough so not to hinder people or led to an ammonia neutralizing system.
- At 30.000 ppm the second alarm will be activated and automatically the refrigerating system will be disconnected.
- When a refrigerating system has an ammonia charge or any other refrigerant that can irritate the eyes or the skin, higher than 50 kg, an emergency shower (wash-eyes shower) will be installed

Design – Construction - PPM

Individual protection equipment. Masks, gloves, suits and autonomous breathing equipment.

- According to EN378 in ammonia installations with ammonia charge lower than 500 Kg., there must be two gasmasks.
- If the charge is over 500 Kg., it will be necessary to have two autonomous equipment and their watertight suits.
- The autonomous breathing equipment and the masks will be placed outside the machine room and at an easy-access site.
- It will be necessary to do the maintenance operations, indicated by the manufacturer, which must always be carried out by a specialized company.

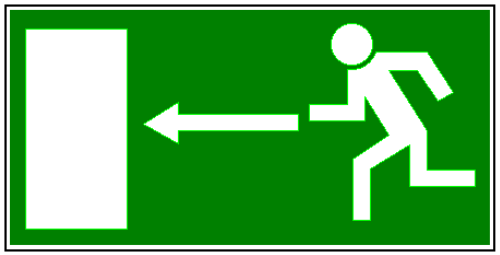
Design – Construction - PPM

Preventive measures / existing plant

- Check the location and the good state of the ammonia watertight suit if applicable.

- Check the location and the good state of the breathing equipment.

- Locate the evacuation ways.



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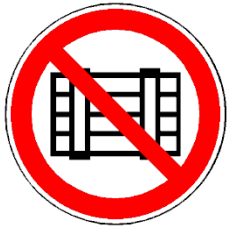
Safety Issues

Prohibitions

No smoking

No open flames / fire

Do not cross / walk through



No storage of materials / goods

Not for non-authorised persons

Safety Issues

Warnings

against the risk of explosion

against possible risk of fire

against the existence of toxic gas (NH_3)

existence of pressurised cylinders with NH_3

Commandments

Wear safety goggles and canister respirator mask

NH_3

Wear suitable working clothes and hard hat

Wear suitable working gloves

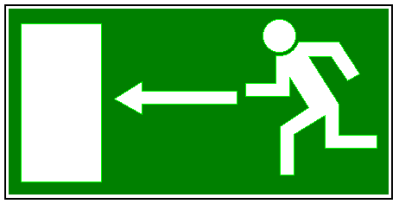
Wear ear protection

Disconnect from electrical mains when servicing

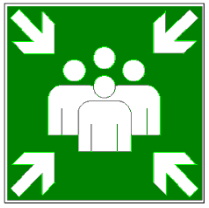
Safety Issues

First Aid

First aid station



escape / rescue way



People assembly point

Place of water shower

Place of eye shower / equipment

First aid / emergency telephone

Fire Protection

Place of fire extinguisher – CO_2 or powder

Place of fire hose – if applicable

Location sign

Fire fighting telephone

Overcoming Obstacles - Toxicity

Toxic effect greatly is related to substance dose (NH_3)!

Dose for ammonia exposure is a combination:

Concentration of ammonia in the atmosphere….

….and length of time the exposure lasts

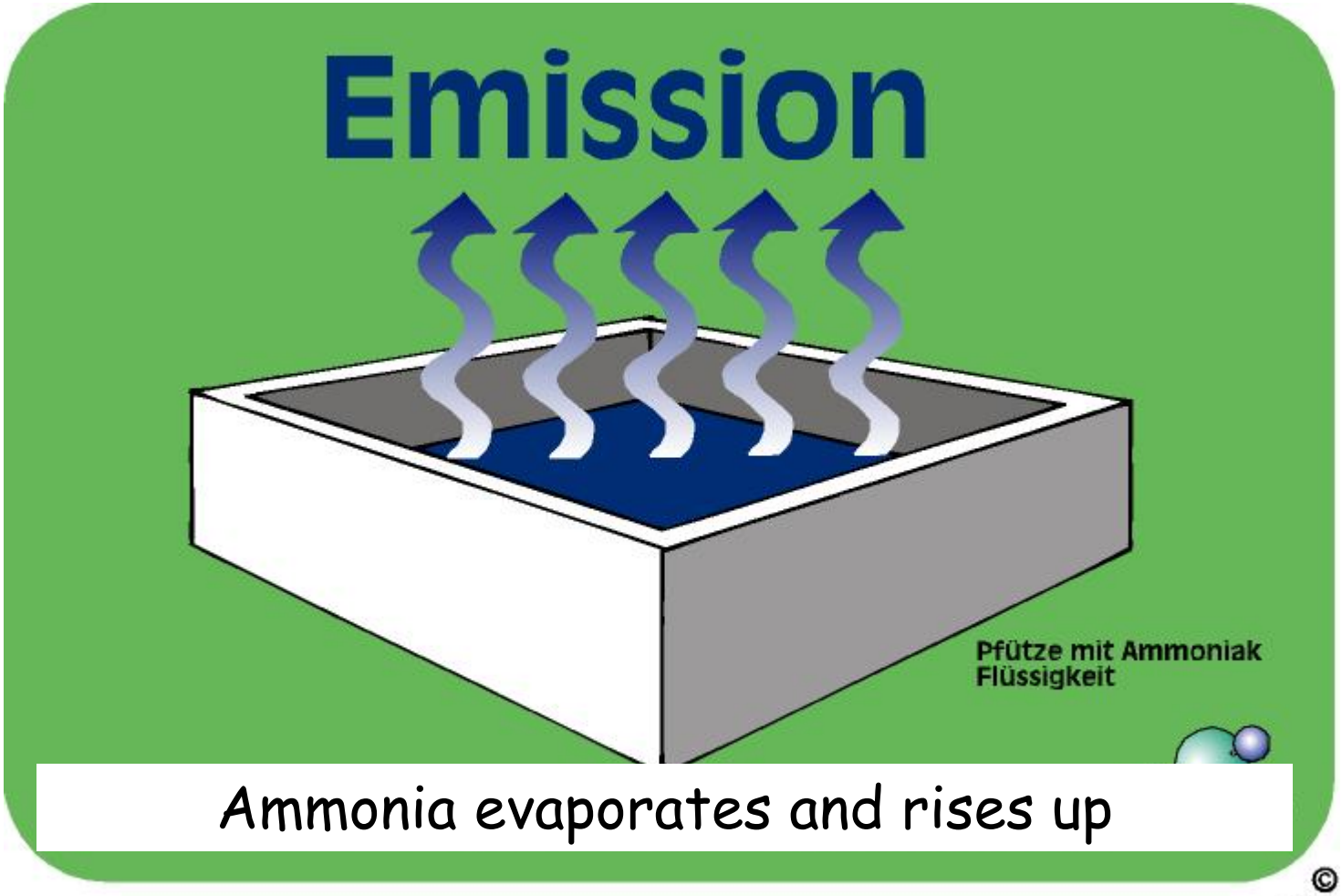
- In the short term, high doses can be tolerated:
- For example a dose of 5000ppm would likely be fatal after two hours exposure….
- ….but it is not likely to cause any injury if the exposure lasts for less than one minute

Nevertheless, great care is advised always if being in contact with Ammonia.

Effects of the ammonia on the human health. Liquid and gas states. Penetration routes.

- The ammonia, at normal temperatures and pressures, is a colourless gas, lighter than the air and with a characteristic scent. Its warning properties are considered as appropriate, before a serious damage takes place. The perception threshold varies and depends on the persons. In general, it is said that it is detectable from 5 ppm, easily detectable at 20 ppm and moderately strong at 100 ppm.
- Although it is a toxic substance, it is not cumulative.
- The combination ammonia-air is inflammable in concentrations from 16% to 25%.
- As it was mentioned before, the ammonia is in the installation in gaseous or liquid state.

Overcoming Obstacles - Toxicity

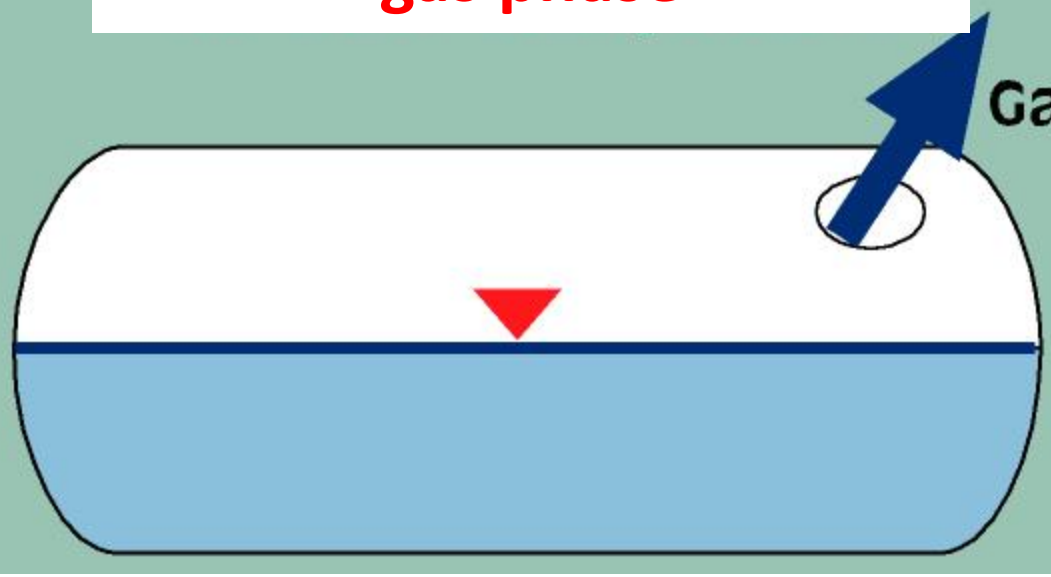


Gaseous state

- The ammonia in gaseous state reacts with the humidity, forming a caustic solution that, in high concentrations, irritates tissues.
- Air, with 50 ppm of ammonia, produces dryness in the nose and the throat.
- Air, with over 100 ppm, produces irritation of eyes and mucous membrane.
- A lengthy exposure to air with 400 ppm ammonia can cause the destruction of the mucous membrane.
- At 700 ppm, the irritation of the eyes is evident, being intolerable at greater concentrations.
- At 1.720, a convulsive cough appears.
- Over 2.500 ppm, during 30 minutes, can cause a pulmonary oedema.
- Over 15.000 ppm, there will be skin damages owing to the caustic solution which has been generated by the ammonia and the skin humidity (sweating).

Safety issues

Ammonia leakage in the gas phase



10 to 15 % of the vessel content escape until equilibrium is reached (pressure equalisation)

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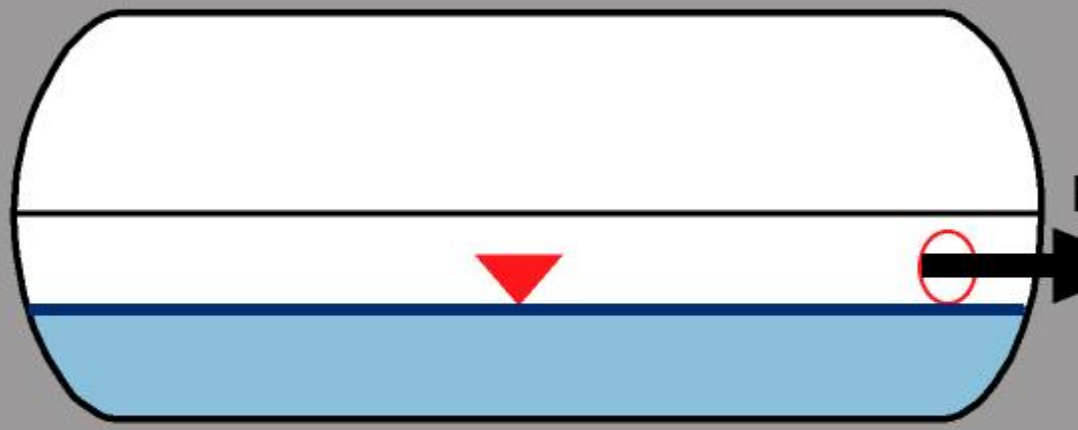
Liquid state

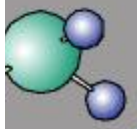
- The most serious danger is the damage in the eyes. If the eyes make contact with the ammonia, the result can be permanent damages or even the blindness.
- In contact with the skin and since it is an irritate and corrosive product, the ammonia will produce the destruction of the tissues with formation of blisters and chemical burns.
- In addition, thermal burns by freezing can be produced.

Safety issues

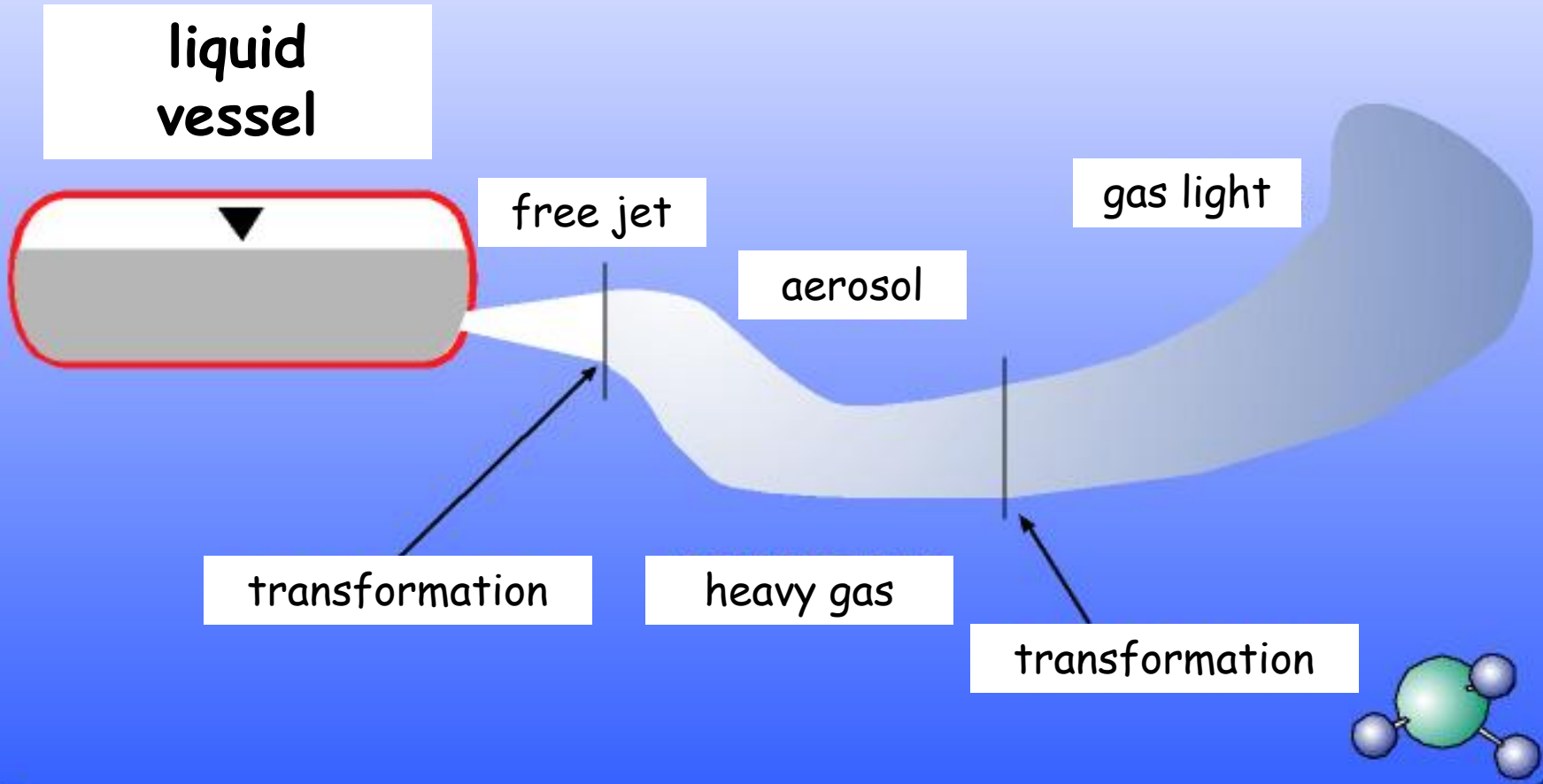
Ammonia leakage in the liquid phase



Loss of Ammonia up to the level of the leakage spot. In addition 10% “wet steam” until equilibrium is reached (pressure equalisation)



Ammonia liquid leakage



Overcoming Obstacles - Toxicity

Accidents occur when the rules are not followed, so make the rules easier to follow!

Do not impose excessive constraints or restrictions; too much PPE can cause accidents!

- Always make sure that you work together with colleague(s)
- Always have a canister respirator mask at hand when opening a system
- Wear the respirator when the ammonia smell is “strong”
- If in doubt, retreat!
- Only trained experts should use SCBA

(Self Contained Breathing Apparatus)

Gasmasks

- The gasmasks will be used together with a special filter for ammonia. This filter is easily recognizable since it **always has a green colour sticker** and the code 87K (K2P2).
- It is important to keep correctly the mask and the filters after their use, in order to avoid scratching the crystal or plugging the filter.
- Wear the mask by using the adjustment strips, so that it is totally watertight. It can not be used with glasses.
- To check its watertight, place the hand on the filter inlet and breath. The air CAN NOT enter.

Gasmasks

- Please check always expiry date of the filters before use
- Opened filter cartridges must be used within 6 month
- Breakthrough time at NH_3 concentration of 5000 ppm is 40 minutes
- With higher concentrations (above 5000 ppm) and longer exposure time Self Contained Breathing Apparatus must be used
- Respiratory protection devices are LIVE-SAVER







Suit and gloves

- As it was mentioned before, the ammonia has an effect on the humid zones and the skin, that is the reason why it is important to protect the hands and the body.
- In situations of low risk, the use of mask and nitrile rubber gloves will be correct.
- When the situation can cause a greater leak, it will be necessary to wear the mask and the chemical protection suit.
- In situations, when the use of the autonomous breathing equipment is necessary, the use of the watertight suit will be always required.

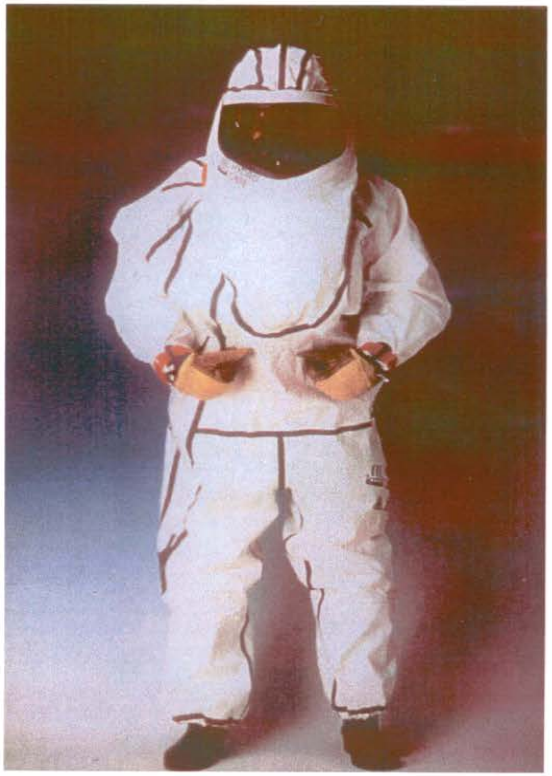
Safety issues

Protective suit with ammonia concentration < 5.000 ppm

260

Safety issues

Protective suit for ammonia concentration
> 5.000 ppm, Temp. min < -50°C



Autonomous breathing equipment

It is an individual protection equipment, used for the protection of the respiratory tract during the work in contaminated atmospheres and/or in areas with lack of oxygen.

Pressure checking

- Take the pressure gauge. It will be at zero, without pressure.

- Open the valve a little, turning it smoothly.
- With the valve of the bottle in "open" position, check that the pressure gauge indicates 200 kg/cm2.

- Depressurize the unit, by using of the drain valve.

Wear of the individual protection equipment

How to place the bottle or cylinder

- Place the bottle in inverted position at your back, that means, that the valve must be downwards.
- Make sure that the bottle is firmly tight to the body by using the harness of waist and the braces.

Wear of the mask

- Do not work with prescription glasses.
- Place and lean your chin at the bottom part of the mask.
- With both hands, cover your face with the mask and place the rubber bands around your head.
- It is important to secure first the superior band.
- Throw backwards of the two ropes, located at temples level, until noticing that the mask adjusts to the face.

Connection of the cylinder and the mask

- Coil the hose to the mask, as if it were the ammonia filter.
- Open the valve to allow the air to enter inside the mask.
- Take one first deep breath, in order to open the demand valve. Breathe calmly.

Alarm

- An audible alarm will be activated when the air pressure goes to **50 pressure bars.** Leave the zone immediately.

End of the mask carrying situation

- Disconnect the automatic regulator, separating it from the mask.
- Take the mask off.
- Close the valve of the equipment bottle, and press the sweeping button to purge the unit.
- Loosen the strips of shoulders.
- Take the equipment off. Do not throw it abruptly.
- After being used, the equipment must be checked and recharged with air, never with oxygen.
- The autonomous breathing equipment are very sensible and need an appropriate maintenance.

Overview: Modules and Sections

- History and importance of Ammonia
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- First Aid
- Review of tools and equipment
- Commissioning and maintenance
- Mechanical integrity

First Aid (Generally al workers should have First-Aid training)

Eyes

The affected person must be immediately transferred to a non-contaminated zone or outdoors.

- Wash the eyes with abundant water during at least 15 or 20 minutes. It is important, that there is a wash-eyes shower outside the machine room. It is necessary to keep the eyes opened to make sure that the water is in contact with the ocular globe and the internal eyelid.
- The personnel who works in facilities of ammonia should not use contact lenses, since these can cause major damages because of their capacity to retain ammonia in the eye.
- Go as fast as possible to the hospital.

Eyes

The affected person must be immediately transferred to a non-contaminated zone or outdoors.

- Wash the eyes with abundant water during at least 15 or 20 minutes.

Inhalation

The affected person must be immediately transferred to a non-contaminated zone or outdoors.

- Place the affected person, lied down on his back, relaxed and covered with a blanket.
- Call a doctor, mainly if the victim is complaining of pain in the chest, or has pain when breathing or has a persistent cough.
- If he does not breath, do the artificial breathing.
- DO NOT GIVE liquids, person is unconscious.
- Go as fast as possible to the hospital.

Swallowing

The affected person must be immediately transferred to a non-contaminated zone or outdoors.

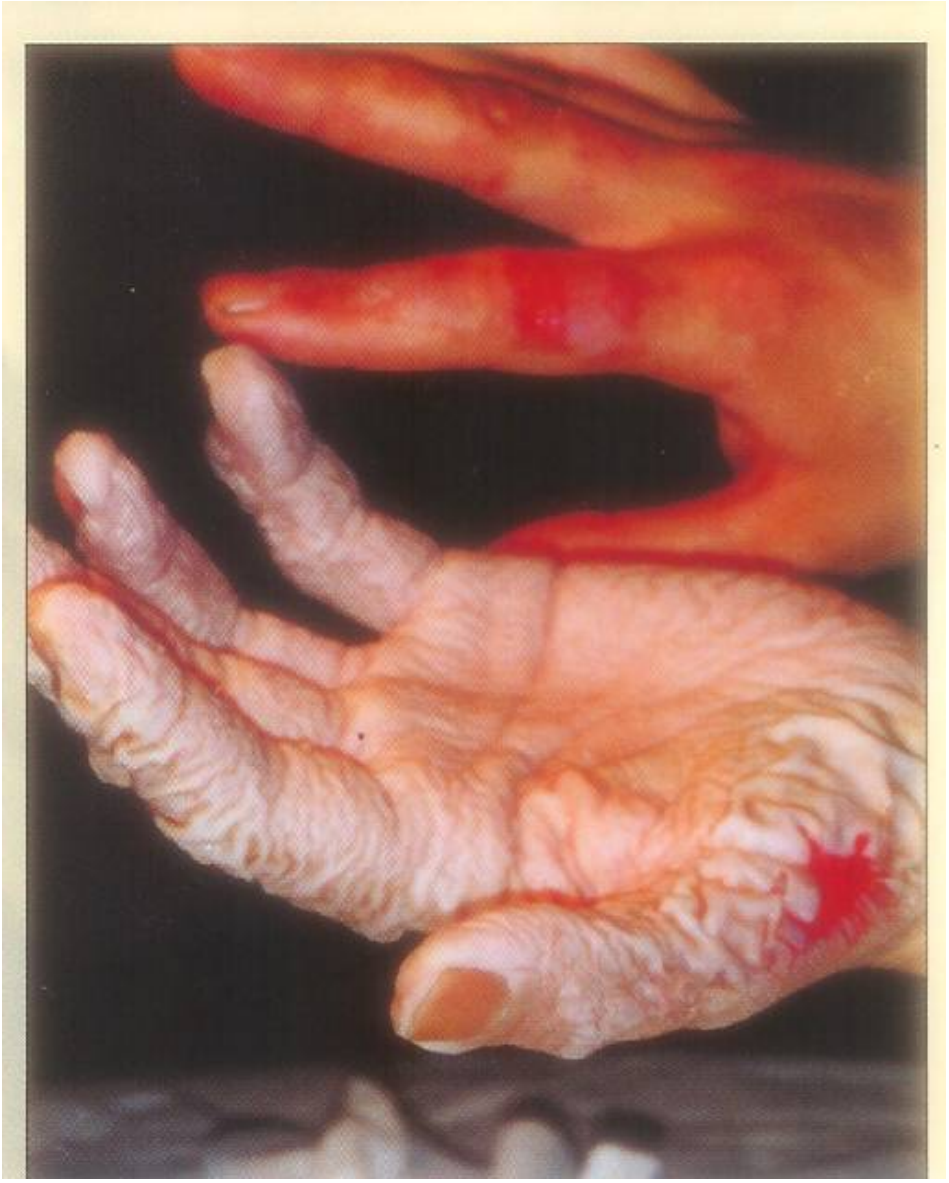
- If the victim is conscious, he must drink a lot of water.
- If he vomits, his head will be placed down, with this one more lower than the hips to avoid that the vomit enters the lungs.
- DO NOT GIVE liquids, if the person is unconscious.
- Go as fast as possible to a hospital.

Contact with the skin

Wash the skin with abundant water and carefully at least during 15 or 20 minutes.

- If there is a great affected surface, place the victim completely dressed in the shower. It is important, that there is an wash-eyes shower outside the machine room.
- Remove clothing carefully, after the shower, if they are already defrosted.
- Go as fast as possible to the hospital.
- Do not touch the humidity burns until arriving at the hospital.

First Aid



Liquid gas causes violation on technician unprotected skin

Think before acting

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Review of Tools and Equipment

Nitrogen cylinder and pressure regulator

- Leak and strength testing of the NH3 refrigerant circuit
- Circuit flushing
- Inertisation

Review of Tools and Equipment

R717 requires specific tools and equipment

- Equipment for the use with halogenated refrigerants are NOT for the use with AMMONIA R717 / NH3 !!!
- No brass or copper!

Recovery/recycling and charging machines

Review of Tools and Equipment

Special V-Pump for the use with
AMMONIA R717 / NH3 !!!

Vacuum pump

Recovery cylinder

Manifold gauge set

- A heavy duty manifold generall features a cast iron body and full size metal handles.
- Dual temperature/pressure R717 gauge bar with °C and psi with °F ammonia scales.
- Finger-tight one-piece valve stem for positive seal on nylon seat
- PTFE refrigerant hoses; working pressure max. 55 bar, bursting pressure 220 bar;

Vacuum pump

- Exemplarily: Vacuum pump for Ammonia refrigerant R717, two stage, 226,5 L/min (8 CFM) ultimate vacuum 1x10-2 mbar; vacuum pump supplied with oil separator filter; protection classification IP54; CE confirmation; 3/8” and ¼” SAE/UNF connection; Gas ballast valve; exhaust port with hose adapter (venting hose use)

Gas detector

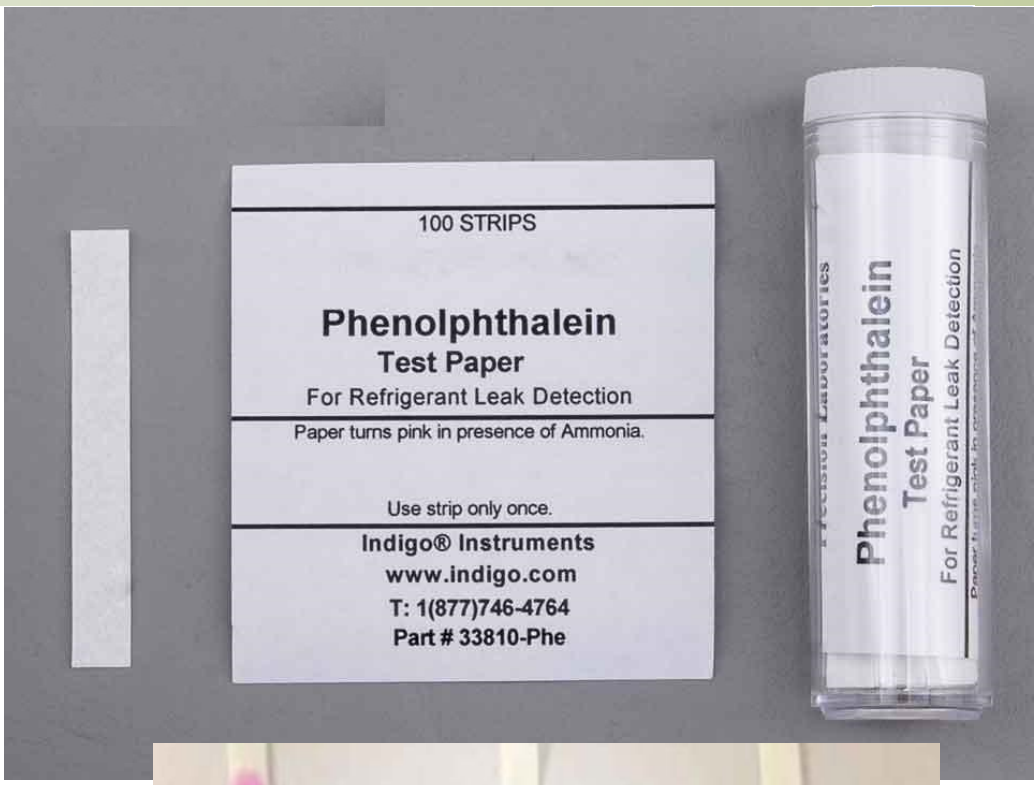
- Exemplarily: Combustible Gas detector (Leak finding instrument), sensitive to most combustible gases including NH_3. Variable audible signal as well as multiple LEDs to indicate leeks; automatic adjustment (zeroing) to combustible gas in leak test area for greater stability. CE confirmation; intrinsically safe for class I, Division I; Groups A-D; T4 and rated II 3G Ex nA nL IIC T4 X.

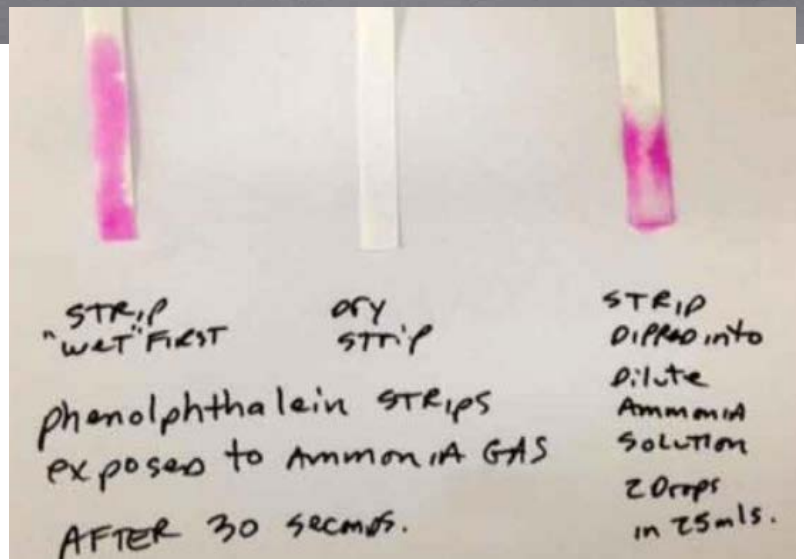
Review of Tools and Equipment

Gas detection stripes

- Exemplarily: Ammonia leak test stripes

- The image shows test strips infused with Phenolphtalein that change color in response to the alkaline pH of ammonia. Note that the strip on the left which shows the response was wetted with a drop of water while the one in the middle shows no change at all.





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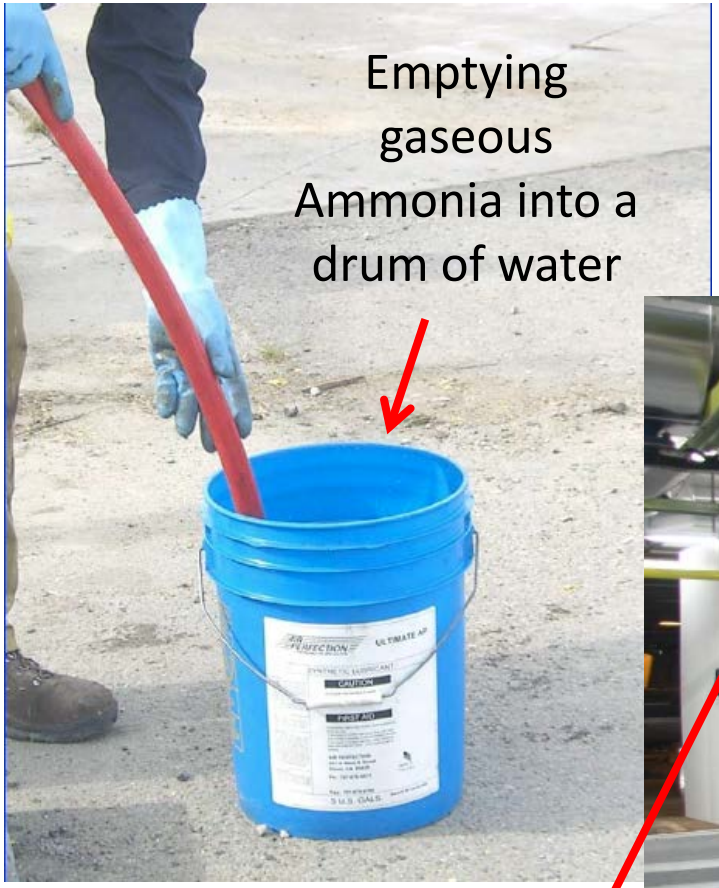
Ammonia charging

Ammonia charging is an operation that takes place during the start-up of the installation and, afterwards, during refilling of the refrigerant.

- Before the first charge with R717 the system must be evacuated to a deep vacuum (about 1000 micron) and then the ammonia must be charged generally trough the valve located in the liquid filter.
- If the refrigerant amount is not 100% charged, then close the valve before the liquid filter and start the compressor.
- During this process keep the compressor at his minimum capacity (10%) and check continuously the low pressure gauge (it may not drop under 0 bar).
- The same procedure applies in case of refill.

Commissioning, Maintenance

Bubbling ammonia vapours and neutralisation with water

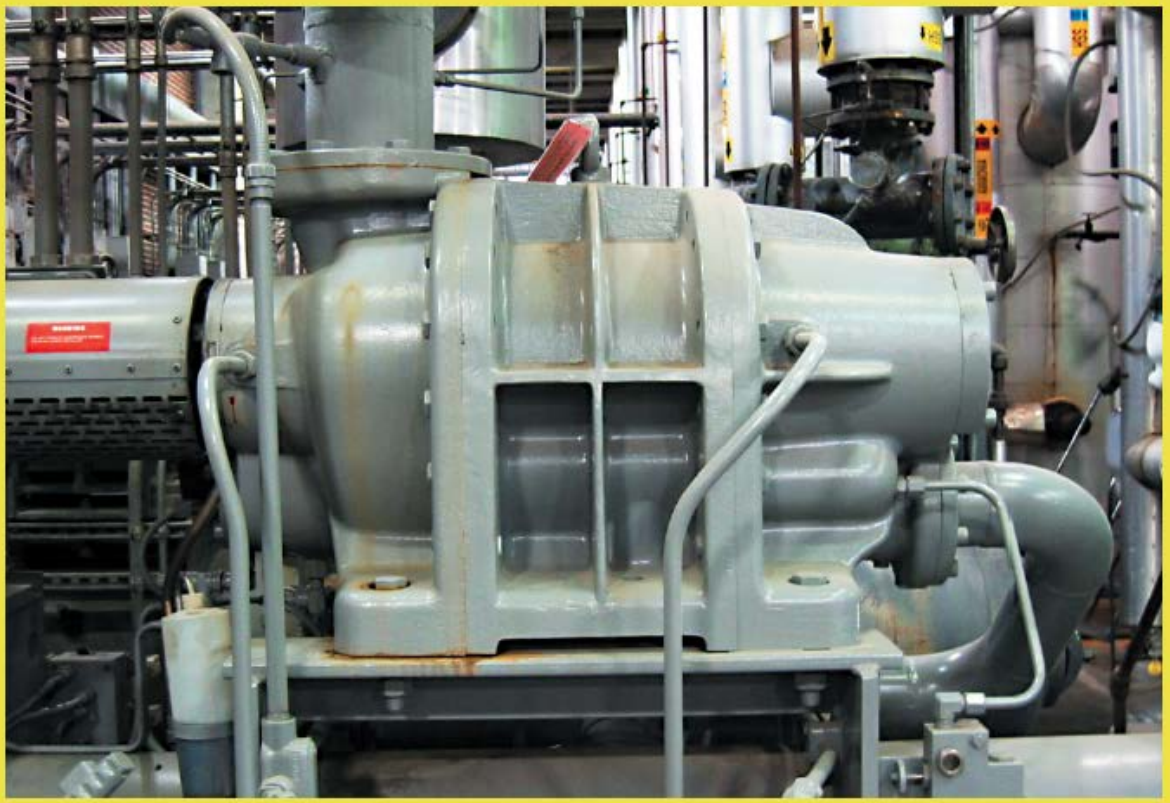


Emptying gaseous Ammonia into a drum of water

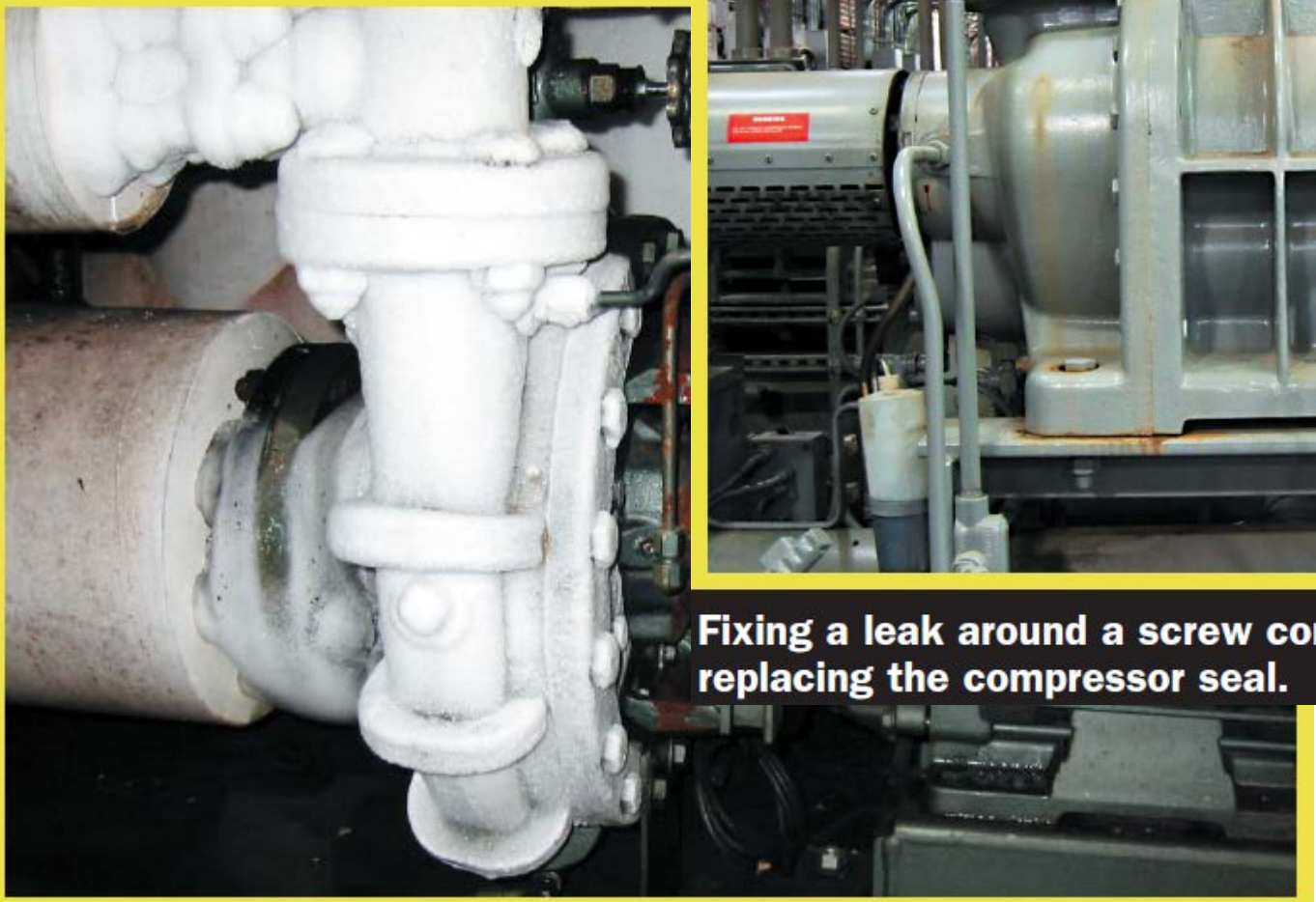
Done safely, can reduce the likelihood of employee exposure and harm.
Reduce likelihood of offsite consequences, and reduce potential exposure to the public.

Example: Automatic Ammonia Neutralisation with “Scrubber” within the Plant-Room

Leak finding



Fixing a leak around a screw compressor might require replacing the compressor seal.

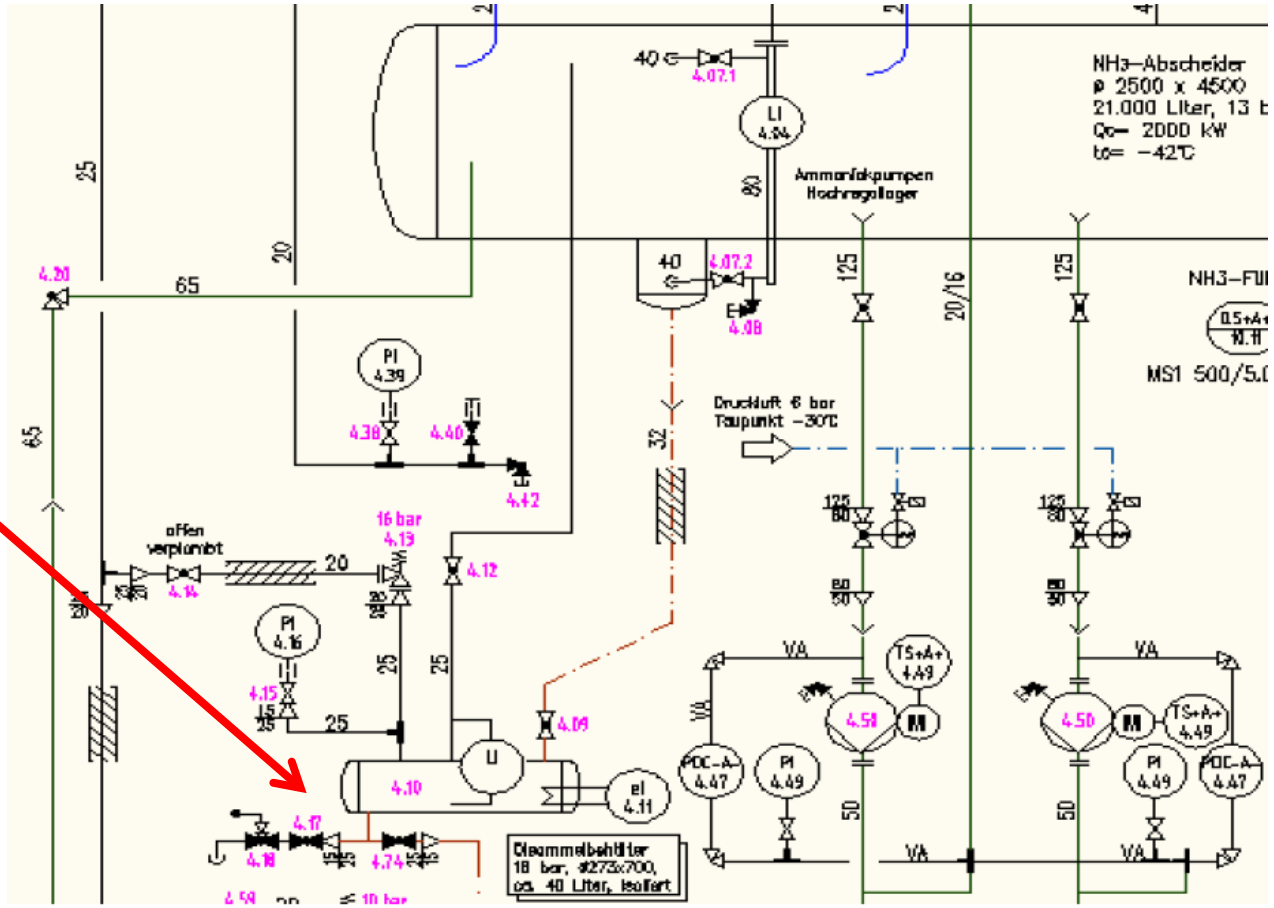


Some liquid refrigerant pump seals leak more often than others, requiring replacement.

Oil removal

Generally oil (up to lare amounts) accumulates at certain spots (evaporator and oil-separator) within the refrigerant circuit and should be removed carefully from the system frequently.

Oil Removal Section



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Mechanical Integrity (MI)

- Mechanical integrity comprises the necessary inspections, tests, and routine maintenance necessary to prevent unintended failures of refrigeration system (NH_3) components that can lead to refrigerant releases that present safety and health risks to personnel on-site and the surrounding public.
- Effective mechanical integrity programs ensure equipment remains reliable to support the supply of continuous “cold” to processes.

Mechanical Integrity (MI)

- The inspections, tests, and maintenance necessary to ensure safe and reliable refrigeration system operation.
- Cradle-to-grave approach
- Initial verification of newly installed equipment or modifications to existing equipment
- Ongoing inspections, tests, and maintenance to ensure continued safe & reliable system operation
- Continuous improvement of program

Mechanical Integrity

Why?

To avoid that:

- A pipe that unexpectedly fails?
- A pressure vessel that begins to leak without warning?
- Hydraulic hammer that causes piping or valves to fail?
- Refrigeration compressors or pumps that experience unplanned downtime?

Mechanical Integrity

Why?

To avoid that:

There are unplanned refrigerant releases led to:

- Plant evacuations (full or partial)
- Ammonia exposure to personnel onsite
- Deflagration
- Contaminated products in process or storage areas
- Ammonia exposure to surrounding neighbors

Effective MI programs prevent these situations!

Mechanical Integrity

Piping and vessels

- comprise the majority of pressure containment and the largest by exposed surface area

Mechanical Integrity

Our goal is!

Mechanical Integrity

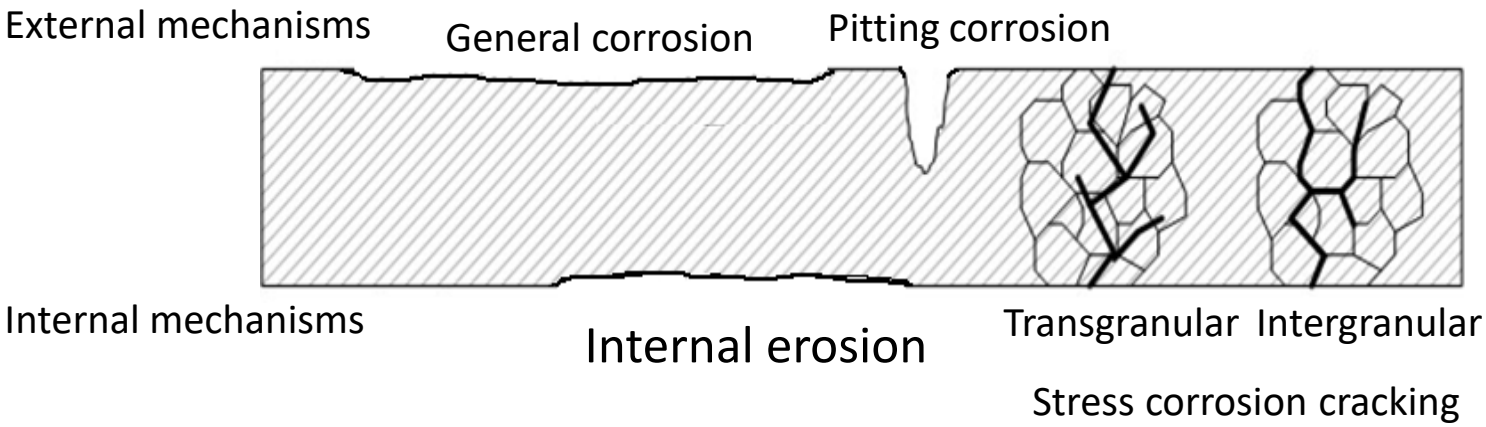
Failure mechanics of ammonia piping and vessels

Risk	Failure Mode	Comments
Highest	**External corrosion**	**Greatest risk to loss of MI**
	Hydraulic shock & hydraulic lock-up	Risk is minimized by design and operations
	Internal erosion	Occurs @ high velocity but risk is minimized by proper design
	Stress-corrosion cracking	Risk is minimized by design, construction, and operation
Lowest	Internal corrosion	Not a significant issue for ammonia systems

Mechanical Integrity

Methods

- Before inspecting, we must know what we hope to find (or not find)
- Thus, we must understand:
  - How do systems typically fail?
  - Where is failure most likely to occur?



Mechanical Integrity

Corrosion

"The deterioration of a material, usually a metal, by reaction with its environment"

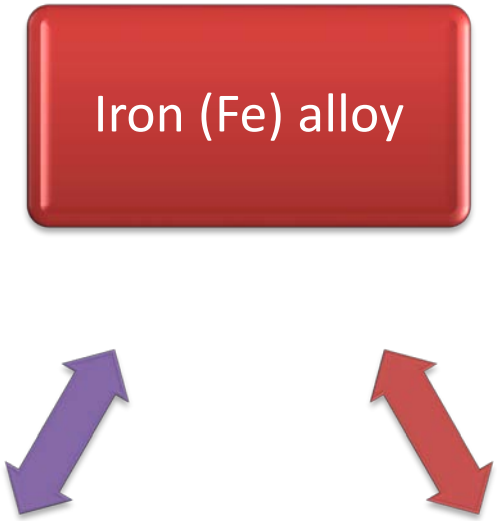
Corrosion is an anodic-cathodic reaction

- Positive ions travel through an electrolyte (i.e. water, ice, etc.)
- Material is sacrificed
  - General (uniform) corrosion
  - Localized (pitting) corrosion

Mechanical Integrity

Oxidation or corrosion of steel

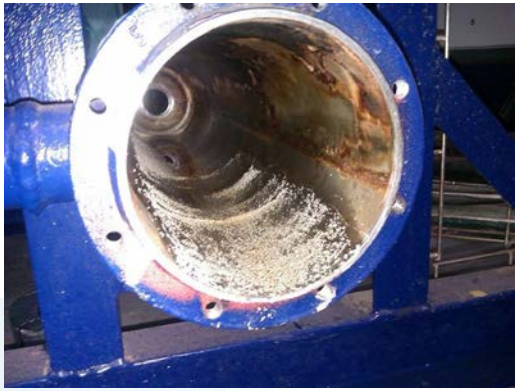
Three “ingredients” are required:



Mechanical Integrity

General (uniform) corrosion

- Gradual thinning of wall material
- Danger is wall thinning that allows eventual compromise of pressure envelope

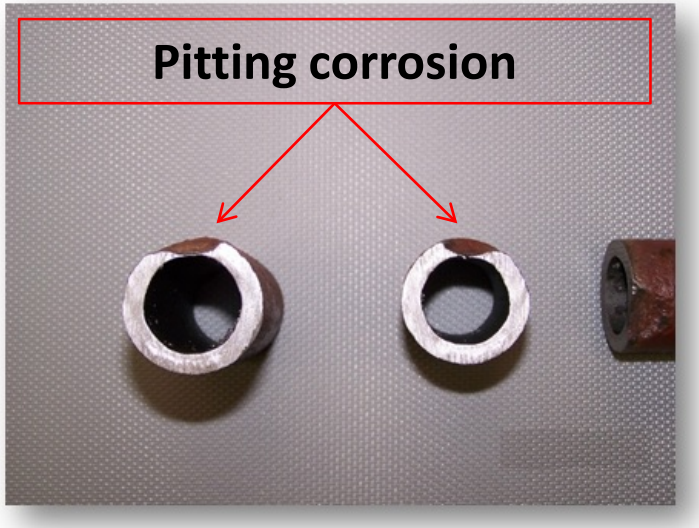


Mechanical Integrity

Pitting corrosion

Localized severe loss of wall material

- Can be difficult to locate (under insulation)
- Risk of pits completely penetrating pipe or vessel wall

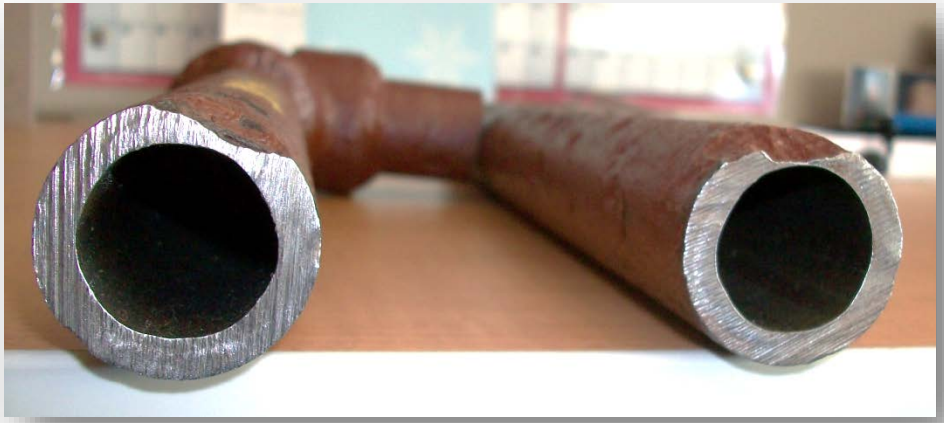


Mechanical Integrity

Examples

Uniform corrosion

Pitting corrosion

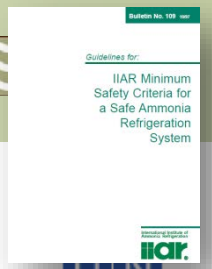


Corrosion Under Insulation

This is any type of corrosion that occurs underneath piping insulation

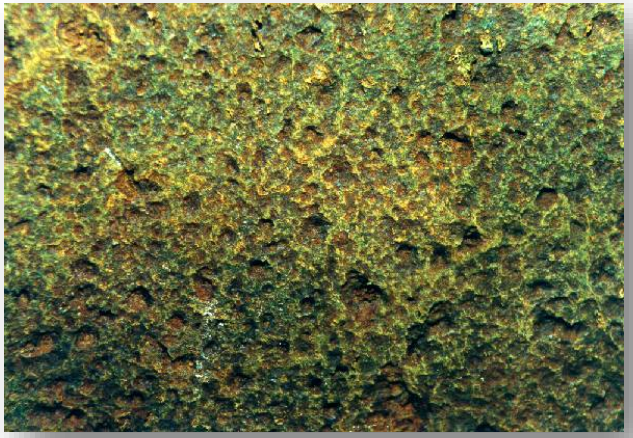
1. Water vapor infiltrates insulation system through breaks in jacket/vapor barrier & condenses on cold pipe
2. Insulation holds water tight to the pipe or vessel surface
3. Pipes without surface coating (i.e. pipe paint) are susceptible to CUI

Mechanical Integrity



Key Points

Piping Systems



- Uninsulated piping should be examined for signs of corrosion. If corrosion exists, the pipe should be cleaned down to bare metal and painted with a rust preventative paint. Badly corroded pipe should be replaced.
- Insulated piping showing signs of vapor barrier failure should have the insulation removed and the pipe inspected. If corrosion exists, the pipe should be cleaned down to bare metal and painted with a rust preventative paint. Badly corroded pipe should be replaced.

Mechanical Integrity

Key Points

Uninsulated Piping

- All uninsulated piping and associated components such as flanges and supports shall be inspected annually for any damage to or deterioration of the piping or its protective finish; take remedial action where necessary.
- Areas affected by slight corrosion should be cleaned off and appropriately treated before reinstating the protective finish.
- Deeper pitting or loss of metal, where considered by subjective assessment to be greater than 10% of original wall thickness, should be checked accurately by using techniques such as ultrasonic measurements.

Mechanical Integrity

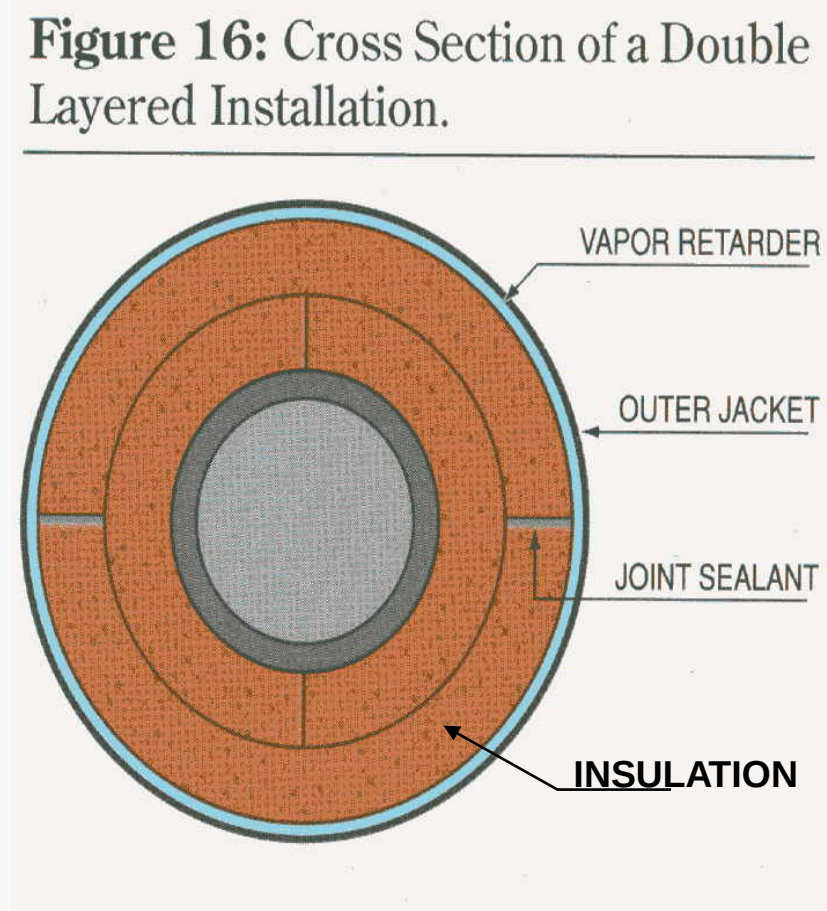
Key Points

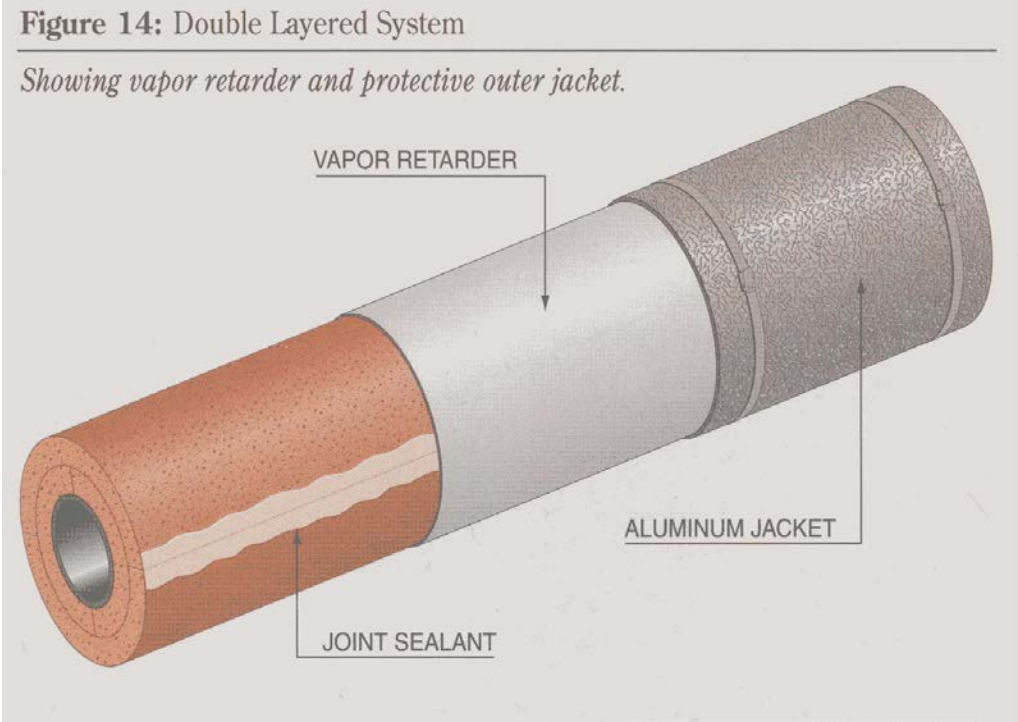
Insulated Piping

- Any mechanical damage to insulation should be repaired immediately & vapor seal reinstated to prevent access of water vapor which will lead to breakdown of insulation & corrosion of pipework.
- At least as part of the annual piping inspection the external condition of the insulation and supports shall be inspected.
- Sections of insulation which are obviously in poor condition shall be removed and the integrity of the exposed piping determined with the aid of non-destructive testing techniques, as appropriate.
- Piping shall be replaced as necessary, and protective coatings, insulation and vapor seal re-applied.

Mechanical Integrity

Piping insulation components





Source: DOW "Trymer Pipe Insulation Guide," 1997

Mechanical Integrity

Importance of base pipe treatment

- Treatment of piping that will be insulated is essential – prime/paint or gel coat
- Applies to piping, welds, control valve groups, unions, flanges, etc.
- Essential to minimize external corrosion under insulation
- Continue to maintain piping in a primed-painted condition throughout service

Mechanical Integrity

Gel coatings

- Compound applied as a gel and remains in gel form once applied (no hardening or curing)
- Chemical elements in the gel react with elements in the steel surface forming an ultra-thin glasslike mineral surface
- This surface, along with pH adjusting chemistry in the gel guards against corrosion under insulation

Mechanical Integrity

Gel coating existing piping

Mechanical Integrity (MI)

Conclusions

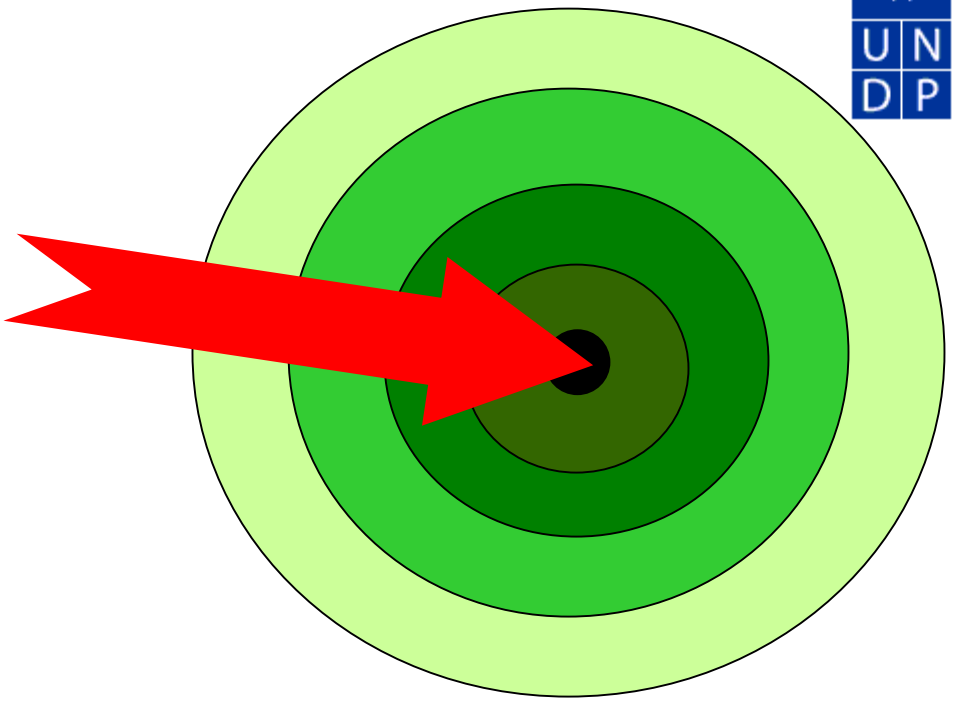
Effective mechanical integrity programs

1. Reduce or eliminate accidental refrigerant releases
2. Enhance safety to personnel on-site
3. Minimize risks of business interruptions
4. Provide increased reliability of providing “cold”

Development & implementation of a MI program cannot wait – start before it is too late

Our goal!

Targets



no Accident

no Environment Pollution

no Health Hazard

Thank You for Your attention!