



# Safety Guide for Ammonia Refrigeration In New Zealand



**GAUGE**  
REFRIGERATION MANAGEMENT

## Safety Guide for Ammonia Refrigeration in New Zealand

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## Disclaimer

Gauge Refrigeration Management Ltd believe the information contained within this manual to be correct at the time of printing. Gauge Refrigeration Management Ltd do not accept responsibility for any consequences arising from the use of the information herein. The training manual is provided as a reference manual for the fundamentals of Ammonia Safety only and therefore should not be relied upon as an exhaustive record of all possible risks or hazards that may exist or potential improvements that can be made. Gauge Refrigeration Management Ltd does not endorse the competency of any person unless specified in writing.

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‘More deaths and serious injuries have occurred to;  
the personnel who repair, maintain, and operate the systems than to  
the emergency responders and downwind customers and public  
combined’


Gary.W Smith (2005) CEO/President of the Ammonia Safety Training Institute,  
*International Institute of Ammonia Refrigeration Technical Paper #8 (p.279)*

## Preface

A surprising fact to most; Ammonia is a critical substance for our survival. From the synthesis of our own DNA, all the way to food growth; its production, storage and its decomposition. It is thus a natural cycle.

Industrial production of synthetic refrigerants seems like it will never end, the ever-increasing list of refrigerants numbers is long since overwhelming. We hear of a new liberating substance entering the marketplace almost every other week.

Whether you agree that climate change is due to anthropogenic reasons or not, the world is heating up and HCFC and HFC and HFO or whatever else comes after that is not part of the answer. We have the natural solutions now, we have the technology now – let's move forward.

 Seventeen of the 18 warmest years in the 136-year record all have occurred since 2001. (NASA, 2018)

Anhydrous Ammonia production currently contributes to approximately 1% of the global energy use, however there are more sustainable production solutions on the horizon. Its high latent heat capacity, coupled with a low boiling point, make it an excellent refrigerant. To put the cherry on top - Its sharp self-warning odour allows for rapid leak identification. Your natural defence mechanisms, your eyelids or the glottis in your throat, tell you when it is causing you harm unlike most other chemicals we work with.

Anhydrous Ammonia hazards, risks and controls are not well understood by many, even by those who may be familiar with its use. Consequentially attitudes can be found at opposite ends of the spectrum between those that have some knowledge or complacency; "She'll be right bro' - to an unfounded fear or oblivion by those that know nothing. Through training and understanding, by properly resourcing businesses, operators, engineers and technicians, we can remove the stigma that envelopes Ammonia. We can increase its use and we can also minimize incidents.






At this point in time, there is no specific qualification for Ammonia Refrigeration in New Zealand. Although we have a National certificate in Refrigeration and air conditioning, the recent NZQA elective unit standard 30127v1 (Demonstrate knowledge of anhydrous ammonia and safe practices for its use as a refrigerant) has only just been added as an elective unit standard (2018) however it is yet to be taught in the current curriculum. The aforementioned qualification effectively permits all workers who possess it to service and maintain Ammonia refrigeration systems whether their particular skillset was installing residential air conditioning (Heat pumps) or commercial supermarkets, there is no demarcation. Ammonia refrigeration and handling requires well guided experiential training specific to the substance. It involves an obeisance that is only truly attainable through time. Effectively Ammonia Refrigeration is a separate trade all together.

I have been involved with Anhydrous Ammonia refrigeration since 1996, I am not afraid to admit that I made a deadly mistake that almost cost me my life and subsequently put others at risk. The very nature of this incident prompted me to take a somewhat obsessive journey into all facets of the industry as well as asking some earnest questions of myself, all in favour of minimising the chance of reoccurrence of the same type event in the future.

Looking at the incident under a microscope, I soon grasped the notion that there was a lot more to this than simply being at the centre of an accident. In my opinion, there are no such thing as accidents in the workplace, only preventable incidents or events. With respect to our industry's short comings – I can summarise the following four points;

1. Our curriculum does not support Industrial refrigeration and we are reliant on establishing best practice procedures from our mentors, unbeknown to us whether our mentors even know what they are doing is correct at all.  
Looking outside our borders at the time (2004), I was unable to obtain any insight internationally either which brought us to commence the development of NZQA 30127v1
2. The Hierarchy of control pyramid will tell you that personal protective equipment is the least effective form of control. It should no way be regarded at the bottom of the heap in any industry sector. Without PPE resources and training you are unable to perform safe handling practices period, let alone mitigate the hazardous energy of Anhydrous Ammonia in an emergency situation.
3. Benchmark guidance for the design and installation of Refrigeration systems has been available for many years, however it is common still to this day to find most systems with some form of major safety deficiency from; underdeveloped fixed gas detection, ineffective ventilation that recycles into engine-rooms, ignition sources after shunt trip activations – no shunt breaker installed, pressure relief termination into occupied spaces and emergency irrigation showers that will put people into hypothermic shock. Having these systems installed poorly is like installing an air bag in the boot of your car. Policing is required.
4. Emergency response is often left in the bottom kitchen draw, you know the one with all the bits and bobs we are unsure what to do with. We can't throw them away as we will need them one day – that is for certain. But when it comes to the day we do need them, we can't remember where they hell they are or how to use them. It must be practiced, and stress tested just like wearing hiviz and filling out permits.

Ammonia is a low likelihood, high consequence risk. It doesn't go bad often, but when it does, the potential for devastation is high. One saying I have heard frequently from the Engineers onboard Purse Seine vessels is, "One metre you live, one metre you die." It all starts with Awareness – which then allows for good Prevention and Preparedness strategies to manage Anhydrous Ammonia in all its applications, this includes;

-  Good initial design following hazardous operability study or Bowtie.
-  Continuous Process Safety Management (PSM)
-  Regular Electro-mechanical safety systems testing
-  On-going training and worker awareness
-  Emergency stress testing of management plans

We endeavour to discuss all of these throughout this booklet and presentations. Do not hesitate to contact us if you require any further information or advice.

Thanks, Padraic (Paddy) Durham M. IIAR, M. NZIHS, M. IRHACE [info@ammonia.co.nz](mailto:info@ammonia.co.nz)



## Introduction

The primary purpose of this publication is to provide the reader with an essential understanding of Ammonia as a Hazardous Substance together with a fundamental understanding of the methods of control that have been developed both locally and internationally to keep Anhydrous Ammonia contained solidifying its position as the natural refrigerant of choice.

Anhydrous Ammonia handling ethics have come a long way in the past 20 years but unfortunately there has not been any consistent industry standard adopted by end users or technicians. This is not entirely a bad thing as it allows for innovation and alternate ways of achieving the same thing. What is important, is that we are all doing what is considered to be best practice.

The following publication has been developed through international research, regular discussion with skilled technicians and hands on industry experience, all in the aim to improve the current standards of Ammonia safety in New Zealand.

It is vitally important to be clear that all persons operating Anhydrous Ammonia systems must be proven competent to do so. The Refrigeration qualification alone or time served operation does not necessarily authenticate competency.

Throughout this booklet as well as our on-site face to face training programs, we often refer to Anhydrous Ammonia as just Ammonia unless specifying another compound.






There are a number of acronyms and initialism's that we commonly refer to, these will be explained as they arise and will also appear at the rear of this booklet.

We will cover the safety systems and processes that have been engineered to contain Anhydrous Ammonia along with the best practices in its safe handling and mitigation of emergencies.

With a greater understanding, we aim to remove the stigma which surrounds Anhydrous Ammonia as well as convey the much-needed respect it deserves.

We ultimately aim to inspire a holistic safe working culture which will not only minimize the risk to all stakeholders and the environment but also increase efficiency, longevity of refrigeration systems and overall business continuity.

## Main objectives








-  Understand the chemical and physiological properties
-  Develop knowledge of Hazard control systems
-  Gain insight of safe routine maintenance practices
-  Improve Emergency response awareness
-  Increase workplace Health and Safety awareness holistically

## General Health and Safety

Removing the emphasis on prison or fines, good Health and Safety practice is not the indoctrinated tick and flick systems. It is the ritualistic procedures that everyone was engaged to develop specific to the workplace. It must be identified and managed, it must be monitored, it must be reviewed.







At the very core, Health and safety is about care and communication, it's about consideration for yourself, your wife your kids, friends, family and the environment.

Regardless of what system is in place, the following guarantees must be established prior to any work taking place. Almost all industrial accidents have a shortage from the examples below;








-  Identify all hazard and risk (Risk = Likelihood x Consequence)
-  Is there a functional and tested best practice engineering control in-place?
-  Is there a system to ensure the people performing the task(s) are competent?
-  Is there a system in place to check you are ready for work in the first place?
-  Is there a system in place to peer review your risk assessment?
-  Is there a system to ensure you have enough time in the job to complete it safely?
-  Is there an emergency plan in place? Has it been stress tested?

## Duty of Care

There is a legal obligation to ensure the safety or well-being of others. A duty of care is a legal obligation which is imposed on an individual requiring adherence to a standard of reasonable care while performing any acts that could foreseeably harm others. So far as is reasonably practicable (sensibly possible). The PCBU must manage all risk to workers, visitors, the general public and the environment from their operation. This includes both physical workplace hazards as well as environmental effects that may be accumulated over time such as;






-  Noise induced hearing impairment
-  Ergonomic hazards (poor positioning, manual handling, repetition)
-  Excessive exposure to vibration
-  Inferior quality air, toxic, dust, low oxygen
-  Biological, safe drinking water
-  Temperature extremes, radiation

Furthermore, PCBU must also maintain a safe psychological place for their workers, including but not limited to;

-  Drugs and Alcohol testing
-  Fatigue management – pre and post
-  Work or non-work-related stress
-  Tight deadlines
-  Safe sleeping arrangements working abroad
-  Bullying and Harassment
-  Intentional negligence

## Hazard and Risk



Hazards are sources of energy that have the potential to cause harm, they can be accumulated as well as attributed to behavioural attitudes. Risk is both the likelihood of harm occurring and the consequence of the exposure to the hazard. It is important that although the potential for a disastrous event exists we must not simply focus our energy on the “worst case” we must ask the following questions taking into all possible scenarios;

-  What could go wrong?
-  How often could it happen?
-  How severely could it harm people?
-  What can we do to reduce the impact or eliminate the hazard?
-  How do we monitor the effectiveness of our controls?

## PCBU – Person Conducting a Business or Undertaking

The Health and Safety at Work Act 2015 (HSWA) uses the term PCBU to describe all types of working arrangements throughout the legislation to include both non-profit such as; Schools, Councils as well as typical profit structures. It also now uses the term “workers” instead of the previous Act’s definition “employees”, this is to include employees, contractors, sub-contractors and volunteers. It places duties on those persons, who by their acts or omissions from or associated with work being undertaken, affect health and safety.

The HSWA Act also places additional duties on PCBUs who carry out specific activities associated with work or workplaces:

-  Primary PCBU - Designers, manufacturers, installers, constructors, importers and suppliers of plant, structures or substances
-  Secondary PCBU - Persons with control of a workplace.

The Health and Safety at work Act 2015 does not specify how particular hazards should be made safe, rather it allows for workplaces to find alternative ways ensure that their hazards do not cause harm. The Act sets out duties and processes.




The HSWA Act is supplemented by regulations, approved codes of practice, and guidelines developed by, or in conjunction with Industry and Worksafe New Zealand.

## Regulations

Health and Safety at Work General Risk and Workplace Management Regulations (2016) in particular; Part One, General duties.

Regulations made under the Act describe some of the requirements that apply to specific work situations. Like the Act, regulations are enforceable, and breaches may result in prosecution and fines.

Regulations are made under the Act:

-  To set minimum standards for the management of particular hazards where alternative control measures are not always effective.
-  To deal with administrative matters provided for in the Act (such as appointment of inspectors); and
-  To elaborate on some general duties in the Act.

Where a Regulation exists, its requirements are mandatory. However, while regulations must be complied with, the overriding responsibility is to comply with the duties set out in the Act. There may be instances where this involves taking further steps than meeting the regulations.

## Hazardous Substances Regulations 2017

These controls are mostly exempt where 'anhydrous ammonia' is used as a refrigerant. Some of the controls which do apply are set out in Emergency Management in Part five (5).

This is expected to be amended in 2019 with removal of the exclusions for anhydrous ammonia in refrigerating systems and will require that all systems comply with joint New Zealand Standard ASNZS 5149. Pt1-4.2016.

## Standards

Standards are used by a diverse range of organisations to maintain safety and a level of quality, meet industry best practice, and support trade into existing and new markets.


By referencing standards in legislation, regulators draw on existing best practice developed by expert committees using a consensus-based and transparent process.

Incorporating standards also allows regulators to provide detailed requirements without encumbering the regulation or guidance with technical detail. They are in a way the "how to guide for dummies".

-  Ensure a consistent approach to quality and safety controls.

*Standards can be;*

- A. Referenced in Acts or regulations as legally mandatory.
- B. Can be referenced in Acts or regulations as a means of compiling to a benchmark – this ensures compliance with legislation but does not prevent the use of an alternative method, provided it meets the specified legislative criteria.
- C. Used by Insurance companies or in business tenders.
- D. Can be incorporated into non-regulatory material such as good practice or guidance booklets for industry. Standards may be cited in court as proof that steps were taken to prevent harm or alternately used in court in prosecutions where benchmark compliance was not met.

-  A standard is not, of itself, mandatory or legally required. A standard has to be incorporated by reference in legislation in order for it to be mandatory.

## Approved code of practice (ACOP)










Approved code of practice are guidelines which have been approved by the Minister of Labour, under the Act. Their requirements are not mandatory or enforceable as such, but their observance is accepted in Court as evidence of good practice.

They form part of the current state of knowledge that must be taken into account when taking all practicable steps to meet the Act's requirement.

## Safety Data Sheet

A Safety Data Sheet (SDS), previously called a Material Safety Data Sheet (MSDS), is a document that provides information on the properties of hazardous chemicals and how they affect health and safety in the workplace. SDS are typically issued by the manufacturer and are available for download online. SDS sheets must be reviewed every 5 years from issue.

*The SDS contents must contain;*

-  Sixteen sections
-  Hazard classifications
-  Handling guidelines
-  Storage guidelines
-  Firefighting and Emergency response guidelines
-  Toxicology information
-  First Aid advice
-  Environmental guidelines
-  Hazard phrases







*Safety data sheets are very important for understanding how to handle a substance in the workplace and how to respond in an emergency therefore should be referenced and available as rapid reference tools in conjunction with an Emergency response plan.*

## Resource Management Act (RMA)

The RMA states that Anhydrous Ammonia cannot be released into open air in any quantities without consent and approval from the relevant Regional Council. Ammonia in any form must never enter water courses.





## Transportation and Storage

For the transportation of Anhydrous Ammonia, we must hold a dangerous goods license or commonly referred to as a (DG) endorsement. Small quantities of up to 50Kg or 50L are allowed without DG however controls must be in place that include;

-  Cylinders secured correctly
-  Segregated from non-compatible chemicals
-  Spill resources available that are suitable
-  Personal Protective Equipment
-  Safety Data Sheets
-  Quantities of 100 kg or more of anhydrous ammonia must have a location certificate to be stored on site for any length of time.

## Ammonia Awareness









Education and hands on practical training are essential factors for safety and trouble-free operation. This includes not only the persons tasked with servicing and maintenance but the persons who are responsible in the administration, not to mention the CEO the Accountant, every person.

-  PCBU and Officers of the PCBU must understand their obligations under Health and Safety legislation to keep workers safe.
-  Contractors, visitors as well as onsite staff must have a level of understanding about physiochemical effects of the substance and what actions to take in an emergency.
-  Emergency plan and testing should be performed regularly even if this is only a desktop scenario once a month, that leads up to an integrated exercise once a year.
-  Third Party Service Providers must be included in your emergency planning and testing.

## Service Personnel - Training pathway

As we have mentioned early on, although technically qualified, not every refrigeration technician can execute Ammonia service and maintenance activities. Operators may have worked on a particular facility for years and quite rightly know the place inside and out. They do not necessarily have the technical aptitude to know what is happening all of the time and if sent to work on another system they may be out of their depth. At the very least they should receive further training and or instruction in standard operating procedures that are specific to the plant they operate or maintain.

As a rule; if an operator does not hold a Refrigeration Qualification or a Certificate of competency in the task they are performing they should not be performing that task. This is of particular importance in reference to intrusive tasks that involve line opening of the system. They may be capable of getting the work completed however they may or may not be performing the task safely or to what would be deemed standard industry practice. Human error is attributed to almost every major incident. The PCBU have overlapping duties and are obligated to ensure their workers and sub-contractors are up to the task. It is therefore pertinent for an end user to request the following competency documentation from their service provider;





-  Refrigeration and Air Conditioning Qualification(s)
-  Number of years' experience that is Ammonia specific
-  References
-  Electrical service technician qualifications or higher
-  Ammonia awareness training
-  Ammonia standard operating procedures competency
-  Emergency response training
-  Self-Contained Breathing Apparatus and Level 4 Gas Suit

## What is Ammonia?

Pure Anhydrous Ammonia is a chemical compound that consists of one part nitrogen and three parts hydrogen which are tightly fused, this gives the molecule the alpha numerical symbol of (NH<sub>3</sub>.) In its purest form Ammonia is one of the most fascinating compounds in nature, its versatility is immense and can be found in rocket fuel to hair dye.

Anhydrous Ammonia, (CAS number 7664-41-7, UN number 1005).

Hazard classifications:

	<b>2.1b Flammable</b>
	<b>6.1c Toxic</b>
	<b>8.2b, 8.3a Corrosive</b>
	<b>9.1a Ecotoxic</b>

To the general public Ammonia typically suggests retail products such as window sprays, oven cleaning foams, floor cleaner, hairs dye, wax removers and other household cleansers. Anhydrous Ammonia is easily soluble into water as a solution, so it is used in many cleaners. Aqueous Ammonia or Ammonium Hydroxide often contains between 5 to 10 (%) percent ammonia. Commercial cleansers, which often contain 25 percent to 30 percent ammonia, and are more hazardous because they are highly caustic. Next to water and oxygen, Ammonia has to be one of the most versatile chemicals on the planet. Ammonia is natural and although its acute toxicity renders it a dangerous substance, it is a lot safer and more efficient than almost all of its competition.

R717 is used to identify the purer Refrigerant Grade Ammonia. The 700 indicates the Natural refrigerant class and 17 the molecular weight (g/mol). For example; CO<sub>2</sub>, molecular weight is 44 hence the R number R744. Ammonia is a liquefiable gas -similar to LPG, it has a very characteristic odour, described as sharp or pungent. In low concentrations Ammonia is almost harmless however as the concentration increases, its hazardous nature becomes exponentially more dangerous. Even in low quantities caution should always be used when one is handling this chemical

Many other chemicals retain no odour and can reach harmful concentrations without our knowledge. By contrast, ammonia's very distinctive aroma serves as an early warning before concentrations can become either flammable or toxic.



## Properties

Ammonia has many defining properties however most of which we will never be required to comprehend. As Ammonia technicians and operators, we do require an understanding of the basic properties and thermodynamic principles.

- i Depending on which vapour pressure chart we use, @ atmospheric pressure (the pressure that surrounds us), Anhydrous Ammonia 'boils' at approximately -33°C.
- i Ammonia has one of the highest latent heat values (The heat required to change a chemicals state of matter without a change in temperature) This combined with its low boiling point Ammonia makes an excellent refrigerant.
- i Ammonia is a clear liquid, an invisible vapour and when in an Aerosol state it will form a dense white cloud.
- i Anhydrous Ammonia is less dense than water and air therefore will rise in its gaseous state. However, it is imperative that we grasp that Ammonia in a liquid or Aerosol will gather at ground level and in a vapour state combined with high humidity it will react differently dependent on certain weather conditions.

Property	Details
Melting point (Freezing)	-78°C
Boiling point	(1.013 bar) -33.5°C
Power of Hydrogen (pH)	Basic >11.6
Volumetric Expansion	>850x
Gas density	(1.013 bar at boiling point) : 0.86 kg/m <sup>3</sup>
Latent heat of vaporization	(1.013 bar at boiling point): 1371.2 kJ/kg
Specific Heat Capacity	(@300 K: 4.75 kJ/kg/K)
Vapor pressure	(at 21°C or 70°F): 8.88 bar
Critical point	132.4°C - Critical pressure: 112.8 bar
Ignition temperature	651°C
Dangerous Reactions	Acid creates strong heat during neutralization, Forms Explosives mixed with Chlorites
Other dangers	Attacks Copper, Zinc

- i Ammonia is Natural, Abundant, Cheap but most importantly it is Self-warning.

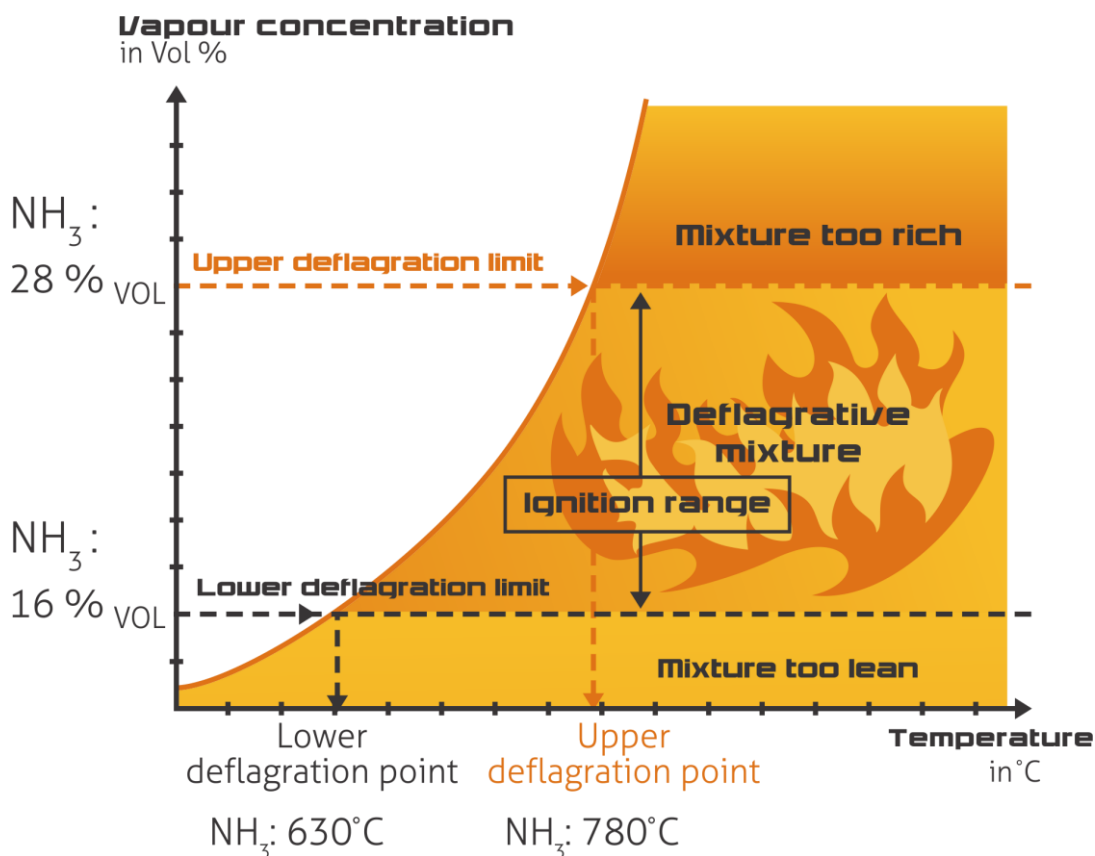
## Flammability

Anhydrous Ammonia is a class 2.1.1B flammable substance; it is deflagrative meaning it burns down. Anhydrous Ammonia ignition requires a large amount of energy (680mJ) in comparison to say Acetylene (0.017 mJ). For example a spark plug will deliver 25 mJ. The flame propagation speed of Ammonia is also slow between 8-10cm/s. Hydrogen (28 m/s) (Mynarz, 2018)

- i This occurs between 16-27% of air (160,000-270,000 ppm). It is said, in the presence of an oil mist the Lower explosion level (LEL) can be reduced to as low as 10% volume.
- i An Ammonia system must have a remote emergency shutdown system in the event of large release as an ignition prevention measure.
- i Most global standards suggest a parameter that is  $\leq 1/5^{\text{th}}$  of the Lower explosion level.

It is important to note, EX rated or intrinsically isolated LEL sensors should be installed on every plant. Ammonia is difficult to measure accurately, an LEL sensor is not a low-level toxicity sensor and vice versa.

An LEL allows the fixed gas detection system to remain operational when the toxicity sensors have over-ranged. It also allow the system to have protection whilst maintenance activities are taking place by eliminating the LEL from any bypass functionality.



## Eco-toxicity

Ammonia is highly ecotoxic. In the first instance, it can cause increases in the power of hydrogen (pH) of the water. Organisms exposed to excess ammonia, may suffer loss of equilibrium, hyper-excitability and increased respiratory activity.

- i Research have shown that the lethal concentration for a variety of fish species ranges from 0.2 to 2.0 mg/L therefore as a handler, you must never let Anhydrous or Aqueous Ammonia enter water courses.

Waste Ammonia must be disposed of correctly in accordance of local legislative guidelines. This is typically through a chemical waste organisation that will neutralise through a trade waste system. Additionally, Anhydrous Ammonia in a gaseous state cannot be released into open air in any quantities without consent from the relevant Regional Council.



## Chemical segregation

Ammonia must not ever be allowed to come into contact with other bases, such as Chlorine unless trained to do so, highly toxic chloramines gases and explosive reactions can occur. It is important to check regulations and guidelines in reference to proper segregation distances and separation requirements of hazardous substances.

- i Hydrazine (Anhydrous Ammonia and Chlorine) is used in the production of rocket fuels

## Toxicity and Corrosivity

There is no compiled research that suggests Ammonia has any long-term health effects in repeated low concentrations, however there are links to Asthma and respiratory conditions. Nevertheless, Ammonia will not poison your body long term. Ammonia is hydrophilic, soluble in water, forming Ammonium solutions ( $\text{NH}_4+\text{OH}$ ) therefore it is attracted to moist tissue, eyes, throat and the respiratory system. Liquid and Aerosol contact can result in a triple combination of; chemical, dehydration and thermal (Low temperature) burns.

Physical effects may include;

- i Mild to severe irritation.
- i Vision impairment
- i Respiratory difficulties
- i Cryogenic (Low temperature) burns
- i The formation of highly corrosive Ammonium Hydroxide on moist tissue such as the skin, Eyes, Mucus membranes, Respiratory system, Throat, Sinuses, Urethra,
- i Pulmonary Edema, Blindness, Organ malfunction Psychological (PTSD)
- i Most victims of Ammonia inhalation die of suffocation due to the trachea swelling.



Image courtesy of DR N. JITHENDRAN, M.S. (ORTHOPAEDICS),  
M. Ch. (PLASTIC SURGERY), D.N.B. (PLASTIC SURGERY)



## Concentration markers

The following table specifies internationally recognized standards for Anhydrous Ammonia concentration effects and limitations. The initialism PPM stands for 'Parts per Million'. It is the unit for measuring a concentration of a foreign substance within another.





For example; How many Ammonia molecules within One million molecules of air. 25 ppm = 0.0025% volume. Anhydrous Ammonia can be detectable by humans as low as 0.3 ppm

- i The self-warning properties of Ammonia will initiate the closure of Eyelids and Glottis (Larynx) to minimise harm.
- i For Workplace Exposure Standards (WES) we use three indicators; Time awaited average (TWA), Short Term Exposure Limit (STEL) and Immediate Danger to Life and Health (IDLH)

PPM	Effect	Action	Exposure
25	Ammonia easily detected by most people	No action required	TWA, Time Weighted Average*WORKSAFE NZ
35	Inexperienced persons are repulsed by the pungent odour	Leave within 15min or wear K type respirator	STEL Short term exposure limit *WORKSAFE NZ
50	Very distinct smell will want to vacate area	Leave asap or wear K type respirator	
100	No danger but unpleasant	Leave asap or wear K type respirator	
>300	Irritation to eyes sinuses and respiratory system	Evacuate immediately Positive Pressure Respirators with Gas tight suit, Following risk analysis	IDLH Immediate danger to life and health
>1,500	Serious irritation to eyes skin, sinuses, Laryngospasm Serious injury may develop in 30 min	Positive Pressure Respirators with Gas tight suit, Following risk analysis	AEGL-PAC 3(Acute Exposure Guideline Levels) 60 min: 1100 ppm
>2,000	Serious Irritation to eyes sinuses and respiratory system, Bronchospasm Pulmonary edema	15 min or less may result in death, Positive Pressure Respirators with Gas tight suit, Following risk analysis	AEGL Maximum Acute Exposure Guide line 2700 ppm 10min
>5,000	Lethal in minutes, Respiratory arrest, Pulmonary edema	Manage pressure where safe to do so and wait for decline in concentration, Positive Pressure Respirators with Gas tight suit, Following risk analysis	
>10,000	Respiratory arrest, rapidly fatal, Skin irritation or burns from moist tissue	Manage pressure where safe to do so and wait for decline in concentration, Positive Pressure Respirators with Gas tight suit, Following risk analysis	
>30,000	Rapidly fatal, 1/5" Lower Explosion Level, Possible visible Plume or Cloud	Isolate all potential sources of ignition, manage pressure where safe to do so and wait for decline in concentration.  DO NOT ENTER PLUME	

## Acute Exposure Guideline Levels (AEGLs)



Developed by the US defence force and EPA; Acute Exposure Guideline Level (AEGLs) are values that are intended to protect most individuals in the general population, including those that might be particularly susceptible to the harmful effects of the chemicals.

-  <AEGL 1 – Mild odor, Knowledge
-  <AEGL 2 – Discomfort
-  <AEGL 3 – Serious injury
-  >AEGL 3 – Life threatening or fatal effects

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

## Immediately Dangerous to Life and Health (IDLH)

In the 1970's the United states Occupational Safety and Health Administration developed Immediately Dangerous to Life and Health (IDLH) as a respirator selection standard. "An atmospheric concentration of any toxic, corrosive or asphyxiant substance that poses an immediate threat to life or would cause irreversible or delayed adverse health effects or would interfere with an individual's ability to escape from a dangerous atmosphere" (29 CFR 1910.120).

-  Immediately Dangerous to Life and Health (IDLH) for Anhydrous Ammonia = 300 ppm
-  Immediately Dangerous to Life and Health (IDLH) for Chlorine = 10 ppm

## First Aid

*“In all instances contact 111 for specialist medical assistance.”*



### First Aid for Eye Contact:

The extent of eye injury is dependent upon the duration of the exposure and concentration of the gas or liquid. Even low air ammonia concentrations can be very irritating to the eyes. Permanent eye damage is not unlikely in higher concentrations. Contact lenses should never be worn when working with ammonia.

- i Immediately flush eyes for at least 15 minutes keeping the eyelids open.

### First Aid for Skin Contact:

Ammonia gas may cause skin irritation especially where skin is moist (perspiration). Patients exposed to only mild ammonia gas and have no skin or eye irritation do not necessarily require decontamination unless advised by a medical professional. Ammonia liquid may cause extensive skin damage resulting from dehydration, freezing and the corrosive action of ammonium solutions.

- i Seek fresh air upwind of the source. Flush exposed areas thoroughly and preferably with luke-warm water. This is to firstly encourage de-contamination in the first place as well as prevent hypothermia. It also provides better cleansing by enlarging the skins surface. If only cold water is available, irrigate in short intervals and provide blankets and quickly shelter them in a warm and dry environment to maintain safe body temperature.
- i If clothing is frozen to skin, thaw out area first with water before removing clothing. Clothing that is contaminated with ammonia can cause secondary exposure to responders so use extreme caution.

Only once the decontamination has occurred or advised by a medical professional, Vaseline® or opaque oils can be used to seal the wound, initiate the healing process and some provide pain relief (Note this is from personal experience and not medically approved)

### First Aid for Inhalation:

Even at low concentrations, ammonia vapour is very irritating to the nose, mouth, throat and lungs. The airway may swell and constrict, making respirations difficult for those exposed. Because of a child's narrow airway, they are especially susceptible to breathing difficulties if exposed.

- i Move the person to fresh air up wind. If breathing has stopped, perform artificial resuscitation with caution as lungs may be highly contaminated, administer medical oxygen if available and trained.

## Natural Occurrence

There is several billion tons of Ammonia recirculating through Earth's atmosphere, waters, and life forms annually. Ammonia is naturally produced from the putrefaction (decay process) of nitrogenous animal and vegetable matter.

- i Mammalian kidneys secrete ammonia to neutralize excess acid.
- i Ammonium salts are found distributed through fertile soil and in seawater.
- i Ammonia is also found throughout the Solar System -in the atmosphere of Jupiter.
- i Daily human production is approximately 1700 mg, according to the Fertilizer institute you may absorb up to 1300 mg by eating a 200-gram steak alone. Breathing 25 ppm for 8 hours will accumulate just 379 mg.

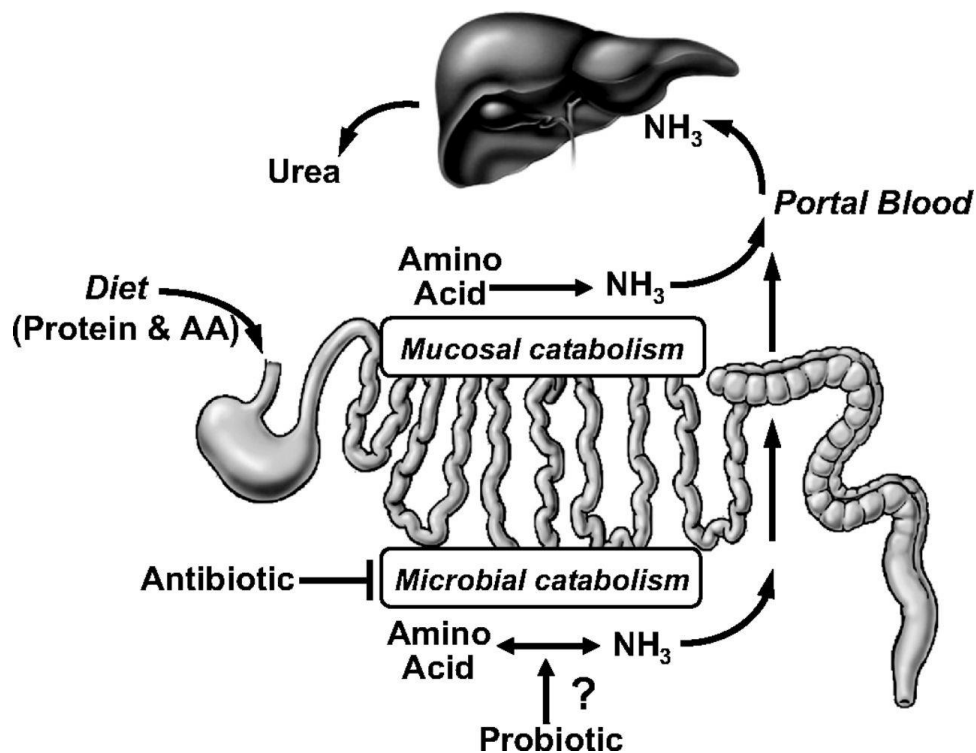


Image: The American Physiological Society (2013) *Modulation of the gut microbiota with antibiotic treatment suppresses whole body urea production in neonatal pigs*



## Phases -states

Ammonia is a non-permanent gas; its state can be altered with pressure and temperature. Liquid Ammonia is colourless and appears like water.

At atmospheric pressure (The pressure around us) Anhydrous Ammonia is a vapour due to its low boiling point of  $-33^{\circ}\text{C}$  however due to its high latent heat capacity it can be witnessed for extended periods as a liquid.

Anhydrous Ammonia will form an aerosol cloud when liquid enters the atmosphere at a high velocity. This cloud is highly concentrated ( $>45,000\text{ppm}$ ) and due to the effects of partial pressure and evaporation, it can achieve extremely low temperatures ( $-74^{\circ}\text{C}$ ).

You must never enter an Ammonia cloud, even when wearing chemical Gas suits and breathing apparatus. Many suits are not designed to withstand extremely low temperatures.

As a superheated vapour, Anhydrous Ammonia is invisible to the human eye. The number one positive characteristic of using Ammonia over alternative substances is that it is self-warning. Your body will not take a breath of this stuff if it can help it.

- i When working with Ammonia it is of the utmost importance to ensure the area of work is placarded and cordoned off to limit exposure to others.
- i Involuntary contact by persons not assimilated to Ammonia can cause mass panic.
- i Higher ambient temperatures will cause Ammonia to rapidly expand, this can be particularly hazardous in enclosed spaces.
- i It is not expected to reach flammable concentrations in external releases.

*We can use a rule of thumb calculation to determine the potential concentration of any given enclosed space: (Ammonia kg  $\times$  1.43 (Assuming full Expansion at  $25^{\circ}\text{C}$ ) / room volume  $\text{m}^3 \times 100 = \text{percentage concentration \%}$ .  $\times 10,000 = \text{parts per million}$ .*

*We can also use the calculation in reverse to estimate the amount of refrigerant lost during a release.*

Estimating possible concentration	Estimating refrigerant loss
$150\text{kg} \times 1.43 = 214.5$	$145\text{ppm} / 10,000 = 0.0145\%$
$214.5 / 900\text{m}^3 = 0.238$	$0.0145 / 100 (\%) = 0.000145$
$0.238 \times 100 = 23.83\%$	$0.000145 \times 900\text{m}^3 = 0.1305$
$23.83\% \times 10,000 = 238,333.33\text{ppm}$	$0.1305 / 1.43 = 0.0912\text{kg} (91.2\text{g})$

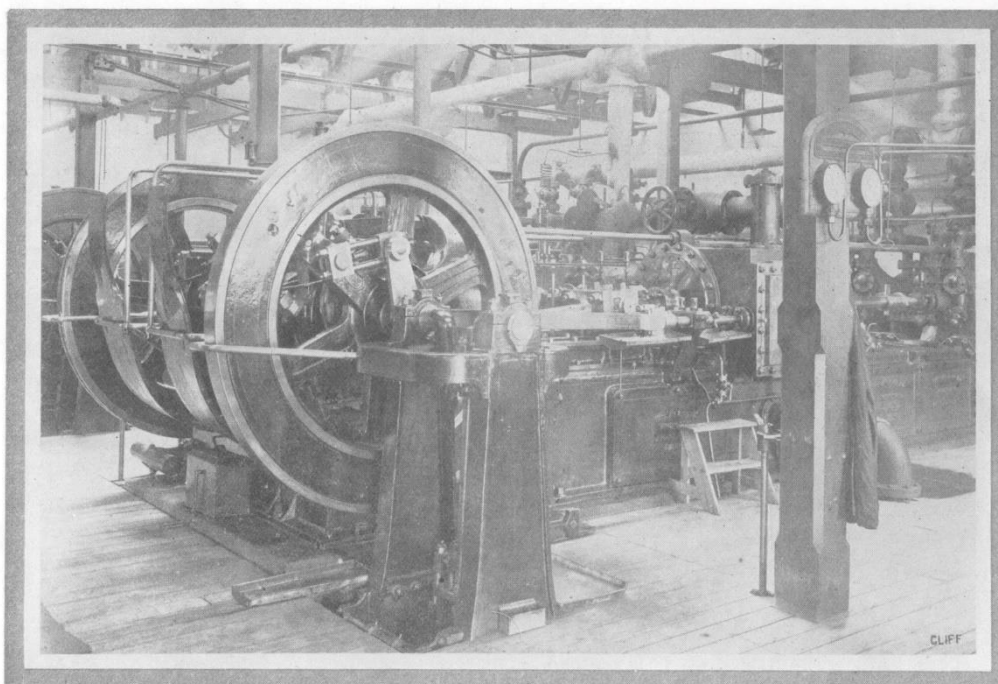
## The Brief History of Ammonia

The Romans gave the name Sal Ammoniacus (salt of Amun) to the ammonium chloride deposits they collected from near the Temple of Amun.

Ammonium chloride salts was used for various medicines by early alchemists.

By the middle-ages Ammonia was used for tanning leather by fermenting urine. The saying "without a pot to piss in" or piss poor, came from not even having a pot to sell your own urine. Gaseous ammonia or as they named it "alkaline air" was first discovered in the 18<sup>th</sup> century. Ammonia was first industrially manufactured to produce fertilizer for greater agricultural yields as well as detrimentally to produce chemical weapons and explosives to sustain war efforts. Fritz Haber, a German chemist, created this process in 1909 which was further developed when teamed with Carl Bosch to make it economically viable and produce on a mass scale. Both chemists won the Nobel Prize for their work in this field. Ironically the invention that allows us to feed our rapidly growing population also cost hundreds of thousands of lives.

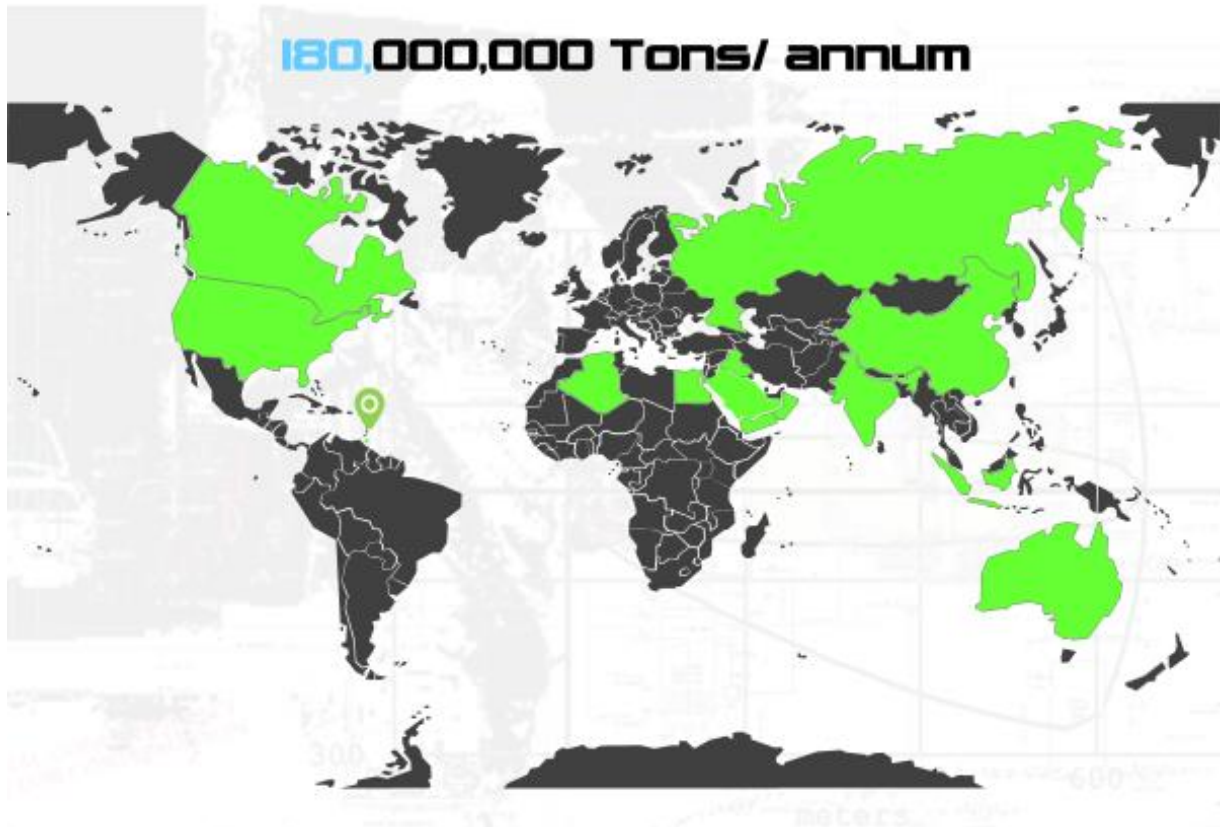
- i The first commercially viable "Ice machine" utilizing an Ammonia vapour compression cycle was built in 1851, Geelong Victoria by a British Australian Journalist come engineer by the name of James Harrison. After failed attempts of refrigerated sea freight from Australia to England. James returned to his work as a journalist in Victoria where he was forgotten for his revolutionary innovation and died with the inscription on his tombstone "One soweth, another reapeth". (Bruce-Wallace, 2018)
- i The first Ammonia Freezing works in New Zealand was commissioned at Burnside 1881. Almost a year later, thanks to the pioneer efforts of M.V Dunedin, New Zealand successfully transported almost 5000 carcasses of sheep and lamb to the United Kingdom thus opening the door for Aotearoa to become one of the worlds heavy hitters in agriculture even despite our remote proximity on the globe.



Tamona Freezing works (Bay, 2018)

## Production

Using the Boch-Harber process; China, India, Russia, the United States and Trinidad and Tobago are amongst the highest producers of Anhydrous Ammonia. Currently, global production is in excess of 180 million tons every year with approximately 20% used for industrial process such as refrigeration.



## Fertilizer - Fuel

Commonly used throughout the United States, Anhydrous Ammonia is injected directly into the soil, which is used to increase the yield of plants. Without ammonia as a fertilizer, it would be almost impossible to feed the rapidly growing population on earth.

The most unknown attribute of Ammonia is its marvellous ability to store hydrogen in a safe state. Although it has been used as a fuel prior, it has only recently been researched for a solution for global transport and energy generation.

## Refrigerant

Anhydrous Ammonia's low boiling point, excellent latent heat capacity, natural occurrence, non-carcinogenic, zero ozone depleting characteristics make a superior refrigerant. It is widely used all over the world in a vast variety of applications for over one hundred and fifty years. Due to the impending phase out of synthetics refrigerants we will see technological advances in smaller low charge Ammonia based packages.

## Refrigeration process

An Industrial refrigeration system can be single or two staged and include multi pressure or temperature control circuits. It can consist of hundreds – thousands of valve configurations and components, however the fundamental principle remains the same as your house hold refrigerator in your kitchen. Theory can be complex at first but to provide some insight we will convey some elementary thermodynamic principles;

## Saturation Point

Saturation is the point of which a refrigerant is changing state from either a liquid to a vapour or vice versa. It can also be colloquially termed boiling point or evaporation. Saturation temperature is variable with pressure which we call the pressure temperature relationship. For example; we can accurately identify the temperature outside by establishing the pressure of a static liquified gas. The higher the pressure – the higher the temperature and visa versa.

## Latent heat capacity

Latent heat is the energy required to change the phase of a substance without a change in temperature. It is the energy in the form of heat that the refrigeration cycle absorbs from a refrigerated space or product and then must reject from the Condensor.

Ammonia has an excellent latent heat capacity, which is why it is widely used as a refrigerant.

To put this into perspective; The latent heat of Ammonia can be up to two hundred and eighty times the amount of energy required to change 1kg of a substance by 1°C (Specific Heat) Which is why the refrigeration effect is so efficient.

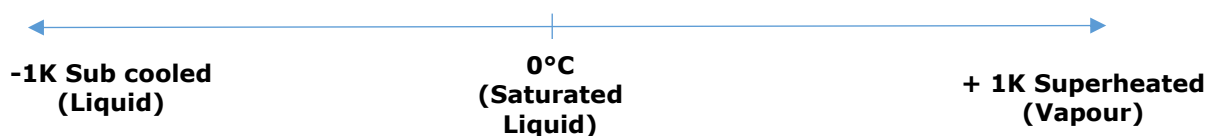
## Superheat

This can be identified in three words "Temperature above saturation"

e.g. Saturated Ammonia at 300 kPaG is equal to 0°C.

Where we measure 10°C at the same pressure this represents 10°C of superheat

When discussing temperature variation, we use Kelvin (K) instead of °C



## Sub cooling

This can also be identified in three words "Temperature below saturation"

e.g. as above Saturated Ammonia at 300 kPaG is equal to 0°C.

Where we measure -17°C at the same pressure this represents 17 Kelvin (K) of sub cooling

## Ammonia Refrigeration Systems

There are some basic differences from that of a synthetic refrigerant system these include;

- i Large Industrial Scale
- i Carbon or stainless-steel pipework
- i Float configurations
- i Single or two stages
- i Open drive compressors
- i Liquid Pumps
- i Purger's | Purifier's
- i Oil rectifiers
- i Desktop Data acquisition systems
- i Modifiable Programmable logic control



Circa 1970-1980 Liquid pumps and low-pressure oil rectifier



## Vapour compression and liquid reticulation cycle

The basic “bare bones” Ammonia vapour compression cycle utilises seven main components to form an integral system;

1. Compressor(s)
2. Condensor(s)
3. Receiver(s)
4. Pressure reducing device(s)
5. Suction accumulator(s)
6. Liquid feeding method
7. Evaporator(s)



Analogue Ammonia Refrigeration Gauges

- i** There are of course various sub sets that are required to maintain efficiency and stable performance such as oil separators, control valves, pressure regulators, oil coolers etc. These will be covered in a later edition.

## Compressor(s)

The Compressor is simply a vapour circulation pump, sometimes referred to as the heart of the system, it performs the duty of moving refrigerant around as well as raising the pressure of the returning low temperature gas, ready to force a phase change at the Condensor. These days, Ammonia Compressors are generally reciprocating or screw type consisting of either single or twin rotors.



Mycom V series Screw Compressors

## Condensor(s)

The Condensor is called such, as that's what it does. It is a heat exchanger that receives high pressure, high temperature refrigerant vapour, it uses a medium generally air, water or both to expel the heat and force the refrigerant into a liquid.

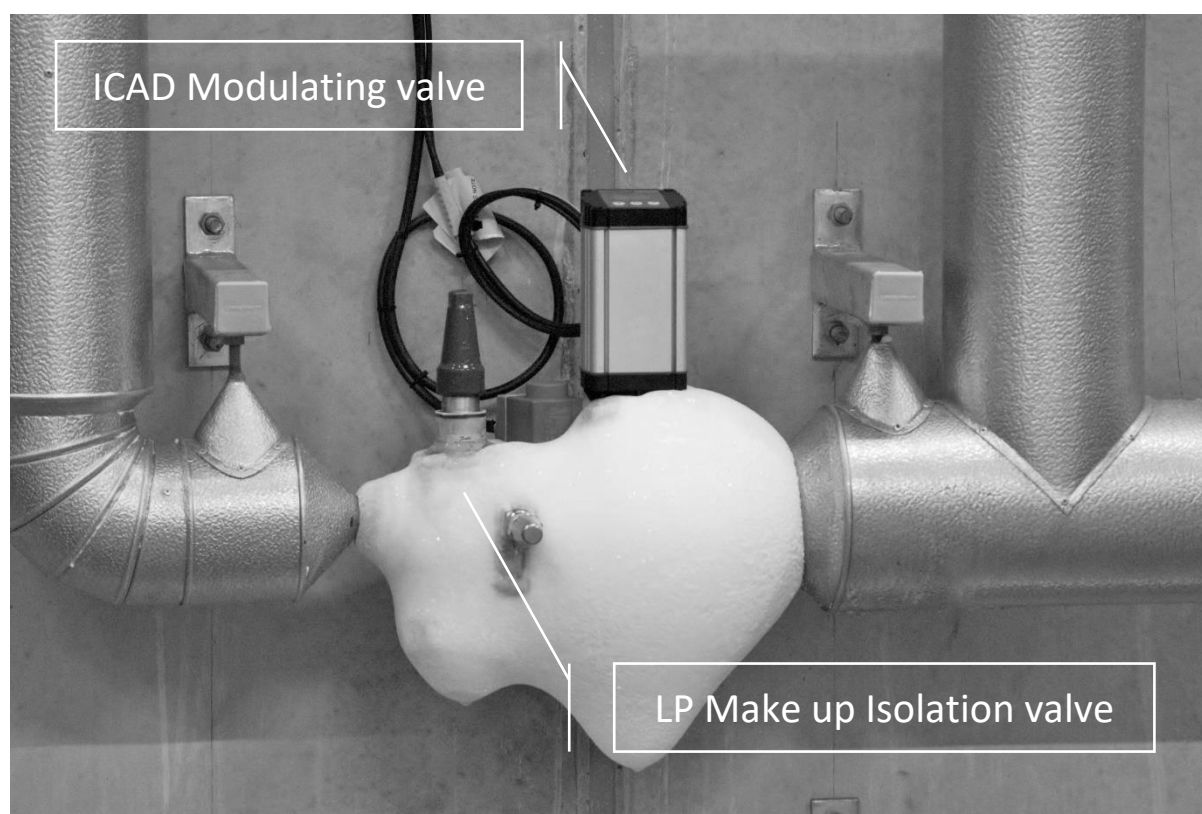
For example; Where the Condensor is at 1000 kPaG the equivalent saturation temperature of Anhydrous Ammonia is 28°C so by reducing it to this temperature or lower with ambient air or water it has no choice but to condense. We require liquid refrigerant, so we can force it to boil at the evaporator thus absorbing heat.

## Receiver(s)

The receivers are simply high-pressure storage vessels that are also used to ensure that only liquid is provided to the low-pressure side of the system.

## Pressure reduction device(s)

The pressure reduction device can be a fixed orifice or an open or closing type, as well as modulating in function, its primary purpose is to control the flow of refrigerant together with lowering the pressure of the liquid and therefore lower the temperature so that when heat is provided by the medium (Space or product being refrigerated) it is forced to boil thus creating a latent heat condition. They can supply high pressure refrigerant directly to an evaporator or maintain a control level in a pressure vessel.



Danfoss ICAD modulation valve and LP make up station

- i The LP and IP Make up valves are critical isolation valves and should be clearly identifiable as well as freely available to operate in the rare event of an emergency.



## Suction accumulator(s) or low-pressure vessel(s)

The low-pressure vessels are made up from the refrigerant supplied from the pressure reduction device(s). Accumulators are used for storing low temperature refrigerant that will be supplied to the refrigerated spaces or product coolers via liquid pumps. Where any refrigerant that has not fully boiled off in the evaporator, the low-pressure vessels secondary function is to minimise the risk of liquid refrigerant entering the compressor(s). These low-pressure vessels can vary in pressure therefore vary in temperature so that there can be a multitude of temperature-controlled zones. (Rapid freezing, Cold storage, Chillers)



IP and LP Suction Accumulators with control level columns

## Liquid feed method

There are three common methods of supplying refrigerant to an evaporator, no one is better than the other, they are selected to meet the individual design considerations of the plant;

- i Liquid overfeed recirculation via mechanical pump from the accumulators – applied to cold-storage and rapid freezing. The pump draws saturated liquid from an accumulator vessel and raises the pressure in order to supply the low-pressure evaporator. This liquid then becomes theoretically sub cooled. The benefit of this method is most of the evaporators internal surface area can be “wet” with already saturated liquid Ammonia. The refrigerant must be controlled via hand expansion valves to ensure the correct amount is supplied, too little and the evaporator will starve, too much and the evaporator performance will be reduced due to “brining” that is; no latent heat effect taking place.
- i Gravity flooded thermosyphon -Usually applied to process cooling operations through a Plate Heat Exchanger (PHE) Overfeed quality without the need to pump.
- i Direct-expansion (DX) – Provides the benefit of minimising the system charge.

## Evaporator(s)

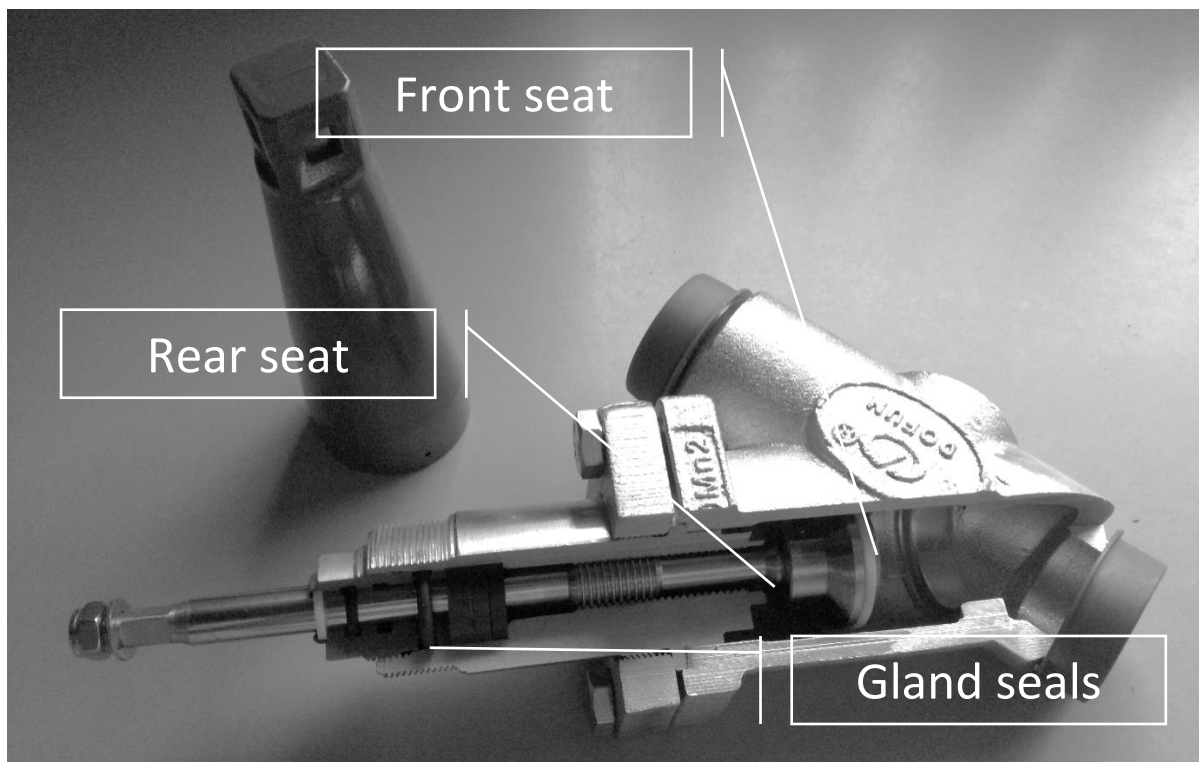
Once the Anhydrous Ammonia has entered the evaporator it begins to evaporate or boil. Remembering the “latent heat capacity”; The evaporator absorbs the ambient energy that surrounds it, combined with the continued suction by the compressor(s), at the beginning of the cycle to change the state of the Ammonia therefore removing heat and creating the refrigeration effect.

The evaporator suction pressure will also determine the temperature of the space being cooled. e.g 190 kPaG = -10°C saturation point. This is the minimum temperature achievable.

To confirm we are absorbing heat we recognize “superheat”. At the evaporator outlet we wish to see superheat to ensure all Ammonia is utilized efficiently.

## Refrigeration Isolation Valves

Ammonia valves should be constructed from steel or stainless steel and provide both front and rear seats to allow for replacing packing glands whilst under pressure as well as minimise leaks. This being said it is recommended that live or “hot swaps” of packing glands be undertaken only as a last resort and only after all possible control measures are implemented. Removal of caps as well as operating any valve require the use of personal protective equipment. In enclosed or restricted areas as well as when working on elevated platforms or ladders – it is recommended to wear respiratory protection.



Dofun 32mm Straight through Stop valve cut away

## Essential Personal Protective Equipment

PPE is essential for work on any engineering work site or workshop and when handling Anhydrous Ammonia it is no different. It is important that all personal protection is carefully selected for its intended use. This includes but is not limited to the following;

### Full length Overalls

It is paramount that when performing Ammonia works that full length protective clothing is utilised.



### Steel cap footwear

As we are already well aware, Safety boots are required on all worksites. Selecting the right boot for your needs is important not only for incidents but to also support the skeletal system.

### Safety Eye wear

Whenever operating pressure equipment – Ammonia or otherwise, safety glasses are a minimum requirement.



### Chemical resistant gloves

Gloves that provide protection from the corrosive properties of Ammonia as well its low boiling point should be selected. Preferably gloves that allow optimum dexterity when performing complex tasks to ensure they are not removed when in use

## Hearing Protection

There are approximately 90 New Zealand workers diagnosed with Noise induced hearing loss (NIHL) every working week. That number is increasing every year. NIHL is a predominate issue in our industry as we work in high noise environments every day.



There are limited opportunities or even possibilities for elimination or substitution through engineering. Limiting the distance from “ear shot” and the amount of time working around heavy machinery play a contributing factor in reducing noise induced hearing loss.

The two lowest form of controls serve as a primary tool in the effective management of NIHL in all industries. Good administration through identification of the severity of the noise hazards as well as good selection maintenance and training remains at the core of prevention strategies



New technology is the key to an increased use of HPE as well as increased productivity, this includes such technology that is focused not simply on noise reduction ratings but speech enhancements as well unwanted noise suppression. This brings better spacial and situational awareness and communication that categorically, industry standardised hearing protection does not account for, (Sensear, 2017) An Australian HPE developer has multiple case studies provided by heavy industry that support and encourage the use of the technology.



## Apron or Splash suit (CBRN overalls)

Where there is liquid splash potential, chemical protective clothing must be worn. This can be in the form of an apron or a CBRN splash suit. Examples of liquid splash potential are draining oil from high or low- pressure vessels. Transfer of refrigerant and Emergency response.

- i** "A well trained and resourced operator can prevent a hazardous situation from becoming a serious harm incident"



Microchem 5000 Splash suit



Drager CPS 7900 Ammonia Gas Suit

## Gas tight suit

Due to Anhydrous Ammonia being  $-33^{\circ}\text{C}$  in our atmosphere, it is paramount that any gas tight suit (Level 4) be certified for cryogenic temperatures. There are only a handful of manufactures that can supply this level of protection and it must be noted that standard FENZ appliances not equipped with these.

The Self-contained Breathing apparatus (SCBA) is worn on the inside of the suit which is then double zipped on either the side (Pass through) or the rear. Once you're in, you are not getting out without the help of a buddy. Wearing Level 4 protection is not for the faint hearted and requires both a degree of operational competency as well as psychological evaluation.

## Respiratory protective equipment

There are a number of Respiratory protective devices or RPE that can be utilized for working with Ammonia. RPE is a requirement when working above concentrations of 35 ppm or the STEL (Short Term Exposure Limit).

- i The prerequisite is annual Medical surveillance and fit testing.
- i RPE can be worn anytime as a preventable measure, if you are not comfortable with any concentration of Ammonia or any other substance or odour for that matter.



### Negative pressure respirator (Ammonia Mask)

A Negative pressure Ammonia mask requires the user to draw air through a (K) type filter, they are generally classed as an egress only respirator. They are used when opening a system and carrying out maintenance tasks and although most are rated above 1200 ppm they must not be used above 300 ppm. (IDLH)

Too often the RPE is left off due to either comfort, communication, poor training or simply laziness. The decision to don and start RPE is simple, if the task involves line opening or may require the RPE in the rare event of an emergency... put it on!



Drager FPS 7000 – COM 5000 unit

- i It is important to ensure RPE are used in conjunction with personal gas detection as well as a buddy system. This ensures firstly you do not exceed the capabilities of the respirator and secondly reach hazardous concentrations outside the immediate workspace.

## Self-contained breathing apparatus (SCBA or BA)

Self-contained breathing apparatus are positively pressurized, they are commonly considered a rescue device however it can be used in any situation. When referencing SCBA use, an IDLH or immediately dangerous to Life and health level dictates its use and for Ammonia this is just 300 ppm as outlined in the SDS sheet.

This means for many maintenance tasks required on an Ammonia system, it is recommended to have SCBA available. It is also much cheaper to fill a cylinder of compressed air than it is to replace negative pressure respirator filters. It is also good training and good fitness to wear SCBA in the workplace.



*MSA G1 Self Contained Breathing Apparatus*

In an emergency situation SCBA must only be worn by rescue trained and competent persons such as Emergency response teams and the Fire department Hazardous materials team. When working on Ammonia systems, RPE is your most important piece of equipment; it is a tool, it is a life line.

- i It is imperative that you have your RPE available at all times when onsite or on board a ship and don and start whenever line opening is performed. This includes draining oil.
- i Respiratory protective devices should be used in conjunction with a Respiratory protection management plan.

## Negative pressure respirator use and care

### Inspection

- i Peer review all apparatus to ensure that it is clean and in good condition prior to every use.
- i Ensure filters are current
- i Monthly RPE maintenance should be dated and documented in the company's Respiratory protection plan

### Donning and Starting

1. Check that all straps are fully slackened off.
2. Take breath and fit facemask chin first, adjust head harness buckles, bottom, middle, top. Pulling back on both side simultaneously
3. Exhale breath,
4. Breathe normally then check positive pressure in mask by covering the exhaust, if there are any leaks they will be felt or heard by the user
5. Check the mask seals by covering the filters and taking an inhalation, the mask will suck in towards the face.

### Cleaning

1. Wash mask thoroughly in a Luke warm solution of cleansing and disinfectant
2. Rinse mask thoroughly in clean running water, paying particular attention to flushing out the exhale valve.
3. Hang mask by neckstrap and allow to dry thoroughly away from direct sun light
4. Polish visor inside and out with a clean, lint-free cloth. Fit a Visor guard to protect visor if desired.

### Storage








Ideally RPE filters should be stored in their original packaging however as technicians and operators we should be using our RPE on a daily basis. Therefore, they should be stored in a dedicated soft-shell bag and include silica desiccant. Cooler bags make perfect respirator bags. This bag should also contain a few other items such as spare filters, a torch a knife a small shifter in the case of an emergency





## Safety Observer – Buddy

Whenever performing line opening works on an Ammonia system – it is vital that a buddy system/ safety observer is in place. The safety observer is responsible for controlling, monitoring and maintaining the safety of the activity therefore they must be trained in refrigeration and in particular; Ammonia safety. Duties includes but not limited to;

-  Providing peer review of the work method
-  Ensuring that Ammonia levels outside the immediate area do not become excessive
-  Ceasing works that appear hazardous
-  Assist the operator during works
-  Ensure all works are carried out as per the method statement
-  Carry out snap rescue
-  Assist in emergency actions









## Communication

Wearing respiratory protective devices (RPE), muffles speech. Combine the elevated clatter of a plant room and communication becomes a serious issue.

When conducting routine maintenance, it is important to discuss the work with co-workers prior to commencing the task to ensure everyone is on board with what actions will be taken over the course of the job.

More often than not, the task will require an alternate action or extra series of steps, where we have already donned RPE, communicating the change is almost impossible unless you already have arranged signals, com-set respirators or hearing protection or just having a really good understanding of the job at hand and your co-workers body language.

In an emergency there is very little time for miss-understanding therefore setting a series of general signals is of the upmost importance. It does not matter if your signals are correct sign language, as long as everyone is on the same page. The most important signs to agree on are;


-  Are you Ok?
-  I'm fine
-  Look
-  Danger
-  Ammonia Leak
-  Close / Open (valves)
-  I go – You go
-  Stop



## What could go wrong?

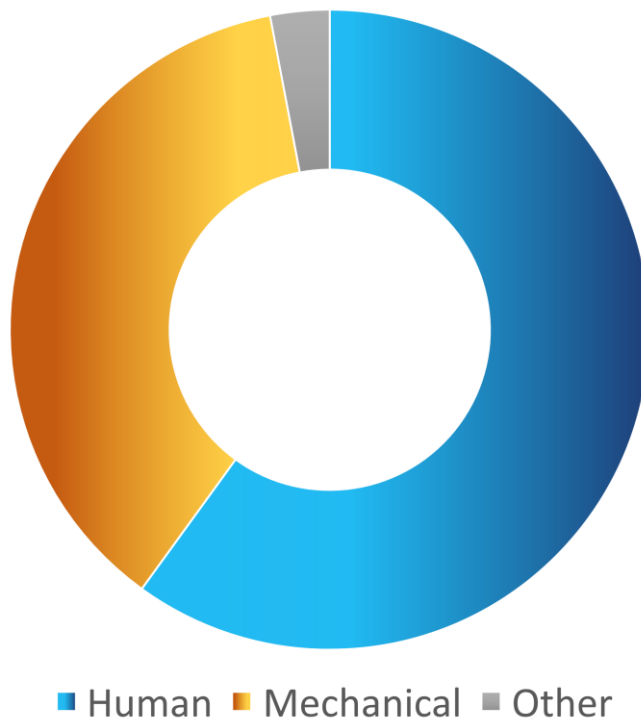
Refrigeration systems are not subject to instantaneous losses of their charge in the entirety. They are comprised of multiple interconnected components that form a refrigeration system. Yet, without rapid response and rectification, the total loss of charge is a possibility overtime. Where a large initial release has occurred, the system can rapidly depressurize, and hundreds of kilograms of Ammonia can remain within the system slowly venting toxic gas for hours or even days. It is important that specialists are on site during an emergency as fast as possible and work with the fire service in an integrated approach to resolve the emergency.

During a worst-case scenario (Plumes/Clouds) a portion of the charge may eventuate in pooling, this is suggested to be up to 20% of the release which will then evaporate at a much slower rate due to cooling of the ground and having no source of heat to “boil” the ammonia into a gas.

 e.g. 1000kg total loss = 200kg pooling potential

Except for natural disasters, (Thomas, 2017) 97% of uncontrolled Ammonia releases are attributed to Human error or Human failures to maintain an acceptable level of mechanical integrity. This is why detailed, trained procedures should be developed and adhered to in every instance.

### CAUSES OF AMMONIA EMERGENCIES



*Causes of Ammonia releases*

## Human Error

In Northland, 1986, a worker with years of experience as a marine class engineer and in large Ammonia plant operation, made a fatal error in judgement. From second hand reports; whilst he was working alone, in a somewhat confined space, the Engineer removed what he thought was a temperature sensor however in the process, removed the entire pocket from a high-pressure liquid line. As a result, he lost his life as well as put many others at risk. This was the last known fatality from Ammonia in New Zealand.

Causes of Ammonia leaks through human error include;

- ❗ Poor training/instruction, technical deficiency
- ❗ Unsafe Behavior or complacency
- ❗ Working too quickly
- ❗ No supervision or Safety Observer
- ❗ No Risk assessment or Permit to Work (PTW)
- ❗ Poor communication / co-ordination – management of change
- ❗ Fatigue, lack of concentration











The image above was taken from a plate freezer liquid supply header. Plate freezers are a method of rapid freezing that permits direct product contact with Ammonia filled aluminium plates that are used to stack product. Once "shelved" they are hydraulically sandwiched together and left to freeze. Due to the direct contact, they require hot gas defrosting to allow the plates to be separated as they would otherwise stick firmly to the product. This system in question had a burnt out hot gas solenoid coil. Instead of procuring and installing a \$50 Solenoid coil, the operators would use large pieces of pipe and the purchase of the valve shafts in order to separate the plates. Hence why they are bent, a very dangerous practice.

## Fatigue

*"Oh, you worked a 70-hour week, I remember when I had a part time job".* This is an internet meme that circulates refrigeration social media. Worker fatigue is something that plagues our industry as well as many other professions that involve a call out roster. Most refrigeration technicians would have experienced several ninety-hour weeks or more at some stage in their career. Shift changes, long hours as well as regular interrupted sleeping patterns during after hour call outs is a recipe for disaster, not just on the job but when driving home. Furthermore, it has been scientifically proven to be counterproductive to work past 12 hours.






The PCBU must attempt to manage worker fatigue before it occurs as well after the signs have been observed.

This may include;

-  Capped daily hours and working week
-  Regular contact with operations managers
-  Higher frequency callout rotation
-  Paid stand down
-  Stand by technician
-  Training staff to monitor the sign of fatigue
-  Cognitive assessment prior to work
-  Options for alternative transport after long shifts

## Vehicle Impact

Vehicles colliding with Ammonia pressure equipment is more common than we would like to imagine. All Ammonia pressure equipment must be assessed and guarded from potential collision with Forklifts, Trucks and Elevated Working Platforms (EWP), this includes such controls as;

-  Warning signs
-  Clarified exclusion zones
-  Low speed zones
-  Bollards
-  Driver training around the seriousness of rupturing Ammonia pressure equipment.

## Mechanical failure

Due to age, leaks can often be caused by a deteriorating system component. Although a failure in mechanical integrity, these are indirectly attributed to human failures to; design, install and maintain the equipment appropriately.



## Points of failure

### Insulated cladding

Insulation can hide a multitude of sins. The point where insulated pipe meets valves or components is a typical location to find corrosion and should be well treated with either a suitable industrial coating and or hydrophobic lubricant such as fish oil or lanolin, or simply wrapping correctly with Denso® prior to cladding. Inspection and documentation of all of these areas should be included on the annual mechanical integrity audit.

- i Cladding joints should be seamed at the bottom (6 o'clock) and where ever possible, all joints should be sealed with silicon to prevent moisture ingress.

### Insulated hot gas lines

Ammonia pipe work that is subject to constant temperature variation is one of the highest positions to find corrosion. It can also go unnoticed for many years. For this reason, it would be pertinent to carry out random inspections at various sites throughout the plant.



## Pipe supports

Pipe should be individually supported and not being allowed to form a thermal bridge to one another. Pipework structure should also be assessed for seismic compliance.



- i** Refrigeration systems are often installed by pipefitters, before an Ammonia technician can oversight any assembly. It is common to have the brackets clamped prior to painting or protection of any kind, it is here that we look first for leaks beneath insulation.

## Hydraulic Shock – Water Hammer

### Defrosting

During the start of a hot gas defrost cycle, if the suction stop valve has not shut correctly, instances have occurred where vapor in the evaporator and suction header rapidly condenses. High pressure and high velocity surging liquid Ammonia can in effect cause a massive liquid projectile that can cause a hydraulic rupture on pressure equipment. It is important to have well designed hot gas defrosting system that includes, equalization times. It must also have stable defrosting parameters. Valves must be given time to both open and close sufficiently and safely to avoid situations where hydraulic shock can occur. Regular defrost checks should be included on maintenance schedules to monitor the safety and optimization of defrosts. On August 23, 2010, Millard Refrigerated Services Inc lost 14,500kg of Ammonia this way, suffering an out of boundary incident where more than one hundred and fifty people were exposed, thirty workers off site had to be hospitalised and landed four of them in an intensive care unit.

### Liquid Flood back and traps

Liquid Ammonia that is allowed to enter compressors may cause major damage to the compressors mechanical parts and possible rupture of the heads or casting. Non-return valves must be installed on Compressor Discharge lines and traps must be fitted with drain floats to avoid all scenarios of hydraulic rupture. Annual checks of the Accumulator High level shutdown safety switch must be physically tested and not just electrically checked.

### Liquid make up valves and pumps

Shaking and Banging is a symptom of something seriously abnormal with the system and must be investigated. Poor or faulty bracketing can be a cause or indicator that make up valves are operating too responsively. Shaking pipework can result in catastrophic incidents due to stressing the pipework and welds through work hardening, hydraulic shock to seals or through flange separation. Liquid pumps that are short cycling through cavitation or poorly programmed low-level failure protection parameters generally don't cause serious hydraulic situations however, repeated events have been proven to destroy gauges and differential switches very quickly. The result is typically minor in nature however even a small quantity of liquid Ammonia in a poorly ventilated room can be cause for concern and possible site evacuations.

### Isolation of pipe work and components

Due to the incompressibility of liquids, by isolating a refrigerant between to components something must give. The ammonia pressure will rapidly increase until pressure is released through a point of least resistance or a pipe bomb style rupture will be the consequence. Components that can be potentially isolated with liquid must have pressure relief capabilities to a lower pressure side of the system or to atmosphere.

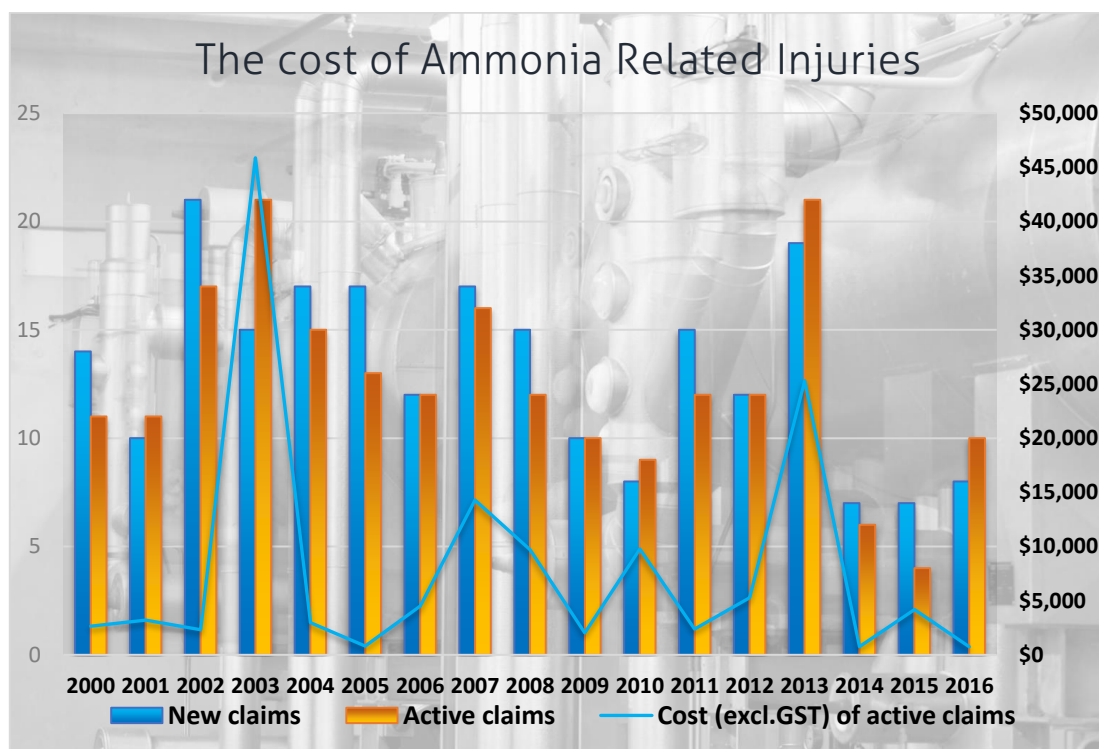
### Compressor Capacity Control

Screw Compressors that have untuned capacity control have demonstrated numerous times to be the cause of major Ammonia leaks. Any continuous hammer will cause the compression fittings to shear clean off.

## How often could it happen?

The potential for accidental release is variable on many contributing conditions, the era of install as well as attitudes of the PCBU toward asset and hazard management are just some. These variables cannot be qualified or quantified without an in-depth review of the facility itself. Accidental releases of Ammonia in all applications, indicated by *Chemical Accident Risks in U.S. Industry-A Preliminary Analysis of Accident Risk Data* from U.S. Hazardous Chemical Facilities, are 0.018 release per year per million pounds stored (Salamy, 2006)

If we examine the accident data between the year 2000 – 2016 received from Accident Compensation (ACC New Zealand) We have totalled 224 recorded injuries, averaging 14 accidents per year. Although we have not observed a fatality in over thirty years, our accident statistics suggest we are close to witnessing another.



- i Variations on probability indicate the risk of death from an Ammonia release at 2:1,000,000,000, (Berghmans, 2009)
- i The Swedish Rescue Service estimate the risk of a catastrophic event at 1 in every 10,000 - 100,000 years per installation,

In comparison;

- i Car accidents are calculated at seven persons per 100,000 inhabitants
- i Earthquake deaths result 1 in every 179,965 inhabitants.
- i The likelihood of winning first division Powerball in New Zealand 1: 38,383,800 (\$11 million) (Lotto\_New\_Zealand#Records, 2017)

By collating data from the US Centre for effective Government, we can start to see evidence of alarming results. Having an approximated 200 installations we have significant injury rate per facility.

Ammonia facilities (United States) Injuries by state 1996 – 2011						
Facilities /state	Injuries	Injury rate/ accident	Injury rate/ facilities	Accidents	Accident rate	Deaths
246	12	70%	4.9%	17	4.5%	0
243	19	126%	7.8%	15	6.2%	1
225	10	90%	4.4%	11	4.9%	0
182	28	107%	15.4%	26	9.9%	0
163	19	126%	11.6%	15	6.1%	0
158	27	150%	17%	18	10.1%	0
156	59	184%	37.8%	32	14.7%	0
147	31	281%	21%	11	6.1%	0
135	28	215%	20.7%	13	7.4%	2
121	2	50%	1.65%	4	3.3%	0
113	133	554%	117.7%	24	17.7%	5
104	16	59%	15.4%	27	9.6%	0
100	45	109%	45%	41	21.0%	0
Anhydrous Ammonia facilities (United States) Injuries Totals 1996 – 2011						
9982	1651	175%	16.5%	939	6.8%	19
Estimated New Zealand Ammonia facilities comparison of actual incident and injury claim data 2000 – 2016 (ACC, Fire and Emergency, 2017)						
200	224	55%	112%	405	202%	0

*Note: due to industrial action of the New Zealand Fire Service between July 2009 – December 2009 and August 2011 – March 2012 information may not be comprehensive.*

 These are only reported incidents.

## Failure Probabilities

The table below Indicates the accidental release scenarios and probabilities for ammonia (The Centre for Chemical Process Safety, 1989)

Accident Scenario	Failure per year per facility
Onsite Truck Release	0.0000022
Loading Line Failure	0.005
Storage Tank Failure	0.000095
Process Line Failure	0.00053
Evaporator Failure	0.00015

*General Accidental Release Scenarios and Probabilities for Ammonia*

## Pipe rupture flow rates

25mm	50mm	80mm	100 mm
16 kg/s	65 kg/s	190 kg/s	300 kg/s

*Pipe rupture rate at 12 bar earthquake example (Linborg, 2006)*

## Aersol plume (Displays "Relief hook")






*Example of Ammonia Plume "hook" (Source unknown) Google*



## Minor Leaks

The most common leaks experienced are minor and are from such components as mechanical seals. These include valve gland packing and compressor shaft seals which act as a rotational sealing surface between the system under pressure and the drive shaft or stem exposed to our atmospheric pressure. They are usually minor in nature and do not normally require intervention from emergency responders. As compressors are housed inside machinery rooms it is important that the ventilation system is sufficient to maintain safe levels (<300ppm) in this type of situation.



*We can define minor leaks as; situations that do not affect areas outside the immediate location of the source. Typical releases of this nature involve:*

-  Compressor mechanical seals
-  Valve gland leaks
-  Flange O-ring/Gaskets






## Major Leaks, Internal/External (Out of boundary potential)

Specific emergencies that are likely to occur are difficult to define steps for a response as there are so many variables; Location, system design, automation. This will be covered in a future module. Making changes to a leaking system without understanding the consequence can have detrimental effects to the outcome of the situation. Do not attempt to remedy a leak without an expert understanding of Ammonia systems.

Categorically many leaks occur whilst conducting maintenance of some form. Where trained and equipped, an operator can minimise a hazardous situation before it becomes a hazardous outcome.









-  Common major leaks are generally attributed to overpressure scenarios or failure during transfer.
-  Emergencies or uncontrolled releases can occur anywhere in your system and can be defined as:

*Situations that affect areas outside the immediate location of the source. Typical releases of this nature involve:*







-  Pressure relief valve operation as a result of High pressure safety switch failure
-  Flange separation O-ring/Gaskets
-  Pipe corrosion
-  Component failure
-  Vehicle impact

## Catastrophic leaks

Catastrophic leaks stem from natural disasters and human error/bad judgment; vehicle impact, hydraulic rupture that cause rapid loss of charge and or a deflagration (flash burning) Likely scenarios of such an event include;


-  Installation malfunction
-  System maintenance
-  Transfer or Charging the system
-  Pipework Corrosion
-  Internal / low level pressure relief valve activation
-  Hydraulic rupture
-  Vehicle impact
-  Imbalance that causes shock

We can further categorize these situations in to levels of severity;


-  Controlled and Contained
-  Uncontrolled, Contained
-  Uncontrolled, Uncontained
-  Level One – site managed emergency, requiring third party assistance
-  Level Two – Requiring third party assistance and Emergency Response Personnel
-  Catastrophic - Requiring third party assistance and Emergency Response Personnel and corporate management

## Incident Reporting

Anhydrous Ammonia leaks that could of exposed workers is a notifiable incident under the Health and Safety Act 2015.




-  Section 24  
*In this Act, unless the context otherwise requires, a notifiable incident means an unplanned or uncontrolled incident in relation to a workplace that exposes a worker or any other person to a serious risk to that person's health or safety arising from an immediate or imminent exposure to (1) (a) Escape Spillage of a Substance (d) Escape of a Pressurized Substance.*

Pressure Equipment (Cranes and Passenger Ropeways) Regulations 1999

-  Clause 9  
*Accident Notification (2) (c) An incident that; might, in different circumstances, have caused a person to be seriously harmed.*

## How severe is the risk of harm to people?












Records are very limited in this area but historically, members of the public have not sustained injury in great numbers. From our research, only a few have resulted in injury or fatality. Most injuries and deaths happen to engineers and emergency responders that are working within meters of the initial release. Hospitalisations or monitoring of the public involved in Ammonia incidents are normally precautionary. The severity of harm is dependent on;

-  Distance from the source
-  Peak Concentration of exposure
-  Time of exposure

E.g. Anhydrous Ammonia Release 2,764 kg / 15 min				
Downwind distance Meters (y=0)	Peak Parts per million	Delay to reach concentration at distance (min)	Elapsed Time of release at peak concentration	Result of exposure
50	54,000	<2	>20	Lethal Greater than 1/5" Lower Flammable Limit
100	12,300	<5	>20	Lethal
200	3,190	<10	>20	Lethal in minutes
300	1,540	<10	>20	AEGL3 30 min max
400	943	<10	>30	AEGL3 60 min max
500	650	<10	>30	AEGL3 60 min max

*Worse case example of inhalation exposure from ALOHA modelling*

The above Table is from gas dispersion software (ALOHA) detailing a massive 181 kilograms/min release. The total elapsed time of the potential exposure before dispersion occurred was longer than the release itself due to contributing weather conditions. The severity is dependent on many contributing factors such as;

-  Internal / external
-  Source strength (Pressure, Size of hole/crack)
-  Source Elevation
-  Topography / buildings
-  Wind direction
-  Wind speed
-  Weather stability class
-  Humidity
-  Distance of downwind receptors
-  Time of day
-  System volume







## The effect of surrounding areas & structures

As Ammonia expands in our atmosphere, it forms a three-dimensional conical shape from the source of the release. In worse case scenarios it can travel many kilometres. The actual length, shape and pattern of movement is determined by atmospheric factors such as; humidity, temperature, Inversions, fronts, wind speed and direction. However, when released at low elevations, it is subjected to the effects of surrounding buildings and topography. Therefore, an example of the toxic threat zone may look like the image below. It is important that evacuation pathways in order to reach muster stations be carefully established and take into account egress points in relation to the prevailing wind direction of the region.



















Effects of three dimensional structures

## Experiences of exposure

-  Awareness of Ammonia presence
-  Inconvenience (repulsive odour)
-  Alarm (no injury but fear of harm / panic)
-  Minor Injury resulting in first aid or observation (Dermal/ocular burns and or Inhalation)
-  Acute injury (Serious burns and or Inhalation)
-  Fatality

## What can we do to reduce the impact of the hazard?

Maintenance and operation as well as any modifications must now be made under the guidance of Joint Australian New Zealand Standards (AS/NZS) 5149-Parts 1-4:2016. the most substantial guidelines are;

-  Periodic Pressure vessel inspection
-  Pressure Relief valves replaced or calibrated 5 yearly
-  High pressure safety controls tested and documented
-  Hazardous area assessment (Flammable equipment)
-  Explosion proof (EX) ventilation
-  Emergency lighting (EX)
-  Emergency ventilation (EX)
-  Fixed gas detection, Sensor locations and Coverage adequate,
-  Remote de-energize (shunt) all non-EX rated equipment
-  Emergency shower to provide tepid water
-  Emergency warning system to be visual and audible
-  Engine room access is secure against tamper and only available to trained specialists
-  Refrigeration equipment sealed from atmospheric communication with occupied spaces
-  Pipework and vessels protected from vehicle impact;
-  Relief vents must vent to a safe location
-  Relief valves to indicate operation

Compliance alone does not ensure the hazard has been controlled. Structured asset management along with good documentation, of regular identification, analysis, action, training and testing is required to maintain mechanical integrity system performance, efficiency and emergency response capability.



## Design

There are many planes of legislation and standards which are required to be considered when designing an Ammonia facility including; the building and electrical regulations. Much of the legislation and corresponding documents can be difficult to clarify and sometimes conflict. Here we will touch on some clear-cut design guides that increase health and safety of an Ammonia facility. The most primary referenced documents in Ammonia Refrigeration are Joint Australia New Zealand Standards;

### 1. ASNZS 1677.2.98 (Superseded)

*Refrigerating Systems Part 2: Safety Requirements for fixed applications*

### 2. 5149.Part 1-4.2016


*Refrigerating Systems and Heat pumps; Safety and Environmental Requirements*

### 3. ASNZS 2022.2003

*Anhydrous Ammonia storage and Handling*

### 4. International Institute of Ammonia Refrigeration IIAR 2 2014




*Standard for Safe Design of Closed-Circuit Ammonia Refrigeration Systems*

-  The Building Act, Electrical Regulations. are among many others that will require referencing.

## Major Hazard Facilities (MHF) Regulations 2016 UT/LT

Not required for most installations however it is recommended as a good strategy in the management of all Ammonia facilities.

The regulation itself includes the aggregate quantities to establish MHF status and then further states; if there is potential to cause serious harm offsite. As we know Anhydrous Ammonia in even small quantities has a high potential to go off site.

-  50,000kg Lower tier
-  200,000kg Upper tier
-  Off-site potential to cause serious harm.

This includes the following strategies;

Providing Safety Cases  
 Notifications and Designation  
 Safety Assessments  
 Emergency planning  
 Accident Prevention Policy ]  
 Safety Management Systems

## Pressure equipment

All pressure equipment should meet the requirements of the Pressure Equipment, Cranes, and Passenger Ropeways Regulations 1999 (PECPR).

Vessels and pipework should be design verified, and non-destructive (NDT) strength tested as well periodically inspected by an independent surveyor for the life of the plant.

Pressure vessels must be protected from over pressure by firstly an electro mechanical safety device and secondly a pressure relief valve which is the last form of defence. If the system safety devices are functioning correctly a PRV should not operate, unless there is another form of heat that can increase pressure within the system. This may include liquid pumps that do not shutdown or hydraulic rupture scenarios.

- i All pressure equipment should be suitably treated with an Industrial coating application or in certain circumstances hydrophilic lubricant.
- i Pressure relief valves (PRV) should be certified or replaced every five years from installation.
- i Pressure relief valves outlets should be atmospherically terminated at a sufficient distance from workers and so there is no possibility for it to re-enter any adjacent buildings.
- i Diffusion tank systems and scrubbers are other methods of terminating pressure relief valves but require intensive engineering to get it right.

Pressure relief lines should be monitored by way of an Ammonia detector, Pressure switch or flow switch to provide an external alarm in the event of an either a mild weep or full-scale overpressure scenario. Each pressure relief valve group (Duplex valves) should have a way of establishing if they have activated. This can be a oil filled column or a rupture disk.












## QCDV – Quick Close Drain Valves

QCDV are spring loaded valves that require the operator to hold the valve in order for the fluid to flow. They are not idiot proof as they can be “jimmied”. Doing will only provide a suitable outcome for only so long, it is a very dangerous practice. Statistically, oil draining is one of the highest origins for Ammonia injury. All drain service points on an ammonia system should be fitted with a QCDV or “Deadman Valve” there is no exceptions.



## Electro-mechanical Safety devices

Electrical and or mechanical devices are critical for a refrigeration plant to prevent failure, they include but not limited to the following cut out protection;

-  High Pressure
-  High Temperature
-  High vessel Level
-  High Current Draw
-  Low Pressure
-  Low Oil Pressure
-  Emergency Stop
-  Manual call points
-  Ventilation controls

Safety devices should be programmed for testing frequently to establish there calibrated within acceptable limits as well as the physical ability to shut down the plant.






## HAZCHEM Placards

As simple as it may seem, signage and labels are one the most cost-effective measures to improve safety on site. They are vital for warning of the dangers of specific hazards. All of areas where Ammonia is present including the entry point to site itself should display HAZCHEM placards. They are important signs that help emergency responders distinguish what they are fighting.

HAZCHEM graphics are multilingual signs that warn us of a specific danger. The alphanumerical code alone is critical for emergency responders as it provides key information of how they manage the situation, as well as what equipment they require.

Despite the importance, our regulations in New Zealand; believe it or not - exempt Anhydrous Ammonia when used as a refrigerant from having signs displayed. Regardless of this fact, installation of HAZCHEM signs are best practice.

<b>HAZCHEM</b>		<b>ANHYDROUS AMMONIA</b>	
		<b>CODE</b> <b>2PE</b> <b>UN NO.</b> <b>1005</b>	<b>IN AN EMERGENCY DIAL 111 - FIRE</b> <b>DO NOT SPRAY WATER DIRECTLY ON LIQUID SPILLS</b>
<p><b>Avoid all ignition sources. Gas under pressure; may explode if heated. Liquid will cause severe freeze &amp; corrosive burns to skin &amp; eyes. Acutely Toxic, do not breathe vapours. Overexposure may result in death. Do not allow to enter drains.</b></p>		<p><b>FIRST AID INFORMATION</b>          In all instances, immediately seek expert medical attention. Use caution – do not become a victim. Remove patient from area of exposure.  <b>Skin &amp; Eye contact:</b>          Rinse clothing, skin, hair &amp; eyes with copious amounts of luke warm water.  <b>Inhalation:</b>          Keep patient at rest. If not breathing use caution if providing mouth to mouth resuscitation.</p>	
<b>Manufacturer:</b> <b>Year of installation:</b> <b>Design Pressure:</b> <b>Refrigerant charge:</b> <b>Lubricant:</b>		<b>Personal Protective Equipment</b> 	
<b>24 hr. Specialist Advice:</b>		<b>WORKPLACE EXPOSURE STANDARDS</b>	
<b>+64223941865</b> 		Time Weighted Average: 25ppm 8 hours max	Short Term Exposure level: 35ppm 15 min max
		Immediately dangerous to life or health: 300ppm	

-  The United Nations number (1005) is an international transport code
-  The two (2) indicates what extinguishing media must be used. For Ammonia this is a fine mist or fog nozzle
-  The first letter (P) indicates that responders require breathing apparatus and gas tight suits as well as whether the chemical is volatile
-  The second letter (E) indicates that there is a need to evacuate
-  The pictograms of the primary classifications are easy to understand, even for a small child. The images of death and burns speak for themselves.

## Identification Signs

Critical shut off valves, Ventilation controls, Emergency Exits, Alarm strobe and sirens, Emergency stops all need clear designation for what they mean and or what they are required to do when operated or activated.

## Pipework and Labels

The general colour of Ammonia pipework is the same as Natural gas. Various paint manufactures will have various trade names for the same colour;

 TWINE – Resene ® Brand

You can have any colour provided there is distinction between other products as well as a clearly established key.

To further indicate what is inside pressure equipment. Labels are suggested by international standard committees. In New Zealand AS1345 is referenced.

Even an experienced Ammonia operator and engineer needs to trace pipework to confirm correct configurations for general operation or line opening.

In the event of an emergency it is even more important to have rapid identification of the correct valves to isolate. This includes valve tags that are accurate to the PandID. Good drawings can allow for offsite advice for both emergencies and asset management.





## Wind indication

Which way is the wind going today? Unless you are an avid sailor or fishermen taking note of the wind direction is not an everyday priority. Having prior knowledge of which way to vacate the area in a toxic gas leak can be life saving.

- i Windsocks is of the highest priority for any effective emergency response capability.

You might often hear that you must evacuate upwind in an Ammonia emergency. In many ways that is not entirely incorrect. If you are downwind, upwind is where the source of the Ammonia leak may be. You wouldn't walk towards a speeding car to get out of the way? The best place is to be behind the car no doubt.

- i Upon hearing an Ammonia alarm or Alert notification it is best practice to shelter in place in the first instance.
- i Identify where the source of the leak is as well as the wind direction. Remembering the way, the wind sock or indicator is pointing is downwind.
- i Evacuate cross wind where possible then position yourself upwind as best as available and at a safe distance from the release.
- i Take note of the weather report as the wind can alter its direction and velocity.

Wind socks should be an easily recognisable colour (Fluorescent orange), be positioned so they can be identified in all lines of sight within the facility, as well as externally of the facilities boundary. They should also be backlit or through lit unless there is sufficient ambient light at night.



## Emergency warning systems

Fixed gas detection, monitoring and shutdown interface systems are mandatory under the building regulations for altering workers as well as protecting the plant from ignition. When used in conjunction with a data acquisition system they can identify minor releases before they become a hazard. Inattentiveness during the design, selection and installation can render a gas detector as good as useless.

- i It is important to have lower range detectors installed for monitoring workplace exposure limits i.e. a 0-300 ppm will provide better accuracy than a 0-1000ppm.
- i It is just as important to have a lower explosion level detector that measures very high concentrations. It must be EX rated or Intrinsically safe to ensure operability in emergency situations. It is there to instantaneously shut down all ignition potential.
- i Fixed gas detection systems should have alerts for when they are in fault.
- i Full circuitry tests should be tested frequently.



*Photonic Innovation OPLD*

Having only a low-level toxicity sensor means that it will be unable to provide engine-room concentrations to emergency personnel in the event of a hazardous incident as they will basically over-range and provide zero feedback. It also means that any service work will require bypassing of the critical early warning system, when it is needed most.

There are various sensors available on the market all with pros and cons;

- i Electrochemical tolerates humidity, high accuracy but they are expensive and have a short service life.
- i Electro – Semiconductor have a long service life, high tolerance, faster response time but have high cross sensitivity.
- i Laser – High Accuracy, faster response time and high fidelity, nil cross sensitivity but have higher initial capital cost.

Fixed gas detection (FGD) should be installed with consideration to the room volume, air flow and geometry. FGD should be positioned above compressors and liquid pumps, It is important that any detection installed has been well positioned to cover all plant. In most situations multiple detection units are necessary.

- i Sensors should be mounted at face height on central structures where possible as well as at high level to capture higher occurring leaks.
- i LEL sensors should be included in every engine-room and where in an enclosed space that can potentially approach 1/5<sup>th</sup> of Lower Flammable range. (30,000ppm)
- i All valve stations should be monitored, in particular when installed in roof spaces.
- i Refrigerated spaces and production areas that have fittings and valves should be monitored.
- i Pressure relief lines should include a detector on the common header.



Systems that have PLC can include further alarm rationale to include, many functions;

- i Debounce – Anti nuisance timers
- i Service bypass low level parameters (high level alarms remain active)
- i Multiple warning and alarm levels
- i Initiating forced ventilation.
- i Controlled pump down of Individual areas
- i Shutdown of evaporator fans
- i Shunt trip engine-room
- i External alerts

Example:

Concentration	Location	Emergency declared	System	Site Action	Ammonia Technician Action (NZQA 30127)	Minimum PPE
25 ppm	Internal	Level One	Strobe / Alert notification Service bypass available	Notify Site IMT and Service provider Sign and secure source location	Two competently trained technicians inspect – completing prior: Wind check, Remote viewing for stability, bump test of Respirators/Emergency Irrigation/Personal NH3 Gas detection. Staged entry	Overalls Safety Glasses Safety Foot wear Personal Gas Detector Respirator (Donned)
>35 ppm	Internal	Level One	Strobe / Siren / Alert notification Service bypass available	Notify Site IMT and Service provider Sign and secure source location	Two competently trained technicians inspect – completing prior: Wind check, Remote viewing for stability, bump test of Respirators/Emergency Irrigation/Personal NH3 Gas detection, Staged entry	Overalls Safety Glasses Safety Foot wear Personal Gas Detector Respirator (Donned and Started)
>300 ppm	Internal	Level Two	Strobe / Siren / External Alert notification. Shutdown liquid pumps, Effected valve groups, Controlled pump down. Force Ventilation on Service bypass NOT available	Notify Site IMT, IRT, FENZ and Service provider Sign and secure source location Set exclusion zone 100m or > Set ICP	Ammonia Technician inspect with FENZ or Site IRT, Two in Two out Note: IDLH Value Requires SCBA usage and NZQA 3272/25044 Staged entry	Chemical Rated CBRN First Response Overalls or L4 Gas suit following risk assessment. Safety Foot wear Personal Gas Detector Positive Pressure SCBA (Donned and Started)
>10,000 - <30,000 ppm	Internal	Level Three	Strobe / Siren / External Alert notification / Shunt trip engine room, Force Ventilation on Service bypass NOT available	Notify Site IMT, IRT, CMT, FENZ and Service provider Sign and secure site Notify neighbouring properties Set exclusion zone 100m or > Set ICP	Provide Tech Support	No Entry
External release	Unknown	Level Three	Strobe / Siren / External Alert notification, Force Ventilation on	Notify Site IMT, IRT, CMT, FENZ and Service provider Notify neighbouring properties Set exclusion zone 100m or > Sign and secure site Set ICP	Provide Tech Support Risk based inspection	Chemical Rated CBRN First Response Overalls or L4 Gas suit following risk assessment. Safety Foot wear Personal Gas Detector Positive Pressure SCBA (Donned and Started)

## Sounders and Strobes

Alarms must be able to alert all work areas on site this includes chillers, freezers and where applicable the surrounding community. Any engine-room alarms will need to be protected from possible point of ignition. They should also be capable of producing enough sound pressure over and above that of any background noise.



## Emergency irrigation

Emergency shower systems should be located externally and within a short distance from the plantroom but in a safe location.

- i They should be hands free.
- i They should be heated to body temperature to primarily encourage the patient to decontaminate. Secondly to avoid shock and hypothermia and to maximize the irrigation of a chemical burn, cold water will shrink the skin, often referred to as closing pores.
- i Warm water is more effective at rinsing chemicals.
- i Incorporating a flow switch to activate an alarm in the event of a worker using the shower would be best practice.

ANSI / ISEA Z358.1-2014 provides guidance on an engineering a safe shower system. Showers and eye washes will be used more often than accident reports would suggest and are essential for a safe facility.



## Ventilation

Well-designed ventilation systems are in place to minimize the accumulation of toxic and explosive atmospheres.



- i Ventilation Fans and corresponding electrical circuitry must be explosion proof. This includes switching equipment and fan blades to be manufactured from non-sparking material.
- i Ventilation can be continuous in operation or where the ambient temperature is too low, it can be cycled via a thermostat.
- i In the event of an emergency, the ventilation should be forced on.
- i Where refrigerating equipment is installed in occupied spaces or has the potential to reach 20% of the lower explosion level (30,000ppm)  
Emergency ventilation should be incorporated to maintain a high volume of fresh air and maintain the concentration below the IDLH. (300ppm)
- i The exhaust of the ventilation must not discharge to occupied areas or in the event of an emergency prohibit safe access for emergency responders. Therefore, it should be terminated as high as possible.
- i Ventilation should have controls both internally and externally to allow for operational containment in the rare event that it is more beneficial to isolate the refrigerant in the plant room. E.g. The weather conditions are causing Ammonia to hook groundward or direct Ammonia toward a boundary of a publicly occupied area.
- i Two or more fans should be incorporated to all plant rooms as both a failsafe as well as to facilitate rapid reduction in toxic and potential flammable atmospheres.
- i Ventilation systems should be designed or modified so that no dead spots occur. This should include both low-level and high-level intakes that promote sufficient air volumes.
- i Any engine room openings should eliminate any chance of Ammonia entering occupied spaces in the event of power failure.

## Emergency Management

In an Ammonia emergency there is a huge risk for severe consequences. Potential injury and loss of life are of course on everyone's minds but more common than not, considerable financial losses are a result of emergencies. These are due to a combination of product contamination, lost production and negative press. There may also be off site effects that cause neighboring business to evacuate their premises as well as subsequent punitive damages from the legislators.

An emergency plan can be defined as; the necessary actions to respond immediately, effectively and safely to any unexpected event which threatens life.

- i This will include the on-site co-ordination of all site personnel, local Emergency Services, and other response specialists.
- i Co-ordination is best achieved using a CIMS based EMP ensuring a focused rapid initial response and ongoing seamless interface with external services on arrival.

During unplanned Ammonia releases the following can be experienced;

- i Involuntary contact (Panic!)
- i Experience and knowledge is very limited.
- i Considerable financial losses due to damaged products and/or lost production or worse – fatalities!
- i The emergency services are not a reliable method of resolution






The Hazardous substances regulations 2017 state a plan is necessary for the correct management of Ammonia systems once system charges exceed one hundred kilograms. Instructions on forming a compliant emergency response plan can be obtained online. It is paramount that the plan be clear and easily followed. It should be conspicuously displayed on site and accessible for all workers.

The plan should provide very simple instructions for staff and contractors on what an emergency is and what actions to take at each point. It shall provide emergency responders with refined protocols, detailed site information, drawings and Ammonia Safety data sheets. All sites holding substantial quantities of Anhydrous Ammonia should ideally have an emergency management team (EMT) of some description. Relying completely on the Fire service is not a recommended method of dealing with engineering problems. The emergency services are not trained in Ammonia system isolation and are an unreliable method of resolving the situation. Their knowledge and experience are to maintain human life and minimize further risk associated with the leak. Having an appropriately trained and confident response team on site can drastically reduce the risk of issues from escalating.

The formation of an EMT does not automatically mean you require personnel to enter a contaminated atmosphere, more importantly it is so there is a dedicated team that forms a hierarchal chain of command to efficiently deal with the incident. An emergency response team should be formed to include members of management, administration, Health and safety committee, Fire wardens, Engineers (technical advisory) and where applicable; a rescue squad.

## Emergency plan contents (ERP)

Consideration factors required to decide on the appropriate level of response for your site include but are not limited to;

-  Site proximity to neighboring properties
-  Distance or duration from expert assistance and emergency responders
-  On site staff capabilities
-  Response equipment and resources available
-  Plant Automation

The plan must be tested and rectified in order to be compliant as well as functional. It should be a capability and not a document. Ammonia is relatively inexpensive, so recharging a plant is normally an insignificant cost compared to the cost of human life, if there are safety issues with isolating the plant, but no further risk to people or product, don't put anyone in further danger by trying to isolate. Answers and instructions for an ERP must include;

1. What incident specific emergencies could take place
2. Where to find information on the substance
3. How to decide what actions to take in various levels of emergency
4. How the ERP activated
5. How you account for all site personnel
6. How you ensure their safety and welfare
7. Who is responsible, what skills they have and how to contact them
8. What is the extent of the exclusion zone based on each level of emergency
9. Where will cordons be established and by whom
10. Whom is within the Exclusion zone
11. What is the specific consequence considered
12. How you notify the local community
13. What information you need to provide
14. If Evacuations required what / where are the designated muster points
15. How you maintain that communication link (escalations / de-escalations)
16. Agreed actions for responding FENZ units
17. Agreed location of any required Incident Control Point (ICP)
18. Incident Management Team responsibilities
19. How you assist FENZ Incident Controller with technical advice
20. How you build an Action Plan and Risk Assessment
21. How and when to provide regular updates to CMT
22. What are the Crisis Management Team (CMT) responsibilities;
  - a) Media
  - b) Welfare / family liaison
  - c) Business Continuity
  - d) Risk (Legal/reputation)

## Emergency Management Duties

An emergency management team may take care of the following duties on site;

- i Carry out daily wind direction check and notify staff of evacuation assembly point.
- i Organise “bump testing” of the Emergency showers and Ammonia monitoring equipment and circuitry
- i Review, document contingency plans and procedures after every variable from the initial plan, evacuation or incident.
- i Maintain all response and safety equipment
- i Carry out notifications of Hazardous works
- i Connect with local Fire department Station officer
- i Carry out simulated evacuations or shelter in place, to test procedures
- i Evacuate staff and contractors in the event of an emergency
- i Rescue staff or contractors (Highly trained Emergency response teams only)
- i Assist Emergency responders in the repairs and isolation.
- i Keep impeccable records of all of the above












## Shelter in Place

Evacuation is the preferred method when;

- a) There is an immediate threat of fire, explosion or building collapse;
- b) There is time to evacuate before a threatening toxic atmosphere
- c) It will take a long time for the fumes to clear from the area
- d) The buildings will not provide sufficient protection to 'protect in place'.

Evacuation should start with the people nearest the incident and those outdoors in direct view of the scene. As additional resources become available, expand the area to be evacuated downwind and crosswind. All movements should be across the prevailing wind by the most direct route.

The following factors will influence the time necessary for a successful evacuation:

-  Time of day
-  Weather conditions
-  Road network
-  Transport availability
-  Number of people to be moved
-  Level of disruption caused to the community
-  Health and mobility of evacuees
-  Ability to shut down any industrial processes
-  Method by which the public are advised to evacuate.

Shelter in place (SIP) when;

- A.** There is not enough time to evacuate the public before the hazard affects the area.
- B.** The incident and hazard are likely to be of short duration (up to an hour or so).

Do not shelter in place (SIP) when;

- A.** The fumes or vapours present a risk of explosion.
- B.** It will take a long time for the fumes to clear the area.
- C.** The building cannot be tightly closed.



## Protective Action Zoning

Protective Action Zoning (PAZ) is a phrase used for simply implementing strategic cordons and placards to prevent involuntary ammonia contact. Protective Action Zoning is necessary to protect people from risks associated with maintenance work as well as more severe incidents. These risks may include fire, explosion, smoke, fumes or toxic gases.



Image: Google Earth and ALOHA threat modelling overlay

In recent years Ammonia work was completed without much consideration for the un-assimilated. Now day's people are much savvier to their rights to a safe workplace, Ammonia will cause some form of respiratory issues and it is irresponsible to inflict this on another.



## Hot Zone (Contamination Zone)

Where there is a risk of coming into contact with Anhydrous Ammonia, thirty (30) metres is the internationally accepted 'initial isolation zone' or Hot Zone for a release <200kg. For larger spills this is One hundred and fifty (150) metres. Dependent on the site layout and topography this may or may not be possible.

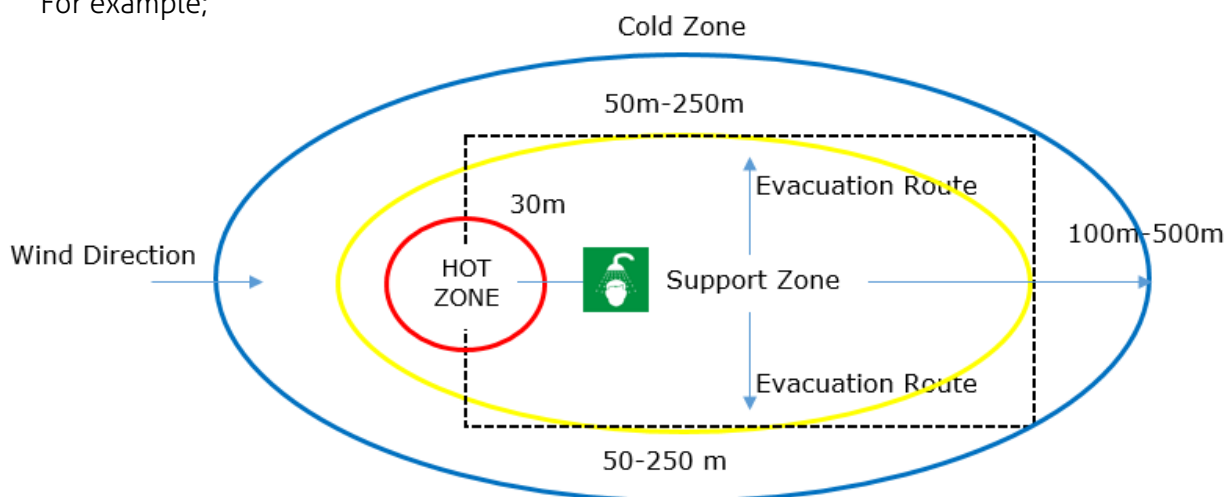
## Warm Zone (Support Zone)

The support zone is a transfer point between the hot and cold zones where you would position decontamination showers. It is a SCBA entry point, basically off limits to anyone not required in the repair or isolation process.

## Cold Zone (Exclusion Zone)

One hundred (100) to five hundred (500) metres is an initial exclusion Zone for a release less than <200kg. For larger spills (>200kg) this is eight hundred (800) metres to two thousand three hundred (2300) metres. Obviously where Ammonia vapour can be traced above safe levels the exclusion zone must be extended.








For example;







When setting protective action zones for maintenance works, generally a single exclusion zone is sufficient, it is simply a defensive mechanism to restrict un-authorised entry.

In an emergency, first responders will decide whether additional protective action zones are necessary. Typically, these are implemented without the need for visual cordons. Competent onsite emergency response teams can set up cordons and equipment in advance to assist the Fire Service. Remember emergency response personnel may have never seen your facility before and require assistance to provide site specific information.

## On site consequences

-  Public Endangerment
-  Loss production due to evacuations
-  Damaged product through, contamination
-  Injury or Fatality
-  Worksafe Investigation
-  Punitive damages
-  ACC increases

## Off-site consequences

-  Negative reputation about company and/or product.
-  Neighboring properties evacuated
-  Punitive damages
-  Road closures

## Summary Emergency Response Actions

- A. Ensure your safety
- B. Alert Site
- C. Notify Refrigeration Specialists and Emergency personnel.
- D. Shelter in place and standby for evacuation note; wind direction
- E. Manage pressure and ventilation where safe to do so
- F. Isolate access and contain liquid spills where safe to do so

## Site Emergency Response Resource Check list

Resource	Quantity
Emergency Management Plan	
Emergency Response Plan	
Trigger Action Response Plan	
PandID drawings	
Site Drawings	
Personal Ammonia Detection	
Full face Respirators	
S.C.B. A	
CBRN Suits	
Neoprene, Nitrile Gloves	
PVC gumboots	
Basic hand tools	
First Aid Kit	
Paraffin wax/ gel	
Vinegar 4:1 mix	
Emergency Shower and eye wash	
Chemical Spill kit	
Spill socks/ booms	
Drain covers	
Tarpaulin	
Fog nozzle	
4x 5kg CO <sub>2</sub> Fire extinguisher	
Torch	
Camera	
Spare Batteries	
UHF radios	
Pipe repair bandage	
2x Rolls Duct tape	
Blankets and Gazebo Shelter	

## Technician and Operators Personal Bail out Bag essentials

1. Negative pressure respirator
2. Spare filters
3. Gloves
4. Eye wash solution
5. Phenolphthalein strips
6. Torch
7. Spanner(s)
8. Screw driver(s)
9. Knife
10. First aid kit

## Controlling Ammonia Leaks

### Pressure and Level Management

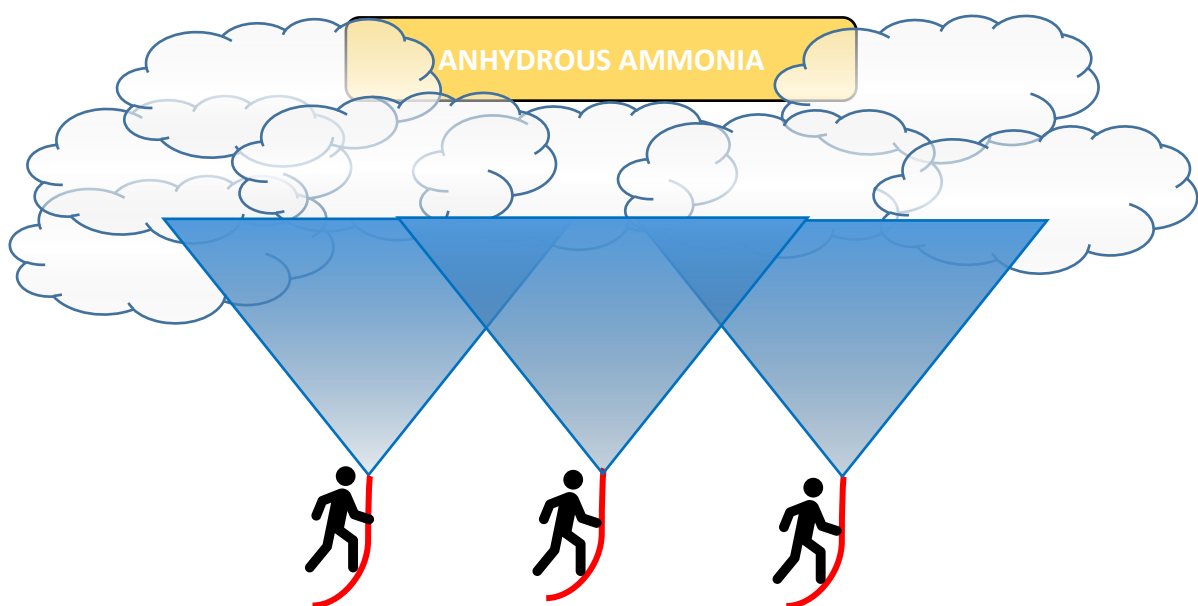
Safe manipulation of the systems pressures and levels is the key to reducing the magnitude of any Anhydrous Ammonia release. It is vital that the right valves are isolated as quick as possible and the nothing is operated or shutdown until either activated by the systems electronic safety devices or an Ammonia Refrigeration Specialist has carried this out, or has instructed you to do so. Additionally; Control Programming has many capabilities that can enable pressure and level management into a fully automated action.

### Shutting the king valve?

- i The king valve is an American terminology used to describe the high-pressure receiver isolation valve. It is used to separate the high & low-pressure sides of the system by backing up liquid Ammonia in the storage vessel. Closing It is not always the solution during an emergency – in fact in many cases it will have no benefit and, in some cases, will be detrimental to resolving the problem at all. Effectively a waste of time and potentially a risky exercise

### Water Containment

Water must not be sprayed directly onto Ammonia Liquid Spills due to the volatile reaction that will occur, nevertheless a fine misting spray or fog nozzle can be used to control the effects of Ammonia gas or Aerosols, by way of bringing to the ground. This is most effectively achieved by creating a deluge curtain. This can be an automated system or implemented by trained Incident response teams and or emergency response personnel.





## Tarpaulin and Cover

Using a simple heavy-duty tarpaulin weighted over a leaking cylinder of vessel has proven to be a very successful strategy in managing uncontrolled releases.

The way this works is quite ingenious;

- i Anhydrous Ammonia boiling point in our atmosphere is  $-33.5^{\circ}\text{C}$ . By using this quality, when the cylinder or vessel is covered, the boiling refrigerant envelops the vessel, sequentially cooling it down.
- i Since Ammonia has temperature has a direct association with pressure, by cooling it down we also reduce the pressure. If we were able to isolate the effected vessel and cool down to  $-33.5^{\circ}\text{C}$ , hypothetically, we would have 0kPa gauge pressure contained.
- i In addition, covering the vessel or piece of equipment reduces the effects of downwind contamination. It is important to stress Level 4 gas suits and SCBA must be worn in these instances.

## CO<sub>2</sub> Neutralization

A result of an Ammonia leak in a refrigerated space can be disastrous. Moist Cardboard or worse the product itself can be spoiled due to Ammonia's high affinity for moisture.

In certain areas that are poorly ventilated such as roof spaces, injecting CO<sub>2</sub> is a solution that could provide rapid results in lowering the concentration of Ammonia.

If acted upon quickly; product can be saved and or work can continue.

Ammonia and CO<sub>2</sub> react to form Ammonium Carbonate which is a fine powder and from a firsthand account, it was proven to be very effective in reducing Ammonia concentrations in enclosed spaces. 3x 3.5kg Fire Extinguishers were enough to reduce the Ammonia concentration in a roof space approx. 1000m<sup>2</sup> from 300ppm down to 20ppm in a matter of a few minutes.

According to Eric Pugh of Trans Canada Freezer in Toronto 1980, there is also an added benefit to cold storage as any injected CO<sub>2</sub> can also remove heat during evaporation from the refrigerated space that may be offline due to the leak.

He suggests that short doses from as high as possible in the room are most effective and to ensure that the circulation fans remain in operation to distribute the CO<sub>2</sub> more effectively.

- i 1 mol of Ammonia (Anhydrous) will require 1 mol of CO<sub>2</sub>

As an example; If we have estimated 5kg has been lost into an area, we can use the following calculation to estimate the quantity of CO<sub>2</sub> required for neutralization;

$$(44 \text{ mol CO}_2 / 17 \text{ mol NH}_3) \text{ or } 2.58 \times 5(\text{kg}) = 12.9\text{kg of CO}_2$$

There is of course the downfall of injecting CO<sub>2</sub> which is of course, displacing breathable oxygen. It is recommended that any injection procedure into a space of any kind be treated as a confined space and monitor all gas concertation levels.

## System Monitoring

When it comes to monitoring the safe operation and performance of an Ammonia system we must first have an understanding of its optimized state as well as its design limitations.

The system design conditions will be set out in the OEM operation manual supplied by the installer and where correct standards have been followed at the entrance to the facility however this is not always the case. All pressure equipment should be stamped with its design, maximum working pressure and temperature limitations. This includes heat exchangers, compressors and vessels.

In a refrigeration system by identifying the target temperatures together with knowledge of ambient conditions, we can trim or tune the system to an optimized state. We do this by firstly referring back to our good friend 'saturation point'. Where we require  $-40^{\circ}\text{C}$  from a blast freezer we can use the pressure temperature chart to ascertain the optimized Suction pressure for that particular zone. In this case it would be  $-28\text{ kPaG}$  saturation. From here we must allow for pressure and temperature losses but in an ideal situation we would want to run as close to the saturation point as possible to achieve the desired temperature of the product.

For Discharge or Head pressure we must follow the ambient air conditions or the cooling medium to determine what is achievable. In an Ammonia system generally, we use a pump circulation system so as long as we are able to maintain Ammonia liquid flow from the Condensor to the vessels we can afford to run as low as conditions permit.

In New Zealand we design our plants on an average of  $32^{\circ}\text{C}$  Condensing temperature. This means we should see no more than  $1200\text{ kPaG}$  Discharge.

A higher Discharge pressure will incur efficiency losses both in refrigeration effect and utilized power. On top of this we position the system with risks of leaks and imbalance

There is of course no such thing as 'balance' only consequence and correction. We are fighting many thermodynamic forces to find the closest control of an unachievable equilibrium. If you can imagine a pendulum swinging from an axis, it will always move one way or the other dependent on the wind, gravitational pull etc. By having a fine control over compressor capacity, flowrates be that Ammonia, fans or product, we can minimize the 'swing' and stabilize the system as best as possible to ensure efficiency and safety.

## Risk Analysis

Before conducting any task within a potentially hazardous environment or line opening, some form of risk analysis must be completed. When merely entering an Ammonia plant room we must also take a ritualistic approach to minimize the risk to ourselves and others.








## Entering Refrigeration Machinery Rooms

Although we must not accept Ammonia to be present in our engine rooms like we once did with older technology, it is not uncommon to have small concentrations or pockets of Ammonia vapour in engine-rooms with or without fixed gas detectors activating a strobe or siren. The following should be observed in respective order to protect oneself from walking into a dangerous situation;

- A. Wind direction must be observed whenever on site for safe egress.
- B. Emergency irrigation tested for functionality.
- C. Safety Eye Wear worn along with Hearing Protection and Protective Footwear
- D. Atmospheric concentration observed/tested prior to entry
- E. Complete a cursory inspection loop of all equipment noting any mechanical abnormalities, harmonics, surging or "hammer", assess that the status is, satisfactory within design parameters.
- F. Note anything of significance in the log book




















## Log book entries

The log book is used for not only recording the system operation, it is used for communication. "Carried out maintenance" offers very little in the way of credible information. Log books are an integral piece of the Refrigeration system. Entries should be clear and legible. Adding operational data is highly beneficial for future documentation and fault finding. Moreover, during service calls – having a tip from the last technician can save hours. Entries should include the following;

-  Date /Time / System Hours Run.
-  Name:
-  Company
-  Common Pressures
-  What was wrong and or what was performed
-  What needs to be performed in future
-  Sign off

## Process safety management (PSM)







Having the most accomplished and resourced emergency response team on the planet is fantastic but logically, trying to chase a beast that's bolted is not the most ideal solution. Managing the hazard while it is still controlled is a much more intelligent practice. To appropriately manage the maintenance and safety of the system and to provide historical records for inspections or reference a full detailed PSM data base is needed to work in conjunction with the overall hazard and asset management systems;

	1. Design information	21/12/2017 10:50 a...	File folder
	2. Commissioning Data	21/12/2017 10:52 a...	File folder
	3. Hazardous Identification Surveys	21/12/2017 10:51 a...	File folder
	4. Emergency Management	21/12/2017 10:54 a...	File folder
	5. Original Equipment Manuals	21/12/2017 10:57 a...	File folder
	6. Site Drawings	21/12/2017 10:55 a...	File folder
	7. Pipework & Instrumentation	21/12/2017 10:51 a...	File folder
	8. Electrical Drawings	21/12/2017 10:51 a...	File folder
	9. Standard Operating Procedures	21/12/2017 10:52 a...	File folder
	10. Record of Change	21/12/2017 10:58 a...	File folder
	11. Relief Schedule	21/12/2017 10:57 a...	File folder
	12. Compressor schedule	21/12/2017 11:01 a...	File folder
	13. Valve Schedule	21/12/2017 11:02 a...	File folder
	14. Fluid Management & Condition monitoring	21/12/2017 10:53 a...	File folder
	15. Log entries	21/12/2017 10:59 a...	File folder
	16. Training	21/12/2017 11:09 a...	File folder
	17. PPE Schedule	21/12/2017 11:09 a...	File folder
	18. Mechanical Integrity Surveys	21/12/2017 11:10 a...	File folder
	19. Incident Investigations	21/12/2017 11:11 a...	File folder





## Asset management

Good preventive maintenance is essentially detective work for a crime that is yet to be committed. Maintenance is of course the primary principle for improving the safety and reliability of any workspace. A spotless and organised facility will identify issues long before they become a problem. The most important part of implementing any successful regime is of course the strategy and structure, without it simple tasks either get missed or put on hold indefinitely. All categories of maintenance serve as fundamental components of the overall structure. These include;





### A. Preventative Inspections

-  Monitoring operating conditions
-  Visually inspecting condition of equipment
-  Trend analysis
-  Lubricant recovery
-  Leak identification
-  Innovation





### B. House-keeping

-  Painting
-  Cleaning
-  Lubrication
-  Ice management

### C. Condition monitoring

-  Lubricant analysis
-  Thermography
-  Vibration analysis
-  Ultrasound

### D. Intrusive Maintenance

-  Filtration replacement
-  De-fouling
-  House keeping
-  Mechanical inspection



*The importance of having well-disciplined documentation and records of procedure cannot be stressed enough.*



## Line Opening

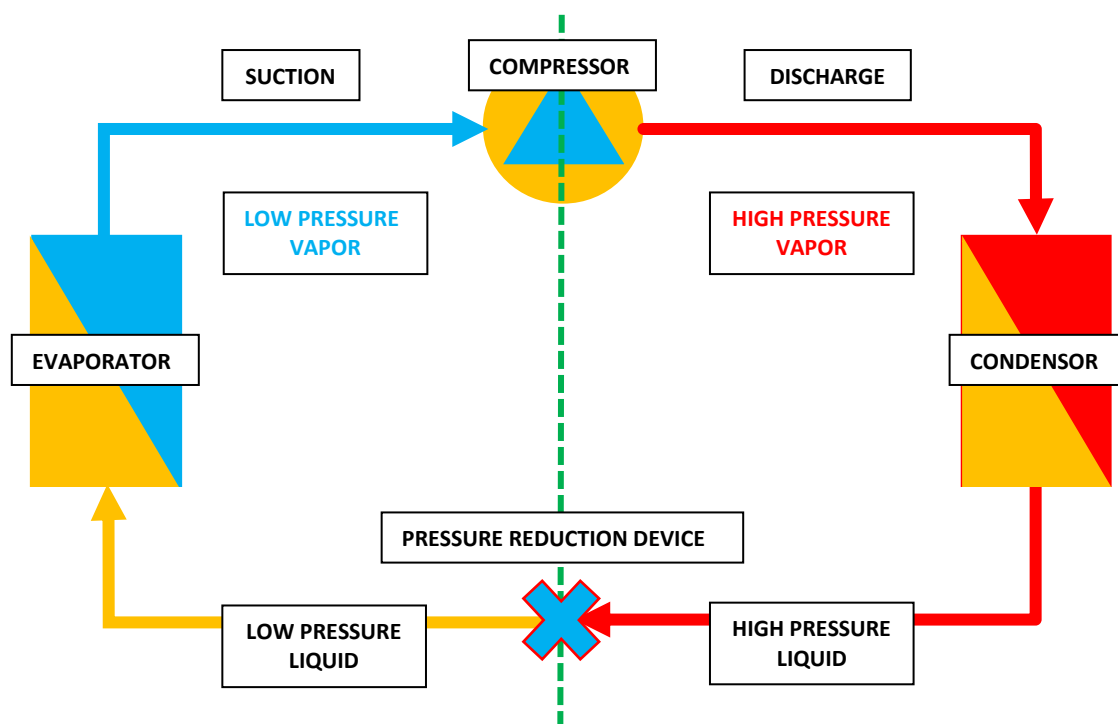
Opening pressure equipment of any kind regardless of the product contained within requires adherence to procedures.

It is paramount that a detailed line opening plan be developed, in particular an isolation schedule and a Pre-System Opening Assessment or line break analysis. These two components form a vital strategy as part of the Isolation, Evacuation and Ventilation (IEV) procedure. There are various on and off-site risks involved in opening an Anhydrous Ammonia system most of which to the persons or workers that operate closest to the equipment including but not limited to the following;

- a) Burns to skin and eyes
- b) Inhalation
- c) Single or multiple fatality
- d) Business continuity – lost production
- e) Reputation – Negative press
- f) Environmental damage

Hazard Management Controls should include but not be limited to the formation of Manual call points, Portable Gas detection, Exclusion zones, Spill Containment and Emergency Planning. Personal Protective Equipment is fundamental which should include; correct selection of Personal gas detection, Apron or Splash suit and respirator(s).

Any valves that require alteration from their normal operational positions should be carefully identified from an up to date piping and instrumentation drawing (P&ID). They will require isolation by way of lock out tag out. (LOTO) which involves securely locking and tagging the valves in the intended setting and then documenting which order they were isolated. The compressors will be utilised to evacuate the Ammonia downstream of what has been isolated, effectively forming part of low pressure system. This is called “the pump down”.



As Anhydrous Ammonia is a pressurised liquefiable gas and due to the high latent heat capacity of Anhydrous Ammonia, it will only move from its liquid phase to a gas if a heat source is provided above its saturation pressure/temperature.

Any Anhydrous Ammonia liquid will therefore sit in low lying areas of pipework and heat exchangers for extended periods until ambient conditions "boil" it into a gas state.

Pipe work and pressure vessel insulation or cladding will have to be removed so that heat can be applied by way of cold or tepid water.

The low-pressure side of the system should be then pulled into a deep vacuum with either the plant compressors or a mobile pump out compressor.

Any rise in pressure indicates there is further liquid pockets within the system which therefore warrant successive vacuums and local heating before it is safe for the vacuum to be broken by atmospheric pressure. (The point of no return)

On small systems or components, a series of closed circuit pump downs is generally a successful process eliminating the need for the use of large quantities of water ( $H_2O$ ) if at all. However, on larger scale projects, the system may require multiple pump downs followed by "air sweeps" or repeated vacuums to atmosphere (air) via water ( $H_2O$ ) to minimise external toxic contamination when opened. Where fiscally viable, using oxygen free nitrogen (Dry  $N_2$ ) as a sweeping mechanism would be best practice however generally uncommon.

- i Prior to any line opening works, a notification to the Fire Communications centre is recognized best practice as a both a courtesy and providing a technical advisory contact in the rare event of an emergency. The Fire and Emergency Northern Communications Centre has been receiving calls of this nature for the last 10 years or more so don't be shy.

Depending on the quality of the pump down process, any residual Anhydrous Ammonia gas or vapour may require venting or purging through water ( $H_2O$ ) to prevent elevated concentrations effecting the workers or exiting the boundary of the site thus ensuring the system can be safely opened to atmosphere.

The water is rapidly converted into a new compound; An Ammonia Solution or Ammonium Hydroxide due to Anhydrous Ammonia's high solubility in water;

- i Fundamentally Ammonia requires intimate contact to dissolve in water therefore it should be distributed through a series of smaller holes in a controlled manner rather than one large one. This minimizes large bubbles of Anhydrous Ammonia that may reach the surface without being sufficiently absorbed.
- i Ammonium Hydroxide has a considerably lower boiling point at atmospheric pressure than water ( $100^{\circ}C$ ) which dependent on concentration, for Ammonia Solutions, is between approximately  $15^{\circ}C - 60^{\circ}C$ .

Due to the exothermic chemical reaction taking place, heat is generated. Subsequently, as the temperature rises, less Anhydrous Ammonia will be absorbed as it is simply boiling through the Ammonium Hydroxide solution. This process can become violent therefore secondary containment is obligatory to catch splashes and overflow as well as for any failures in the mechanical integrity of the container.

The process may require numerous containers typically International Bulk Containers or IBC's which allow for safe containment, transport and disposal.

- i On completion, the Ammonia solution must be sent to a waste management organization for neutralization and or processed through a trade waste system.
- i Superseded Uniform Mechanical Code (UMC) 2009 Section 1120.0 States that At least one gallon of water (3.785L) is required per pound (0.454kg) of Anhydrous Ammonia that will be released in one hour.

ANSI/IIAR 2 2014 Chapter 15 Section 15.5.3 also suggests for Ammonia Absorption to a level of 10% Ammonium Hydroxide solution 8.3L of water is required every 1kg of Anhydrous Ammonia that will be released in one hour.

From personal experience, it is best to have a number of IBC on hand as there are many variables during the process that may change the water to effectively absorb Anhydrous Ammonia. IBC are cheap to both rent or purchase outright. In some instances, I have chosen to utilise 30,000L vacuum loaders to ensure I had enough capacity. With IBC you can always send the unused ones back empty for only a small collection fee.

- i Always utilize double isolation of pressure equipment when line opening.
- i Never leave the system open without keeping a watch full eye or plugging.

Work Permits and general Job Safety Analysis require the addition of a line opening rituals.

- A. Isolation – LOTTO and recording of isolation schedules.
- B. Evacuation – Removal of all Ammonia in circuit.
- C. Ventilation – Safe ventilation to atmosphere.

## Pre – System Opening Assessment

This is simply confirming the IEV by way of ensuring it has been sufficient.

- A. 15 min holding vacuum. Any rise indicates refrigerant and will need further evacuation and inspection. Once this step is complete the Vacuum can be broken to Atmosphere.
- B. 15 min holding Atmospheric pressure with Nil trace Ammonia Vapour (<25ppm)

*For larger or smaller pump outs the time can be adjusted to suit however 15 minutes is a general rule of thumb.*

## Specialist equipment

Ammonia service operations require specific resources to perform the work safely.

### Hoses and Fittings

Ammonia hose should be Teflon internal with stainless braid and include outer sheath protection. The ferrules used in New Zealand are commonly ½" BSPT Male swivel. Joint Australian New Zealand Standards AS/NZS 2022:2003 provide guidance.

- i No seals or PTFE thread tape is required as the fittings seal on a tapered internal steel surface with the exception of the service valve sockets that seal on the tapered thread. Parallel fittings should be avoided where possible.
- i Ammonia transfer cylinders seal on the flat face which will require a gasket.
- i Hoses should be regularly inspected and pressure tested to 2400kPa.

### Manifolds

When transferring Ammonia, there must be a means of;

- i Double isolation,
- i Safe venting or purging of non-condensable,
- i Bleeding hose in controlled manner,
- i knowledge of line and system pressure.



## Mobile Pump-out Compressors

Where ever possible during line opening – Ammonia should be transferred to another location within the system or a mobile transfer cylinder, minimising any need for purging through water and creating a secondary hazard and precondition for disposal.

- i Pump out compressors must be selected for Ammonia duty.
- i Should include wheels and means of safe lifting.
- i Include pressure equipment certification where required by local regulations.
- i Include High Pressure safety devices.

## Hydraulic transfer Pumps

As anhydrous ammonia systems are categorically much larger, the lubrication requirements are also. In order to safely and efficiently charge initial or additional lubricant to reciprocating compressors or especially the oil separators of screw compressors, a hydraulic oil pump is recommended to be used – unquestionably easier than hand pumping.

- i The pump and lines must be purged of air and primed with oil.
- i Transfer lines on the high pressure or delivery side of the pump must include non-return valves (Check valves) to prevent back flow of Ammonia.
- i The pump must have a pressure relief valve.





## System contamination

As we have already covered, Ammonia has a high affinity to water. Unlike synthetic refrigeration systems Ammonia systems do not suffer such rapid deterioration when subject to moisture contamination. It is often assumed that small amounts of moisture are not detrimental at all however this is not entirely the case;

- i Efficiency and performance losses due to altering the properties.
- i Higher energy consumption
- i Chemical breakdown and Organic acid formation in lubricants.
- i Non-condensable (Air, Nitrogen) insulate heat exchange surfaces and take up space causing high pressure.
- i Moisture in air will be absorbed into Anhydrous Ammonia.

The fundamental rule is to prevent moisture entering the system in the first place, but on large systems and particularly low-pressure systems – moisture is a fact of life.

We can prevent moisture and non-condensable by using best practice maintenance procedures. It may not be clear that there is a problem at first, which is why it is important to perform daily cursory inspections and logs to compare operation variables. On low pressure systems we must periodically shut down the plant to test for low pressure leaks. Where automatic purger's are used, we must monitor the length of the purge cycle – excessive purging indicates a low side leak and the need to resolve the issue before a problem occurs.



During service works, we remove contamination by firstly using a vacuum pump or vacuum ejector to remove non-Condensable's and reduce the pressure in equipment in turn reducing boiling point of water vapour. It is not often viable due to time constraints to perform a suitable vacuum but any vacuum is better than none.

If the system already has an issue with moisture, it will be apparent through lubrication problems or build up in components witnessed during servicing. There are no driers available to remove water. We must use either a specially designed purifier to de-still the Ammonia from the water and then drain the water off, in a similar process to that of oil draining. If the water contamination is severe it is recommended that the Ammonia be disposed of.

## Non-Condensable Purging

Removing non-condensables from a system is not as easy as you may think. It can take months of dedicated efforts.

Non-condensables are heavier than Ammonia therefore will accumulate in the liquid outlet of the condenser but can also find its way to the receiver.

To establish the level of contamination we can perform a static test which involves shutting down the plant and letting it sit until reaching ambient temperatures.

By using a pressure temperature chart or application, we can identify how much excess pressure is in the system.

We then must purge through water until the pressure matches that of the P/T chart. Purging must be performed in a controlled manner to ensure only non-condensables are being removed. This is best completed at a very slow "bubble rate."



- i Where required to purge from a point that is not permanently piped. Ammonia rated hoses must be used and they should include double isolation to protect from possible failure of the service valve as well as a needle regulating valve to safely control the flow of Ammonia/non- condensables through the water.
- i The purge container should be labelled and banded and have a sealable lid for later transport. It is worthwhile to add a phenol reagent to the container so that to indicate when the concentration is getting strong. (Turns purple)

## Standard operating procedures

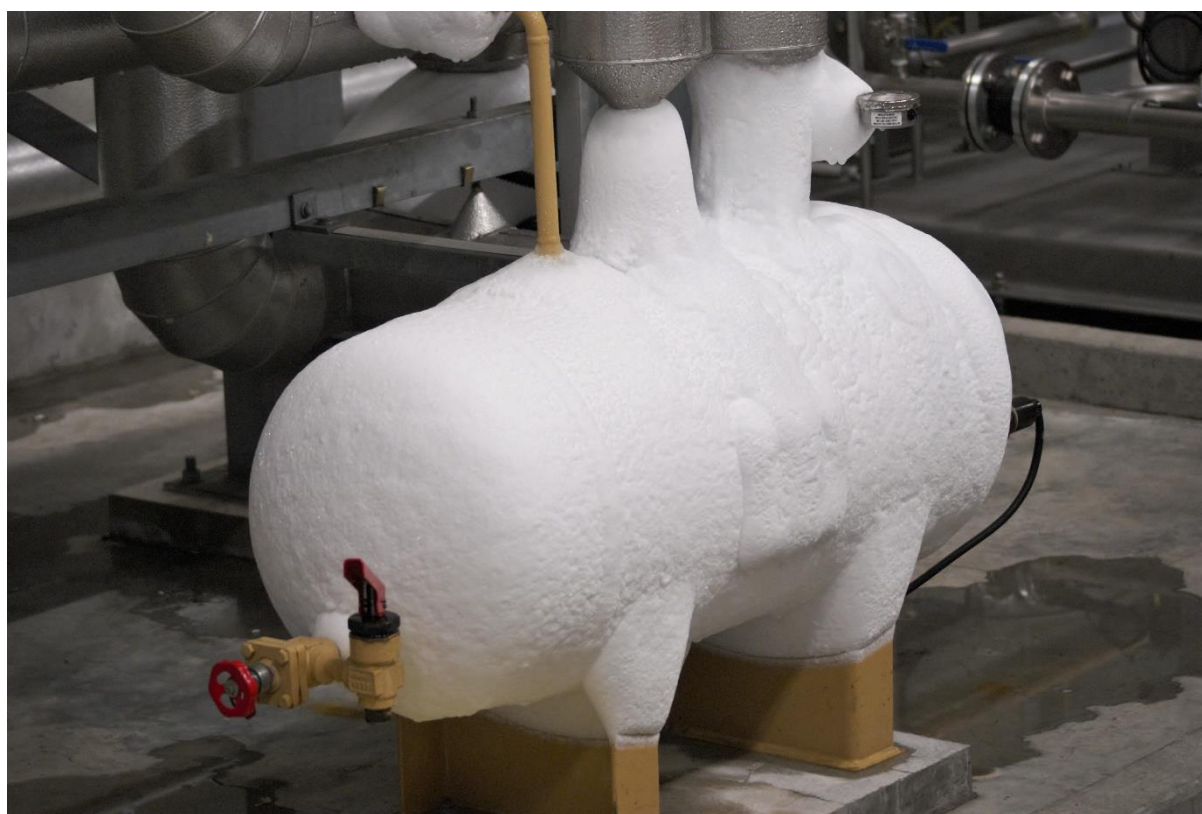
For tasks that are to be frequently repeated, a Standard operating procedure (SOP) can be formulated to ensure the task is executed safely and can be taught in a consistent manner to other staff in the future.

Example one:

AR-ER- LPV-SOP R1.4

*Standard operating procedure refrigeration oil draining.*

Equipment type: Positive pressure Ammonia rectifier # WR329567



Objective:

To describe the technical specification for the safe operation of draining oil.

Purpose:

The purpose is to provide a description of the process defining its function, conditions, limits, consequences of deviation from these limits, describing its controls instrumentation and safety systems

## Primary Concerns:

- A. Careful attention to wear correct personal protective equipment prevents serious injury. Oil draining is one of the most statistically dangerous activities on an Ammonia plant. It must be considered a line breaking or opening procedure.
- B. Lone working; Work must be completed in pairs
- C. Drain point must have a secondary isolation valve and if it's a fixed installation a QCDV or "Dead man" valve must be fitted as per ASNZS 5149.2016
- D. Drain line should be hard piped and directed away from exit pathways and operators.
- E. Only persons that have been proven competent may perform this task.

## Technical specification:

Removing lubrication oil from the Anhydrous Ammonia system is a necessity. The Lubricant should be accounted for and balanced. This means all oil removed should be tabulated to account for any additional compressor oil charged.

Without removing oil from the low-pressure vessels, pumps can be occupied by degraded oil, which reduces the amount of Ammonia they can pump into the field. Removing oil from low pressure vessels also improves refrigeration efficiency. We must not accept oil loss as normal.

## Personal Protective Equipment required

HAZARD	PPE / Controls
Noise	Suitable Ear Plugs as Ear Muff will not seal correctly
Inhalation of Toxic vapour	Full face Negative or positive pressure, K type or 3M6054 Replace 3 monthly
Burns to body	Chemical Resistant Overalls
Burns to hands	Chemical Resistant Gloves
Foot wear	Encapsulated with protective cap. (Steel caps)
Toxic Vapour	Personal Gas Detector / Ventilation operational
Burns recovery	Emergency Irrigation

## Resources

Labelled container (Waste oil / Black), Secondary container, Spill pad

## Valve Positions

Filling		Preparing	
Item	Position	Item	Position
Fill isolator	Open	Fill isolator	Closed
Vapour return	Open	Vapour return	Open
Drain isolator	Closed	Drain isolator	Closed
QCDV	Closed	QCDV	Closed
Heater	On	Heater	Off
Draining		Equalising	
Item	Position	Item	Position
Fill isolator	Closed	Fill isolator	Closed
Vapour return	Closed	Vapour return	Open
Drain isolator	Regulated	Drain isolator	Closed
QCDV	Open	QCDV	Closed
Heater	Off	Heater	On

*Note: The heater on during the fill cycle has long been a topic of debate amongst Industrial Refrigeration Engineers. It largely comes down to what side of the fence you completed your apprenticeship. Subjectively, having the heater on improves the flow of oil to the rectifier through the thermosyphon effect. The small amount of added heat to a large system is negligible. (500w -1kw) The heater off when "preparing" the rectifier ensures the vessel doesn't get too hot and the element doesn't cause impurities to form as well as slow ambient evaporation improves the chances of water extraction.*



## Process Task Flow

No.	Step
1.	Preparation – Close liquid supply to oil rectifier and switch off heater
2.	Return and check pressure vessel temperature pressure relationship suitable is for draining.
3.	Complete Permit to work and if required supplementary SWMS or JSEA
4.	Advise Site management of commencement of task
5.	Establish and secure work area to avoid involuntary contact
6.	Test emergency showers and Eye wash are functional
7.	Switch on personal gas detection in fresh air and bump test operation.
8.	Clear pathways for rapid egress
9.	Prepare spill resources (recommend secondary containment of container)
10.	Do not bypass gas detection (Stay below STEL)
11.	Ensure Ventilation on and effective air flow established
12.	Safety observer in line of sight and communications clear
13.	Respirator donned and started, negative / positive pressure tests completed
14.	Stand upwind of draining receptacle
15.	Close vapor return valve and monitor vessel pressure
16.	Only drain using Quick Close Drain Valve (QCDV)
17.	Use fixed line (no loose hoses) if long hose use sight glass.
18.	Firstly, bleed QCDV to test if Isolation valve holding pressure
19.	Hold QCDV with one hand – use other hand to regulate the flow from the drain isolation valve.
20.	Maintain engine room below STEL – If Concentrations elevated, close isolation valve and wait for decline in concentration.
21.	On completion of draining, close isolation valve to pump out any residual oil Ammonia mixture pressure from behind the QCDV
22.	Slowly release QCDV closed to avoid damaging the seat – install cap or plug. Test for leaks
23.	Slowly open vapour return valve
24.	Slowly open liquid supply valve
25.	Switch on heater to encourage thermosyphon process
26.	Log oil drained and calculate balance removed.

Example two:

## ER2- IPC1-6-SOP R1.0

### *Standard operating procedure for starting high stage compressors one – six*

Equipment type: Refrigeration Compressors

#### Objective:

To describe the technical specification for the safe operation of refrigeration compressors

#### Purpose:

The purpose is to provide a description of the process defining its function, conditions, limits, consequences of deviation from these limits, describing its controls instrumentation and safety systems

#### Primary Concerns:

- a) The system is ready for compressor operation
- b) The compressor is ready for operation
- c) Careful attention to wear correct personal protective equipment
- d) Only persons that have been proven competent may perform this task.

#### Technical specification:

From time to time the compressor(s) may be left manually isolated during maintenance procedures and require reinstating due to system capacity demands. A methodical approach is required to ensure the compressor is safe to operate and ensure during the initial stages of operation there are no signs of imminent failure.

#### Personal Protective Equipment required


HAZARD	PPE / Controls
Noise	Suitable Ear Plugs as Ear Muff will not seal correctly
Toxic vapour	Personal Gas Detector / Ventilation operational Full face respirator available for use within 2 metres
Body	Full length Overalls
Foot wear	Encapsulated with protective cap. (Steel caps)
Burns recovery	Emergency Irrigation

## Valve Positions

Offline		Pre- Online	
Item	Position	Item	Position
Suction	Closed	Suction	Open
Discharge	Closed	Discharge	Open
LP Pump out	Closed	LP Pump out	Closed
Oil cooler inlet (H2O)	N/A	Oil cooler inlet (H2O)	Open
Oil cooler outlet (H2O)	N/A	Oil cooler outlet (H2O)	Open
Heater	N/A	Heater	On
Evacuating			
Item	Position		
Suction	Closed		
Discharge	Closed		
LP Pump out	Open		
Oil cooler inlet (H2O)	N/A		
Oil cooler outlet (H2O)	N/A		
Heater	On		

## Process Task Flow

No.	Step
1.	Monitor system operation – evaluate demand.
2.	Check compressor pressures in its isolated state
3.	Confirm oil level sight glass must be above $\frac{3}{4}$ full
4.	Confirm oil temperature between 30-40°C if not wait till reached
5.	Advise Site management of commencement of task
6.	Check LP pump out valve closed and tagged shut.
7.	Slowly open suction valve all the way to its rear seat – note any rise or fall in pressure
8.	Complete cursory inspection for leaks
9.	Re-visit oil level – check for rise, bubbling or temperature difference
10.	Slowly open discharge valve all the way to its rear seat - note any rise in compressor pressure which would indicate check valve failure.
11.	Check oil cooling valves are open
12.	Complete cursory inspection for leaks
13.	Check any permits closed and LOTO isolations removed as per schedule.

 If the compressor power train has had any modifications or replacements a rotation test is mandatory prior to starting compressor.

14.	Start compressor and monitor initial pressures for any abnormalities
15.	Complete cursory inspection for oil or Ammonia leaks
16.	Check oil pressure satisfactory – between 250-300kPaG
17.	Check oil level must be no lower than $\frac{1}{3}$ sight glass
18.	Monitor and record operational variables for 15 minutes
19.	Record hour run meter and all above in system log book.

Example three:

## ER2- NH3 - LEAK - SOP R1.0

### *Standard operating procedure for Minor Ammonia Leak*

Equipment type: Refrigeration Pressure Equipment

#### Objective:

To describe the technical specification for the safe response to Ammonia leaks <300ppm

#### Purpose:

The purpose is to provide a description of the process defining its function, conditions, limits, consequences of deviation from these limits, describing its controls instrumentation and safety systems

#### Primary Concerns:

- a) Communication and Situational awareness
- b) Only persons that have been proven competent may perform this task.
- c) Careful attention to wear correct personal protective equipment
- d) Restricted access and confined space entry
- e) Escalation

#### Technical specification:

Minor non-emergency Ammonia leaks will occur in various locations of the throughout the life of the plant. The following procedure outlines the steps required to ensure safe inspection and clear communication. Minor leaks are classed below 300ppm.

#### Personal Protective Equipment required

HAZARD	PPE / Controls
Noise	Suitable Ear Plugs as Ear Muff will not seal correctly
Toxic vapour	Personal Gas Detector / Ventilation operational Full face respirator and SCBA where applicable, Buddy system
Body	Full length Overalls
Foot wear	Encapsulated with protective cap. (Steel caps)
Burns recovery	Emergency Irrigation

#### Resources

Phenolphthalein Paper, Hand Tools, Torch

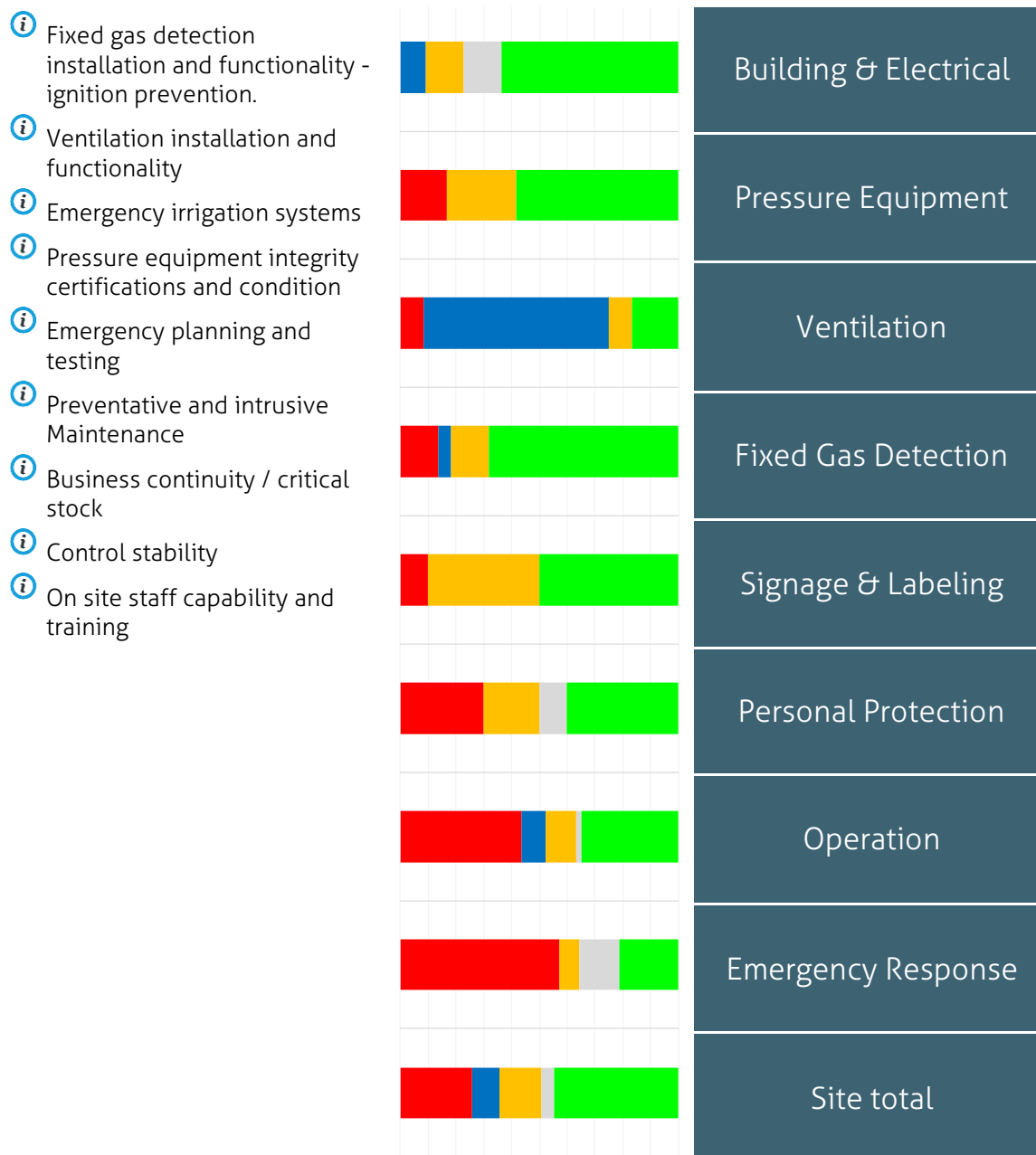


## Process Task Flow

No.	Step
1.	Advise Management / Emergency Management team of release.
2.	Evacuate all personnel from immediate area
3.	Isolate the area
4.	Obtain Concentration and Stability remotely where available
5.	Ensure Competent Ammonia Technician (CAT) has been contacted – Will become Technical advisory to lead agency.
6.	Primary CAT to contact supervisor for back up CAT. Supervisor to only communicate with Back up CAT
7.	Backup CAT to monitor the welfare of first technician – Fatigue, Water, Food as well as communication link to supervisor/manager.
8.	Bump test shower and Personal Ammonia Detection
9.	Don and Start respiratory equipment
10.	Approach upwind
11.	Test Atmosphere at entry point and in subsequent 1m Intervals
12.	Scan the area for abnormalities
13.	If Personal detection does not exceed 35ppm remove RPE and search with senses
14.	If Personal detection greater than 300ppm, exit contaminated space and review <span style="color: #0070C0;">i</span> Self-contained Breathing Apparatus is required
15.	Provide situational report back to management

## Gap analysis

Ongoing hazard identification is a fundamental element in the Health and Safety management system. Risk inspections are an essential part of operating every two years by a subject matter expert or CPEng, (Chartered Professional Engineer), Assessments should include but not limited to the following criteria;



## Definitions

Abbreviation	Explanation
NH <sub>3</sub>	Anhydrous Ammonia (Nitrogen x1, Hydrogen x3)
RCL	Refrigerant Concentration Limit
TWA	Time Weighted Average (8 hours workplace exposure)
STEL	Short Term Exposure Limit (15min workplace exposure)
IDLH	Immediate Danger to Life and Health
AEGL	Acute Toxicity Exposure Guideline
PLC	Programmable Logic Controller (Automation)
SCADA	System Control Data Acquisition (Controller)
ICP	Incident control point
EMP	Emergency Management Plan
IMT	Incident Management Team
ERP	Emergency Response Plan
CMT	Crisis Management Team
TARP	Trigger Action Response Plan
AEROSOL	Liquid and Gaseous Anhydrous ammonia (Two phases)
SIP	Shelter in Place
MUSTER	Evacuation Safe Point / Assembly area
PPM	Part Per Million, number of foreign particles within one million particles of another
LEL/LFL	Lower Explosive Level – equivalent to 16% (160,000ppm)
SCBA	Self-contained breathing apparatus (Positive Pressure)
RPE	Respiratory Protective Equipment (Ammonia Mask, SCBA)
Mg/m <sup>3</sup>	Milligrams per Metres cubed (ppm/1.34)
R717	Refrigeration Grade Anhydrous ammonia

## Legislation reference

The following references may have served in the development of this report;

Resource management act 1991  
 Building Legislation:  
 Building Act 2004  
 Buildings Regulations 2005  
 New Zealand Building Code Handbook  
 Building Code Compliance Documents (B2, C3, E2, G4, G1, G12, H1 AS and VM docs)  
 Compliance schedule handbook  
 Health and Safety Legislation:  
 Health and Safety in Employment Act 1992  
 Health and Safety in Employment Regulations 1995  
 Dangerous Goods Act 1985  
 Hazardous Substances (Emergency Management) Regulations 2001  
 Hazardous Substances and New Organisms Act 1996.  
 Hazardous Substances (Compressed Gases) Regulations 2004  
 Hazardous Substances (Identification) Regulations 2001  
 Hazardous Substances Regulations 2017  
 Health and Safety in Employment (Pressure Equipment, Cranes, and Passenger Ropeways) Regulations 1999  
 Electricity (Safety) Regulations 2010  
 ASNZS ISO 817.2016  
 ASNZS ISO 5149.1.2016  
 ASNZS ISO 5149.2.2016  
 ASNZS ISO 5149.3.2016  
 ASNZS ISO 5149.4.2016  
 ASNZS 1677.2-1998 Refrigeration systems  
 ASNZS 2022-2003 Anhydrous Ammonia-Storage  
 ASNZS 1200-2000 Pressure equipment  
 AS 3788:2006 – Pressure Equipment – In service Inspection  
 AS 3873:2001 – Pressure Equipment, Operation and Maintenance  
 ASNZS 3877-2001 Section 4 Vessel inspection frequency  
 AS 1668.2 2002 Ventilation and Air Conditioning  
 NZS 4303-1990 Ventilation  
 AS 1345-1995 Identification of pipes  
 AS-NZS 60079.0-29 (2007-2011) Explosive atmospheres - Gas detectors  
 AS/ NZS 4641:2007 Electrical apparatus for detection of oxygen and other gases  
 NZS 5263:2003 Gas detection and odourisation  
 NZS 4512:2010 Fire detection and alarm systems in buildings  
 ASNZS 1715-2009 Respiratory protective equipment's  
 ASNZS 1716-2012 Respiratory protective devices  
 AS/NZS 2865:2001, AS 2865: 1995 Safe working in a confined space  
 SAA/SNZ HB76-201 Dangerous Goods Initial ER Guide  
 First Aid for Workplaces – (Worksafe NZ Guide)  
 Best practice guidelines for working at height (Worksafe NZ Guide)  
 Safe working in a confined space (Worksafe NZ Guide)  
 Safe operation of cold storage facilities (WorkSafe AU Guide)  
 Safe use of machinery (Worksafe NZ Guide)  
 Department of labour NZ exposure standards 2002  
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- WorkSafe Victoria (2008) Appendix 6 of *Safe operation of cold storage facilities*
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- Worksafe British Columbia (2007) *Ammonia refrigeration systems*
- IIAR Bulletin\_109.1382.pdf Minimum safety guidelines



## Ammonia Pressure Temperature chart

Temperature	Pressure (gauge)
-50°C	-60.4 kPa
-45°C	-46.7 kPa
-40°C	-29.5 kPa
-35°C	-8.1 kPa
-33°C	0 kPa
-30°C	18.2 kPa
-25°C	50.3 kPa
-20°C	88.9 kPa
-15°C	135 kPa
-10°C	189.6 kPa
-5°C	253.6 kPa
-0°C	328.1 kPa
+5°C	353.8 kPa
+10°C	513.7 kPa
+15°C	627 kPa
+20°C	757 kPa
+25°C	972 kPa
+30°C	1062 kPa
+35°C	1250 kPa
+40°C	1455 kPa
+45°C	1682 kPa











## Appendix

### There is no such thing as an Accident in the workplace.

*"An accident is typically deemed an unfortunate or unplanned event without deliberation that leads to a near miss, injury or fatality. This suggests that a degree of chance or misfortune was involved." – This maybe indeed the case?*

*On October the 5th of 2004, 1218 pm, I was undertaking a routine task; something I had completed a thousand times before. Draining oil from an Ammonia refrigeration pressure vessel. The result of what occurred that day changed my perception of safety in an instant; the importance of hazard management. There is no such thing as a freak accident, every incident has a series of preventable events or actions that lead and follow a near miss, injury or accumulated illness. For the last 14 years I have researched and developed training methods to educate both technicians and end users on the importance of safe work practices regarding Anhydrous Ammonia. Admittedly the following details are difficult to share with the world as they point out my failures as a professional, it is something that i usually save for my presentations as a ice breaker, particularly when pointing out the areas where i received the most cryogenic and corrosive burns to my body. I think its important to share my experience and complacency with others. It not only highlights unsafe acts but it indicates the need for continuous identification and enforcement of risk controls in the workplace. The gritty details of incidents are rarely shared therefore we never learn from them.*

#### The incident

*I was sent to a job to perform a maintenance on a relativity large two stage Ammonia cold-storage facility. The week prior i prepared the oil rectification vessel for draining oil. So this week was drain week and then filling for its next cycle. My preparations for the task were somewhat minimal i might add, no JSA (What the hell was that?) just a spanner in my pocket and my respiratory protection which i hung over a compressor lifting eye some 3-4 metres distance. On opening the drain valve unbeknown to me, I snapped its shaft, after the oil was drained an Ammonia oil mixture began to appear. The valve was then attempted to be front seated, however the Ammonia continued to flow. At this stage I had turned this valve shut twice over and realised something was terribly wrong. In an attempt to direct the Ammonia stream and splashes away from my body, I found that the industry standard 'rubber hose' connected to the valve by a hose clamp had frozen solid. Ammonia liquid was now splashing all over my body and the vapour was forming corrosive Ammonium Hydroxide on all of my moist tissue. Yep...Knowing there was three ton (3000 kg) of Ammonia directly connected to this oil rectifier vessel and a primary school less than 200 metres away, I remember thinking "Even if i die in the process, I must isolate this system." Rapidly, the entire plant room was thick with an Ammonia aerosol and I was forced to hold my breath and close my eyes. The Ammonia blanket i was now wearing was immensely cold and i could feel its weight on my face and body. I was unable to locate my respirator that should of already been on my face.*

*The vapour return valve (That should of been shut) had a rubber gland packing, it was dry and therefore incredibly tight, it seemed like it took forever to isolate the circuit. Finally, i front seated the valve and the remaining content of the vessel was left to vent slowly reducing in pressure as it was released.*

*On exiting the plant room blind and breathless, to add heat to the already dire situation, I managed to stand on a garden rake which smacked me square in the face. I Bruce Lee kicked the plant room door open and went directly to the emergency shower and pulled the chain. However, in an unthinkable occurrence, someone had isolated the water supply, as i later found out due to it leaking on to the pavement.*

*The ball valve was just out of reach as well as had the handle removed, my hand tools were stuck inside the plant-room together with my keys to the back of my vehicle. By carefully breaking into my Ute (wild rage) , I was able to get a spare spanner and box to stand on and open the valve. The cold water hitting my burns was excruciating and put me into further shock. I had removed most of my clothes and stood there shaking and with a hose down my boxers as the shower head does nothing to accommodate groin injuries. Workers just watched, no one came to my aid or offered assistance.*

*After gathering my composure... a little, I checked the plant room, it was still full of Aerosol and very "HOT". I realised the plant room ammonia alarm was in bypass for maintenance which meant the fans did not force on and neither did the evacuation alarm. There were no controls outside, and there was no shunt trip to stop the plant from igniting the ammonia.*

*I hustled to the office to advise the staff to call the Fire Service as well as evacuate the site. Unfortunately it must have been difficult for the staff to take a half-naked man dripping wet and in shock too seriously and they went about their business.*

*Furious of the stupidity of the situation, I jumped in my Ute and drove to the closest AandE which had no clue on how to treat me and sent me to the next hospital, they still were also unaware of what to do. After waiting for what seemed an eternity, I demanded a Luke warm Shower, I was given petroleum jelly to apply to burns the ordeal was over.*

## The learnings

*Although I was holding a Refrigeration Qualification and been working on Ammonia systems for 10 years, I was never formally trained in the procedure because there was none. I was trained by someone who had 40 years experience but knowing what i know now, even he was doing it wrong. By double isolating the vessel using the vapour return valve, even if the worst occurred, i would of been able to walk (Swiftly) away knowing only minimal Ammonia would be released.*

*Lone working is something that should never happen when conducting hazardous operations. A second person may of noted my lapse in procedures or been able to perform other duties including notification of release, first aid, or rescue. My superiors also had no idea where i was. Imagine how that phone call to my family would of went down. Still to this day, I come across service procedures that include statements like, "Ammonia mask should be available" If an Ammonia Hazard exists, the personnel protection should be worn, full stop.*

*Many works on Ammonia systems create a localised high concentration pocket often exceeding IDLH values. In the case of Ammonia this is just 300 ppm. Personal gas detection must form an integral part of respirator use to identify the correct selection of equipment as well as its limitations. Self Contained Breathing Apparatus should be utilised in many occasions of service work for this reason.*

*The design of Ammonia systems has suggested the installation of Quick close drain valves (QCDV) or "Dead-man valves" for many years prior but for some reason; im guessing financial they were not installed on almost all plant we worked on. This would of prevented the incident all together by way of double isolation. Upon my recovery, i went about installing them everywhere often without consultation with the owners. They had to have them or we wouldn't be draining oil. I keep a spare ball valve in my tool box when ever i need to test a service point that does not have a double isolation. This includes transferring ammonia or oil.*

*Flexible hose should never be used for draining oil, not only is it not designed for the low temperatures but when an unfixed line is incorporated into the process it can snake under the hammer of Ammonia expansion. Any fixed line should be directed away from the body and away from the path of escape. It should not be reduced in size as this increases the velocity of oil/ammonia exiting the line.*

*Gas detection service bypass. Where installed the service bypass on most plants impairs the entire alarm rationale. An lower explosion level (LEL) sensor must be installed and operate independent of the service bypass. An LEL also allows to increase the shunt trip set point as toxicity sensors alone shunt early which can increase the pressure of a leak source, effectively making it worse. Many instances of leaks, the plant is needed to operate so that the management of pressure can occur i.e using the compressors to reduce the pressure and evacuate the Ammonia. Restart after a shunt can destabilise the entire plant and delay the restart. An LEL can remain on and visible to emergency responders where a toxicity sensor can not.*

*Emergency ventilation should be automated to start by the Fixed gas detection set point, this should be capable of limiting the concentration within the plant-room and just as importantly exhaust of the contaminants must not be allowed to recirculate or vent to ingress or egress doorways.*

*Emergency shutdown, Luckily that day either the concentration mixture was not in range to ignite or by chance it did not. Shunt or remote trip from the gas detection should of remove all potential for ignition and a manual emergency stop should be available inside and outside of the plant-room.*

*What did they use to say? "House keeping is the first rule of safety" yeah so why on earth were garden tools all over the floor of a fridge plant? And why on earth did i not ensure my escape path was clear?*

*Cold water is not an effective method of decontamination, but more importantly no water at all is even worse! Showers should be tested ritualistically prior to Ammonia service works and regularly "bumped" by the facility to ensure the water supply is actually online and the flow is sufficient for decontamination. Luke warm water opens the pores of the skin to flush chemicals. Cold water closes the pores reducing the decontamination effectiveness.*

*Awareness and training is lacking by many facilities, but ignoring emergency action is mind-blowingly idiotic. Engaging all responders and personnel in the process of emergency management is vital. This does not mean all facilities must have a rescue squad but it does mean there must be a chain of command to deal with the situation appropriately. In this situation activating the plan by communicating with the right person or manual call point. In hind sight activating the fire alarm would of been sufficient to evacuate the workforce.*

*Another lucky occurrence that day was the as the ventilation was not operating it did not exhaust Ammonia all over the show and was allowed to slowly dissipate via the duct. If it did there may have been a problem evacuating. In the case of this facility it did not vent upwards however it did vent just metres of the office entry point.*

*Of course there was no wind indication so knowing which way to evacuate or shelter would have been a problem. The last event in my ordeal was what made my jaw drop the most, there was no available information for nurses or doctors to know what to do with me. Just as bad, sending someone away to drive themselves to the next hospital in shock is downright negligent. Knowing what actions to treat someone who has been involved in a chemical accident is priceless.*

*I have undoubtedly learnt the hard-way, but as such have spent many a night studying and developing ever evolving works to combat the above and more deficiencies in refrigeration design, installation, operation and emergency recovery. I have since established Gauge refrigeration Management Ltd to assist companies with there concerns with Ammonia hazards in the workplace. Our focus along with a list of collaborated businesses is training end users and technicians alike on both sides of the bow-tie. Prevention and preparedness. Removing the stigma and educating the benefits of its efficiency and natural occurrence in nature but at the same time educating of the risks through surveys and hazardous operability studies. If you believe your business could use help with identifying your Ammonia risk potential or developing procedures for recovery, please do not hesitate to contact us at Gauge.*

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