WATER CORPORATION

Assets Planning and Delivery Group
Engineering

DESIGN STANDARD DS 75-01

Small Gas Ammoniation Systems – Basis of Design

VERSION 1
REVISION 0

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FOREWORD

The intent of Design Standards is to specify requirements that assure effective design and delivery of fit for purpose Water Corporation infrastructure assets for best whole-of-life value with least risk to Corporation service standards and safety. Design standards are also intended to promote uniformity of approach by asset designers, drafters and constructors to the design, construction, commissioning and delivery of water infrastructure and to the compatibility of new infrastructure with existing like infrastructure.

Design Standards draw on the asset design, management and field operational experience gained and documented by the Corporation and by the water industry generally over time. They are intended for application by Corporation staff, designers, constructors and land developers to the planning, design, construction and commissioning of Corporation infrastructure including water services provided by land developers for takeover by the Corporation.

Nothing in this Design Standard diminishes the responsibility of designers and constructors for applying the requirements of the Western Australia's Work Health and Safety (General) Regulations 2022 to the delivery of Corporation assets. Information on these statutory requirements may be viewed at the following web site location:

Overview of Western Australia's Work Health and Safety (General) Regulations 2022 (dmirs.wa.gov.au)

Enquiries relating to the technical content of a Design Standard should be directed to the Senior Principal Engineer, Water Treatment Section, Engineering. Future Design Standard changes, if any, will be issued to registered Design Standard users as and when published.

Head of Engineering

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Any interpretation of anything in the Standards/Specifications that deviates from specific Water Corporation Project requirements must be referred to, and resolved by, reference to and for determination by the Water Corporation's project manager and/or designer for that particular Project.

REVISION STATUS

The revision status of this standard is shown section by section below:

REVISION STATUS						
SECT.	VER./ REV.	DATE	PAGES REVISED	REVISION DESCRIPTION (Section, Clause, Sub-Clause)	RVWD.	APRV.
1	1/0	Nov 2023	All	New Standard	NH	BM

2	1/0	Nov 2023	All	New Standard	NH	BM

3	1/0	Nov 2023	All	New Standard	NH	BM

4	1/0	Nov 2023	All	New Standard	NH	BM

DESIGN STANDARD DS 75-01

Small Ammoniation Systems – Basis of Design

CONTENTS

1 SCOPE

This design standard provides an overview of the design of the Water Corporation's standard gas ammoniation module and an explanation for the features it incorporates.

1.1 Related Documents

The documents related to this design standard are:

DS70-20	Small Chlorination Systems (Water) - Control Function Description
DS70-25	Sequenced Vacuum System Control Function Description
DS75-02	Ammonia Gas Module Functional Description Overview
DS79	Design of Chemical Systems – Legislative Requirements and General Principles
DS79-02	Emergency Safety Showers and Eyewash Stations
PTM	Specification for Prefabricated Treatment Module
F70-01	Procurement Data Sheet for Chlorine Module
AEL	SCADA Approved Equipment List (Aquadoc#16977329)
NP50	Drawings for Ammonia modules:

NP50-60-88-01	Ammonia Storage P&ID
NP50-60-88-02	Ammoniation P&ID
NP50-91-01	Ammonia Module General Arrangement

1.2 External Standards

This design standard refers to the following external standards:

AS2022	Anhydrous Ammonia – Storage and Handling

1.3 Definitions

DG	Dangerous Goods
ESD	Emergency Shutdown Device
Ex	Explosion Protected
IDLH	Immediately Dangerous to Life or Health
LEL	Lower Explosive Limit
OSH	Occupational Safety & Health
PLC	Programmable Logic Controller
ppm	Parts Per Million
PTFE	Polytetrafluoroethylene
SCADA	Supervisory Control and Data Acquisition (system)
STEL	Short-term Exposure Limit
UEL	Upper Explosive Limit

UPS	Uninterruptible Power Supply

2 BACKGROUND

Water Corporation deployed eight ammoniation modules between 2004 and 2022, but in the absence of a design standard, each is slightly different in potentially significant ways. This design standard provides a basis for new modules and the retrofitting of existing modules.

The Australian Standard for anhydrous ammonia systems (AS2022) has only a limited number of design requirements compared to the Australian Standard for Chlorine AS2927:2019, so the latter standard provides the best design basis apart from two clauses that are specifically relevant for anhydrous ammonia (clauses 2.11.1 and 5.3.2).

2.1 Building Configuration

The standard ammoniation module consists of a transportable building with integral pre-stressed concrete foundation that incorporates two rooms:

1. An Ammonia Storeroom in which the ammonia cylinders are located;
2. An Ammoniation room in which the ammoniators and "wet" equipment such as ejectors, softeners and analysers are located.

The room functions have been specifically chosen so that:

(a) Equipment normally subject to pressurised ammonia is located in just one room;

(b) All "wet" activities are confined to one room and are separated from electrical and SCADA equipment.

Note: A dedicated control room is normally not required for an Ammonia module because control and SCADA equipment and functions are handled by the accompanying Chlorine module control room.

Water Corporation "Prefabricated Treatment Module" Specification PTM defines the physical requirements of the module in detail.

Ammoniation modules have to date only be deployed in concert with chlorination modules. As a result, the F70-01 Procurement Data Sheet is used to provide relevant information to Contractors, including any design options required. The data sheet shall form part of the contract specification. F70-01 shall be completed by the Water Corporation Design Manager or Engineering Panel Consultant during Engineering Design.

2.2 Key Differences between Ammonia Gas and Chlorine Gas Systems

The following is a summary of the major design differences between Ammonia Gas and Chlorine Gas systems:

1) Ventilation – Anhydrous Ammonia is potentially flammable (LEL ~ 150,000 ppm) resulting in more significant ventilation requirements. The two opposing external walls of both the Ammonia Store and Ammoniation Room shall be ventilated with floor to ceiling louvres. The louvres shall take up as much of the wall area as is practical.
2) Ventilation fans (minimum of 2) in the ammoniation room shall activate upon detection of 35ppm ammonia. This ensures that any ammonia gas released into the room via a gas or solution leak is rapidly dispersed before reaching a flammable concentration. Fan operation shall be monitored by the Plant Control System with individual fan status and fan failure alarms sent to SCADA. While 35ppm ammonia is present, operation of the ammoniation system shall be interlocked to stop if no fans are running.

3) Electrical equipment in the Ammonia Store, other than the ESD actuators, shall be Ex rated (refer section 3.4.1).
4) Ammoniators have a secondary pressure relief valve which provides redundancy in case of failure of the primary relief valve that is part of the vacuum regulator. This therefore prevents release of ammonia gas into the ammoniation room – the secondary relief shall be piped back to the Ammonia Store and discharge at the same location as the primary relief vent.

Leak Sensor set-points –Anhydrous Ammonia is slightly less toxic than Chlorine so its alarm set-points shall be:

- High alarm - 35ppm
- High Alarm - 100ppm
- High Alarm - 300ppm

This compares to Chlorine alarm settings of: 1ppm, 5ppm and 20ppm). The Immediately Dangerous to Life and Health (IDLH) values for Ammonia and Chlorine are 500ppm and 100ppm respectively.

5) Leak Sensor ranges – Anhydrous Ammonia leak sensors shall be ranged 0-100ppm and 10-2000ppm (compared to Chlorine leak sensors which are ranged 0-20ppm and 5-100ppm).
6) Leak sensors are located near the room ceiling rather than near the floor as ammonia gas is lighter than air (while chlorine gas is heavier).
7) Material selections – Ammonia solution is aggressive to certain materials including zinc, so ammonia ejectors require different materials to chlorine ejectors.
8) Softening system – ammonia ejectors are prone to calcium carbonate scale formation when ammonia solution is formed. This is due to the high pH of ammonia solution which results in precipitation of practically all the temporary hardness present in the solution water. To prevent the scale blocking the ejectors and solution lines an ion exchange type softening system is provided for the ejector water supply. Note that Calgon™ based softening systems have been tried unsuccessfully in this application.

2.3 Ammonia Module Overview

Refer drawing NP50-91-1.

2.3.1 Control Room

No control room is normally provided for an Ammonia module because control and SCADA functions are handled by the accompanying Chlorine module control room.

2.3.2 Ammonia Store

The ammonia store contains the following equipment:

- Ammonia containers (up to six cylinders)
- Fixed scales (Ex rated)
- Emergency shutoff device actuators
- Ammonia leak sensors (Ex rated)
- Ammonia vacuum regulators
- Ammonia absorbent canisters (mounted 1m to 1.5m below a leak sensor and installed on vacuum regulator relief vent and ammoniator relief vent relief lines)
- Lighting (Ex rated)

As noted above, certain electrical equipment shall be Ex rated given the potential for an explosive atmosphere to occur if the ESD actuators fail to close the ammonia cylinder valves. Any electrical junction boxes located in the ammonia storeroom shall be Ex rated.

2.3.3 Ammoniation Room

The ammoniation room contains the following equipment:

- Ammoniator(s)
- Ejector booster pumps and ejectors
- Softeners (for ejector water)
- Ventilation fans (redundant) fitted with a failure interlock (i.e. fan fault triggers shutdown. Fans activate on detection of 35ppm ammonia)
- Ammonia leak sensor
- Analyser(s)
- Sample water return system.

2.3.4 Building External

The following equipment is mounted on the exterior of the building:

- Safety Shower
- Warning strobes

2.3.5 Ventilation Requirements

As has been noted in section 2.2, Anhydrous Ammonia systems have specific requirements as per s5.3.2 of AS2022 (reproduced below):

> **5.3.2 Ventilation**
>
> Any enclosed area in which anhydrous ammonia is used shall be ventilated to atmosphere by either of the following means:
>
> (a) The area shall be open to outside atmosphere on at least two sides.
>
> (b) A mechanical ventilation system with a supply from outside the enclosed area shall be provided, and arranged so that in the event of airflow failure, the supply of ammonia is shut off.

Following hazardous area risk assessment, the above requirement has been translated into a requirement that two opposing walls of both the Ammonia Store and Ammoniation Room be ventilated with floor to ceiling ventilation louvres, and the Ammoniation Room having redundant fans (2 minimum) that activate if 35ppm ammonia is detected. The louvres shall take up as much of the wall area as is practical. If all fans are failed, then this shall trigger shutdown of the ammonia system. The physical layout is detailed in drawing NP50-91-1.

3 AMMONIA SYSTEM – BASIS OF DESIGN

The following section discusses the ammonia system components in detail.

3.1 Ammonia Cylinder Room Components and Operation

(Refer P&ID NP50-60-88.1)

3.1.1 Ammonia Cylinder Systems

Housed in the Ammonia store are up to 6 ammonia cylinders. The maximum number of cylinders normally permitted for connection, are four; in a two duty – two standby configuration. Two further "spare" cylinders (i.e. unconnected) may be stored on either side of the doors.

The connection of 6 cylinders (in a three duty – three standby configuration) is not recommended because of the likelihood that the cylinders will run out of ammonia at different times, resulting in one cylinder having to provide the entire required supply rate once two have become exhausted. This arises because the vacuum regulators draw at different rates due to slightly differing spring tensions within each vacuum regulator assembly.

If three duty cylinders are required to provide the design ammonia supply rate, then a sequenced vacuum system should be employed – refer to DS70-25 for guidance.

Due to the two open wall sides required in the Ammonia Storeroom, the use of an air-conditioner to raise ambient temperature is not feasible.

Each cylinder that is connected to the manifold shall have an emergency shutoff device mounted on it in accordance with DS70-03 so that supply from the cylinder can be terminated in the event of a leak being detected – see section 2.2 pt 3).

Scales for ammonia cylinders shall comply with DS70-05. Weight measurement is only used for monitoring purposes and is not used as part of the cylinder changeover system. The reason for this is historical and relates to the poor accuracy and reliability of scales in the past.

3.1.2 Ammonia Cylinder-Vacuum Regulator Connections

The online ammonia cylinders are each connected to a vacuum regulator using a nitrile washer which sits between the valve outlet and the vacuum regulator to provide a seal.

3.1.3 Vacuum Regulators and Ancillaries

The vacuum regulators reduce the pressurised gas supplied from the ammonia cylinder to vacuum (the vacuum is created by the ejectors - see below). Vacuum regulators have three states: "standby", "online" and "exhausted". When a vacuum regulator in standby experiences a high vacuum on its suction side, it gets "sucked" into its "online" state. When the ammonia cylinder is empty, a second high vacuum state occurs that "sucks" an "online" vacuum regulator diaphragm into its "exhausted" state.

The vacuum regulator incorporates a relief valve that vents if the pressure on the downstream side of the vacuum regulator nears positive pressure. The relief valve outlet shall be piped through a flexible hose to a cannister containing ammonia neutralisation material to deal with minor "puffs" of ammonia that can be released if the hydraulic conditions in the vacuum line change suddenly – see section 2.2 pt 4). The cannisters shall each be close to an ammonia leak sensor so that if they become saturated with ammonia (~60g), any release will be detected and alarmed.

The vacuum (outlet) line from the vacuum regulator is connected to the ammoniator which controls the flow rate of ammonia gas.

3.2 Ammoniation System Components and Operation

(Refer P&ID NP50-60-88-2)

3.2.1 Ammoniators

The flexible tubing between the vacuum regulator and ammoniator shall include the following:

- A manual isolation valve downstream of each vacuum regulator.
- A manual isolation valve on the inlet to each ammoniator.
- A pressure transmitter to detect loss of vacuum.
- A pressure relief valve on the inlet to each ammoniator that relieves back into the ammonia storeroom.

Duty and standby ammoniators shall always be provided. Control functionality shall be as per DS70-20 Small Chlorination Systems (Water) - Control Function Description and DS75-02 Ammonia Gas Module Dosing Functional Control Description Overview and shall be specified in the F70-01 Procurement Data Sheet that forms part of the project specification.

Located on the line between each Ammoniator and ejector is a non-return valve and manual isolation valve.

3.2.2 Ejector Water System

The ejectors can each be supplied water by ejector booster pumps or by motorised valves that supply water from a high-pressure source (the latter design option is normally only possible at dam or pump station sites). The ejector water circuit shall include the following:

- Duty/standby ejector water booster pumps or motorised control valves.
- A flow switch downstream of each pump or valve to detect insufficient flow rate. For sites with ejector booster pumps the low flow switch shall be interlocked to protect the pump from potential dry running or against excessive discharge head.
- A pressure indicator downstream of each pump or valve to allow fault diagnosis in the event of an ammoniator faulting due to low vacuum.
- An isolation valve located on the water feed side of each ejector.
- A non-return valve located on the discharge side of each ejector.
- An isolation valve located on the discharge side of each ejector.
- A pressure indicator downstream of each ejector discharge isolation valve to allow fault diagnosis in the event of an ammoniator faulting due to high or low vacuum.
- An isolation valve located at the dose point.

3.3 Sampling and Analysis

A sampling and analysis system is usually provided in the accompanying Chlorine Module in accordance with DS70-20 Control Function Description and the F70-01 Procurement Data Sheet that forms part of the project specification. For all chloramination sites a ChemScan UV-2150/S process analyser shall be used.

3.4 Risk Management

3.4.1 Safety

The standard ammonia module incorporates multiple safety features to prevent or mitigate a possible ammonia release, as follows:

3.4.1.1 Ammonia storeroom

- Remote vacuum regulators are directly connected to the ammonia cylinder valves.
- Two ammonia leak sensors are located in the ammonia storeroom, where pressurised gas leaks are most likely to happen. One sensor is ranged 0-100ppm and the other ranged 100-2000ppm. Alarm settings are:
  - 35ppm (which is also the OSH short term exposure limit (STEL) for ammonia gas)
  - 100ppm; and
  - 300ppm.

- the immediate danger to life and health (IDLH) concentration for ammonia is 300ppm. The operation of the sensors is detailed in the Functional Control Description Overview document DS75-02.

Note: By comparison, the settings for chlorine gas are 1ppm (STEL), 5ppm and 20ppm (IDLH value is 10ppm).

3.4.1.2 Ammoniation room

- Two ammonia leak sensors shall be in the ammoniation room to detect any gas leak due to pressurisation of the vacuum piping, or because of an ammonia solution leak. One sensor is ranged 0-100ppm and the other ranged 100-2000ppm.
- Alarm settings are:
  - 35ppm (which is also the OSH short term exposure limit (STEL) for ammonia gas)
  - 100ppm; and
  - 300ppm
- The sensors shall be interlocked with the ventilation fans to trigger their activation at 35ppm.
- The ammonia leak detector controller is hard-wired to an ESD controller (although data is also provided to the PLC). The leak detector activation of ESDs is periodically tested to confirm functionality. As noted earlier, all ammonia cylinders are fitted with ESDs in accordance with DS70-03.
- The ventilation fan(s) in the ammoniation room ensure that any ammonia gas release into the room arising from system operation is rapidly dispersed. The aim of the fans is also to maintain a high rate of airflow across the ammoniators to limit the gas concentration in their immediate vicinity in the event of a gas leak from nearby tubing.
- Ammoniators have a secondary pressure relief valve which provides redundancy in case of vacuum regulator relief failure and therefore minimises the possibility of a release of pressurised ammonia gas into the ammoniation room – the secondary relief shall be piped back to the Ammonia Store and discharge at the same location as the primary relief vent.
- All electrical equipment in the ammonia storeroom is Ex rated, except for the ESDs which are designed to operate when any ammonia gas concentration is low i.e. 100ppm compared to the lower explosive limit of ammonia which is 150,000ppm).

3.4.2 Water Quality

Water quality is managed using the standard chlorine module interlocking to initiate shutdown of water supply in the event of chlorination or ammoniation failure, or unacceptable water quality (including high or low chloramine residual) being detected.

3.4.3 Reliability

The standard chlorine module (which is normally co-located with an ammonia module) handles all ammoniation system control and incorporates battery backup and redundant communications to ensure that all control and safety equipment can continue to operate in the event of power failure or primary communications failure.

3.4.4 Failure Scenarios Envisaged

The following failure scenarios have been identified and are mitigated by administrative controls and engineering controls in some cases:

1) Vacuum regulator failure

This is potentially a major release event if the cartridge inside the regulator fails fully open. Inadequate maintenance or the accumulation of deposits are the main reasons anticipated for the cartridge to operate incorrectly. This type of event can result in overpressure of piping or equipment resulting in leaks occurring in the ammonia cylinder storeroom and/or the ammoniation room. This event can be mitigated by an ESD. A secondary pressure relief valve is provided to each ammoniator (venting to the storeroom) to prevent pressurised ammonia gas from blowing the vacuum line seals and being released into the ammoniator room, where the equipment is not rated for explosive gas concentrations.

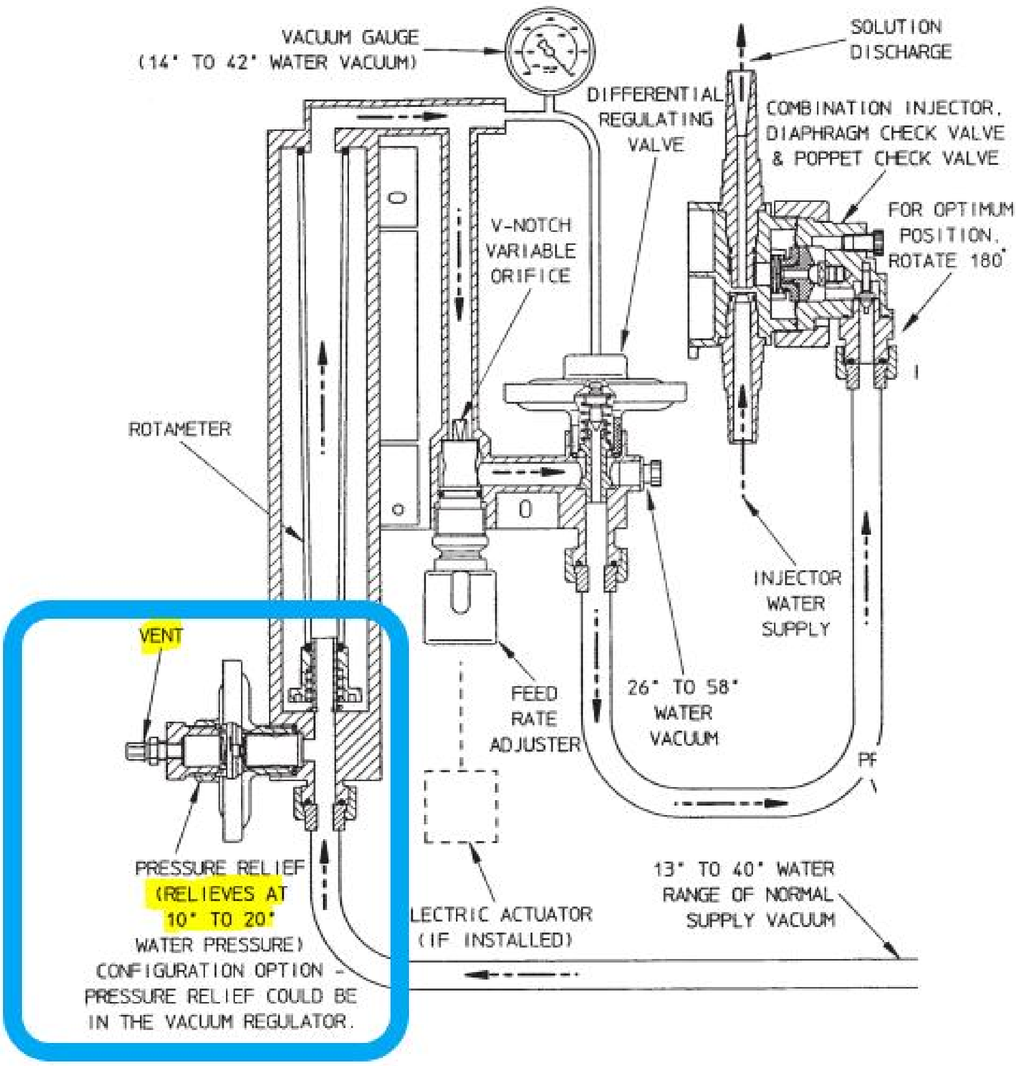

Figure 3-1: Secondary pressure relief valve on each ammoniator

2) Vacuum Regulator becomes loose or disconnected.

This is potentially a major release event if the vacuum regulator becomes significantly disconnected. This event can occur if the vacuum regulator connection has not been tightened sufficiently and is subjected to sudden movement. This type of leak is limited to the cylinder store. The likelihood is low due to the design of the connection and can be mitigated by an ESD.

3) Cylinder is punctured during movement.

This is potentially a major release event but is mitigated with cylinder trolleys that allow the lifting of cylinders by crane trolley hooks rather than slings. The trolleys also allow easy movement of cylinders by personnel and minimise the amount of cylinder manhandling which decreases the risk of a cylinder being dropped.

4) Ammonia solution leak

An ammonia solution leak in the ammoniation room is not expected to reach explosive levels. To prevent localised high concentration of ammonia gas, however, ventilation fans and wall ventilation on two sides are provided.

3.5 Control Functionality

The control functionality for chlorine and ammonia modules is documented in the following standards:

DS70-20 Small Chlorination Systems (Water) Control Function Description

DS75-02 Ammonia Module Functional Description Overview

As has been mentioned in earlier sections, there are multiple optional control features included in the above documents, in addition to the mandatory requirements. The need for the optional control features is determined on a project by project basis and recorded in the F70-01 Procurement Data Sheet that forms part of the contract specification.

4 Process Safeguarding

4.1 Ammonia Leaks

On any High atmospheric ammonia gas detection (i.e. 100ppm) lasting longer than 5 seconds, all ESD actuators shall operate to close valves. This critical safety interlock shall be hard-wired such that it is independent of the Plant Control System. Critical alarms shall be announced to SCADA and initiate external warning strobe and audible alarm (the latter only if the building security is disabled).

The ESD Activated input, shall also initiate shutdown of the ammoniation and chlorination dosing systems via the PLC Water Quality Poor alarm interlock, unless the ammoniation system has been set to Disabled.

4.2 Hazardous Area Management

A Zone 2 Hazardous Area is defined within the Ammonia Gas Storeroom - refer Hazardous Area dossier and drawing(s) for the site. Any electrical equipment and junction boxes required to be located within the defined Hazardous Area shall be suitably rated, installed, maintained and tested in accordance with the Water Corporation Hazardous Area Management System (HAMS) and the current revision of AS-NZS 60079. The Emergency Shutdown Device system has been excluded from this requirement for the following reasons:

1) The actuators are activated at only 100ppm, and only do so for less than 3 seconds. The LEL of ammonia is 150,000ppm which will not be reached in the time it takes for the actuators to complete their operation and be de-energised. No remote activation function shall be provided for the actuators to prevent them ever being energised at elevated ammonia gas concentrations.
2) The controller units are substantially gas tight – enough to prevent explosive levels of gas entering the units.
3) No Ex rated ESD systems have been identified to date. It is considered that the toxic risk management benefits provided by an ESD system outweigh the residual explosion risk of using actuators that are not Ex rated.

Note:

The ESD system has its own integral battery that provides for 4 hours of operation in the event of power failure. The ammonia leak detector is on a UPS circuit and will also operate in the event of a power failure for 4 hours. Hence, if an ammonia gas leak occurrence is somehow associated with a power failure event, the shutdown system is available for up to 4 hours after that event.

END OF DOCUMENT