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MATRIX PDM ENGINEERING

# DESIGN, FABRICATION AND CONSTRUCTION ISSUES ASSOCIATED WITH AMMONIA STORAGE AT VARIOUS SCALES

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# AGENDA AND PRESENTATION OUTLINE

- Introduction
- Codes and Standards
- Storage Concepts
- Ammonia Storage Tank Safety Considerations: Pressure, Vacuum and Level management
- Miscellaneous Safety System

***Acknowledgement:*** *This presentation is put together by the members of Matrix PDM Engineering – Project Engineering, Shell & Plate and Process Engineering Teams*






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# MATRIX SERVICE COMPANY CORPORATE OVERVIEW

Matrix Service Company **(NASDAQ: MTRX)** is a top-tier, publicly-traded Plant Services & EPC contractor to the Energy and Industrial markets

MATRIX SERVICE COMPANY

MATRIX PDM ENGINEERING

MATRIX NAC
Union Subsidiary

MATRIX SERVICE
Merit Subsidiary

MATRIX APPLIED TECHNOLOGIES
AST Products

## ASME CERTIFIED FABRICATION FACILITIES

**HEAVY STEEL PLATE**

- **CATOOSA, OK**
  One of the largest & most modern heavy steel plate fabricating facilities in the U.S.
- **ORANGE, CA**

**PIPE SPOOLING & MODULES**

- **BELLINGHAM, WA**
- **LEDUC, AB**

**PRODUCT FABRICATION/ASSEMBLY**
PAJU (SEOUL) KOREA


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ISO 9001
QMI-SAI Global

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# WHERE YOU WILL FIND MATRIX

## ENERGY

- Storage terminals
- Refineries
- Gas processing plants
- Petrochemical plants
- Compressor stations
- LNG liquifaction and regassification plants
- Peak shaving facilities
- LPG export facilities
- Renewables

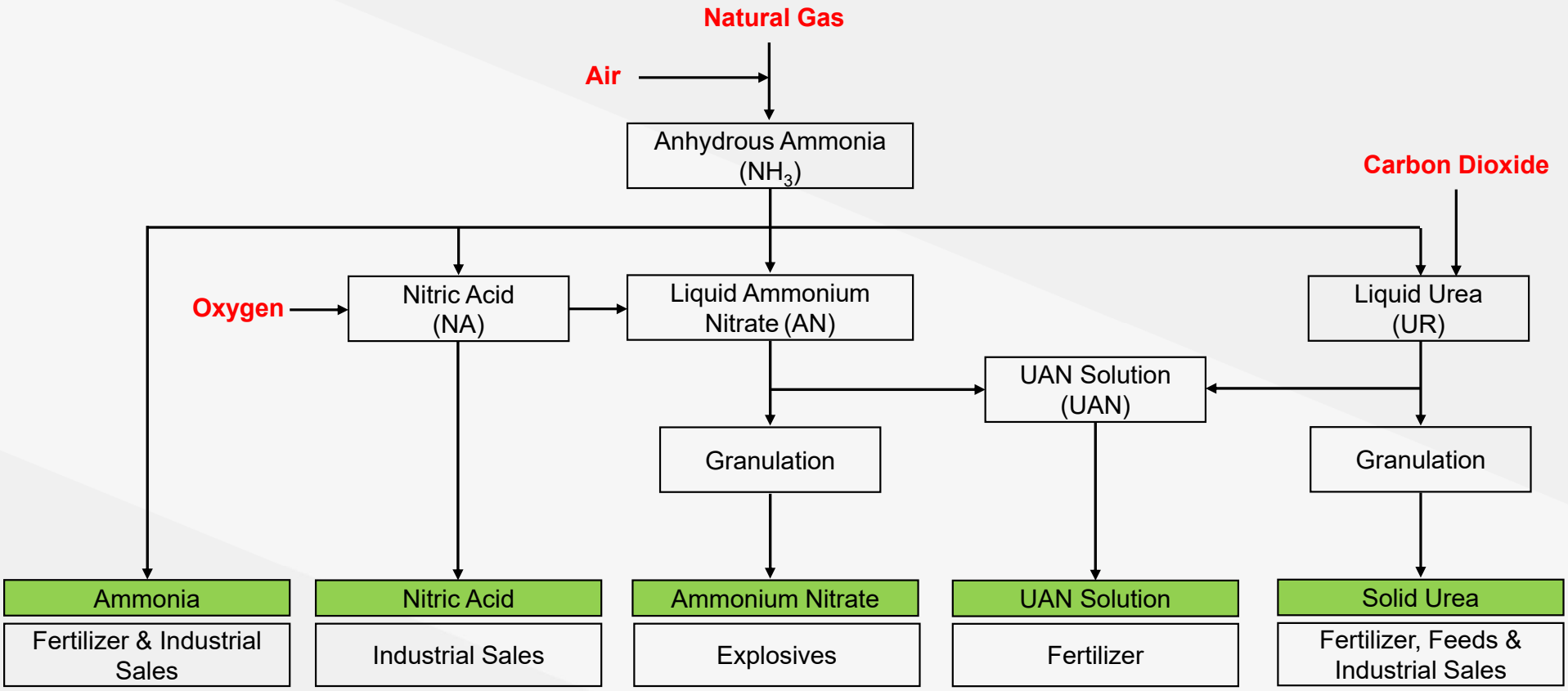
## POWER

- Substations
- Transmission and distribution
- Combined-cycle power plants
- Nuclear plants
- Storm response

## INDUSTRIAL

- Iron and steel mills
- Fertilizer plants
- Cement facilities
- Manufacturing plants
- Mining and minerals

# AMMONIA, A BASIC BUILDING BLOCK FOR NITROGENEOUS FERTILIZERS



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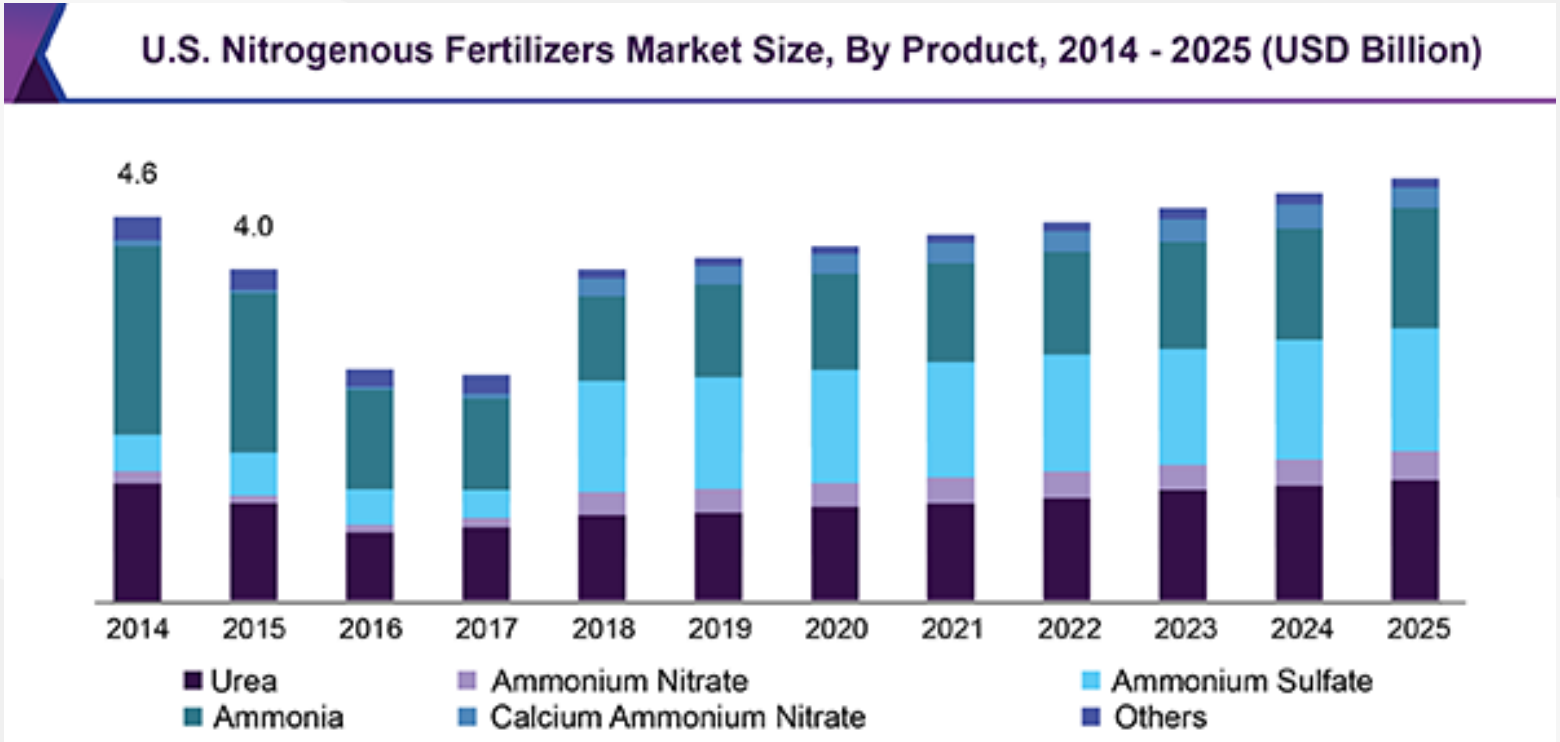
# FERTILIZER MARKET




Reference: https://www.grandviewresearch.com



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# AMMONIA PROPERTIES

| Physical Properties of Ammonia | |
|---|---|
| Molecular Weight | 17.03 g/mol |
| Saturation Temperature / Boiling Point at 14.7 psia | -28 °F |
| Freezing Point at 14.7 psia | -107.9 °F |
| Saturated Liquid Density at 14.7 psia | 42.57 $lb/ft^3$ |
| Saturated Vapor Density at 14.7 psia | 0.0555 $lb/ft^3$ |
| Critical Pressure | 1657 psia |
| Critical Temperature | 271.4 °F |
| Flammability Limits (%in air, by volume) | 16% to 25% |
| Ignition Temperature | 1562 °F |
| Latent Heat of Vaporization | 589.3 Btu/lb |

# AMMONIA – A CHEMICAL THAT NEEDS SAFE HANDLING

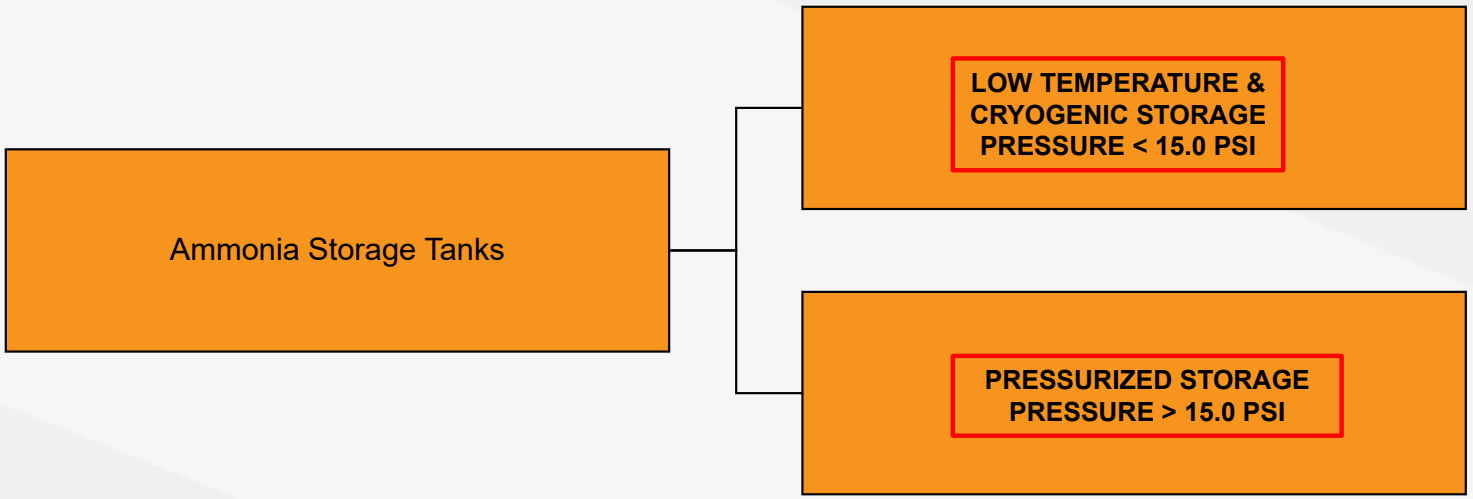
| Concentration / Time | Effect |
|---|---|
| 20 ppm – 50 ppm | Mild discomfort, depending on whether an individual is accustomed to smelling ammonia |
| 50 ppm (OSHA Max exposure limit) | Perceptible eye and throat irritation |
| 100 ppm for 2 hours | Nuisance eye and throat irritation |
| 134 ppm for 5 minutes | Tearing of the eyes, eye irritation, nasal irritation, throat irritation, chest irritation |
| 140 ppm for 2 hours | Severe irritation, need to leave exposure area |
| 300 ppm - 500 ppm for 30 minutes | Upper respiratory tract irritation; tearing of the eyes (lacrimation), hyperventilation |
| 700 ppm – 1700 ppm | Incapacitation from tearing of the eyes and coughing |
| 5000 ppm – 10,000 ppm | Rapidly fatal |
| 10,000 ppm | Promptly lethal |

Reference: CGA G-2.1 – Table 2 - Human physiological responses to various concentrations of ammonia in air

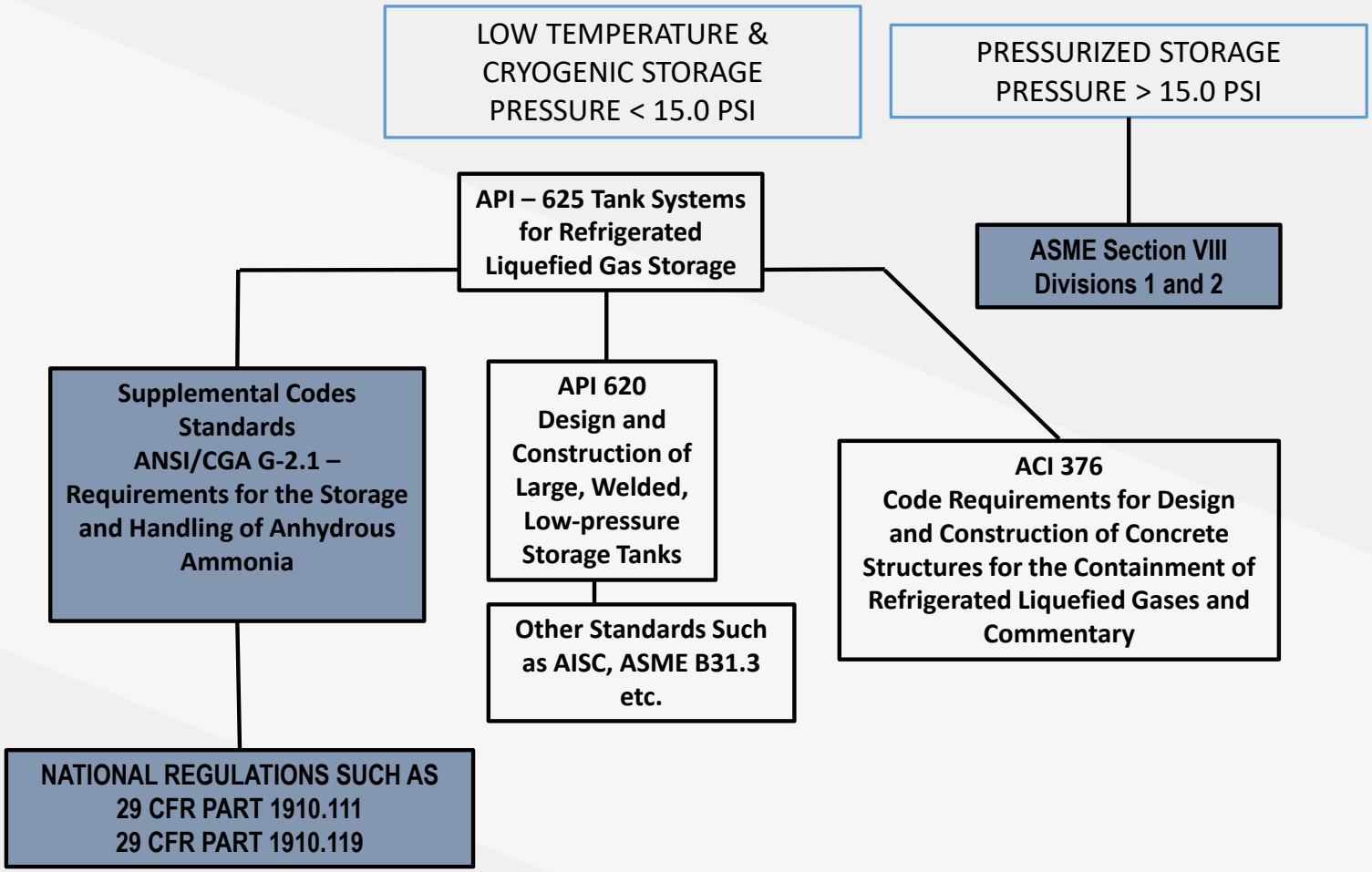
# AMMONIA FACILITES STANDARDS

| Reference | Description |
|---|---|
| 29 CFR § 1910.119 | Process safety management of highly hazardous material: |
| 6 CFR Part 27 | Chemical Facility Anti-Terrorism Standards (CFATS) |
| 29 CFR 1910.111 (OSHA) | Storage and handling of anhydrous ammonia |
| 49 CFR Parts 171-180 | Transportation of Hazardous Materials |
| 33 CFR 105 | Maritime Security of Facilities |
| US-EPA EPCRA | Emergency Community Right-to-know Act |
| US-EPA RMP | Risk Management Plan |
| General Considerations | Quantitative Risk Assessment; Equipment Layout - Ammonia Process Area; Ammonia Process Storage Area; Transportation Send-out Area; Plant Operations and Maintenance; Emergency Response; Natural events – Hurricanes, Flooding, and Earthquake |

# METHODS TO STORE AMMONIA



# TYPICAL U.S. STORAGE CODES AND STANDARDS

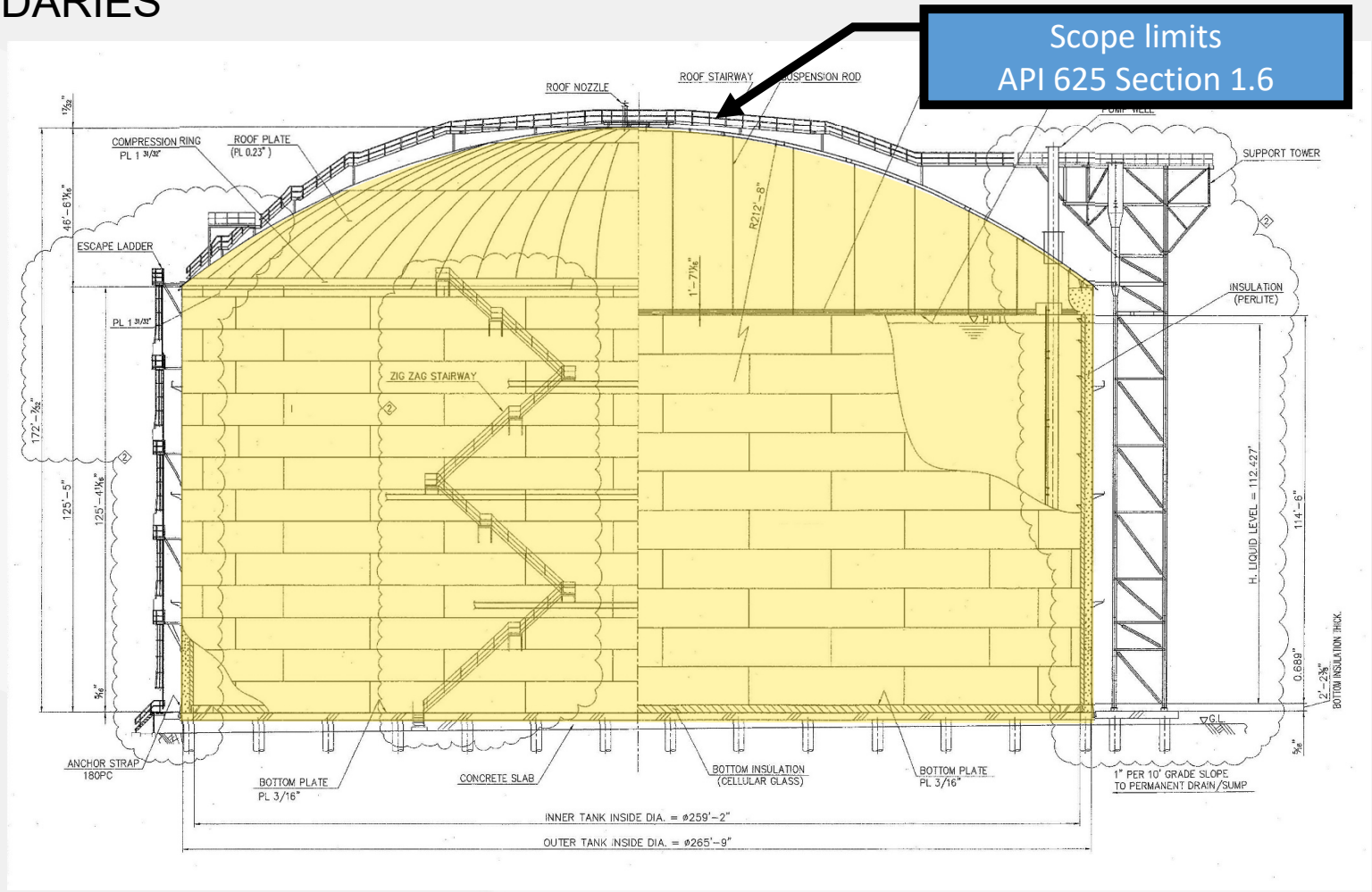


# BOUNDARIES

Boundaries For Storage Tank Standards

Battery Limit

# BOUNDARIES



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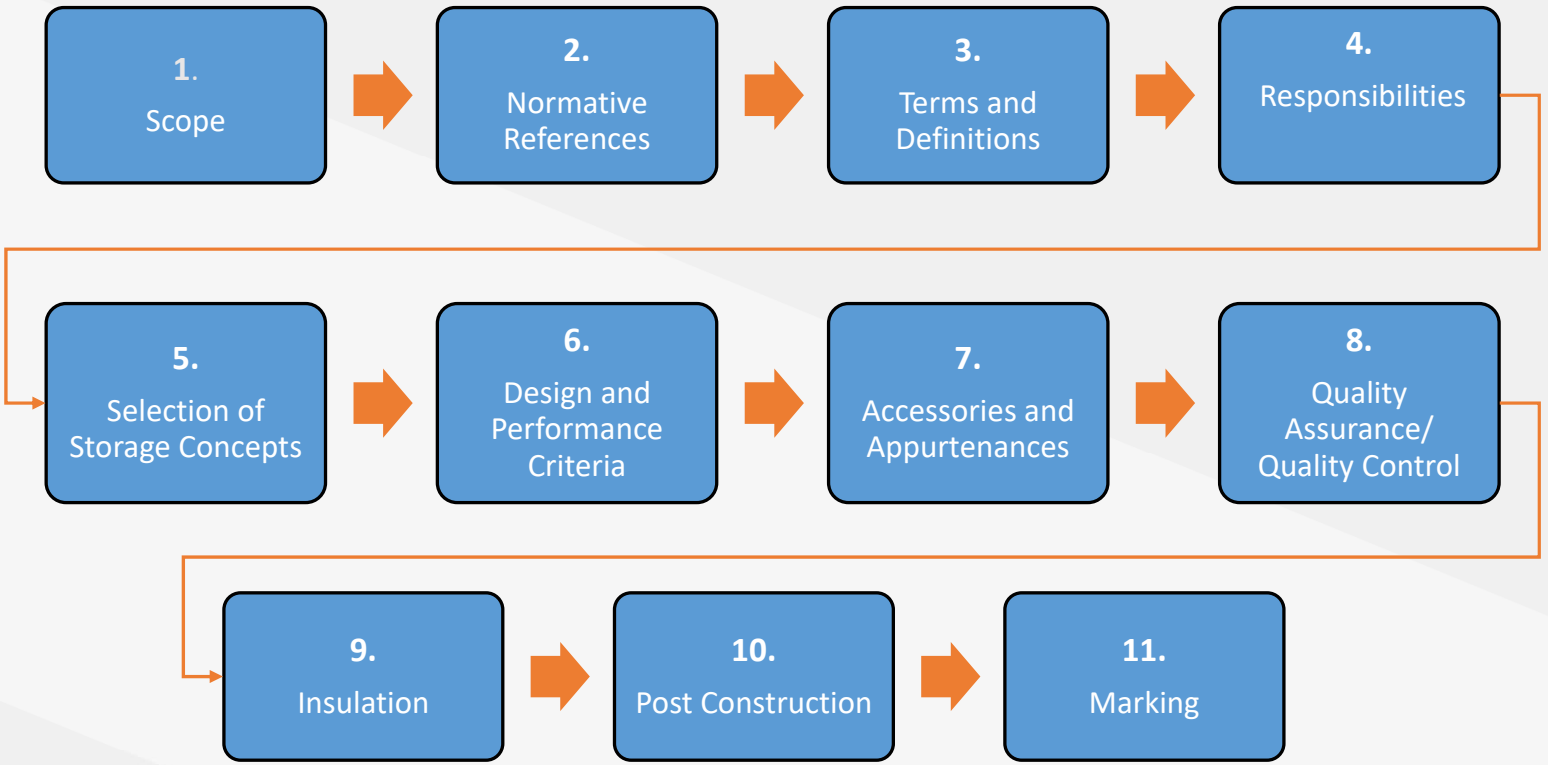
# AMMONIA, STORAGE TANKS

Reference: Iowa Fertilizer Plant, Weaver, Iowa, USA

# AMMONIA STORAGE – DESIGN PARAMETERS

| Description | Value |
|---|---|
| Storage Tank Gross Capacity | 5,000 MT to 50,000 MT (Can go to 70,000 MT or higher.) |
| Design Pressure | 1.0 psig to 4.0 psig (Typ. 2.0 psig) |
| Design Temperature | -35 deg. F |

# API 625 STRUCTURE – STORAGE TANK SYSTEM




**Annex A**
Properties of Gases

**Annex B**
Foundation Settlement

**Annex C**
Commentary on Storage Concepts

**Annex D**
Storage Concept Selection based on Risk

**Annex E**
Inquiries and Suggestions for Change



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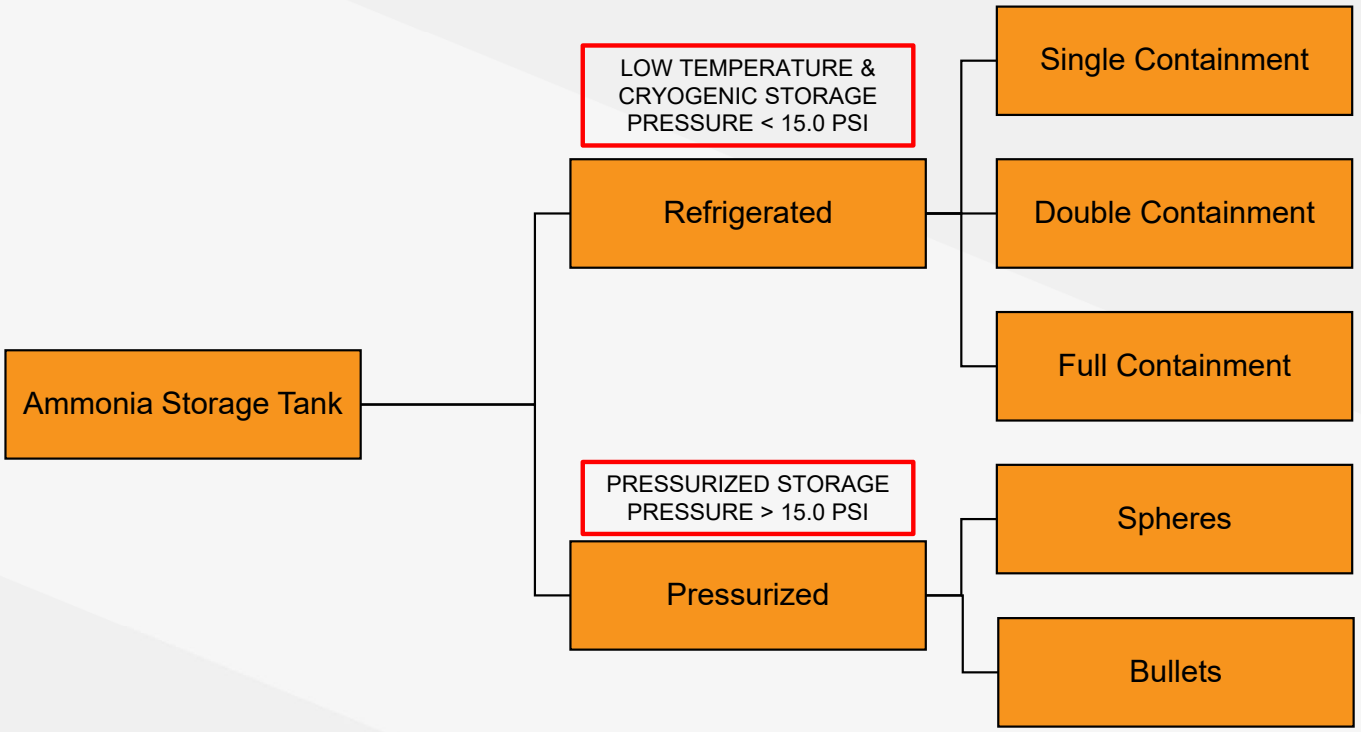
# METHODS TO STORE AMMONIA



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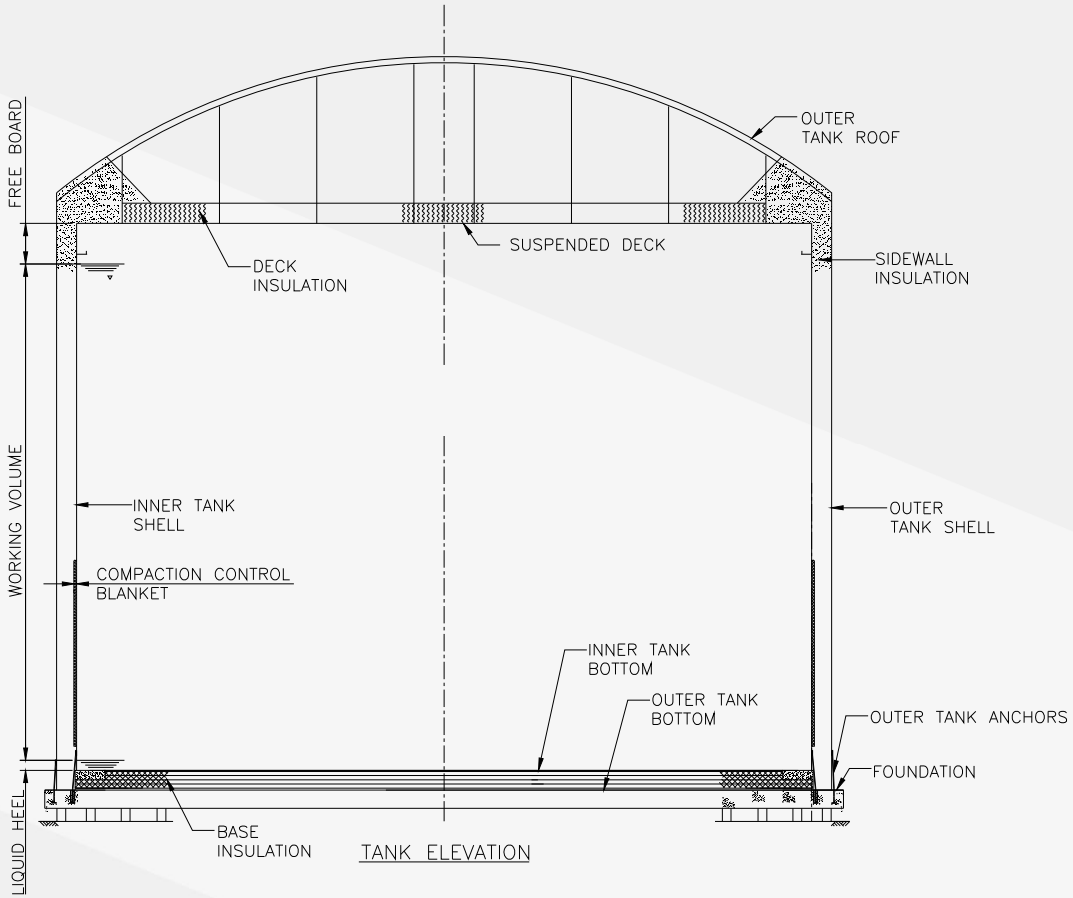
# NOMENCLATURE – BASIC CRYOGENIC STORAGE TANK



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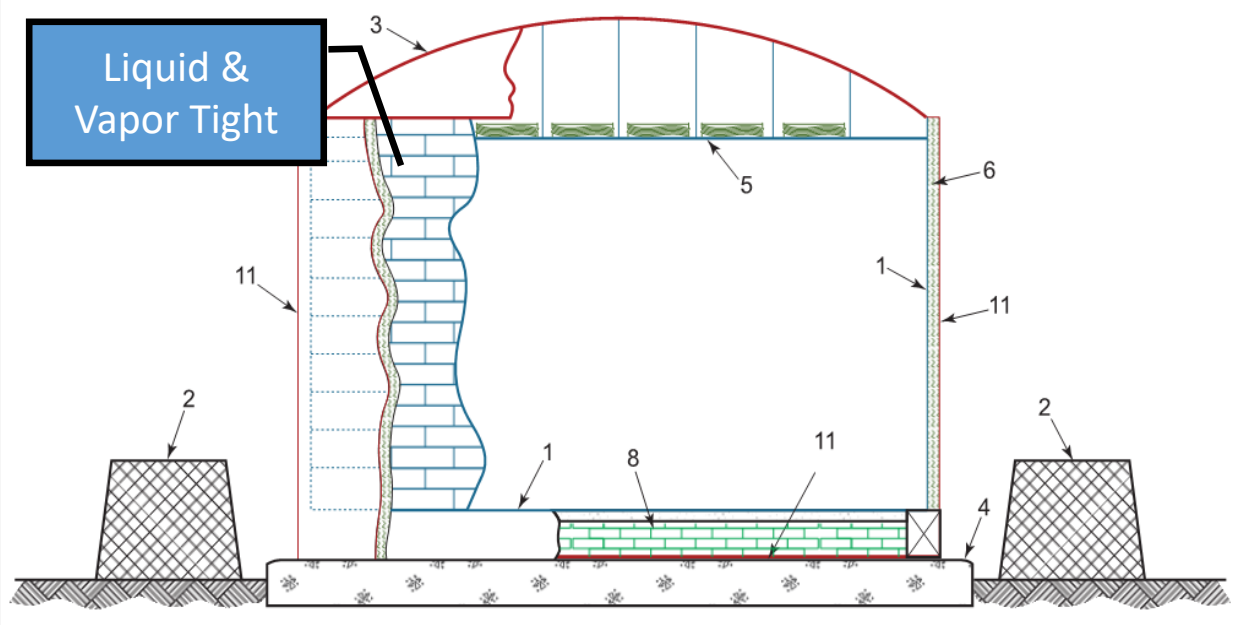
# SINGLE CONTAINMENT TANK SYSTEM
## (API 625, SECTION 5.2 & ANNEX C.2)




**Key**

1 primary liquid container (low temp steel)
2 secondary containment (dike wall)
3 warm product vapor container (roof)
4 concrete foundation
5 suspended deck with insulation
6 insulation (external)
8 load bearing insulation (bottom)
11 moisture vapor barrier
14 ring beam

- Normal Operating Condition: # Primary: liquid and vapor tight
- Emergency Operating Condition: **Dike** will retain the liquid



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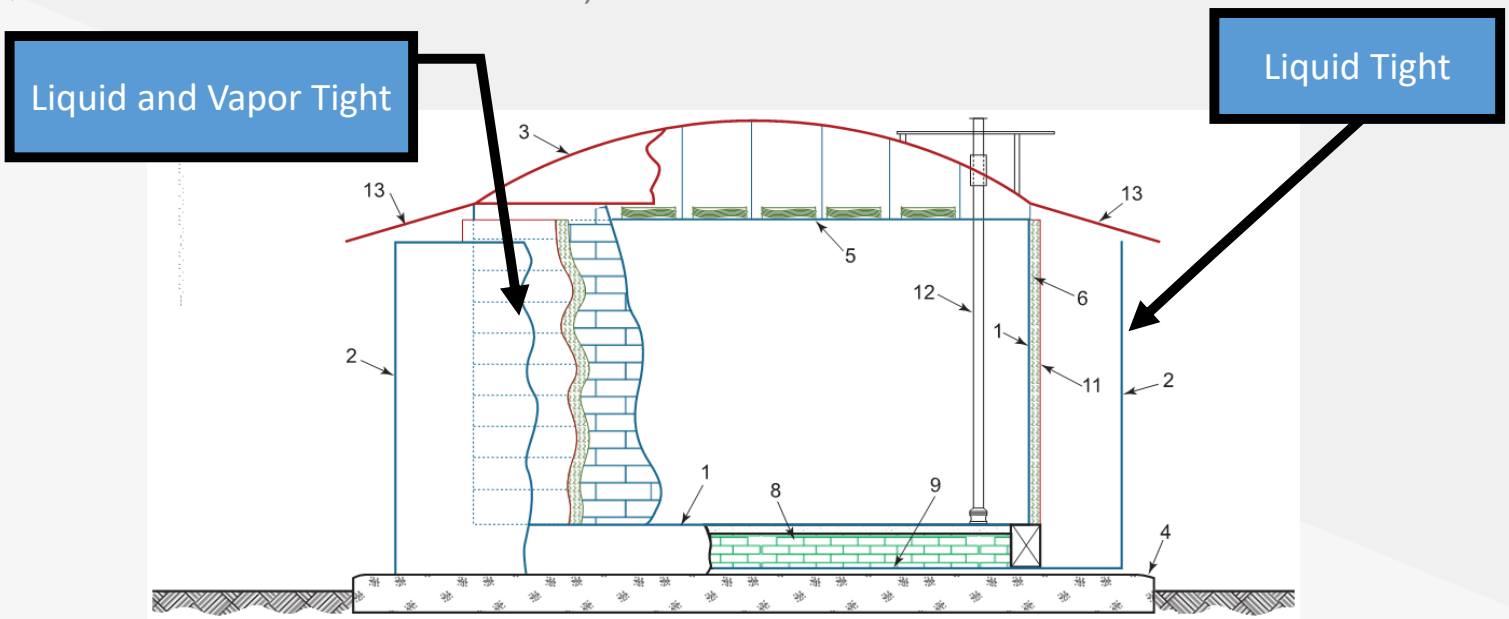
# DOUBLE CONTAINMENT TANK SYSTEM, STEEL DIKE
## (API 625, SECTION 5.3 AND ANNEX C.3)

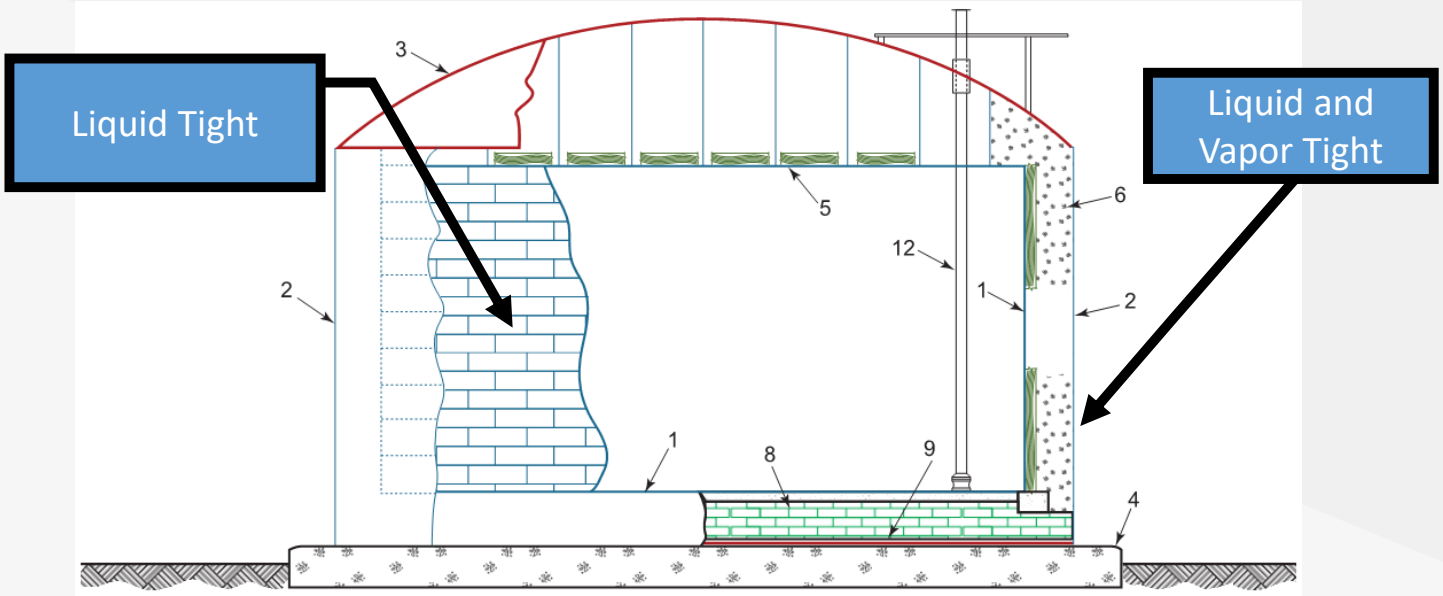



**Key**

1 primary liquid container (low temp steel)
2 secondary liquid container (low temp steel)
3 warm product vapor container (roof)
4 concrete foundation base slab
5 suspended deck with insulation
6 insulation (external)
8 load bearing insulation (bottom) insulation
9 secondary liquid container (low temp steel)
11 moisture vapor barrier
12 pump column
13 rain shield
14 ring beam

- Normal Operating Condition: # Primary: liquid and vapor tight # Secondary: liquid tight
- Emergency Operating Condition: **Secondary** will retain the liquid

# FULL CONTAINMENT TANK SYSTEM, STEEL
## (API 625, SECTION 5.4 & ANNEX C.4)




**Key**

1 primary liquid container (low temp steel)
2 secondary liquid container (low temp steel)
3 warm product vapor container (roof)
4 concrete foundation
5 suspended deck with insulation
6 insulation (annular space)
8 load bearing insulation (bottom)
9 secondary liquid container (low temp steel)
12 pump column
14 ring beam

- Normal Operating Condition: # Primary: liquid and vapor tight # Secondary: liquid tight
- Emergency Operating Condition: **Secondary** will retain the liquid

# FULL CONTAINMENT STEEL TANKS

**Two 74,000 m³ Ammonia Tanks – Orascom – Wever, IA**

*Designed by Matrix PDM Engineering,*
*Constructed by Matrix Service Inc.*



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# PERFORMANCE CRITERIA
## (API 625 SECTION 6.4)

Boil off Rate
6.4.4

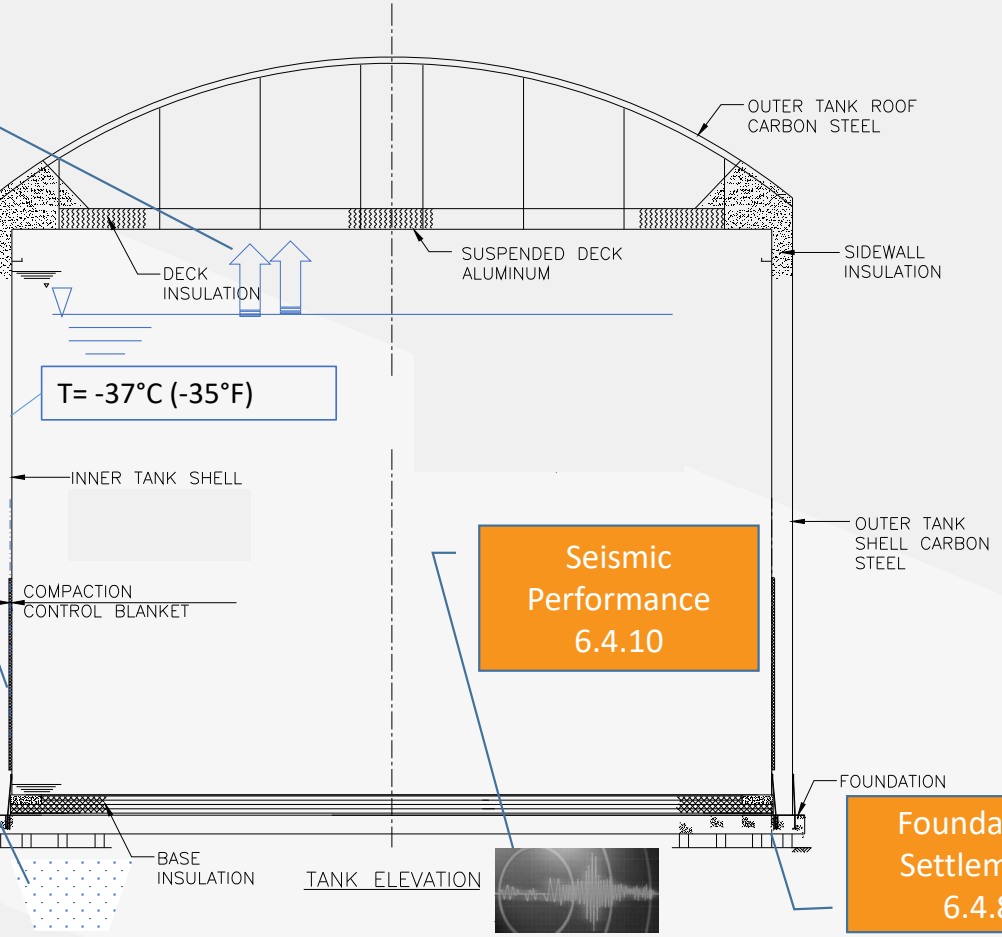
Design Temperature
6.4.6

T= -37°C (-35°F)

T= 21°C (70°F)

Differential Movement
6.4.7

Freeze Protection
6.4.9




Seismic Performance
6.4.10

Foundation Settlement
6.4.8



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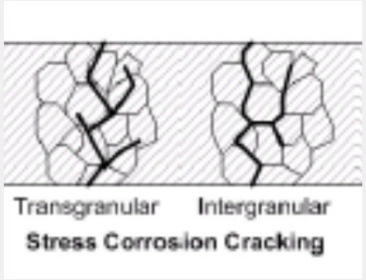
# FOUNDATIONS (PILE CAP REBAR CAGE)

# FOUNDATION HEATING SYSTEM

# AMMONIA STRESS CORROSION CRACKING (NH3-SCC)

- ❖ NH3-SCC affects mechanical integrity
- ❖ Oxygen + Stress enables SCC
- ❖ SCC is less prevalent in low temperature storage tanks

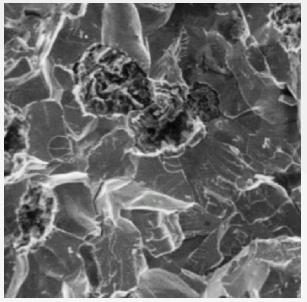



## Prevention

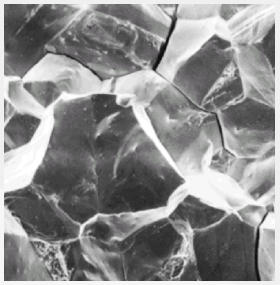
- Design, fabrication and construction details
- Minimization of oxygen contamination during commissioning and operation
- Providing a small amount of moisture (0.2%) during operation

## Inspection

- Wet Magnetic Particle Testing
- UT Testing (Shear Wave + TOFD)
- Acoustic Emissions



Transgranular Fracture



Intergranular Fracture

Reference
Dettmers, Reindell; Stress Corrosion Cracking Update, Presentation, www.irc.wisc.edu
Nyborg, Lunde; Measures for Reducing SCC Anhydrous Ammonia Storage Tanks, AIChE, Aiche-35-005, 1994
Mortenson; In-service inspection of welds in atmospheric ammonia storage tanks, https://www.semfa.eu/Portals/6/Presentations/Inspection%20of%20Ammonia%20Storage%20Tanks

# LOW TEMPERATURE STORAGE TANKS WITH SIDE PENETRATIONS

Double or Full Containment Tanks with Side or bottom penetrations are allowed if:

- Purchaser specifies the penetrations
- Regulations do not prohibit them
- Risk assessment considers the penetrations
- In-tank valves are provided
- A remote dike wall is provided in addition to the secondary containment. The volume contained by the dike shall be equal to 110 % of the flow from a full line break prior to closure of the in-tank valve.

# STORAGE TANKS WITH IN-TANK VALVES

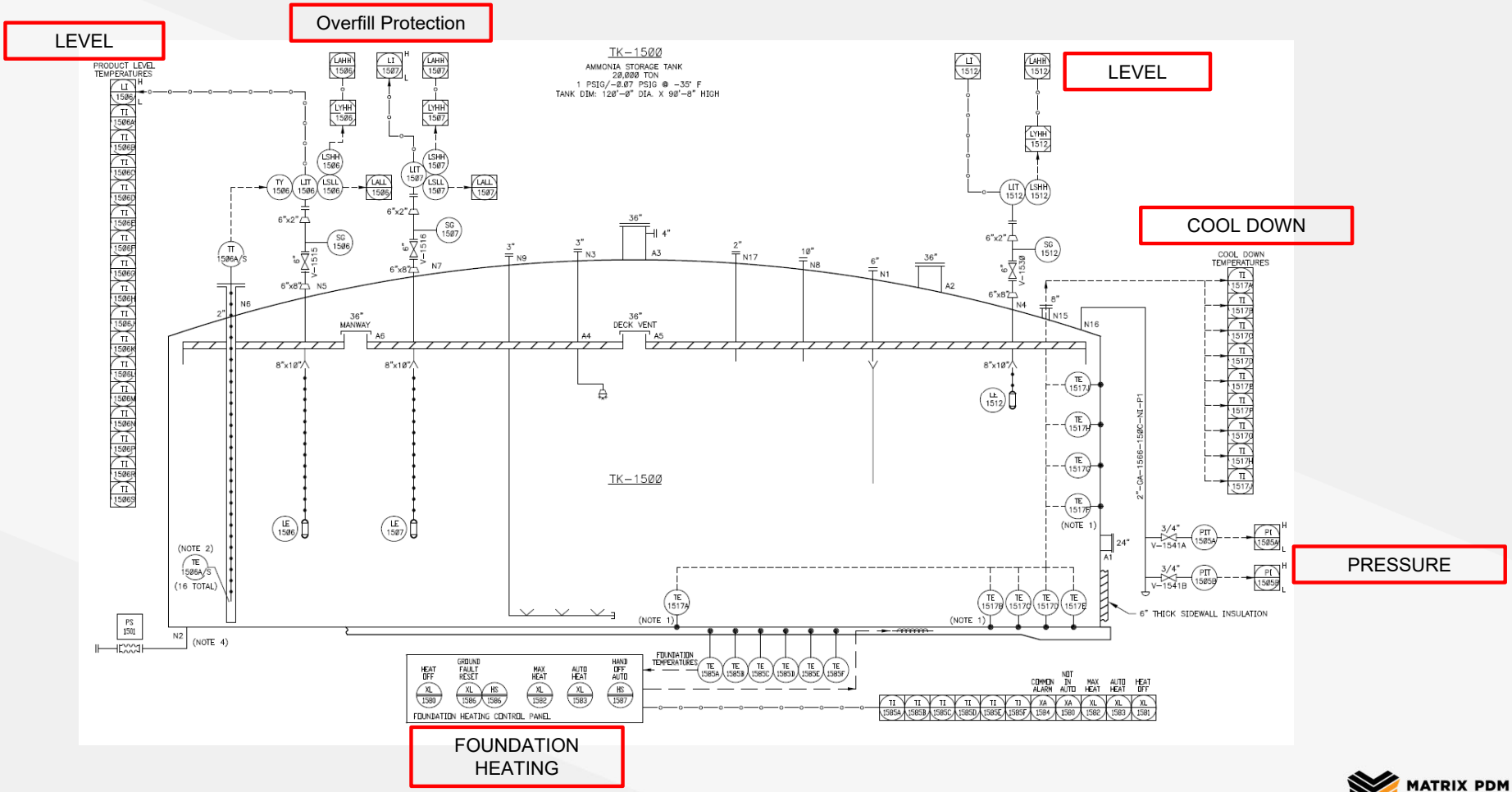
**Requirements**

- Automatic activation - failure of external piping
- Automatic activation - loss of electrical power
- Activation from a remote location.
- Failure of the penetrating nozzle resulting from external pipe strain is beyond the shutoff seats of the internal valve.

# AMMONIA REFRIGERATED STORAGE TANK KEY SAFETY CONSIDERATIONS

- Pressure Management
- Vacuum Management
- Level Management

# GENERAL INSTRUMENTATION FOR AN AMMONIA STORAGE TANK



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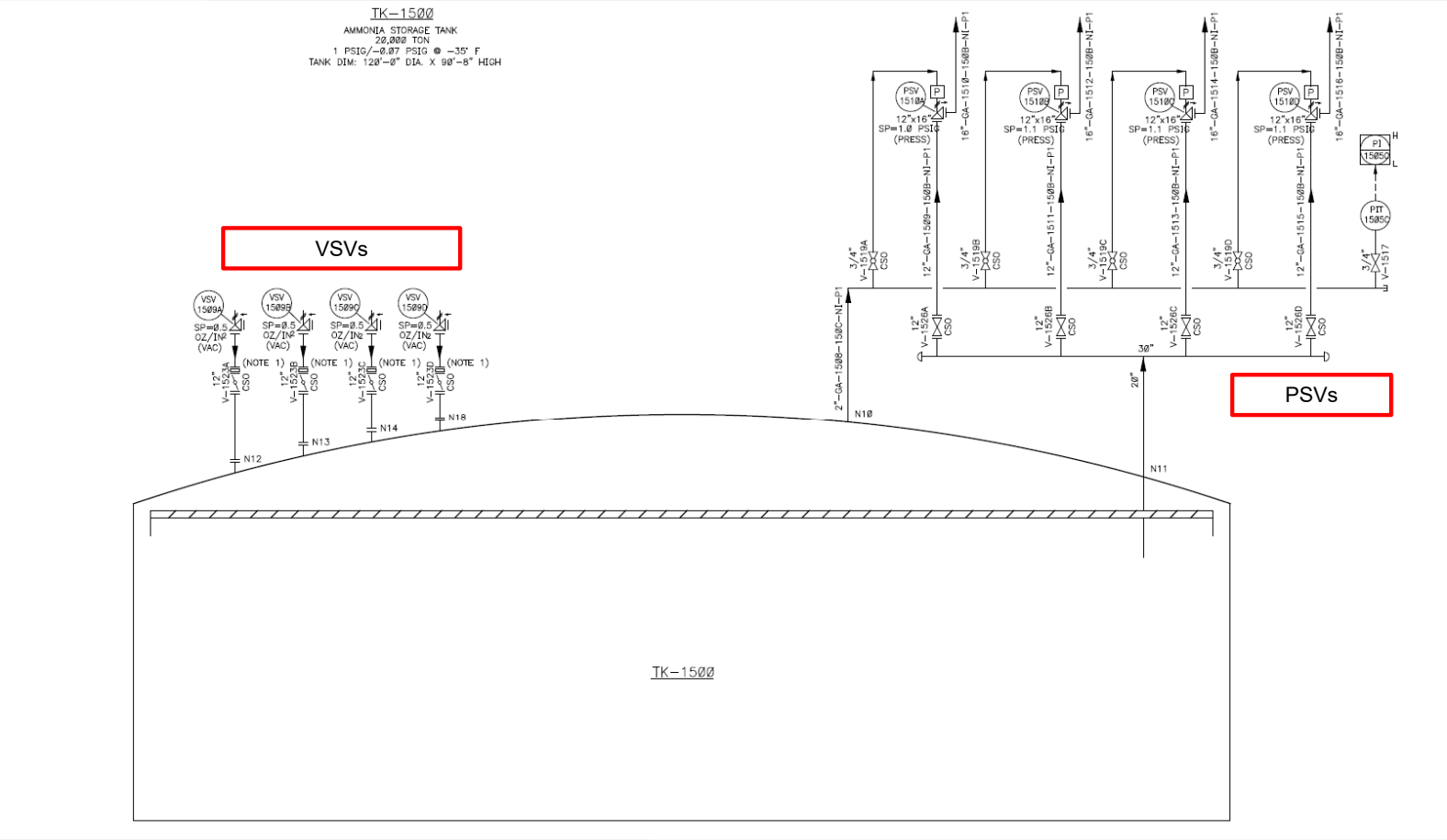
# GENERAL INSTRUMENTATION FOR AN AMMONIA STORAGE TANK



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# CAUSE OF TANK HIGH PRESSURE

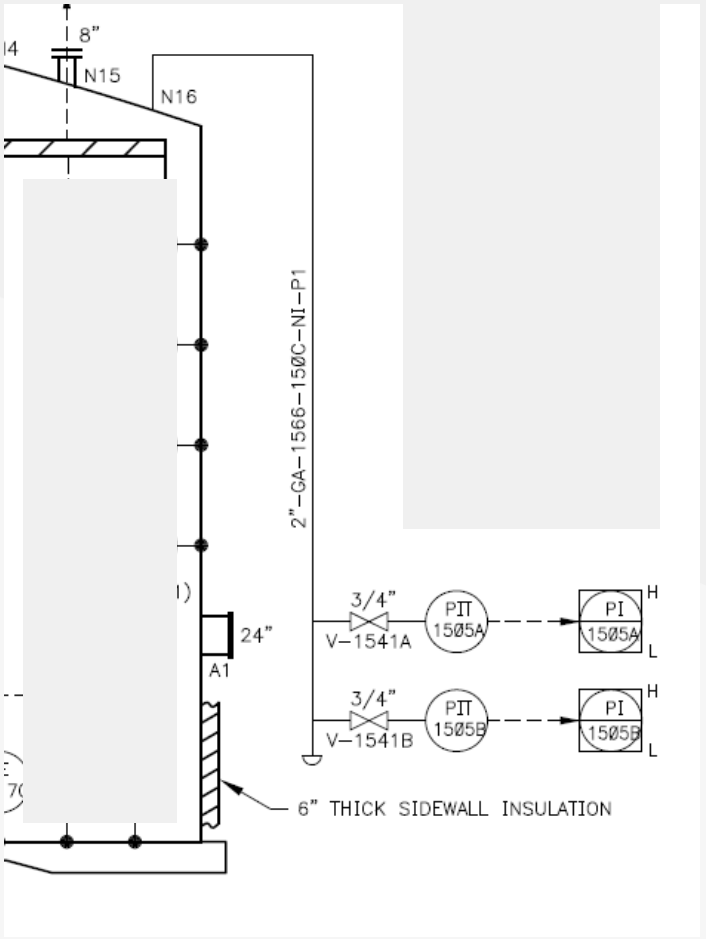
- Tank Heat Gain
- Fill Flash
- Vapor Displacement due to Liquid Filling
- Decrease in Barometric Pressure
- Heat Input from Pump Recirculation
- Abnormal Operating Conditions
- Fire Exposure
- Leakage through Inner Tank

Reference: The Rupture of a Liquid Ammonia Storage Tank Study, Alireza Orooji and Sajjad Hosseininia, Assaluyeh, Iran

# TANK PRESSURE MEASUREMENT

## Pressure Gauge

- Minimum two pressure instruments are required
- Pressure instruments shall be connected to the vapor space above liquid level



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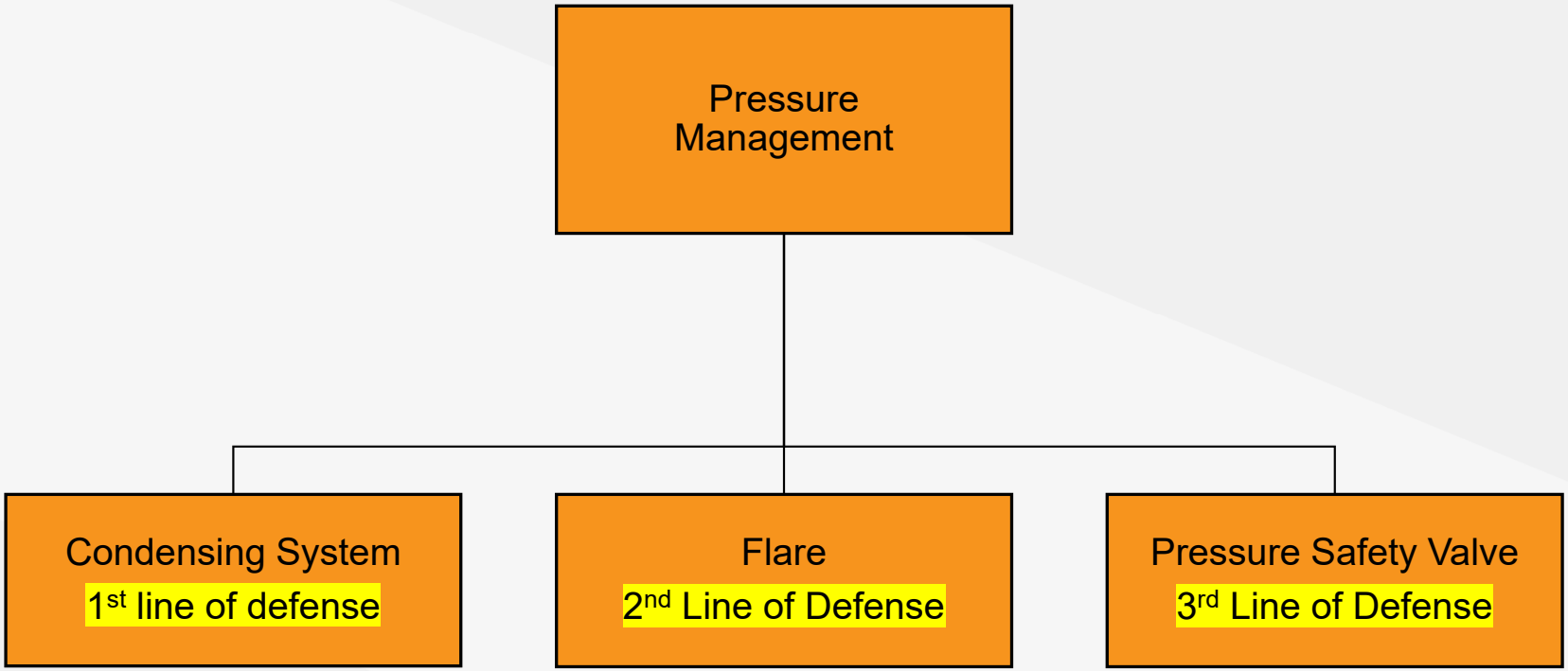
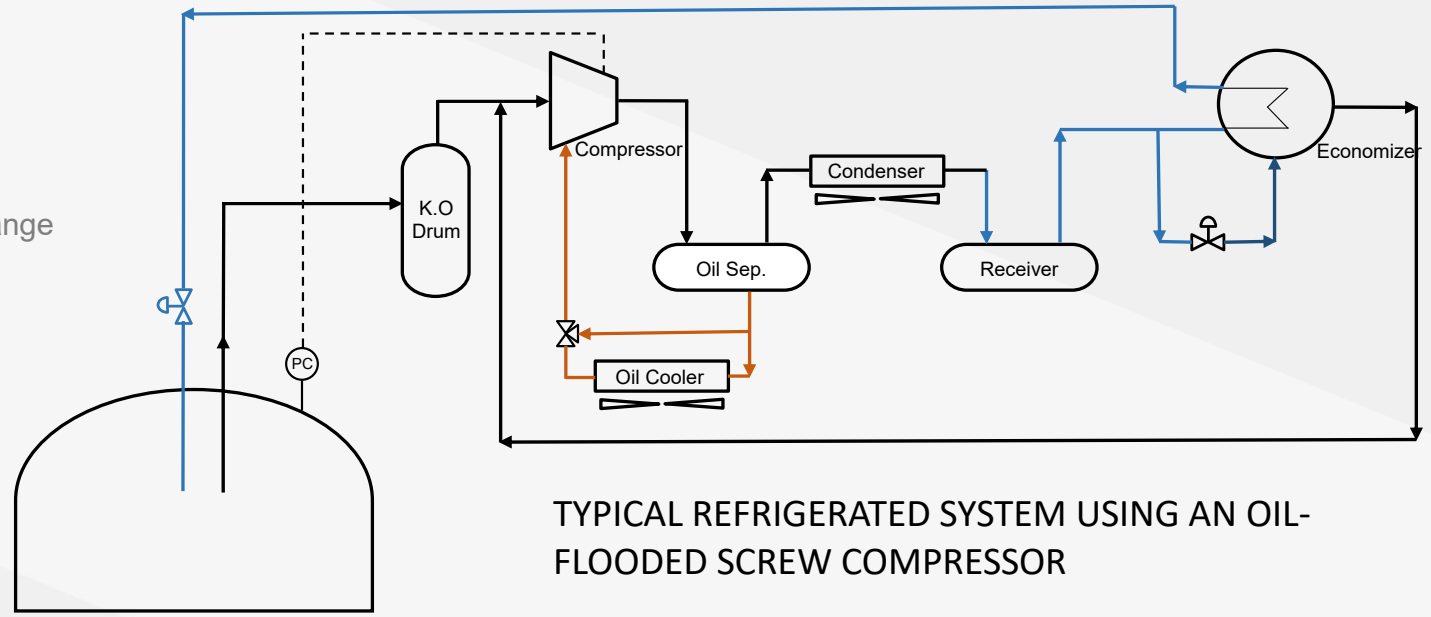

Pressure Management
Condensing System
1st line of defense
Flare
2nd Line of Defense
Pressure Safety Valve
3rd Line of Defense

# PRESSURE MANAGEMENT

## Condensing System / Vapor Recovery

- Design parameters
  - Fill Displacement
  - Fill Flash
  - Tank Heat Gain
  - Recirculation Heat Gain
  - Barometric Pressure Change
- Set pressure

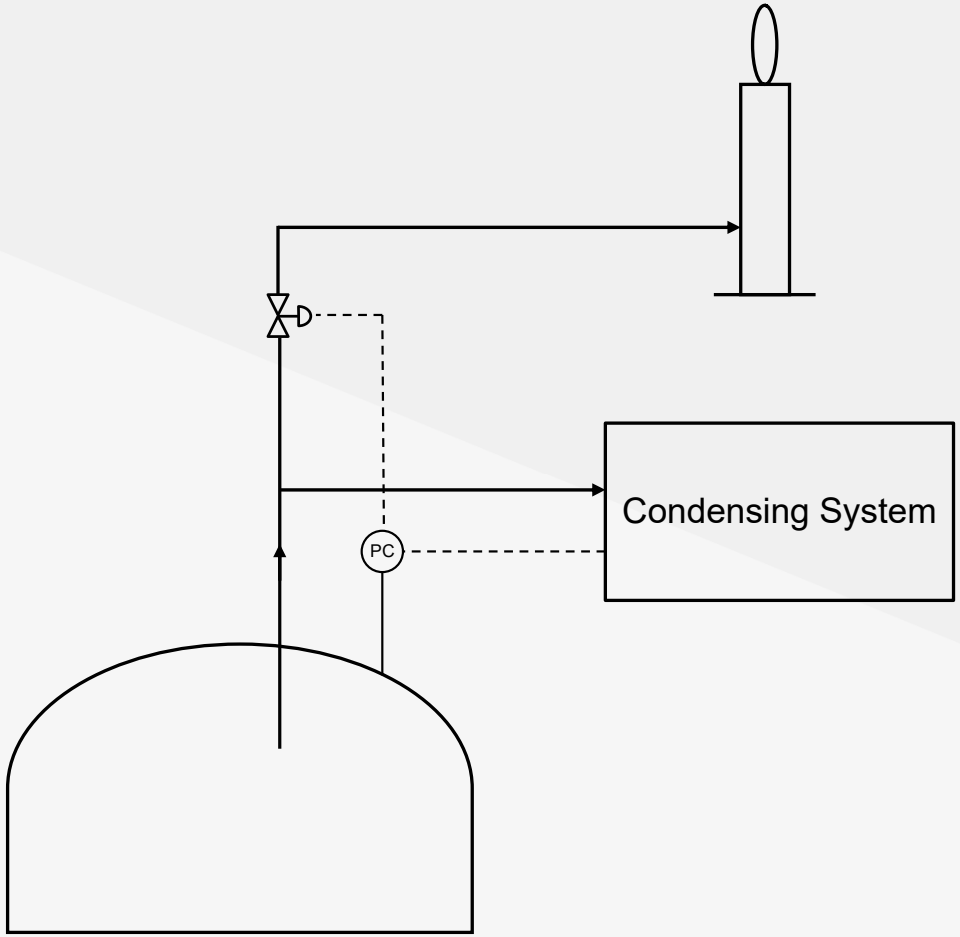



TYPICAL REFRIGERATED SYSTEM USING AN OIL-FLOODED SCREW COMPRESSOR

# PRESSURE MANAGEMENT

**Flare**

- As a Back up for Condensing System
- Design parameters
  - Fill Displacement
  - Fill Flash
  - Tank Heat Gain
  - Recirculation Heat Gain
  - Barometric Pressure Change
- Set pressure



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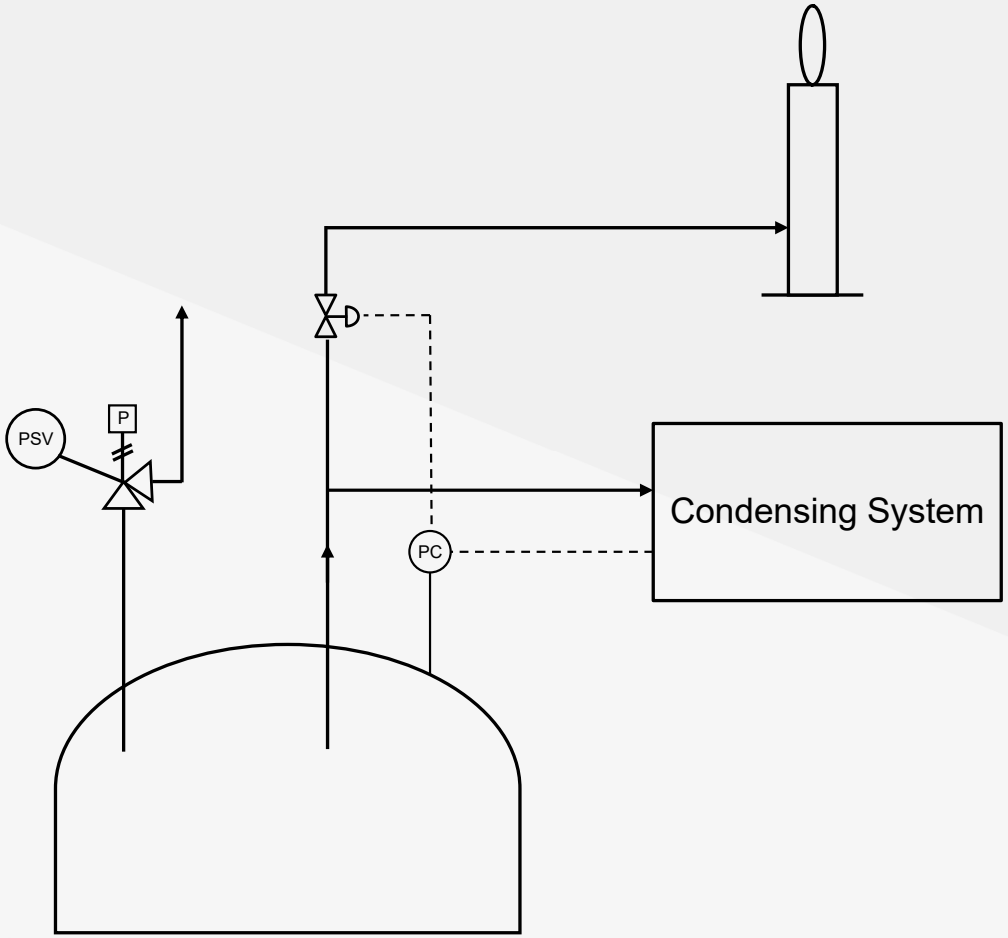
# PRESSURE MANAGEMENT

## Pressure Safety Valves

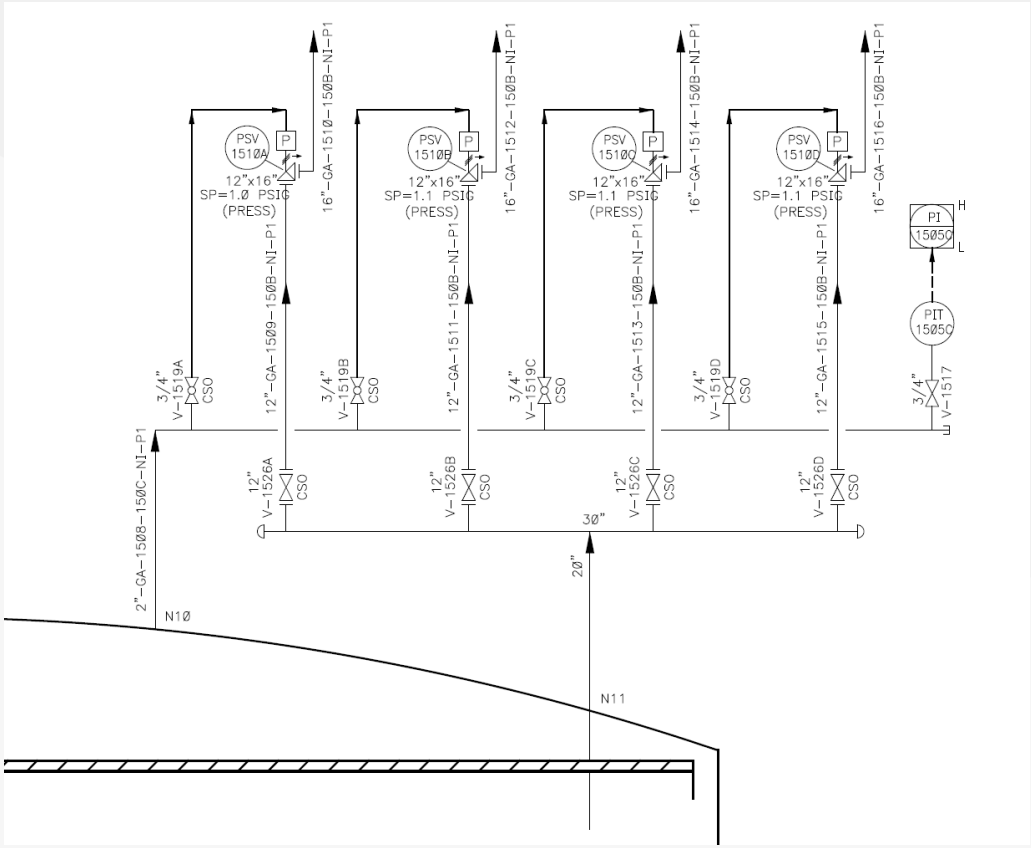
- Design parameters
  - Normal Operating Conditions
  - Fill Displacement
  - Fill Flash
  - Tank Heat Gain
  - Recirculation Heat Gain
  - Barometric Pressure Change



# PRESSURE MANAGEMENT

## Pressure Safety Valves

- Design parameters
  - Abnormal Operating Conditions
  - Fire Exposure
  - Utility or Mechanical failure
- Excessive pumping rates into the tank
- Excessive temperature of ammonia liquid pumped into the tank below the liquid level
- Leakage through Inner Tank and Overfill (Full Containment Tank Only)
- Set Pressure



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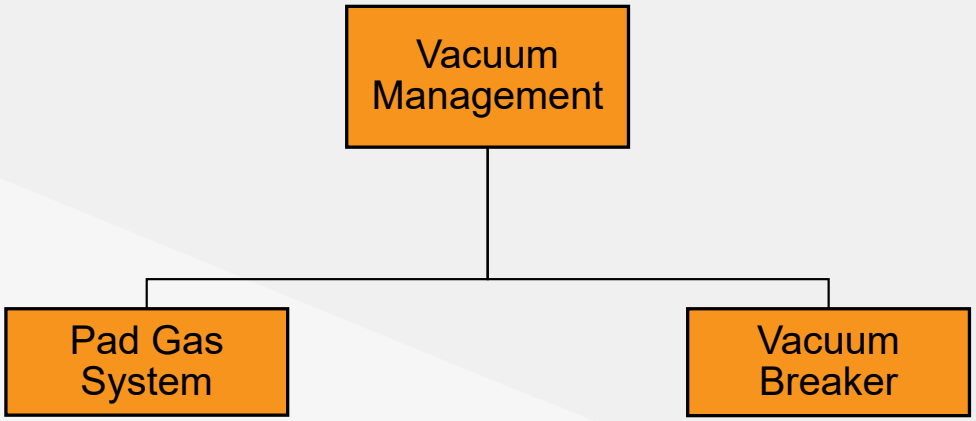
# CAUSE OF TANK LOW PRESSURE

- Withdrawal of Liquid
- Withdrawal of Vapor
- Increase in Barometric Pressure
- Abnormal Operating Conditions

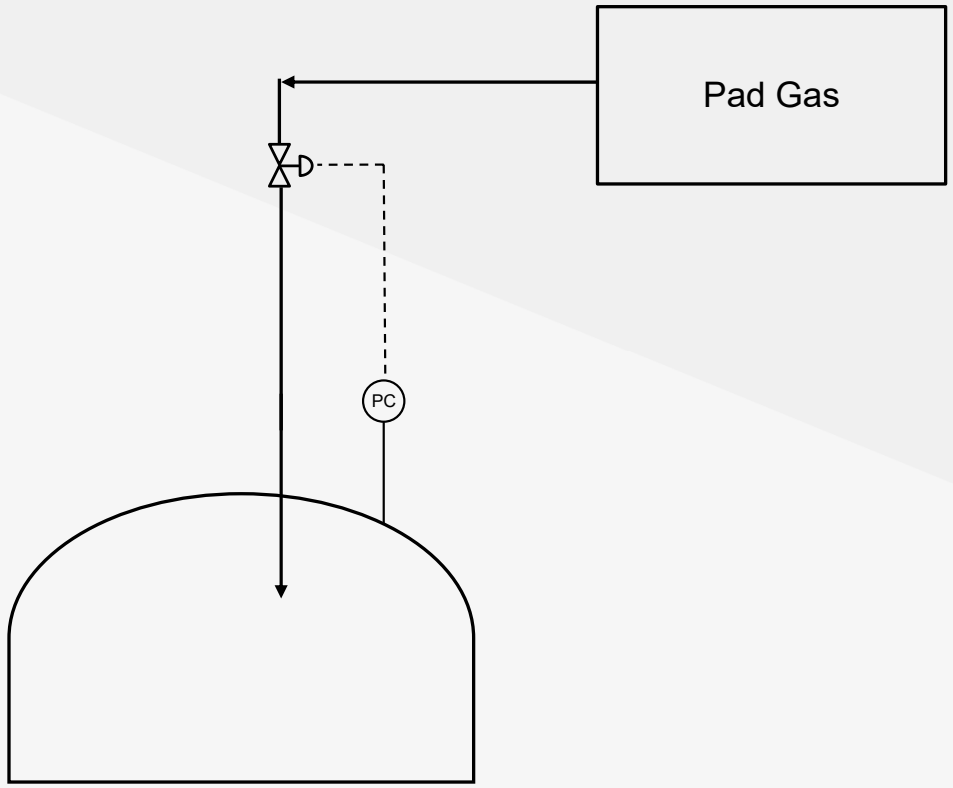


# VACUUM MANAGEMENT

## Pad Gas System

- Design parameters
  - Liquid Withdrawal
  - Vapor Withdrawal

- Set pressure



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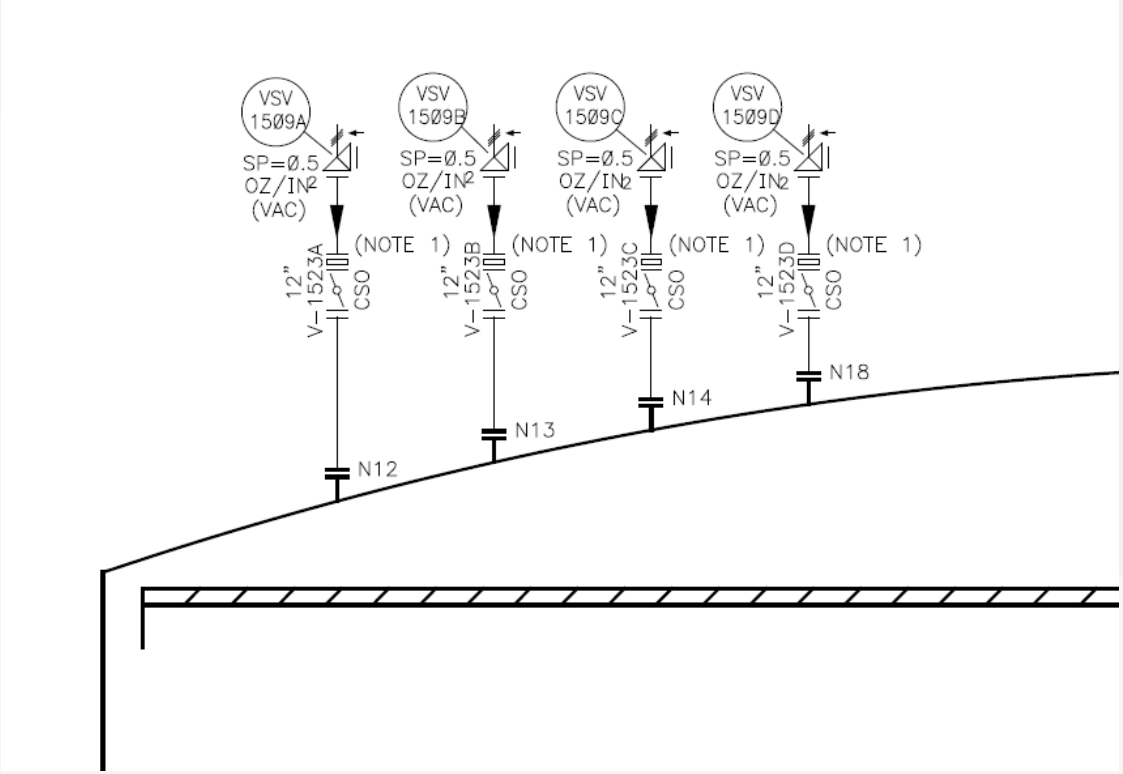
# VACUUM MANAGEMENT

## Vacuum Breakers

- Design parameters
  - Normal Operating Conditions
  - Liquid Withdrawal
  - Vapor Withdrawal
  - Barometric Pressure Change
  - Abnormal Operating Conditions
  - Utility or Mechanical Failure
  - Excessive Withdrawal Rates
  - Set pressure



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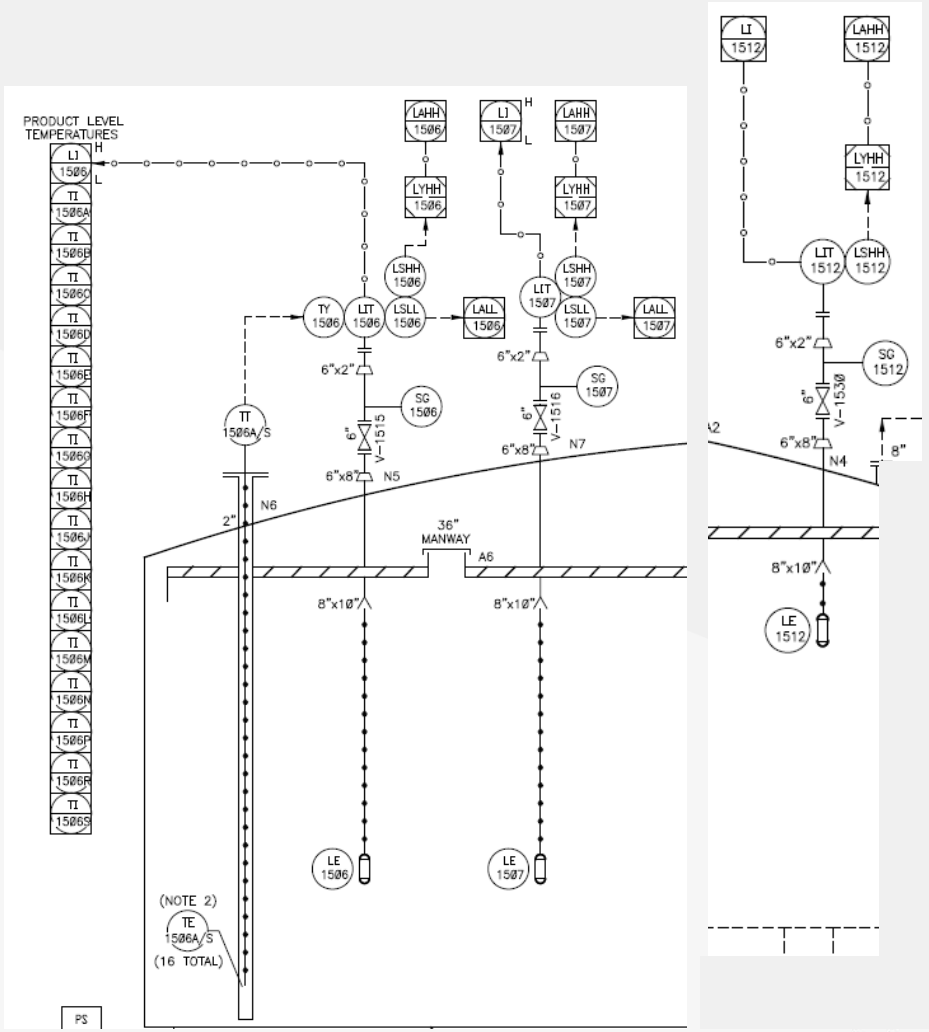
# LEVEL MANAGEMENT

## Level Gauges and Overfill Protection

- Minimum two independent level gauges
- A separate, liquid level alarm and cutoff device, set at the design liquid level
- Overfill protection margin

## Leak detection

- A must for a double and full containment tanks, required for single containment tanks only if specified by the owner or by a result of a hazard study
    - Temperature Change
    - Gas Detection
    - Level (Differential pressure measurement)



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# MISCELLANEOUS SAFETY SYSTEMS

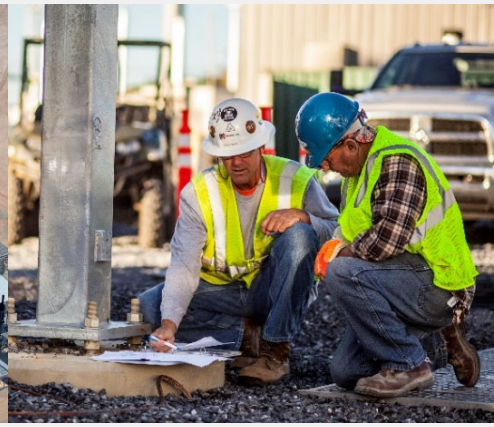
**Hazard Detection**

- Gas Detectors
- Flame Detectors
- Smoke Detectors
- Horns and Beacons
- Hand Switch Stations
- Fire System

# SUMMARY

- Ammonia is a toxic chemical that requires safe handling
- Ammonia Tanks are built using low pressure welded storage tank standards
- Storage Tanks for Refrigerated Liquids are considered a System with many components
- Primary Safety Considerations for Large Scale Ammonia Storage are Pressure, Vacuum and Level management
- These aspects are managed using Instrumentation
- Matrix has a proven track record in the design, fabrication and construction of ammonia tanks at various scales





# THANK YOU

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