Safety considerations for Ammonia storage tanks

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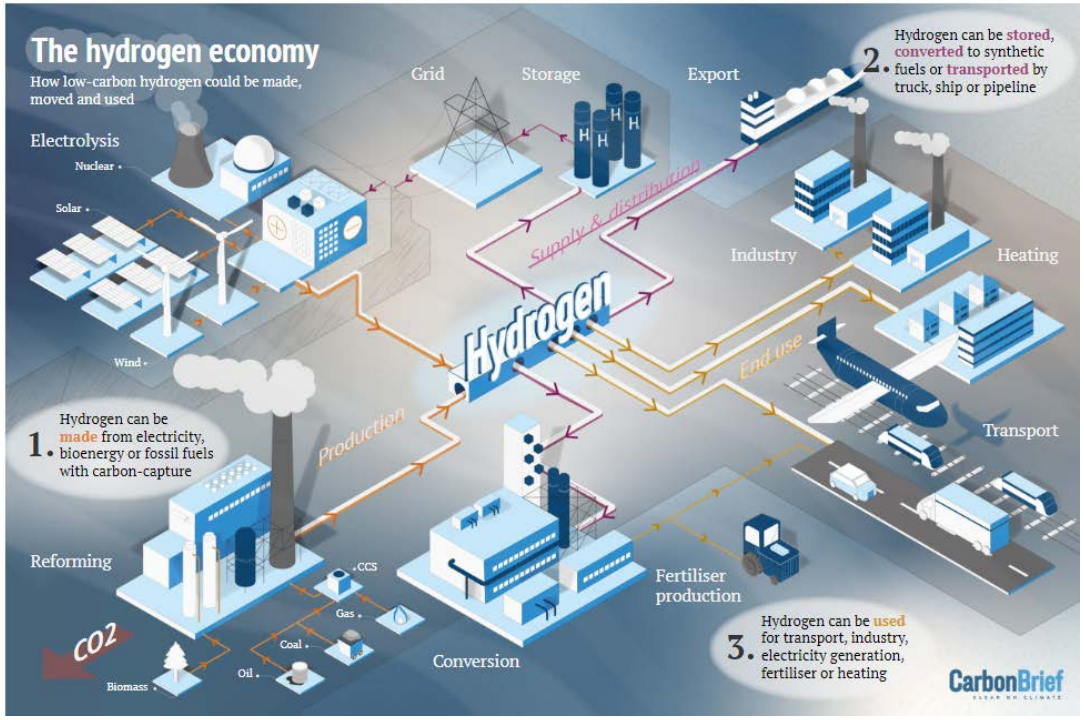
AGENDA AND PRESENTATION OUTLINE

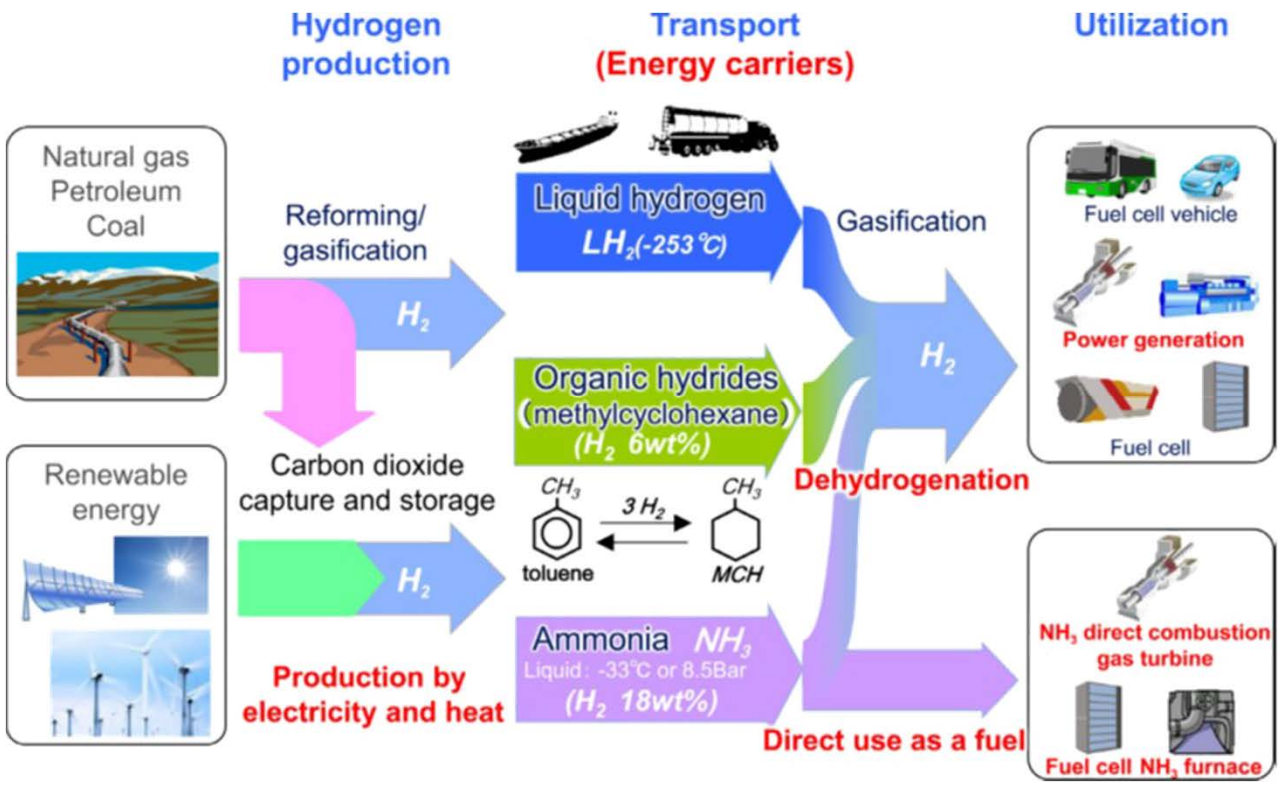
- Introduction
- Codes and Standards
- Storage Concepts
- Ammonia Storage Tank Safety Considerations: Pressure, Vacuum and Level management
- Miscellaneous Safety System

VERSATILITY OF H2



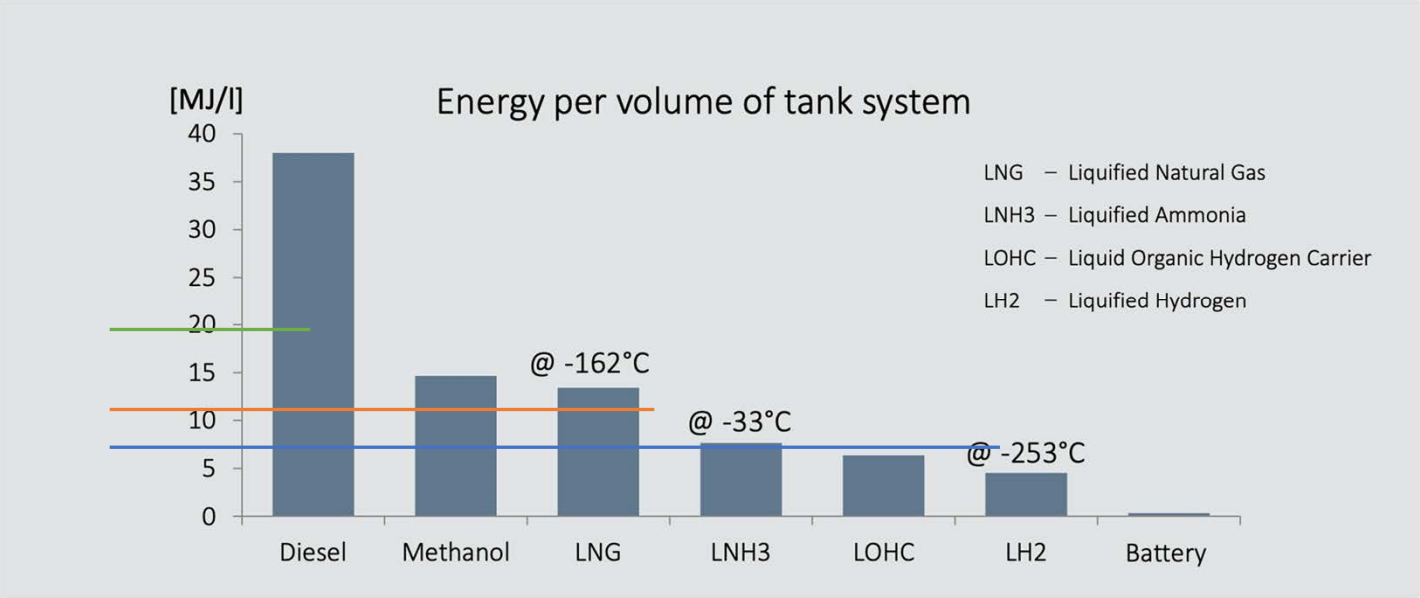
Source: https://www.carbonbrief.org/in-depth-qa-does-the-world-need-hydrogen-to-solve-climate-change/

ALTERNATE H2 CARRIERS



Ref: H. Kobayashi et al. / Proceedings of the Combustion Institute 37 (2019)

FUEL STORAGE VOLUME COMPARISON



Source: https://www.methanol.org/wp-content/uploads/2021/10/Methanol-Future-Proof-Marine-Fuel-Oct-2021.pdf

CURRENT CHALLENGES USING NH3 AS H2 CARRIER

- Thickness considerations (> 2 inches thickness)
- Associated welding and weld processes
- Hardness requirements on the finished welds (Typical 225 Brinell)
- Ammonia when combusted, may generates nitrogen oxides (i.e. NOx and N2O). N2O has a far greater greenhouse warming potential than CO2 (up to 298x greater).

  Source: https://sustainability.crugroup.com/article/green-ammonia-fuel-faces-three-big-challenges

WHY AMMONIA?

Zero Carbon Emission

Hydrogen Combustion

$4\ NH_3 + 3\ O_2 \rightarrow 2\ N_2 + 6\ H_2O$

Vs

Methane Combustion

$CH_4 + O_2 \rightarrow H_2O + CO_2$

Properties of Ammonia – NH_3

NH_3	Ammonia
Molecular Weight/ Molar Mass	17.031 g/mol
Density	0.73 kg/m³
Boiling Point	-33.34 °C
Melting Point	−77.73 °C

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

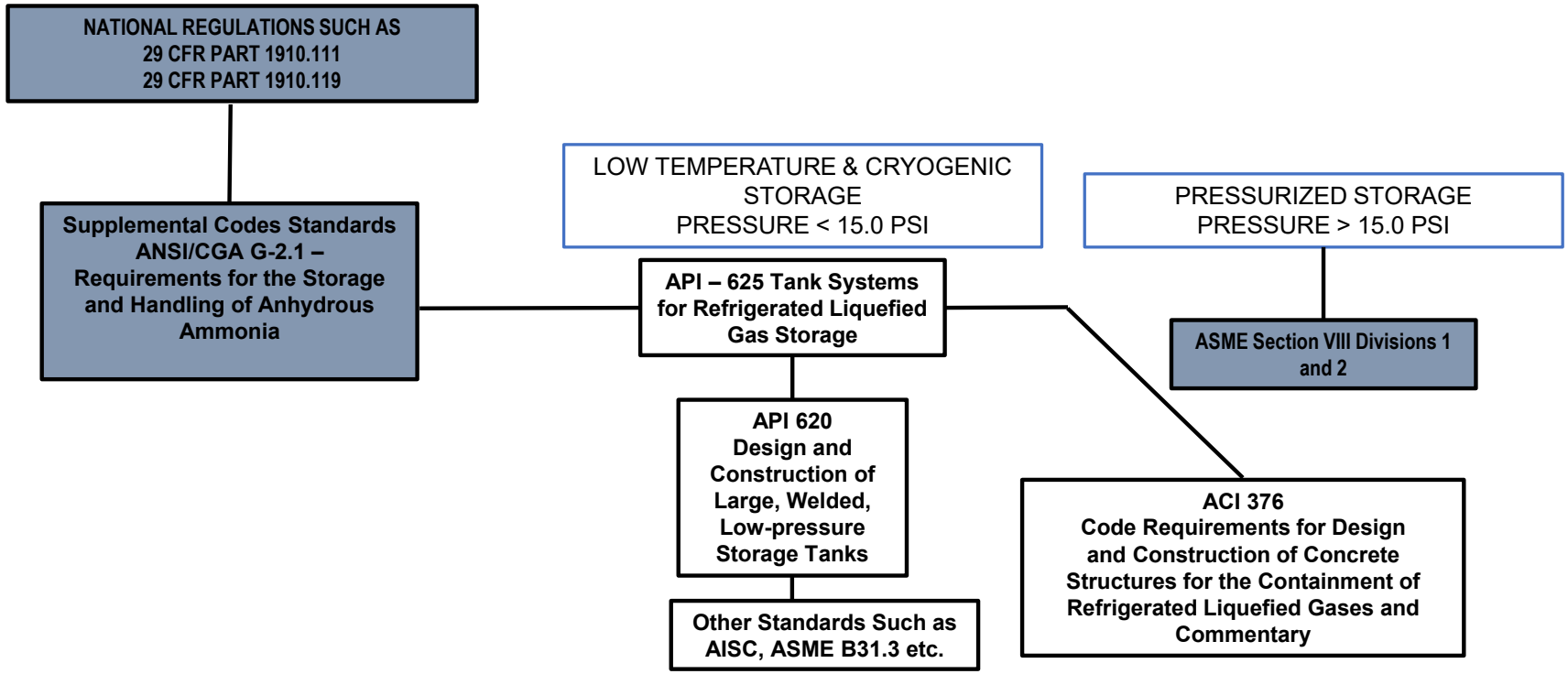
Concentration / Time	Effect
20 ppm – 50 ppm	Mild discomfort, depending on whether an individual is accustomed to smelling ammonia
50 ppm (OSHA Max exposure limit)	Perceptible eye and throat irritation
100 ppm for 2 hours	Nuisance eye and throat irritation
134 ppm for 5 minutes	Tearing of the eyes, eye 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
API Std 2000 (R2020)	Venting Atmospheric and Low-pressure Storage Tanks, Seventh Edition
ANSI/CGA G-2.1-2023	Requirements for the Storage and Handling of Anhydrous Ammonia
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

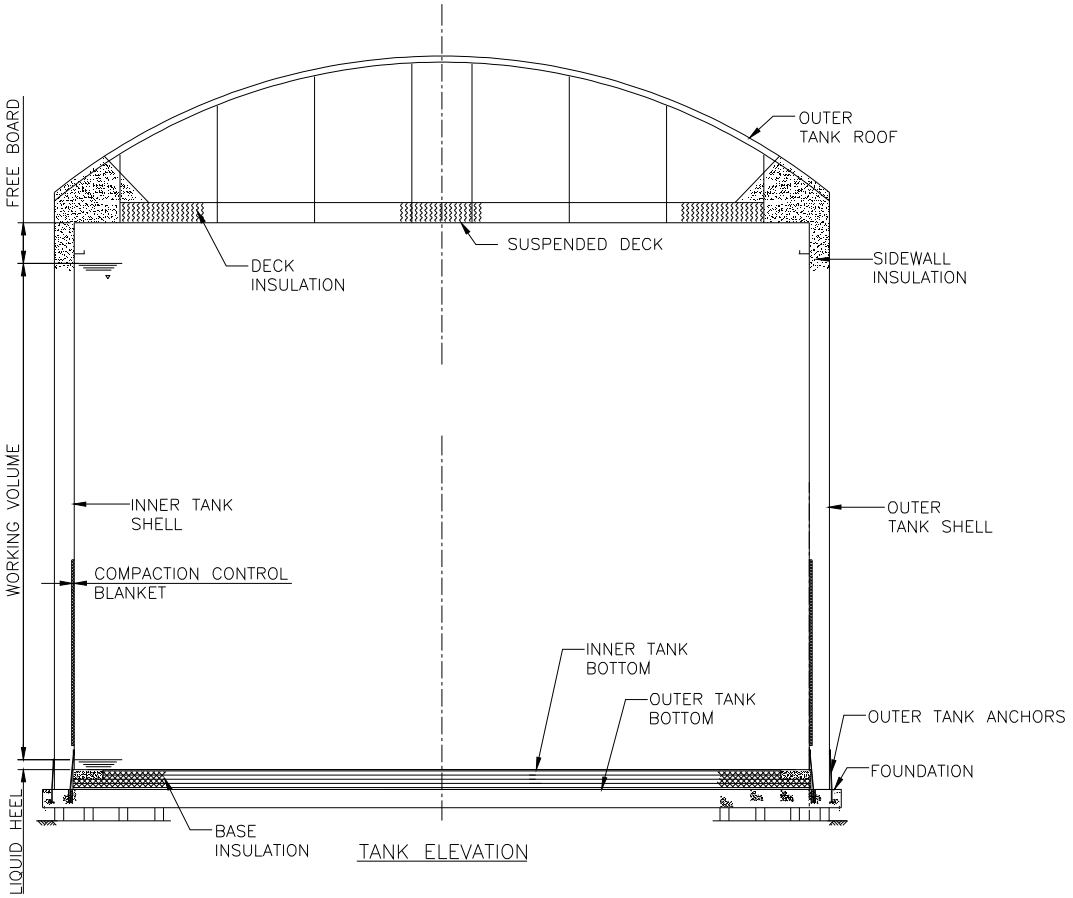
TYPICAL U.S. STORAGE CODES AND STANDARDS



AMMONIA STORAGE – DESIGN PARAMETERS

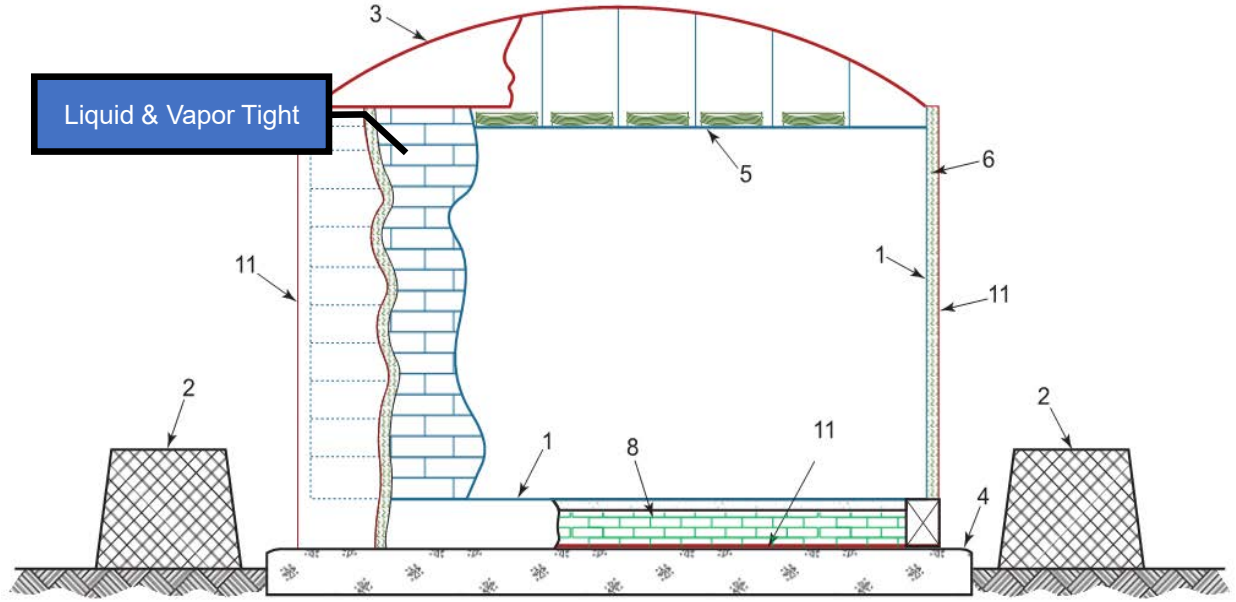
Description	Value
Storage Tank Gross Capacity	5,000 MT to 50,000 MT (Can go to 70,000 MT or higher.)
Design Pressure	1.0 psig to 4.0 psig (Typ. 2.0 psig)
Design Temperature	-35 deg. F

NOMENCLATURE – BASIC CRYOGENIC STORAGE TANK



SINGLE CONTAINMENT TANK SYSTEM

(API 625, SECTION 5.2 & ANNEX C.2)



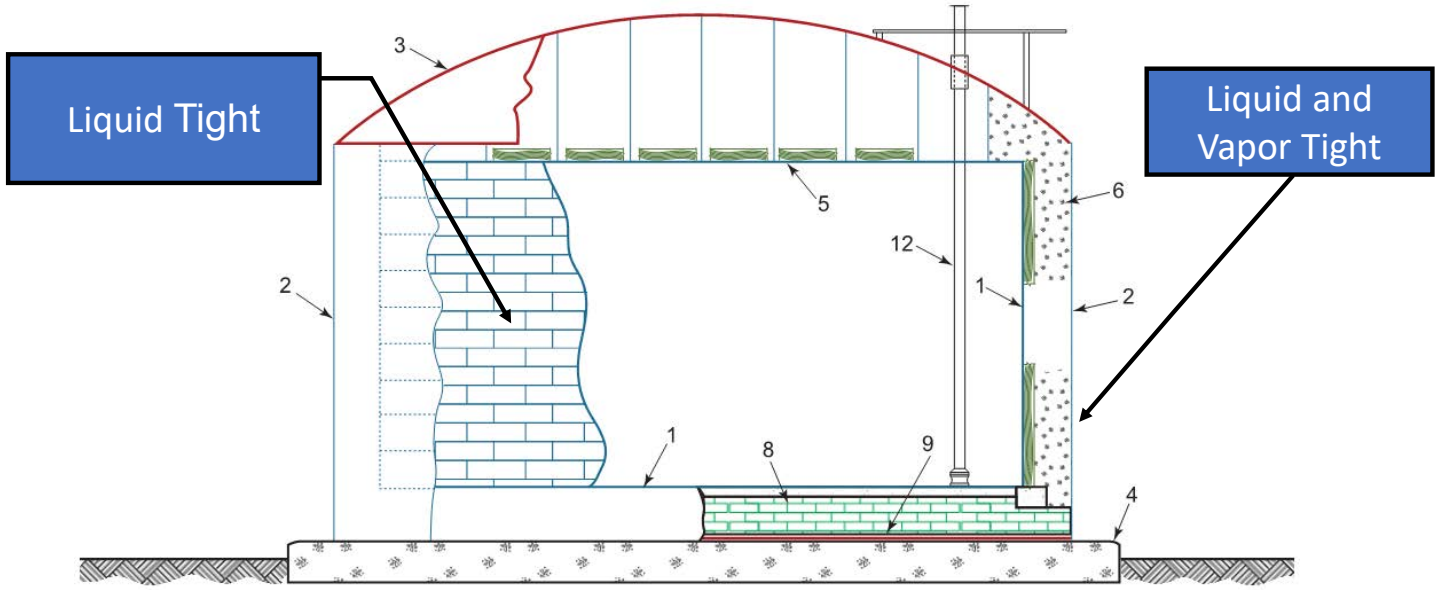
Key

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

FULL CONTAINMENT TANK SYSTEM, STEEL

(API 625, SECTION 5.4 & ANNEX C.4)



Key

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

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

AMMONIA, STORAGE TANKS

Reference: Iowa Fertilizer Plant, Weaver, Iowa, USA

PERFORMANCE CRITERIA
(API 625 SECTION 6.4)

Boil off Rate 6.4.4

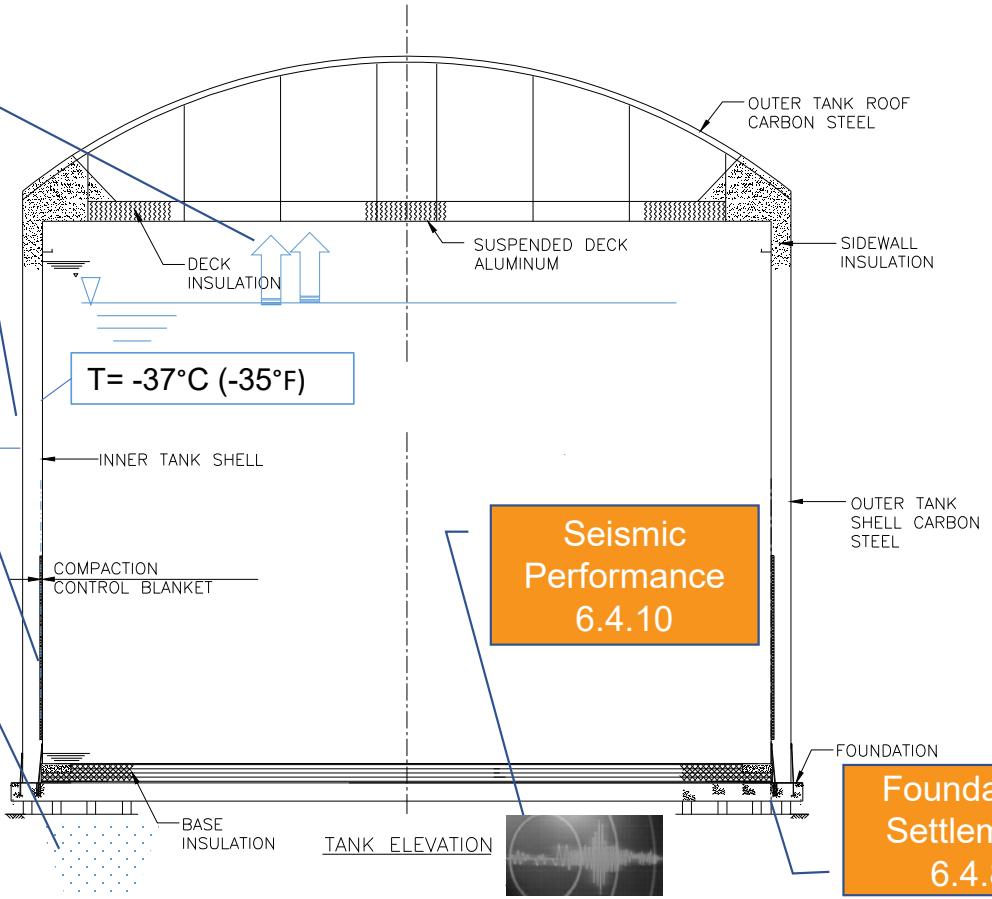
Design Temperature 6.4.6

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

FOUNDATIONS (PILE CAP REBAR CAGE)

FOUNDATION HEATING SYSTEM

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

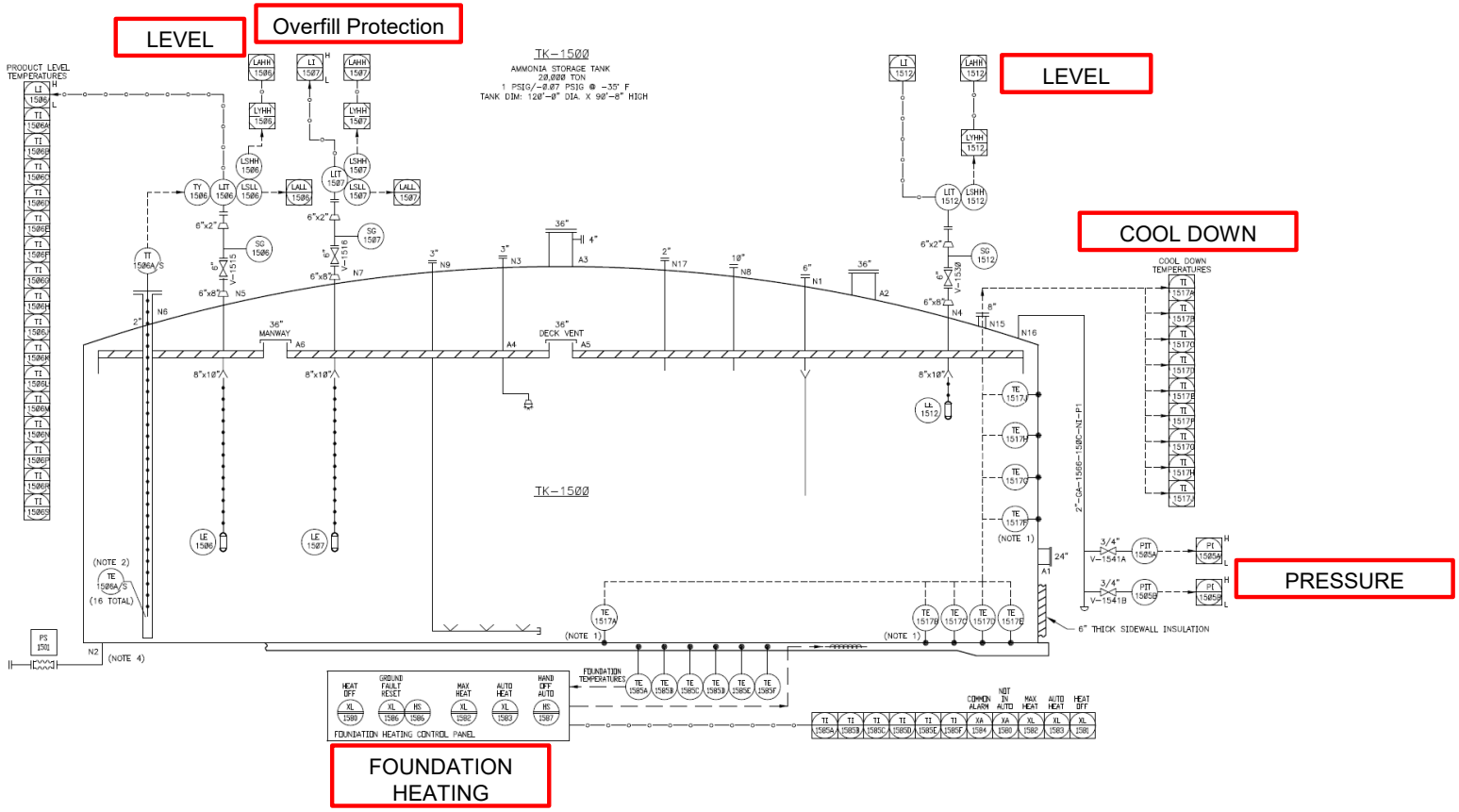
Requirements

- 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

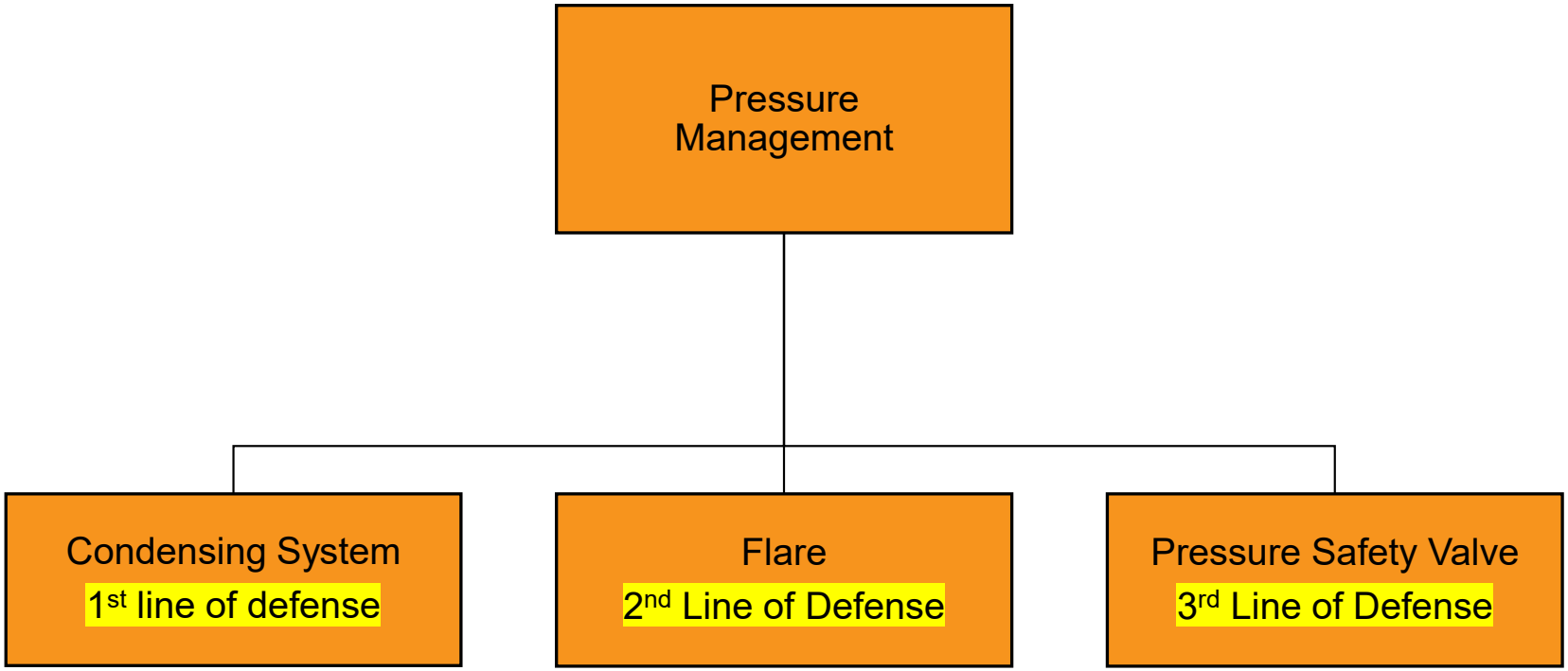
GENERAL INSTRUMENTATION FOR AN AMMONIA STORAGE TANK



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

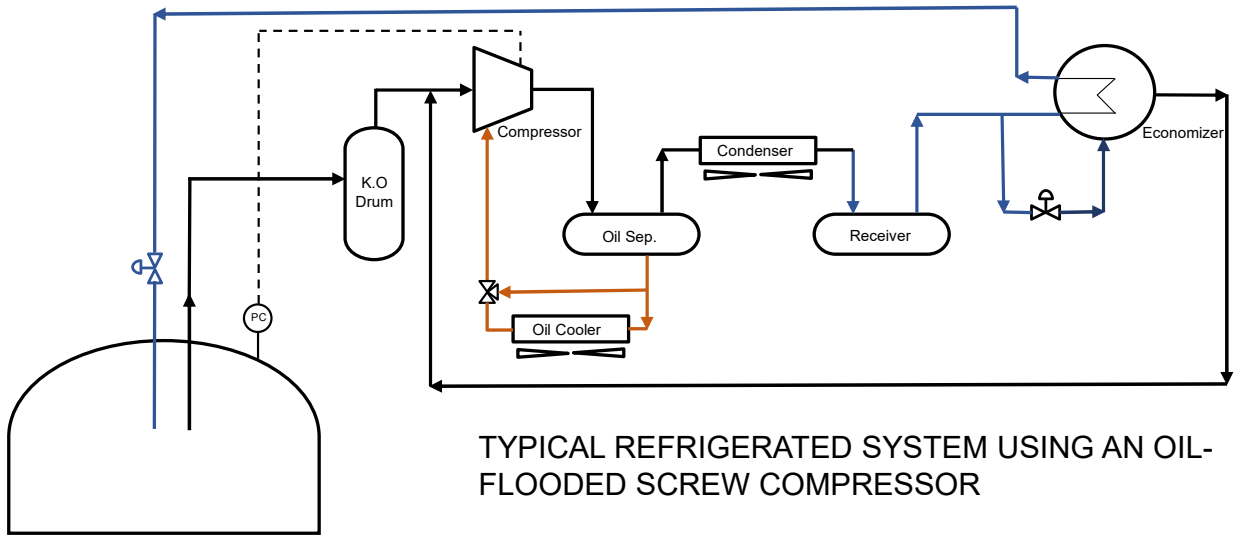
Reference: The Rupture of a Liquid Ammonia Storage Tank Study, Alireza Orooji and Sajjad Hosseininia, Assaluyeh, Iran


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

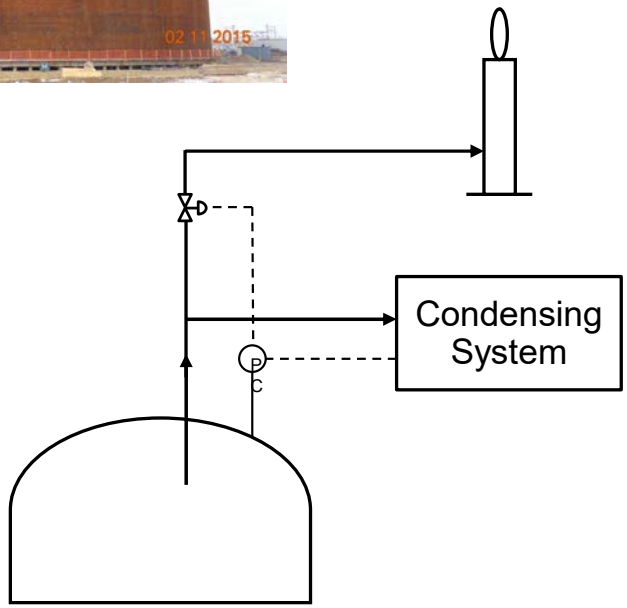


TYPICAL REFRIGERATED SYSTEM USING AN OIL-FLOODED SCREW COMPRESSOR

PRESSURE MANAGEMENT

Flare

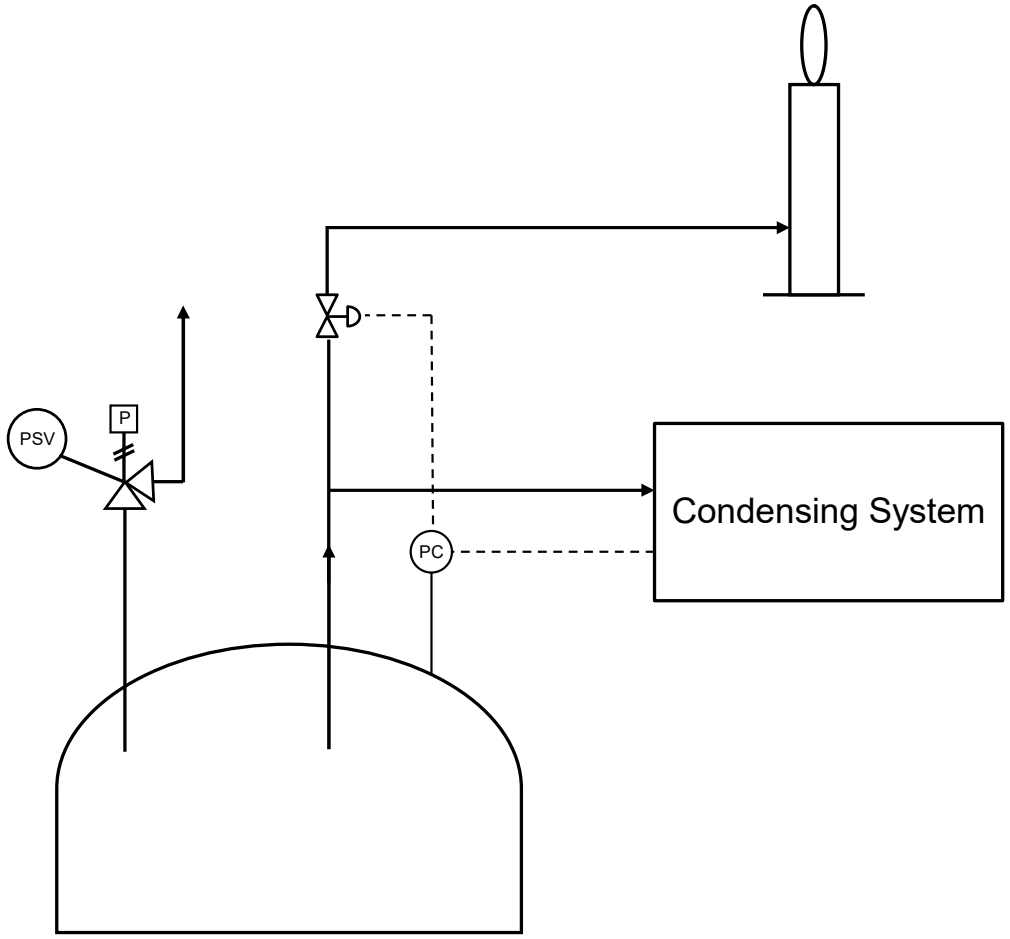
- As a Back up for Condensing System
- Design parameters
  - Fill Displacement
  - Fill Flash
  - Tank Heat Gain
  - Recirculation Heat Gain
  - Barometric Pressure Change
- Set pressure



PRESSURE MANAGEMENT

Pressure Safety Valves

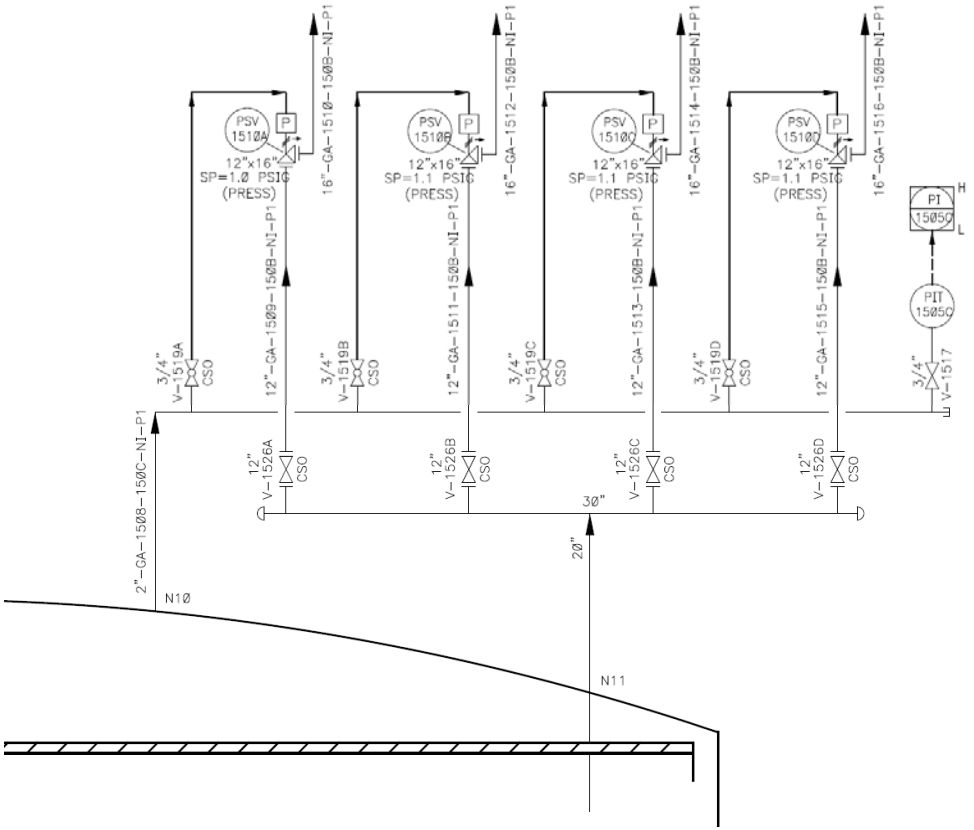
- Design parameters
  - Normal Operating Conditions
  - Fill Displacement
  - Fill Flash
  - Tank Heat Gain
  - Recirculation Heat Gain
  - Barometric Pressure Change



PRESSURE MANAGEMENT

Pressure Safety Valves

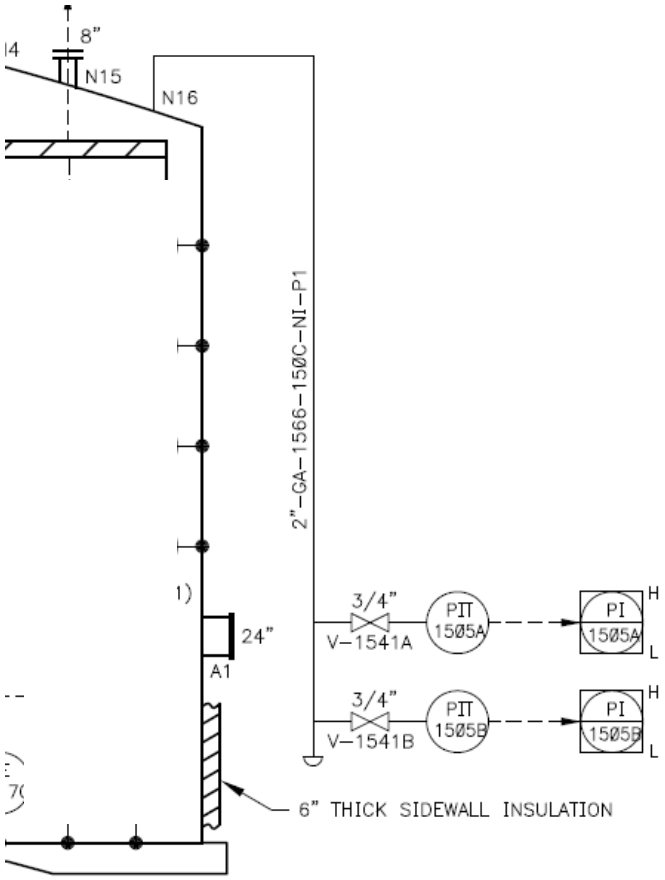
- Design parameters
  - Abnormal Operating Conditions
  - Fire Exposure
  - Utility or Mechanical failure
- Excessive pumping rates into the tank
- Excessive temperature of ammonia liquid pumped into the tank below the liquid level
- Leakage through Inner Tank and Overfill (Full Containment Tank Only)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



TANK PRESSURE MEASUREMENT

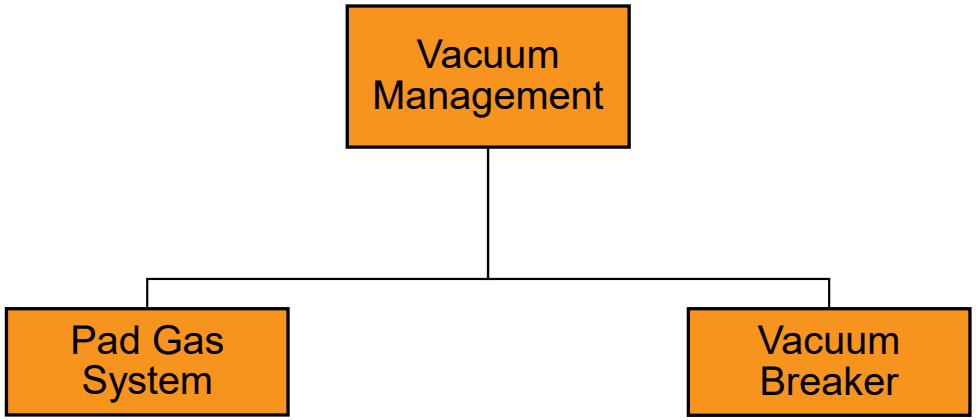
Pressure Gauge

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



CAUSE OF TANK LOW PRESSURE

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

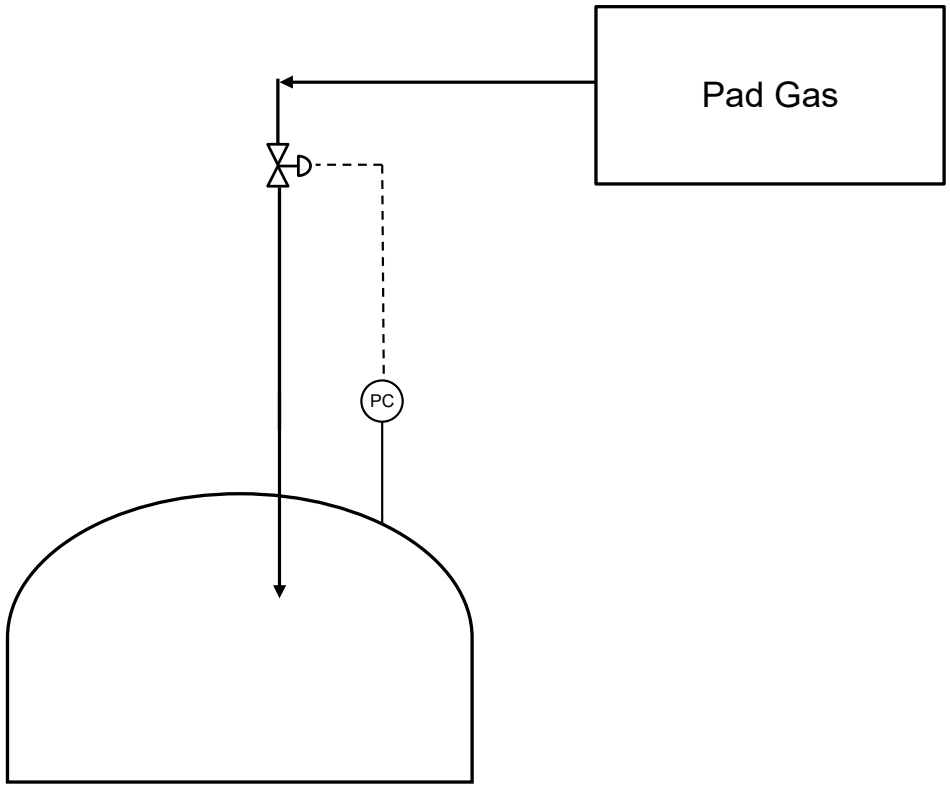


VACUUM MANAGEMENT

Pad Gas System

- Design parameters
  - Liquid Withdrawal
  - Vapor Withdrawal

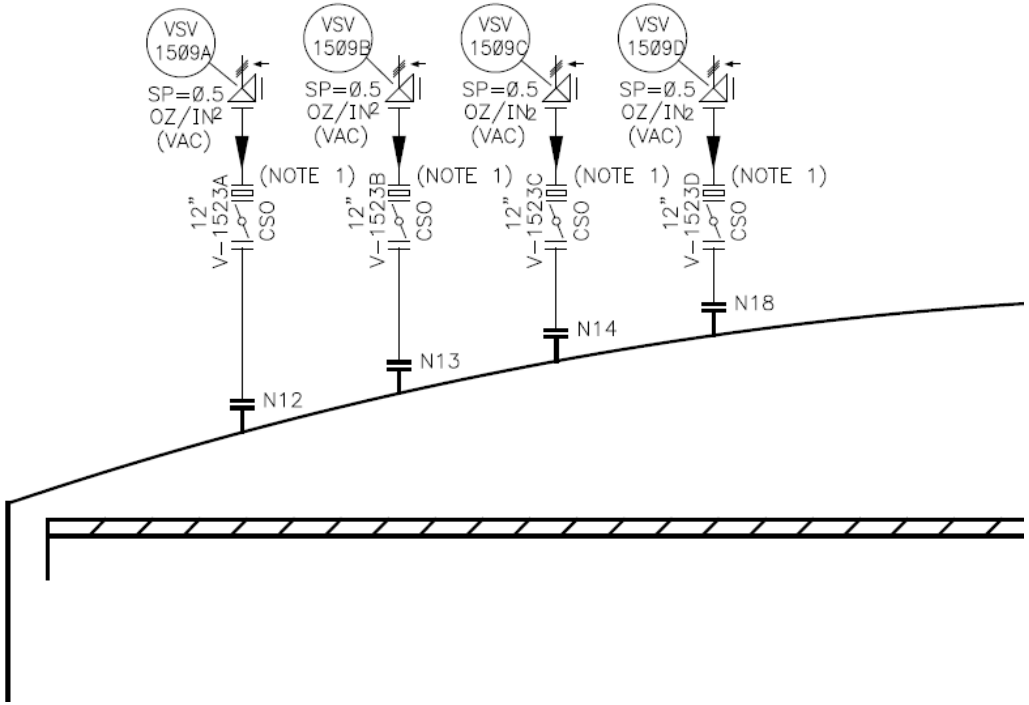
- Set pressure



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



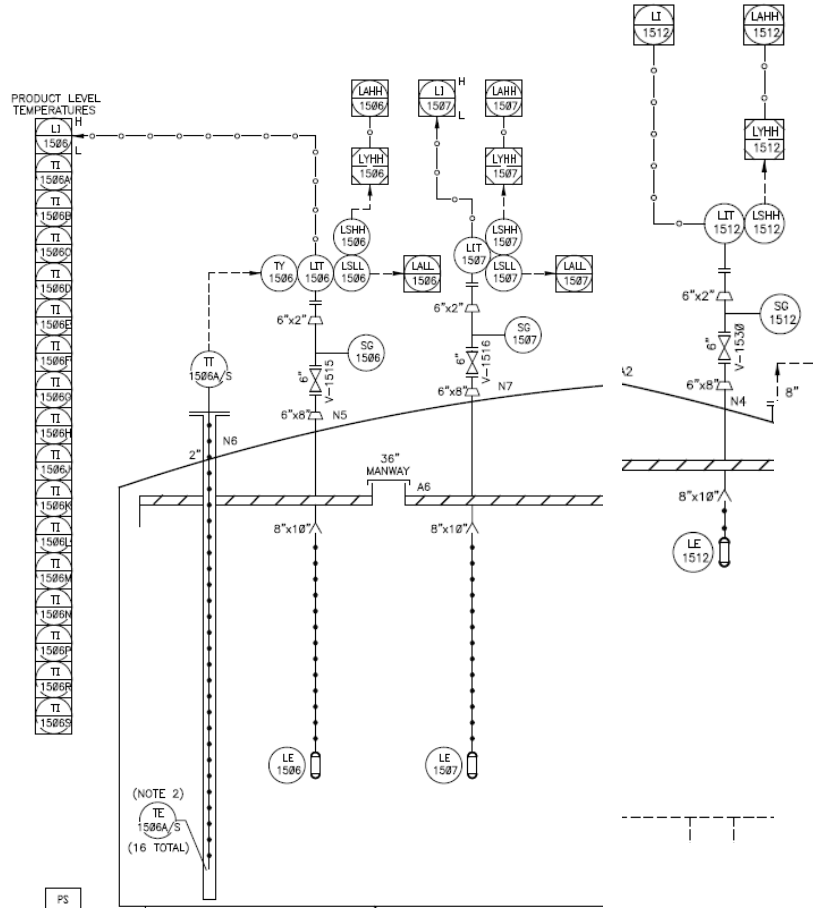
LEVEL MANAGEMENT

Level Gauges and Overfill Protection

- Recommend 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)



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

THANK YOU

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