Ammonia Refrigeration 101
DESIGN AND INDUSTRY

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IMAGE COURTESY OF: STELLAR FOOD FOR THOUGHT
Background

• Joseph Gettemy, PE
  • Graduated ISU 2017
  • Worked for ~5 years as a refrigeration engineer
    • 1.5 years as a field engineer at a pork-processing construction site.

• Now Mechanical Engineer here at Shive Hattery
  • Focused on Commercial and Industrial projects
  • Pursuing Passive-House certification
AGENDA

• Intro to Ammonia Refrigeration – Why and where?
• Ammonia Refrigeration as a Sub-Industry
• Design of Ammonia Systems
• Ammonia Safety – System and Personal
• Experience as a Refrigeration Engineer.
# NH3 Refrigerant by the Numbers

<table>
<thead>
<tr>
<th>SAFETY</th>
<th>Recommended Exposure Limit (REL)</th>
<th>Halocarbons</th>
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<tbody>
<tr>
<td></td>
<td>1000+ ppm</td>
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*Cost given as relative due to fluctuating market costs.

**CO2 is typically most efficient at higher condensing temps.
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Information courtesy of ASHRAE Fundamentals Handbook
Ammonia (NH₃)
REFRIGERANT SUMMARY

• NH₃ as a refrigerant:
  • Negative: Higher Harm Risk – Requires more *engineered* safety.
  • Positive: More efficient and less expensive

• Therefore, NH₃ lends itself to *larger-scale industrial*, especially food production.
  • Greater net benefit from efficiency and cost allows for dedicated safety systems and staff.
  • Results in a *singular central system* for the whole plant.

• Other applications include:
  • Server farms
  • Ice Rinks
  • Sustainability applications (due to low GWP)
NH3 REFRIG. AS A (SUB)INDUSTRY - CODE

• International Institute of Ammonia Refrigeration (IIAR) standards are typically the governing code.
  • IMC defers to IIAR.

• IIAR standards include:
  • IIAR 1, Definitions and Terminology.
  • IIAR 2, Design of Closed-Circuit Ammonia Refrigeration Systems.
  • IIAR 3, Ammonia Refrigeration Valves.
  • IIAR 4, Installation of Closed-Circuit Ammonia Refrigeration Systems.
  • IIAR 5, Start-up and Commissioning of Closed-Circuit Ammonia Refrigeration Systems.
  • IIAR 7, Developing Operating Procedures for Closed-Circuit Ammonia Mechanical Refrigerating Systems.
  • IIAR 8, Decommissioning of Closed-Circuit Ammonia Refrigeration Systems.
  • IIAR 9, Minimum System Safety Requirements for Existing Closed-circuit Ammonia Refrigeration Systems.

FROM IMC 2021 - CH 11:

1101.1.2 Ammonia refrigerant. Refrigeration systems using ammonia as the refrigerant shall comply with IIAR 2, IIAR 3, IIAR 4 and IIAR 5 and shall not be required to comply with this chapter.
IIAR standards include:

- IIAR 1, Definitions and Terminology.
- IIAR 2, Design of Closed-Circuit Ammonia Refrigeration Systems.
- IIAR 3, Ammonia Refrigeration Valves.
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- IIAR 7, Developing Operating Procedures for Closed-Circuit Ammonia Mechanical Refrigerating Systems.
- IIAR 8, Decommissioning of Closed-Circuit Ammonia Refrigeration Systems.
- IIAR 9, Minimum System Safety Requirements for Existing Closed-circuit Ammonia Refrigeration Systems.
  - IIAR 9 Limited Grandfathering.
NH3 REFRIG. AS A (SUB)INDUSTRY - CODE

• Systems containing more than 10,000 lbs need a Process Safety Management (PSM) system (per OSHA):
  • Maintained P&IDs
  • Regular documentation and calculation showing compliance
  • Typically, dedicated staff.

• Updates to these compliance calculations requires frequent engineering visits.
For Engineers, these visits create frequent repeat customers and relationship building.

Because the system is a singular central design, changes to a portion of the system require knowledge of the whole system.
SYSTEM DESIGN - BASICS

- Ammonia refrigeration operates using the refrigeration cycle.
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FLUID SATURATION

• Refresher: *at a given pressure and temperature*: fluid transitions between **liquid and vapor**
  - At temp: **saturated**
  - Above temp: **super-heated**
  - Below temp: **sub-cooled**
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IMAGE COURTESY OF: WIKIPEDIA.ORG
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<tr>
<th>Temp., °F</th>
<th>Pressure, psia</th>
<th>Density, lb/ft³</th>
<th>Volume, ft³/lb</th>
<th>Enthalpy, Btu/lb-°F</th>
<th>Entropy, Btu/lb-°F</th>
<th>Specific Heat cₚ Btu/lb-°F</th>
<th>Cₚ/Cᵥ</th>
<th>Thermal Conductivity Btu/hr-ft-°F</th>
<th>Temp., °F</th>
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SYSTEM DESIGN

- Ammonia refrigeration operates using the refrigeration cycle.
- Comparable to a VRF system (cooling only)
SYSTEM DESIGN - SCALE

IMAGES COURTESY OF: SPRINGER CCM, TRANE, EPA, EVAPCO, STELLAR FOOD FOR THOUGHT, AND WES
SYSTEM DESIGN – DX – ONE STAGE
SYSTEM DESIGN – DX – ONE STAGE

- Most basic system.
- Functions when required temperatures are similar.
SYSTEM DESIGN – DX – TWO STAGE
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• Allows for two temperature ranges:
  • Usually refrigerated and below-freezing.

• Adds to system:
  • Booster compressor
  • Intercooler.
  • 3rd pressure/temperature.
**SYSTEM DESIGN – DX – TWO STAGE**

*In intercooler:*

1. Superheated vapor from compressor enters vessel.
2. Vessel is at saturation with both liquid and vapor.
3. Superheated vapor cools to saturation and converts some of the sat liquid to vapor also.
4. Vessel is maintained with sufficient liquid to keep temp and pressure at saturation.
SYSTEM DESIGN – DX – TWO STAGE

• DX limitation:
  • Evaporator coil size limited.
  • If too large, liquid may evaporate before filling coil.

• Frequent issue with lower temps and heat-exchangers.
SYSTEM DESIGN – FLOODED – TWO STAGE
SYSTEM DESIGN – FLOODED – TWO STAGE

- Adds surge drums above evaporator/heat-exchanger.
- Surge drum contains liquid and fills coils ~2/3 full.
SYSTEM DESIGN – FLOODED – TWO STAGE

- Limitation:
  - Increases lbs ammonia in system.
SYSTEM DESIGN – RECIRCULATED – TWO STAGE
SYSTEM DESIGN – RECIRCULATED – TWO STAGE

- Individual surge drums to central Recirculators.
- Recirculators - vessels with pumps - provide sufficient liquid to evaporators.
- Recirculators may also be intercoolers.
- Heat-exchangers or large coils may still use surge drums.
SYSTEM DESIGN – DEFROST

• Coils will accumulate ice and require defrost. Methods include:
  • Air (if above freezing)
  • Electric
  • Hot gas
SYSTEM DESIGN – DEFROST – HOT GAS

- Most common defrost.
- Hot gas from compressor discharge heat coils:
  - Higher temp: three-pipe
    - Defrost gas returns through suction.
  - Lower temp: four-pipe.
    - Defrost liq/gas returns through separate line to high-stage suction.
OTHER DESIGN – THERMOSYPHON OIL COOLING

• Screw compressors inject oil (lubricant) with ammonia before compression.

• Oil is then separated in vessel below.

• To cool oil:
  • Vessel is suspended above compressors.
  • Liquid ammonia gravity-fed to ammonia-oil HEX at compressor.
  • Liquid converts to vapor as it cools oil.
  • Vapor returns to vessel.

IMAGE COURTESY OF: GENERAL REFRIGERATION COMPANY
OTHER DESIGN – UNDERFLOOR WARMING AND MOISTURE MANAGEMENT

• Hot gas from compressors exchanges heat with glycol.
• Glycol runs under slab to prevent ice.
• Insulation and pipe integrity is (ideally) regularly inspected.
• As needed, additional moisture-management practices are used:
  • Local exhaust
  • Localized fans
  • Dehumidification
OTHER DESIGN – SKIDS

• Shop made skids - for quick install and cost savings.
  • Either as a central machine room OR
  • Distributed system (mini-machine rooms)

• Mini-machine-room skids serve separate parts of facility:
  • Refrigerant reduction.
  • Quick install.
  • Loss of redundancy.
SYSTEM DESIGN - SAFETY

• Detection and Alarm – PPM Limits:
  • 25 ppm – Alarms
  • 150 ppm - Emergency Ventilation
    • Often Emergency Ventilation will start sooner
  • 40,000 ppm – System shutdown
    • For flammability

• Emergency ventilation – Low Louvers to High Upblast Exhaust Fans
  • Sweep the room
SYSTEM DESIGN - SAFETY

• EPCS – Emergency Pressure Control System releases pressure from higher-pressure to lower.

• Pressure Relief System – Releases pressure to the atmosphere at max vessel pressure.
  • These relief valves are tied together in a relief tree, which must be engineered for compliance.
  • Requires iterative calculation and typically software or a spreadsheet macro.
Personal Safety

• Use your nose – Ammonia detectable as low as ~5ppm.

• Ammonia is invisible but will create a cloud during a larger leak.

• When encountering a leak:
  • Stay calm and walk
  • Get low – Ammonia rises
  • When outside – Look for wind direction.
    • Windsocks are required at an ammonia site.

• Buddy-system when entering a cooler, freezer, or other unoccupied territory.
Being a Refrigeration Engineer

• My own experience:
  • 15 months as a field engineer – Pork plant start to finish.
  • Remaining time as safety-systems engineer.

• Pros and Cons often the same:
  • Multi-day site visits ~1-3 times/month coast to coast.
  • Deep knowledge of a specific field – subject matter expert fast.
  • Very engineering-focused, minimal interaction with other disciplines.
Thank you