

Vanderweil Engineers

Ammonia Refrigeration and Risk Mitigation for District Cooling Applications

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INTERNATIONAL DISTRICT ENERGY ASSOCIATION

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- How suitable is Ammonia for use in District Cooling Applications?
  - Risk
  - First Cost
  - Efficiency
- Feasible Applications
- Ammonia Safety
  - Code required components
  - Regulatory requirements
  - Best practices for leak mitigation

Why Consider Ammonia?

- High Cycle Efficiency
- Continuous use since the 1800's
  - Mature technology, large equipment manufacturer and contractor base worldwide
- Zero ODP, Zero GWP
- Self-alarming: pungent odor at less than 10 PPM
  - Readily absorbed in water
  - Lighter than air; leaks rise
- Ammonia refrigeration is widely used in urban and suburban locations throughout the U.S.
- Ammonia is being utilized in a number of District Cooling applications in the U.S. and overseas

Application of Ammonia for Large Scale District Cooling

- Low Temperature Thermal Storage
  - Dual-temperature NH_3 chillers for ice generation/chilled water production
- Evaporative Condensers
  - High cycle efficiency/low first cost
  - Increased NH_3 charge
- Air-Cooled Condensers
  - High cycle efficiency/low first cost
  - No water use
  - Increased NH_3 charge
- Water Chilling/Cooling Towers
  - Low charge NH_3 PHE screw chillers with ammonia mitigation

Ammonia Chillers

- Custom Fabricated Chillers
- Heat Exchanger Skid
  - Plate Frame Evaporator
    - Flooded – 1.5 lb/TR
    - Direct Expansion DX – under 1 lb/TR
  - Plate Frame Condenser
- Compressor Skid
  - Screw Compressors
    - 2,000 TR
    - Horizontal or Vertical Separators
- Multiple Vendors

Low Temp Thermal Storage Applications

- Screw compressors capable of operating at multiple suction levels +15 deg F, +35 deg F
- Duel evaporator chiller: glycol (ice)/chilled water
- Single compressor serves two (2) chiller evaporators
- Positive displacement; stable operation
- Refrigerant economizer cycle increases efficiency
- Variable VI compressors
- Energy and first cost competitive with Freon centrifugal or screw units

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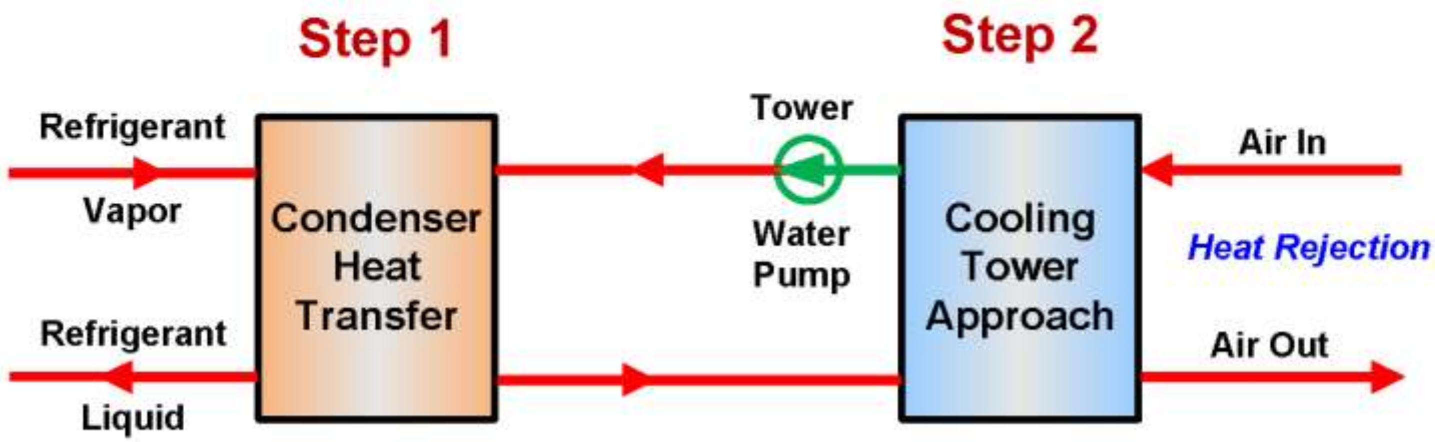
Heat Rejection Options

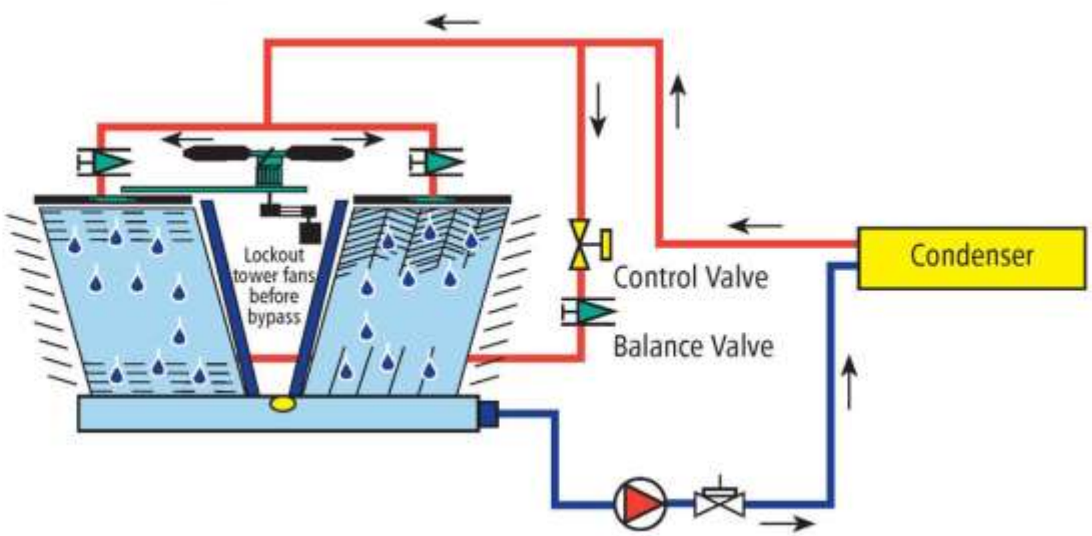
Example: 10,000 TR Cooling Tower System vs. Evaporative Condensers

Cooling Towers:

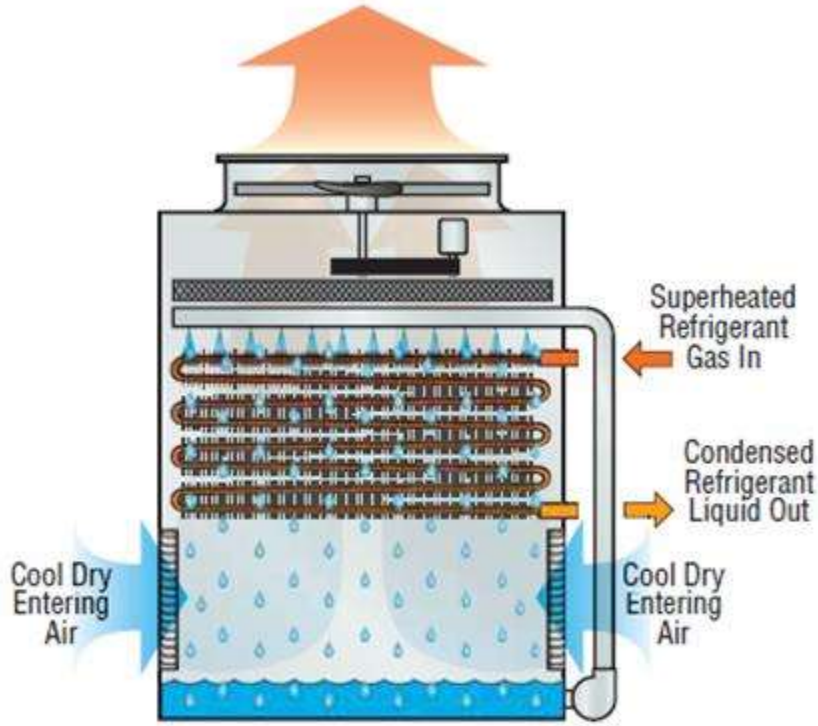
- 20,000 gpm, 85°-100°, 65°wb
  - (5) Tower Cells:
    75 HP, 375 HP
  - (5) Pumps:
    150 HP, 750 HP
  - Total System KW/TR: 0.85 KW/TR
  - 30” Mains
  - 12” Connections at chiller

Cooling Tower





Evaporative Condenser



eco-ATC Evaporative Mode

Evaporative condenser achieves lower approach between refrigerant and ambient heat sink.

Condenser Water System Options

- 2,000 TR Evaporative Condenser:
  - (2) cells per unit,
    Fans 150 HP,
    Pumps 15 HP
  - Total system: 0.73 KW/TR
- Piping:
  - 8” RD line (vapor)
  - 3” HPL line (liquid)
  - Close coupled to chiller

Evaporative Condenser

Pros:

- Improved Efficiency:
  - Saves 15% Plant Power (1,400 HP)
- Piping Savings:
  - Condenser water system eliminated
  - Significant cost savings

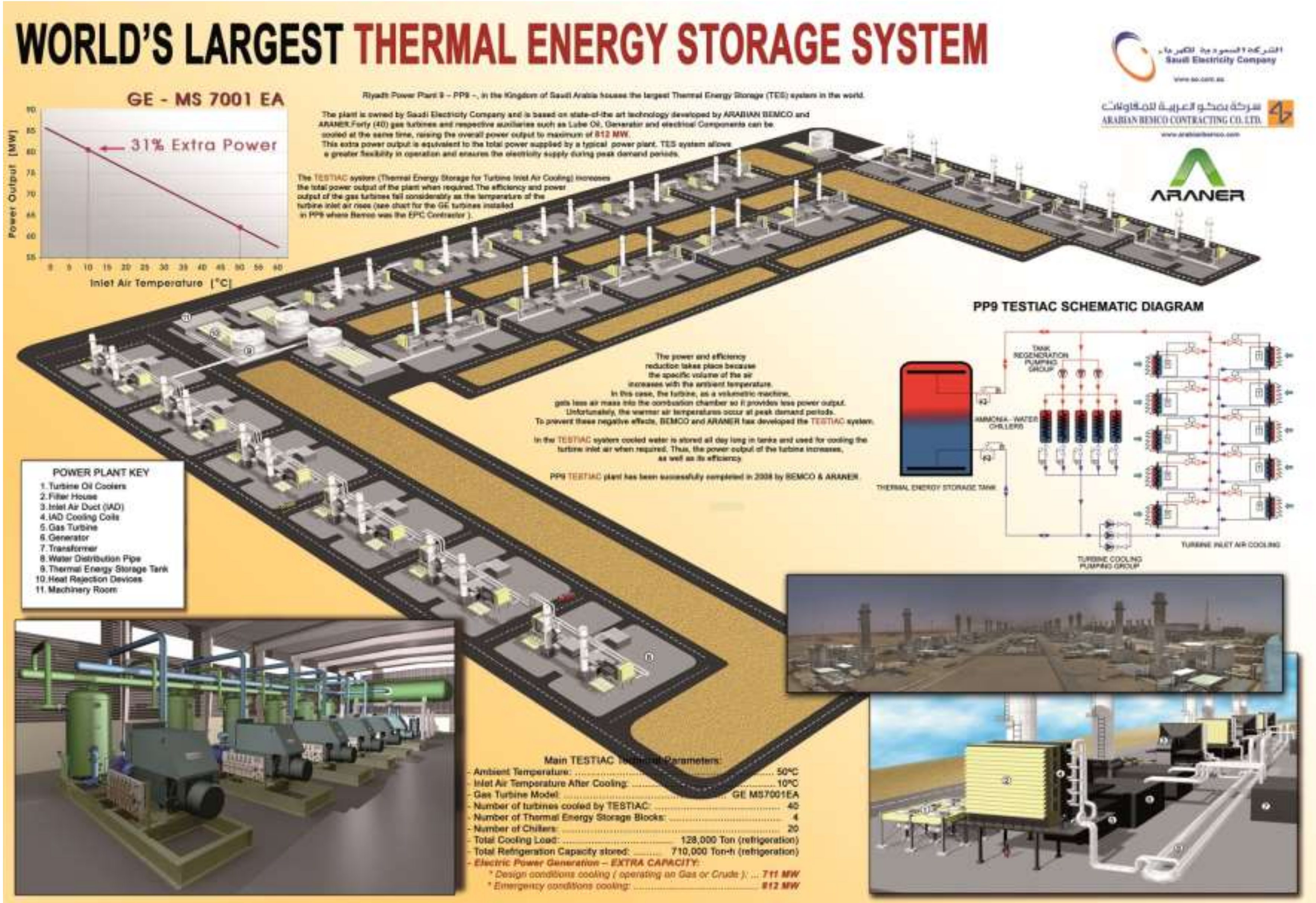
Cons:

- Increased NH_3 charge
- Water treatment at individual basins

Air Cooling

- High cycle efficiency when using direct air cooled condensers
- Middle East application: CHW production 0.95 kW/TR at 40 deg C design
- Lower first cost than many competing technologies

Thermal Energy Storage System



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Ammonia Detection

- Ammonia is a toxic, *Highly Hazardous*, regulated chemical
- OSHA requirements for PSM: OSHA 29CFR 1910.119
- EPA requirements for RMP for systems with over 10,000 lbs: EPA 40CFR, Part 68
- Additional regional regulations: CaLARP, NJTCPA

Ammonia Concentration in Air (ppm)	Health Symptoms
25 <	Detectable by smell.
30	Uncomfortable; breathing support required.
50	OSHA PEL exposure limit.
100	Irritated eyes, throat, and mucous membranes. Mild eye, nose, and throat irritation; may develop tolerance in 1-2 weeks with no adverse effects.
140	Moderate eye irritation; no long-term effect in exposures of less than 2 hours.
300	Immediate danger to life limit (IDLH) .
400	Moderate throat irritation. Damage of mucous membranes with more than one hour exposure.
1,700	Fatal after short exposures - less than half an hour.
5,000	Immediate hazard to life.
15,000 >	Full body protection required.
160,000	Flammable in air (LEL).

Typical Practices

- Safety systems required to meet unified national codes and local code requirements which vary regionally
  - Mechanical room construction
  - Ventilation
  - NH_3 detection with audible and visual alarms
  - Emergency shutdown stations
  - Diffusion systems, fireman control station, siamese dump connection
  - Code compliant construction largely not intended to mitigate releases

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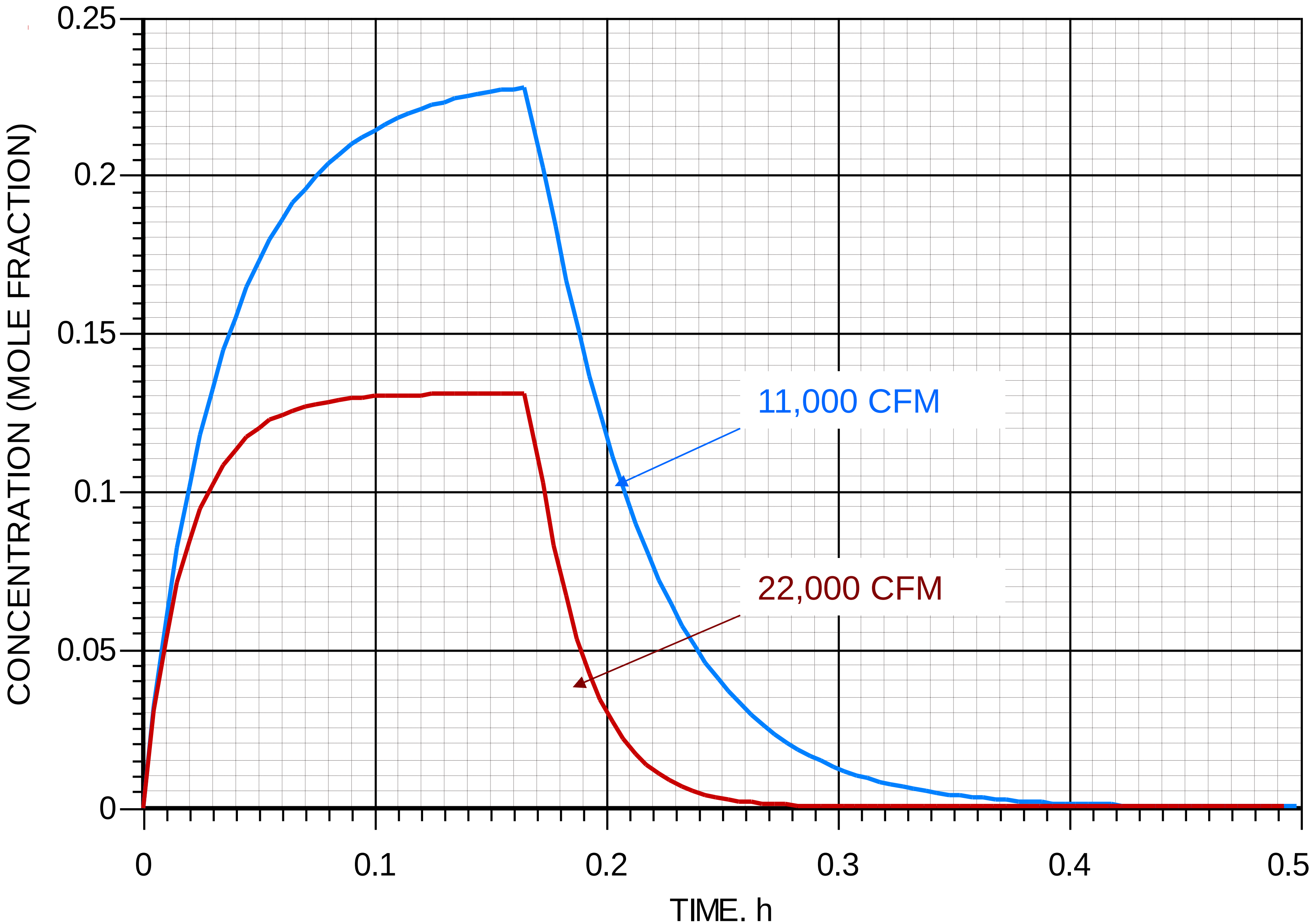
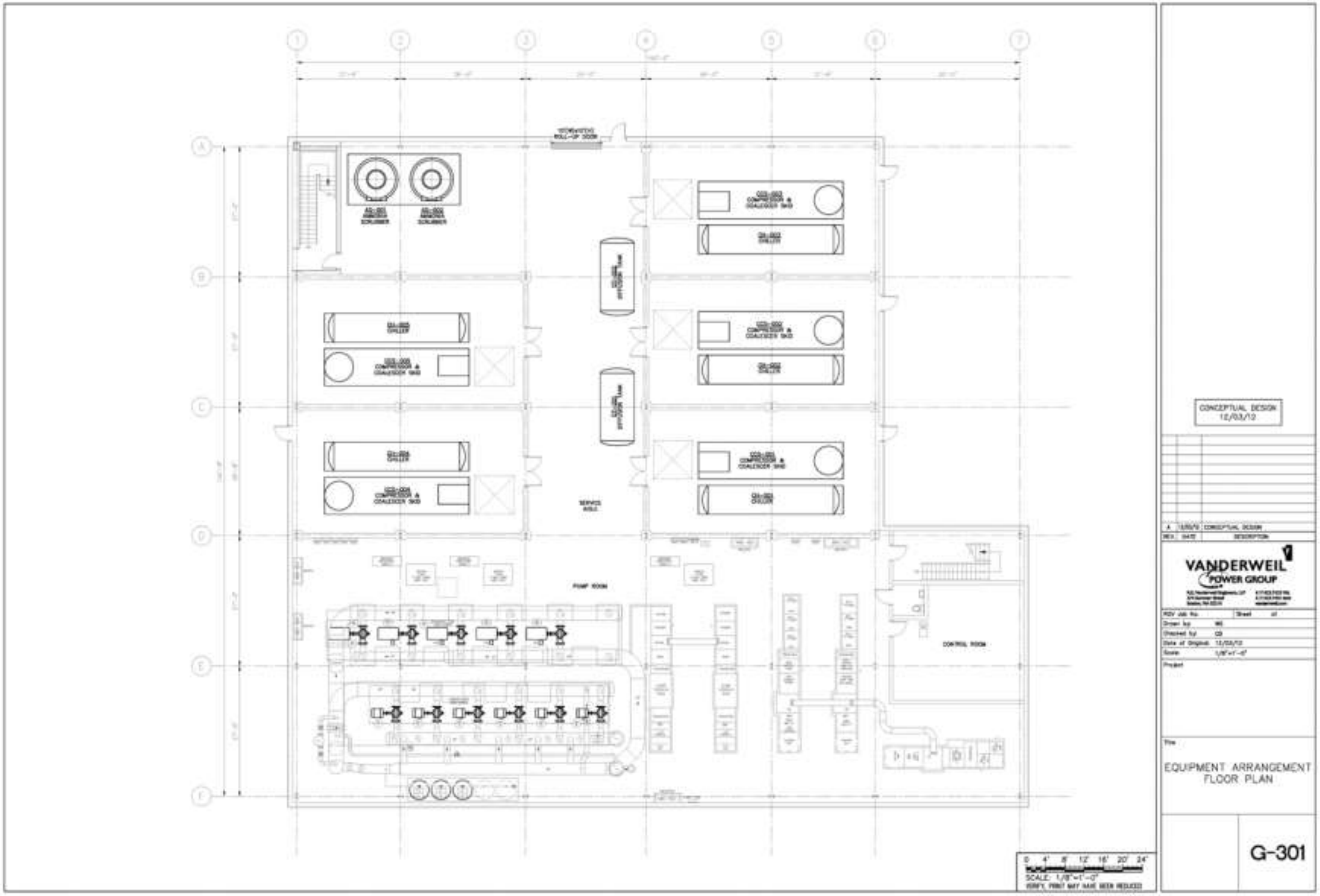
Worst Case Leak Scenario

- *Example:* Loss of system containing 3,500 lbs ammonia charge in 10 minutes
- Average ammonia vaporization rate of approximately 144 lb/min
- Expected maximum room concentration of 130,000 PPM
- How do you mitigate operation of exhaust system discharging large quantity of ammonia?
- Suggested mitigation criteria: Discharge exhaust concentration mitigated to below OSHA PEL (Permissible Exposure Limit)

Worst Case NH_3 Release with 40% Flashed (144 lb/min)



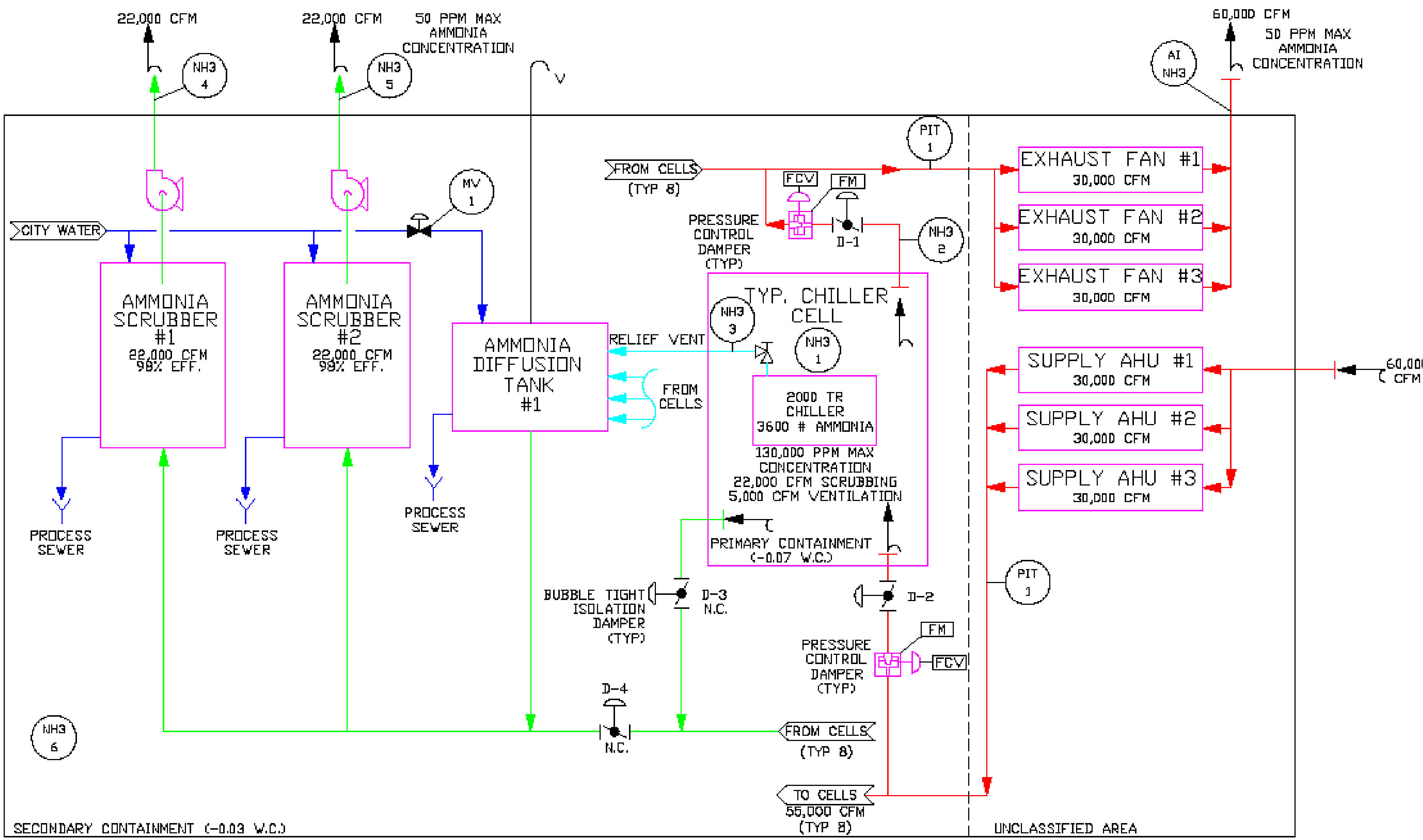
10,000 Ton Equipment Arrangement



New Ammonia Chiller Plant

- New Ammonia Chiller Plant:
  - 10,000 TR
  - Five (5) 2,000 TR chiller modules
    - Low refrigerant charge technology
  - Ammonia Containment
    - Chiller cells provide primary containment boundary
    - Once-through scrubber system
    - Primary ammonia containment and ammonia transfer areas controlled to negative pressure
    - Secondary containment area: remainder of plant room

Recommended Ammonia Containment System Overview



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Typical Chiller Cell

- Contains 2,000-ton chiller and ammonia leak collection sump
- Tight masonry construction
- Explosion blowout panels sized for max room pressure
- Chiller E-stop inside and outside each cell
- Scrubber: Removal of ammonia during leak event
- HVAC: Provides negative pressurization and space conditioning
- Diffusion Tank: Captures ammonia during PSV releases
- NH_3 Sensors: 0 - 20,000 ppm, multiple sensors
- Electrical Room Classification: Class I, Div 2
- Shunt-trip Unclassified Electrical Equipment: 20,000 PPM

Ammonia Scrubber System

- Ammonia scrubber system sized for 100% redundancy
- Packed tower type scrubber; FRP construction
- 22,000 CFM once-through air per chiller cell
- 22,000 CFM once-through air per scrubber (50 PPM outlet)
- Emergency back-up power supply
- Specialty bubble tight isolation dampers on each cells scrubber exhaust duct
- Explosion-proof motors and electrical devices

HVAC System

- Primary/secondary containment areas with active room pressure and flow control
- Headered make-up and exhaust air systems
- 100% fresh air supply to primary ammonia transfer control areas
- Specialty bubble tight isolation dampers at primary containment cells
- 22,000 CFM per chiller cell (air cooled motors)
- 5,700 CFM per chiller cell (TEWAC motors)

Conclusions

- Ammonia is *not* a mainstream technology for District Cooling
- Ammonia *is* efficient and cost competitive in applications that favor available technology
- Ammonia refrigeration is reliable and safe
- Mitigation systems can be employed to reduce risk
- Additional information on Natural Refrigerants can be found at:
  - www.iiar.org International Institute of Ammonia Refrigeration
  - www.reta.com Refrigerating Engineers & Technicians Association
  - www.eurammon.com Eurammon Initiative for Natural Refrigerants
  - www.iifiir.org International Institute of Refrigeration

Heat Recovery Technologies

- Heat Pump Scavenging System
  - NH_3 heat pump compressor connect to 2,000 TR chiller
- Potential Technologies
  - Scavenging compressor utilizing refrigerant discharge gas
  - Heat recovery chiller utilizing cooling tower water
- Multiple Venders Offer “Standard” Products
  - Vilter
  - Frick/Sabroe
- COP of ~6.0

Heat Recovery

- Recover heat from process cooling to offset fossil fuels at distributed boilers
- Requires simultaneous heating and refrigeration loads
- Waste heat low grade 90 deg F with straight refrigeration cycle
- Increase quality of available heat with further compression and temperature increase to 120 - 140 deg F
- Scavenging heat pump NH_3
- Transcritical CO_2
- Evaluate additional power requirements for compression and fossil fuel burned