



Natural Refrigerant System vs. HFC System

Performance Comparison of CO₂/NH₃ vs.
R507 in an Industrial Refrigerated Warehouse

- Emerging Technologies project for California Utility
 - Monitor 1st large industrial CO₂/NH₃ cascade system in CA
- Measure the performance of cascade system
 - Refrigeration capacity, power, operating setpoints
 - Performance metrics calculated in near real-time
- Initially compared cascade system with theoretical conventional NH₃ system
 - Based on the same refrigeration loads
 - Comparing energy usage and efficiency
- Later extended comparison to theoretical R-507 system following same approach

Facility Description



Refrigerated Warehouse

- Total area of approximately 150,000 square feet
- Blast freezers, holding freezer, coolers and dock spaces

Cooling at four separate pressure levels:

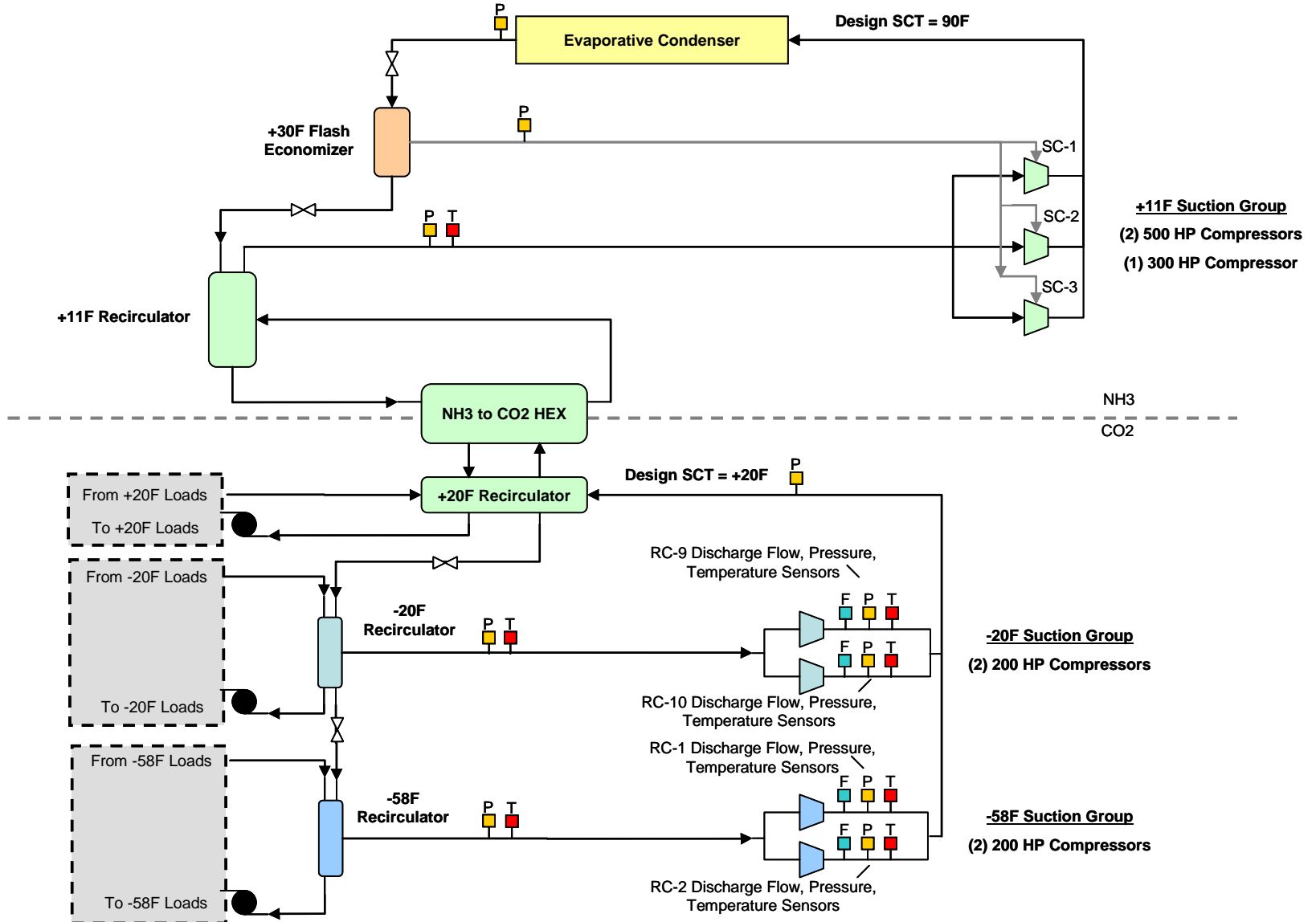
- 58° F CO₂: Blast Freezing
- 20° F CO₂: Freezer Storage
- +20° F CO₂: Coolers and Docks
- +11° F NH₃: High Side

Facility Energy Efficiency Measures:

- Floating Head Pressure with Variable Speed and Variable Setpoint Control
- Flash Economizer on Ammonia System
- Variable Speed Control of Air Unit Fans
- Variable Speed Control of Blast Freezer Fans
- Efficient Compressor Motors
- Increased Insulation R-values Beyond ~2006 Standard Practice
- Cool Roof
- Lighting Control
- High Speed Freezer Doors
- Low Loss Dock Doors

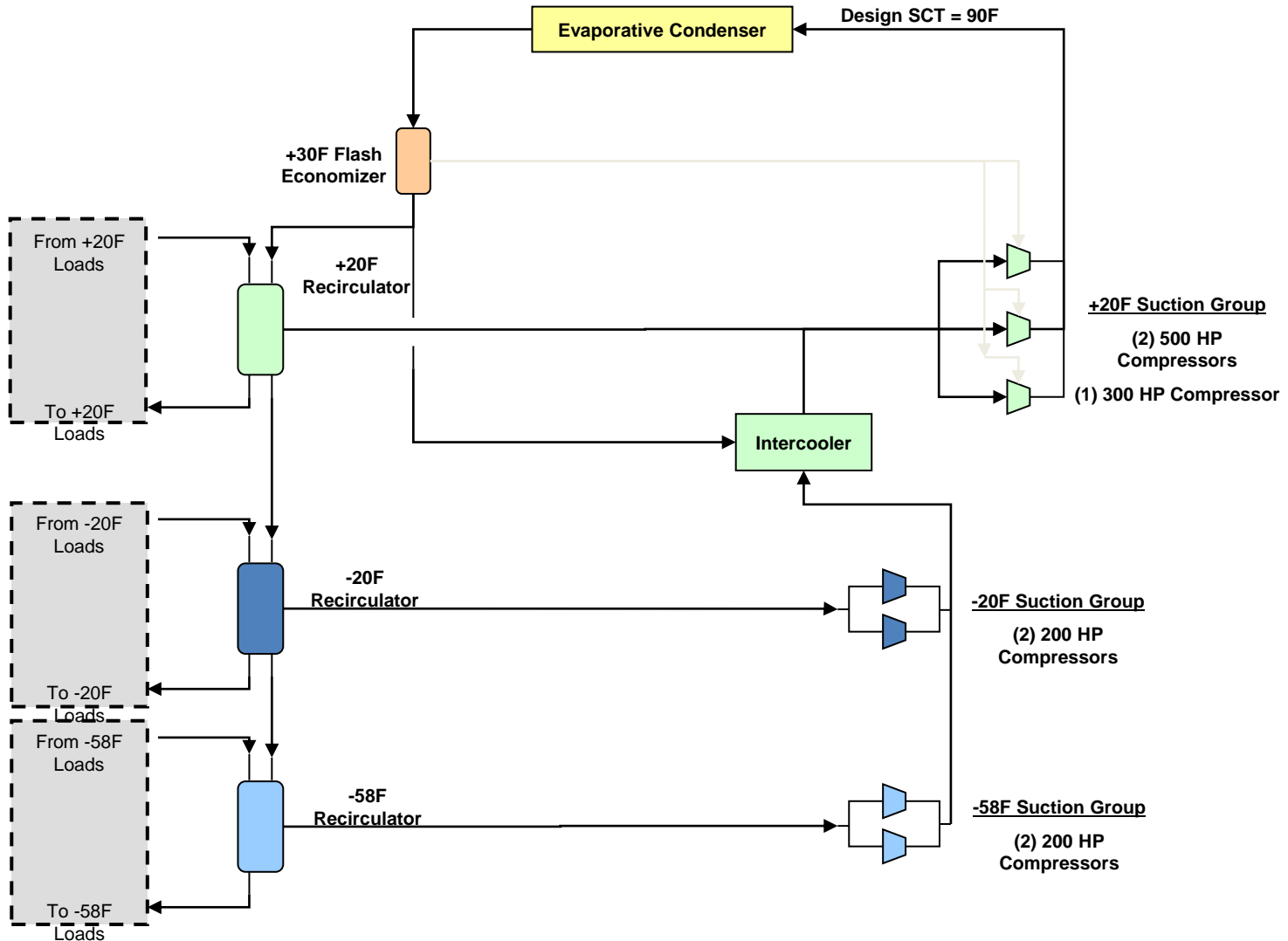
Cascade System

CO₂/NH₃ Refrigeration Schematic



Reference System

R-507 System Schematic



Comparison Methodology

- Instrumentation added to cascade CO₂/NH₃ system:
 - Mass flow meters, pressures, temperatures, and compressor power meters.
- Data and efficiency comparisons processed via EnergyDashboard® performance monitoring software
 - Analytics tool allows flexible user selection of time intervals and methods of comparison.
- Calculated R-507 two-stage system performance based on measured NH₃/CO₂ system loads and conditions

Monitoring Tool Capability

- Measure actual system operation:
 - Go beyond power usage; calculate efficiency
 - Provide high level metrics appropriate to system type
 - Ability to “drill down” to subsystems and key parameters
- Compare with expectations:
 - Observations on routine daily basis or ad hoc
 - Automatic calculated variance and/or expert evaluation
- Provide real time insights into:
 - Energy costs and savings persistence
 - Reliability and availability
 - Identification of system problems and negative trends

Measured and Calculated Performance Comparison

	Base CO ₂ /NH ₃ Cascade System	2-Stage R-507 Ref. System	R507 vs. Base CO ₂ /NH ₃ Cascade	
	Measured	Calculated	kWh	Percent
-20°F Suction	270,408	300,977	30,569	11%
-58°F Suction	440,478	492,004	51,526	12%
Combined -20°F and -58°F Suction	710,886	792,981	82,095	12%
MT Suction Group	1,002,511	981,791	(20,720)	(2%)
Total Compressors	1,713,397	1,774,772	61,375	4%
Compressors + Condenser	1,897,807	1,959,182	61,375	3%
Compressors + Condenser + AUs	2,554,327	2,615,702	61,375	2%

Pump Energy Use

- 58°F Pump	33,002	48,802	15,800	48%
- 20°F Pump	33,612	46,485	12,873	38%
+ 20°F Pump	50,599	61,804	11,205	22%
+ 11°F Pump	24,086	-	(24,086)	(100%)
Total Pumps kWh	141,299	157,091	15,792	11%

Total System kWh	2,695,626	2,772,793	77,167	3%
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CO2 Emissions Savings NH3/CO2 vs. R-507

	R-507	NH3/CO2	Savings
Leak Rate (tons/test period*):	0.6	0.3	0.3
Refrigerant Leak (CO2 equivalent tons**):	2,242	0.3	2,242
Energy Usage (kWh):	2,772,793	2,695,626	77,167
Energy Usage (equiv. tons CO2***):	1,130	1,099	31
TEWI****:	3,372	1,099	2,273

- * Estimated based on 7.5%/year assumed leak rate
- ** Calculated based on R-507 GWP of 3,985
- *** Calculated based on CA generation inventory
- **** TEWI: Total Equivalent Warming Index

- **3% Energy cost savings for CO₂/NH₃ cascade vs. R-507 2-stage**
- **67% Reduction in TEWI**
- **Your mileage may vary**
 - Every system is different. Energy usage a factor of system configuration AND thermodynamic properties of refrigerant
 - Cascaded flash cooling benefits R-507, not necessarily standard practice for non-industrial systems



business case

natural refrigerants

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Thank you very much!