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natural refrigerants • real alternatives

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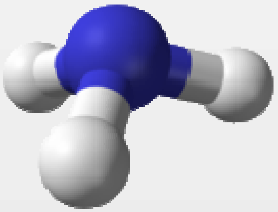
Ammonia and CO_2 Combined Package Systems for Commercial and Industrial Applications

Introduction

Natural substances | Cheap refrigerants
Excellent thermodynamic and heat-transfer properties

Ammonia



•High Toxicity
•Moderate Flammability

Limiting Factors for a Wide Implementation

•Investments to the machinery room design for the direct systems
•Charge restrictions

Introduction

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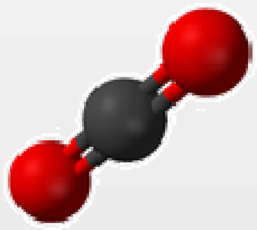
Carbon Dioxide



•Low critical temperature;
•High critical pressure;
•Availability of equipment

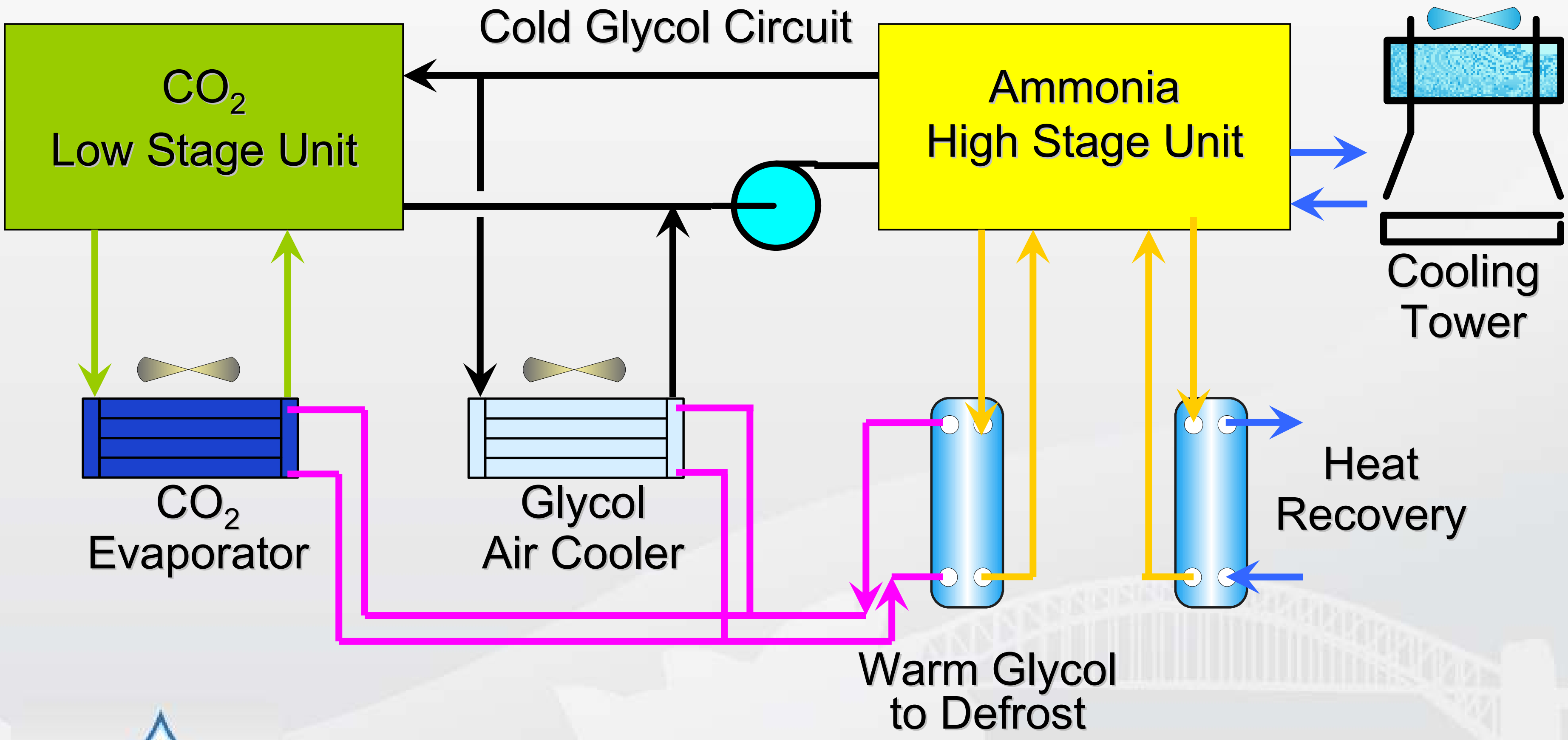
Limiting Factors for a Wide Implementation

•Requires specific design solutions for sub/transcritical operations
•High pressure equipment
•Intelligent control of high pressure in transcritical operation is essential

CO_2-Glycol Cascade System Key Design Features

- Standardized pre-engineered Ammonia chiller;
- CO_2 compressor and vessel packages;
- Equipment to provide defrost by warm glycol;
- CO_2 evaporators with interlaced coils for Low Temperature demand;
- Glycol air coolers for Middle Temperature demand interconnected by pre-insulated polymer pipes;
- Secondary circuit with glycol between Ammonia high stage and CO_2 low stage systems;

Case Study
CO_2-Glycol Cascade System



CO_2-Glycol Cascade vs Direct Ammonia Systems

Data considered in the case study for a facility consisting of a total of 6 rooms:
3 Freezer Rooms - can also be run as Cool Rooms;
3 Cool Rooms only.

Parameter	Direct ammonia system	Cascade system
Low temp saturated suction temperature, °C	-26 (ammonia)	-26 (CO_2)
Medium temp saturated suction temperature, °C	-10 (ammonia)	Ammonia: -15 glycol supply: -12
Condensing temperature, °C	35	35
Low temperature system peak load, kW	537	537
Medium temperature system peak load, kW	675	675

Plant Equipment and Operational Safety

- **Ammonia charge**
  - -ammonia charge in the Cascade System is restricted to the chiller and is classified as an indirect system
  - -it makes 10-15% of the charge in the direct ammonia system

- **Plant room ventilation**
  - •Higher the ammonia charge, greater the minimum ventilation rate.

- **Personal Protective Equipment**
  - •Very basic PPE for the systems with ammonia charge <900kg is required.

Plant Equipment and Operational Safety

- Refrigerant detecting equipment
  - very basic ammonia detection system for the Cascade System
  - Sophisticated detection system could be used for direct ammonia system;

- Electrical equipment
  - Additional safety requirements apply to the electrical equipment if LFL can be reached

Mechanical Equipment Supply and Installation

- Cascade System with pre-packaged equipment is higher in equipment cost
    - Costs of the room cooling units can be reduced if electric defrost is implemented;

- Installation and labour costs of Cascade System are significantly reduced
    - CO_2 compressor and vessel units and ammonia chillers are completely supplier-built

- Pipe-work costs
    - material cost of pipe-work is high for Cascade System
    - on-site installation time and Labour costs are reduced

Mechanical Equipment Supply and Installation

- Electrical and control equipment
  - costs of on-site electrical equipment on the Cascade System are significantly reduced as all these are provided on the supplier-assembled units

- Engineering design and documentation costs
  - Time reduction to produce system design and documentation of the cascade system

Capital Costs

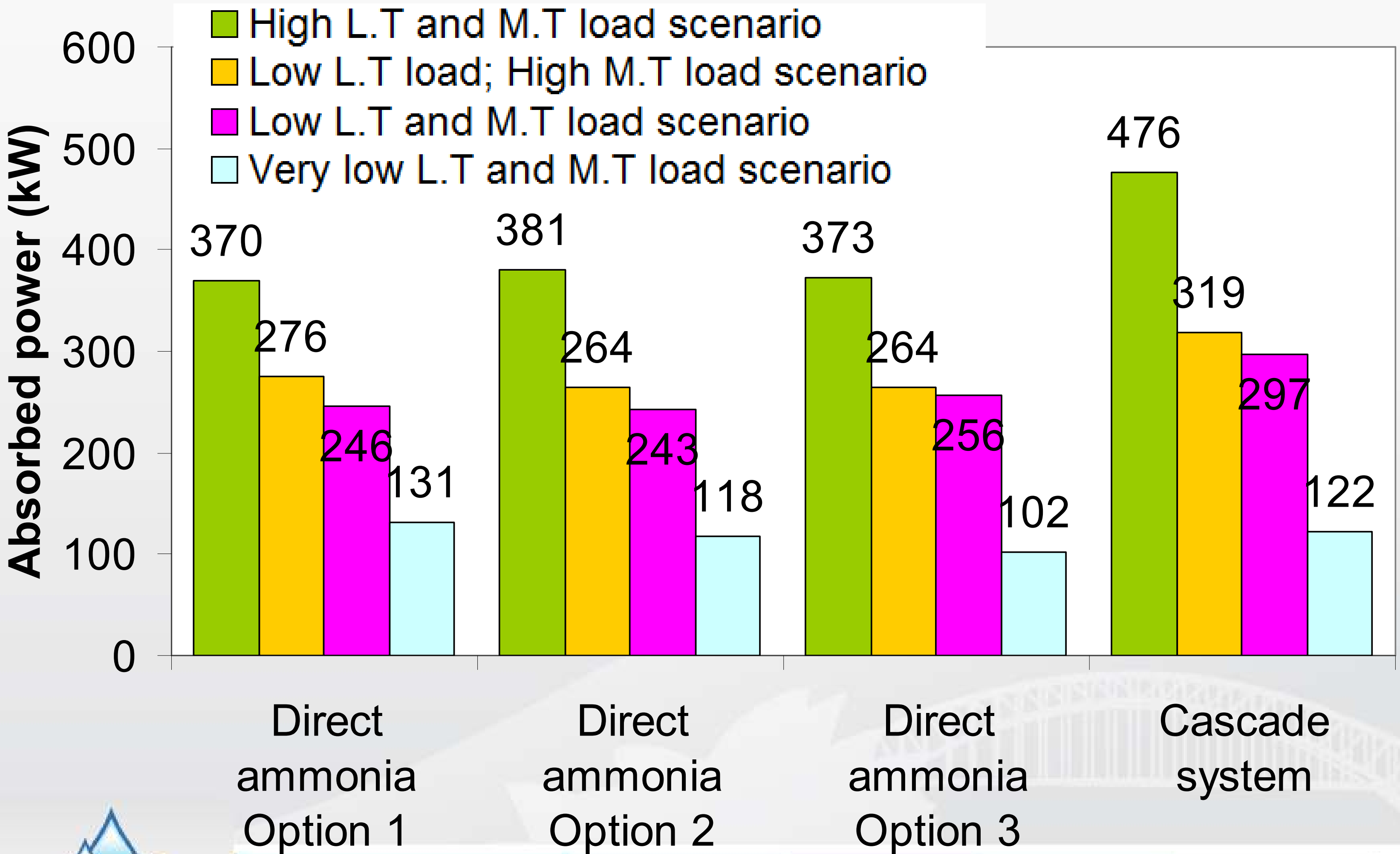
	Direct NH_3 (AUD)	Cascade (AUD)	Savings, %
Mechanical Equipment	$1,400,000	$2,100,000	-50%
Mechanical Installation	$280,000	$125,000	55%
Electrical/control equipment and labour	$620,000	$550,000	11%
PPE, plant room ventilation	$30,000	$14,000	53%
Design and documentation	$170,000	$150,000	12%
Project Management and Commissioning	$80,000	$65,000	19%
Spare parts, maintenance	$30,000	$17,000	43%
Total Project cost	**$2,610,000**	**$3,021,000**	**-16%**

Running Costs

Options for the direct ammonia system

Option number	Option description	Features
NH_3 Option 1	1 screw compressor on 100% LT load; 1 screw compressor on 100% MT load; 1 swing compressor on standby at all times	Full standby available at all times.
NH_3 Option 2	1 screw comp. on 50% LT load; 1 screw comp. on 100% MT load; 1 swing comp. running during periods of high LT load.	Standby not available at high LT load.
NH_3 Option 3	1 booster compressor on 100% LT load; 1 screw compressor on 50% MT load + heat rejection of low stage compressor; 1 swing compressor running during periods of high MT load	Standby not available at high MT load.

Running Costs



Capital and Running Costs

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The result of the case study demonstrates

- Total capital cost of the cascade system is about 16% higher than capital cost of the direct ammonia system.

- The cascade system is less efficient than any of the direct ammonia system options at peak load .

- The efficiency of the cascade system approaches close to the efficiency of the direct ammonia system and at very low loads.

Conclusion

	Pros	Cons
Ammonia Direct System	High efficiency; Simple equipment widely available on the market;	High charge of ammonia in a direct system and associated risk; Risk of product spoilage in case of ammonia release;
CO_2-Glycol Cascade System	Easy and quick installation and maintenance; Ammonia is restricted in the machinery room; Risk is substantially lower; Basic safety equipment;	Higher in running and capital costs

Thank You For Attention