Introducing a New Ammonia/CO_2 Cascade Concept for Large Fishing Vessels

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What fishermen want….

Essentially – Frozen fish, right here - right now

- Rapid freezing is extremely important for product quality
- Available space on board is severely limited
- System must be able to withstand harsh environment on board
- Hazards from refrigerant leaks must be acceptable
- Long terms solution with regards to laws and regulations
- Simple system and good availability of parts and service

MS Kvannøy

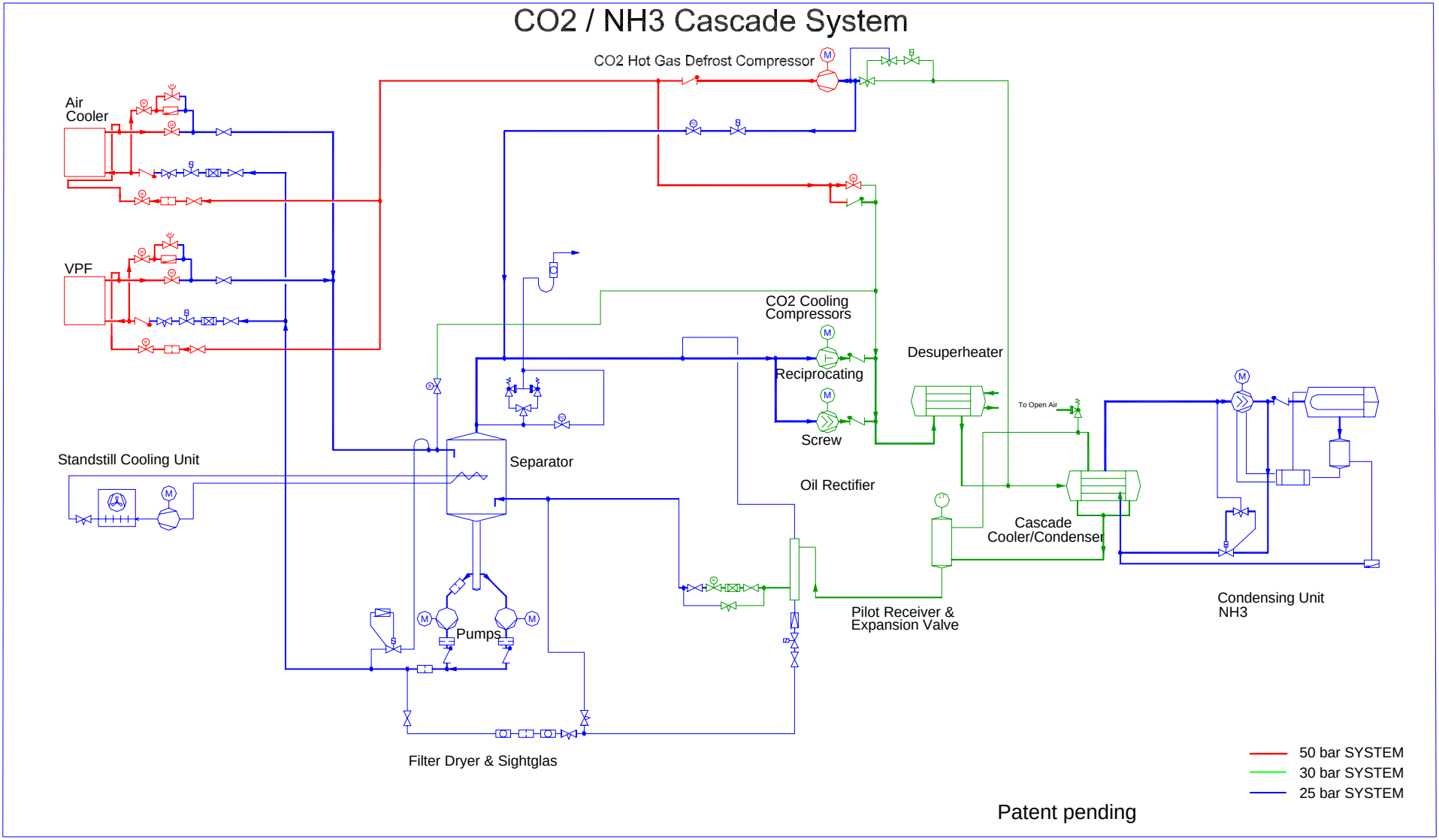
- 75m (250 ft) trawler / purse seiner.
- Freezes 210 tons (463,000 pounds) of fish per day.
- Complete filleting & packaging system
- 2 ammonia Refrigerated Sea Water units
- CO_2 / ammonia cascade freezing system with hot gas defrosting.

The CO_2 / ammonia cascade

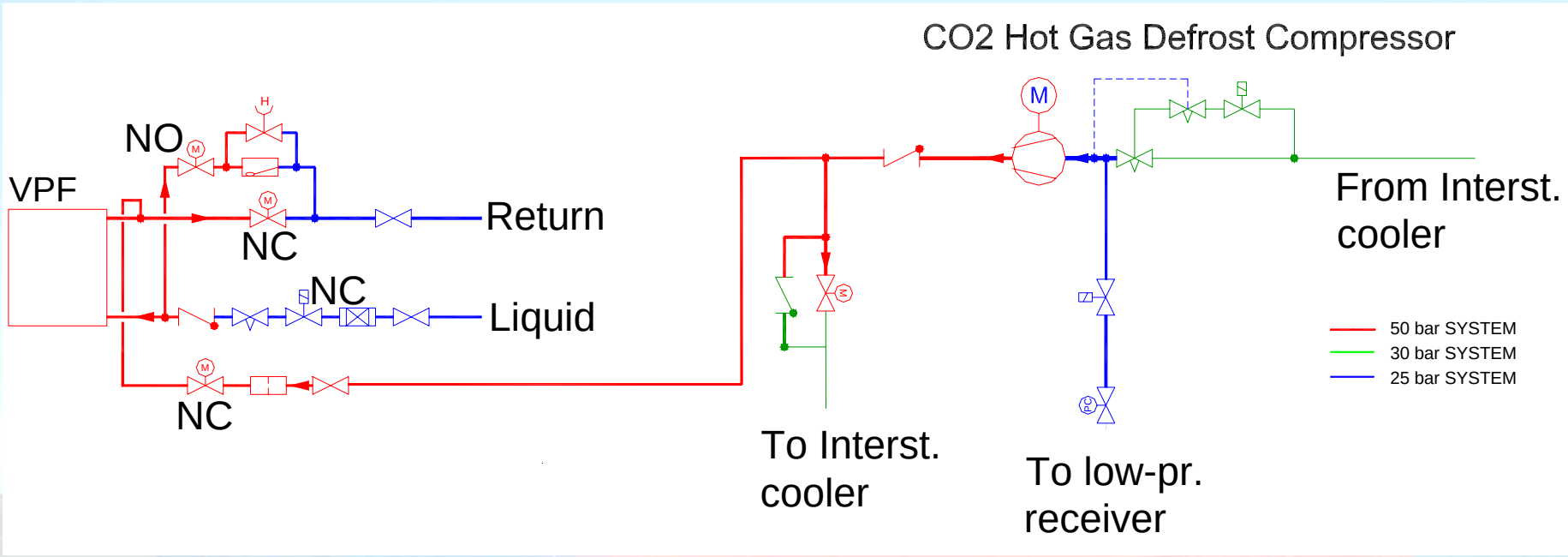
- 6 reciprocating CO_2 compressors, 3 available for defrosting
- 2 screw ammonia compressors
- 11 CO_2 vertical plate freezers, 39 stations each
- 1 CO_2 vertical flake ice machine
- Natural air convection CO_2 coils in 3 cargo holds
- Shell and tube interstage heat exchanger

Total capacity 1350 kW (4,606 MBH) at –48°C (-54.4°F)

Concept diagram

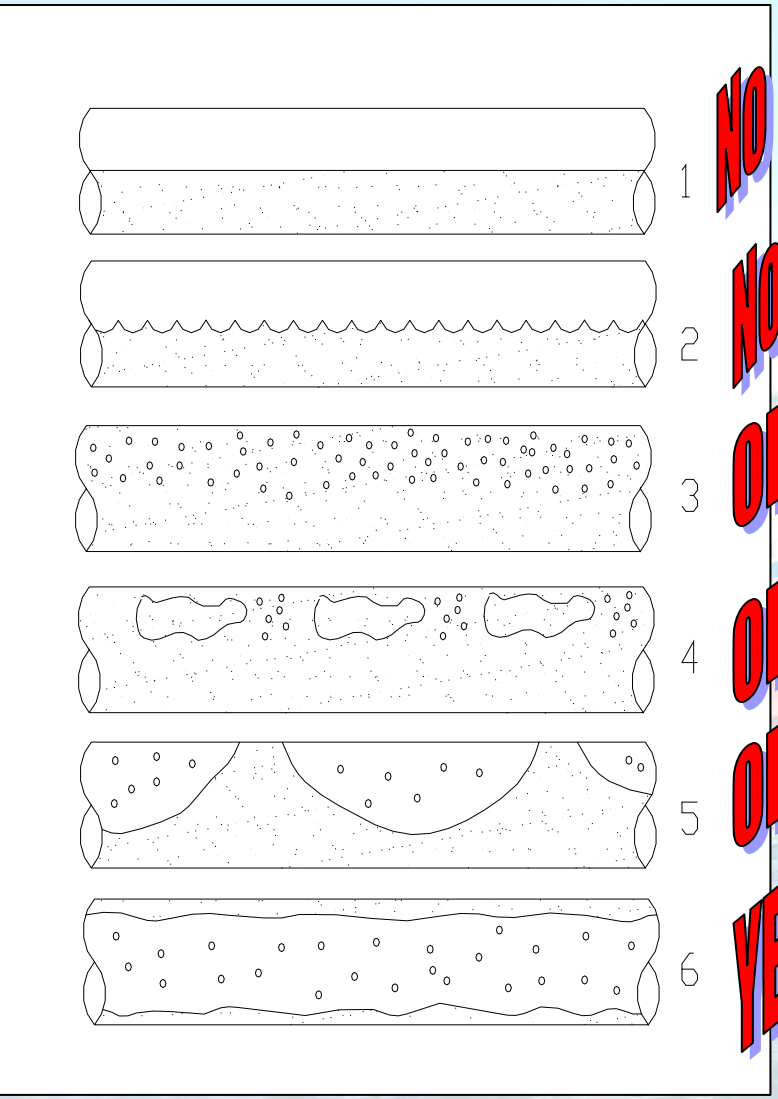


Hot gas defrosting



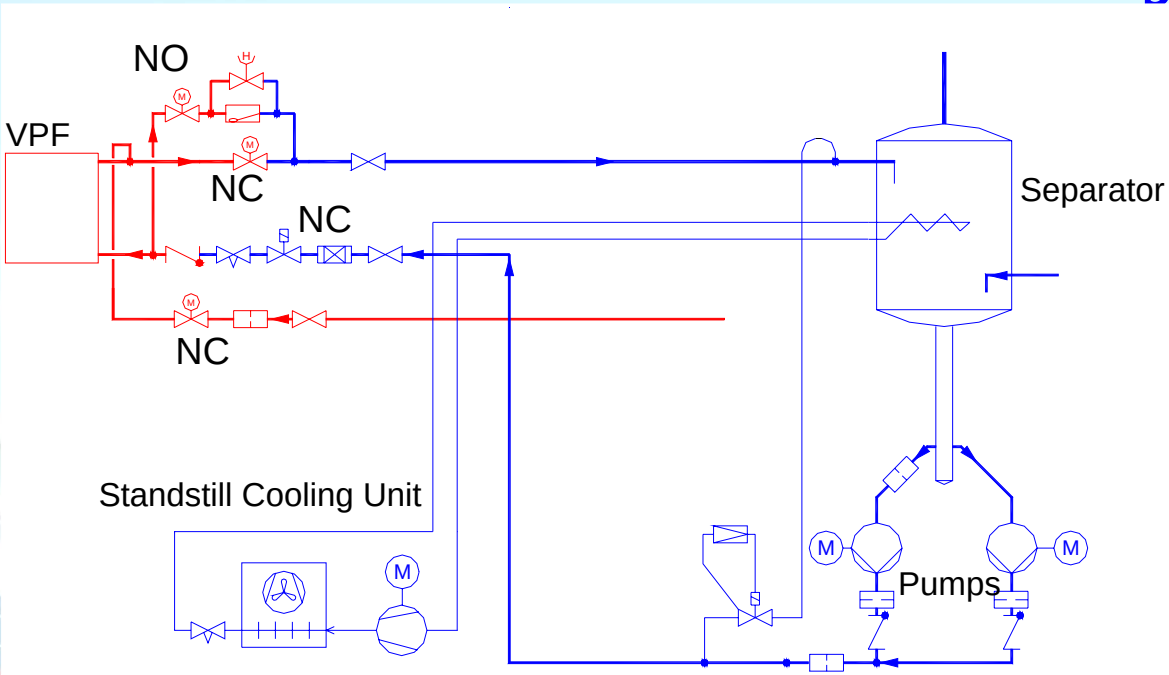
- Defrost system only pressurized when in operation (50 bar,725 psi)
- Minimum gas volume under defrost pressure
- High defrost capacity available, 800 to 1000 kW (2.729-3.412 MBH)
- Overall power consumption saving while defrosting
- Compressor can be used both for freezing and defrost

Evaporator (VPF) design



- Evaporators needs to be specially designed for CO_2
- High vapour density yields low velocity and bad flow pattern (1-2)
- Smaller channels and longer circuits results in better flow pattern (3-6, 6 best)
- CO_2's behaviour keeps pressure loss within acceptable limits.

Stand still unit and safety



- Stand still unit keeps low-pressure receiver at max –25°C (-13°F)
- During black-out, evaporators return liquid and not vapour.
- Stand still unit can handle complete shut-down
- Safety valves fitted at appropriate locations
- Solenoid valve can blow charge under controlled conditions

Lubrication

- Fully miscible Polyol Ester oil (POE) used
- Piping system built like a traditional R22 system.
- Miscible oil an advantage for lubrication of system components
- No negative effects seen with regards to heat transfer efficiency

Be aware:

- Oil is hygroscopic and very miscible.
- No POE oil into the ammonia system.

Special CO_2 issues

- Elastomer compability problems reported above 50 bar (725 psi)
- Below 50 bar (725 psi) some elastomers (PTFE) cause product problems (capacitative rods, ball valves)
- Cavitation is apparently no problem. Implosion energy is approximately 3% of water at 1 bar.
- CO_2 create acid with water. Drying filters is a necessity
- Strong cleaning effect. Careful cleaning during construction.
- Isolated sections with CO_2 present an high pressure hazard
- Evacuation to ambient pressure does not necessarily mean that the system is empty (dry ice)

Controlling the system

- Fast responding control system necessary
- A defrost introduce rapid changes in both the CO_2 & NH3 system
- Defrost compressor must be kept within it's operating limits

- Low capacity situation demands fine regulation (dry ice)
- Small recips offer low minimum capacity
- Some recips can run fully unloaded

Expected concept benefits

- Lowering TE from –40°C to –50°C (-40°F to –58°F) theoretically means a reduction of the freezing time by 20%. Production up 25% (1/0.8 = 1.25)
- Reduction in equipment size increases production per deck area
- No loss of product due to refrigerant leaks (possibly lower insurance)
- Improved quality from faster freezing and fast defrosting
- Pressure loss behaviour of CO_2 is very favourable

Experiences : Freezing

Expectations fulfilled, and:

Whole round herring, frozen to a core temperature of –25°C (-13°F)

- Traditional R22, TE=-40°C (-40°F) 3 to 3½ hours
- CO2 / NH3, TE=-48°C (-54.4°F) 1 ¾ hour

Freezing time compared to traditional systems (R22, TE = -40°C, -40°F) is 40% better

Possible reasons: Smaller temperature difference between plates and low-pressure receiver results in higher gain than the 25%.

Experiences : Defrosting

•No soft spots found on fish blocks after defrost. Handling blocks with soft spots will result in damage which reduce the price. (5 to 15%)

•Uniform temperature distribution on plates during defrost

•Efficient defrost of plates, manifolds and hoses.

•Due to the low temperature, metallic contact is essential to defrost elements not heated

Service

- Evacuation very easy as refrigerant can be blown off
- CO_2 does not expand, but contract when frozen
- Liquid charge can be kept in an open system as dry ice
- Dry ice in filters etc when opened is no problem

Careful!

- Dry ice can block valves, hoses etc during evacuation. Make sure that the section is completely equalized before dismantling.
- Enclosing a dry ice charge can lead to high pressures.

Environment

For the same freezing capacity – old concept versus new concept

“Kvannøy”

Old: 13 tons (28600 lb) R22, TE = -40°C (-40°F)

New: 5.5 tons (12100 lb) CO_2 , TE=-48°C (-54.4°F), 600 kg (1300 lb) NH3

“W. Van Der Zwan”

Old: 55 tons (121000 lb) R22, TE = -43°C (-45.4°F)

New: 12 tons (26500 lb) CO_2 and 1 tons (2200 lb) NH3, TE=-50°C (-58°F)

“Atlantic Dawn”

Old: 5 tons (11000 lb) NH3 + 100 tons (220000 lb) CaCl, TE=-42°C (-43.6°F)

New: 12.5 tons (27500 lb) CO_2 and 1 tons (2200 lb) NH3, TE=-50°C (-58°F)

Conclusion

CO2 is not just the future – it's also the present

- All features normally expected in a system can be realized with CO_2
- System utilizes well known refrigeration components and technology
- Faster freezing – better product quality – higher production
- Environmental friendly – both globally and locally
- Quick reacting control system necessary
- Minimum load situation needs attention during design

The experience actually exceeded the expectations !