



EVOLUTION OF CO₂ AS REFRIGERANT IN ICE RINK APPLICATIONS

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12th IIR Gustav Lorentzen Natural
Working Fluids Conference



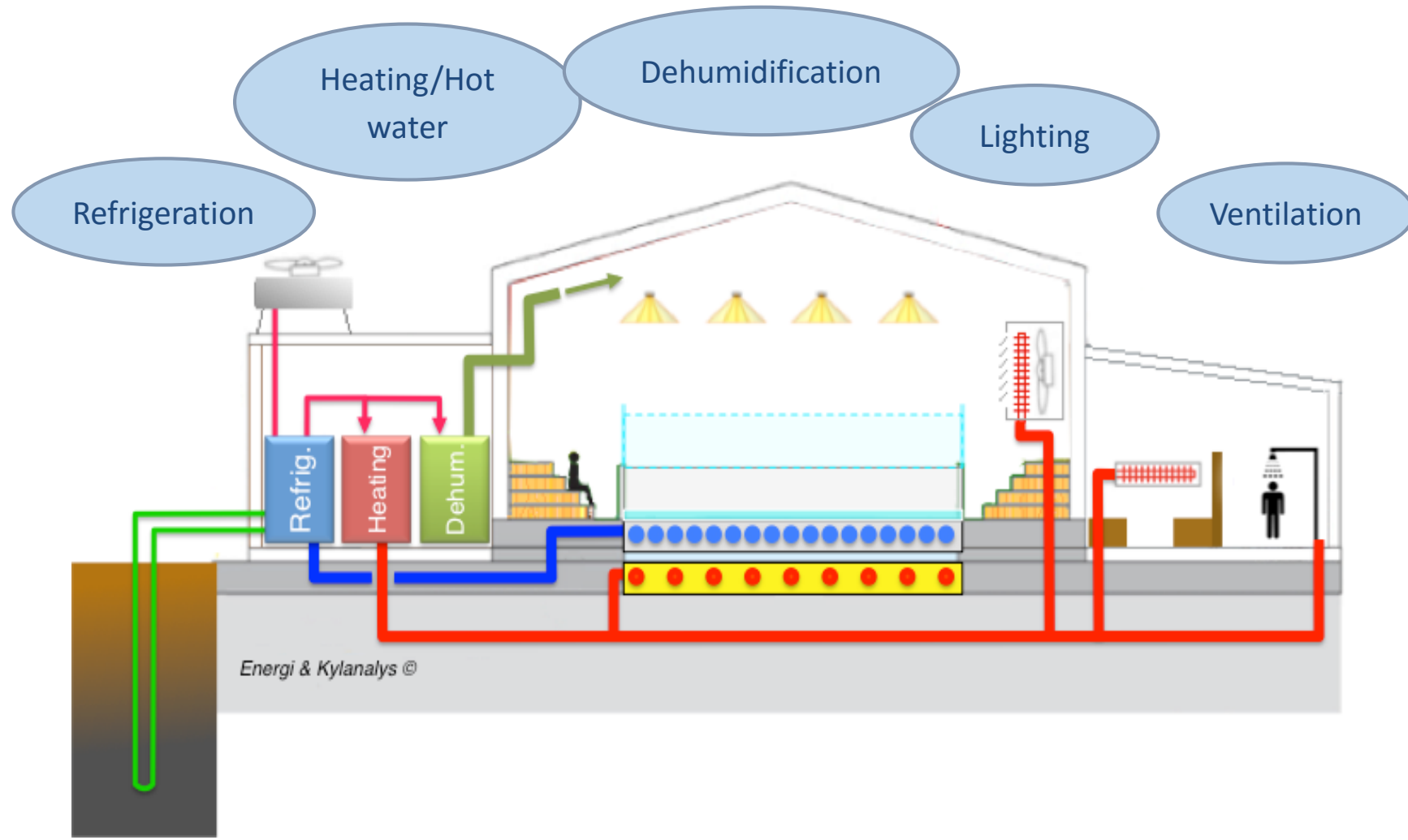
Outline



- Ice rink introduction
- CO2 history
- Properties of CO2
 - Heat recovery with CO2 systems
- Supermarkets with transcritical CO2 systems
- Ice rinks with CO2
 - as secondary refrigerant – 1st generation
 - as primary refrigerant – 1st generation
- Outlook

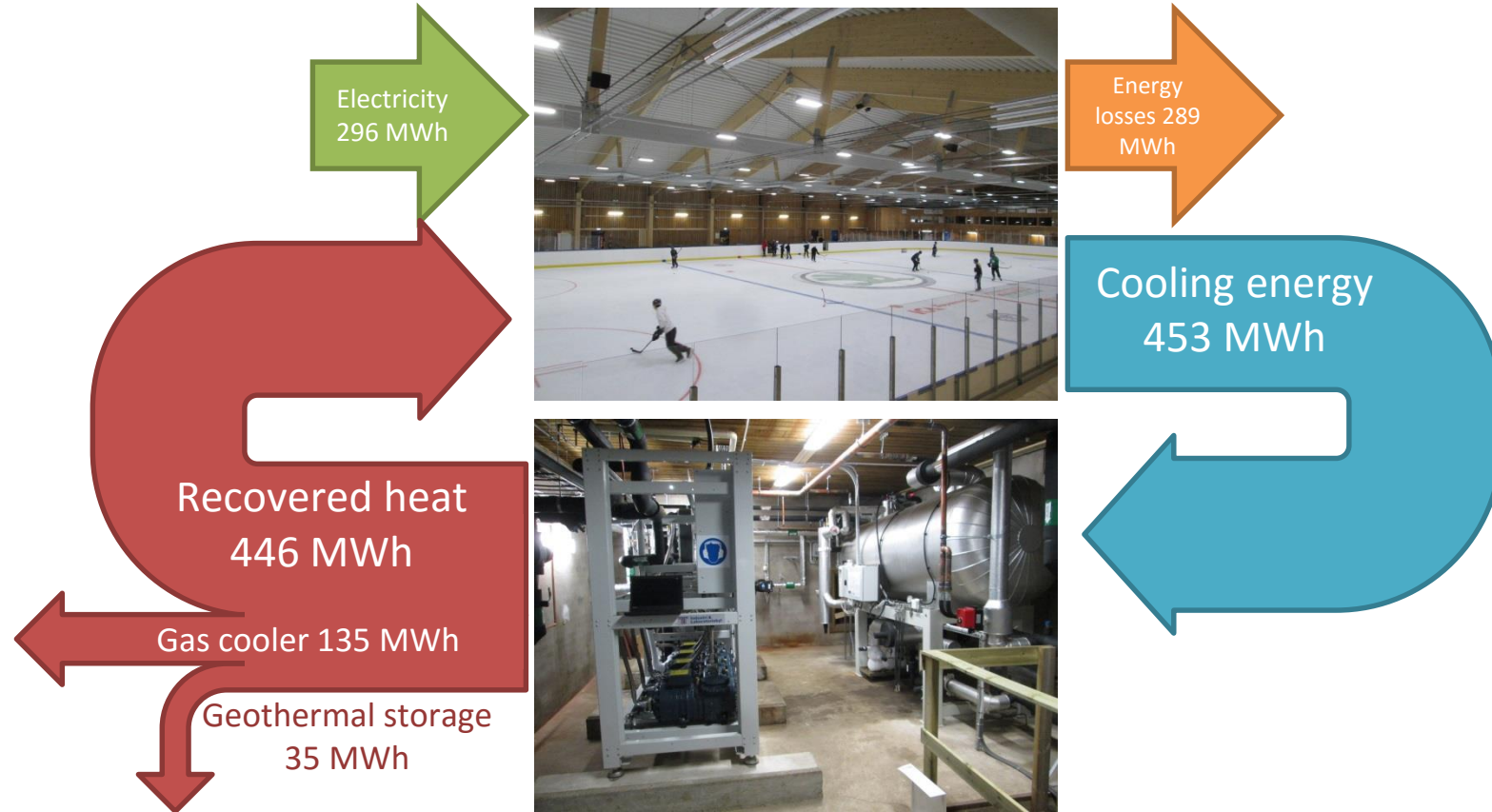


Ice rink energy systems “the big five”





Ice rink energy balance



- This ice rink is self sufficient with heat – no supplementary heat!
- ~70% of the available heat is reclaimed



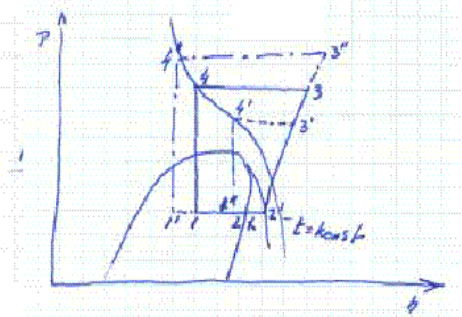
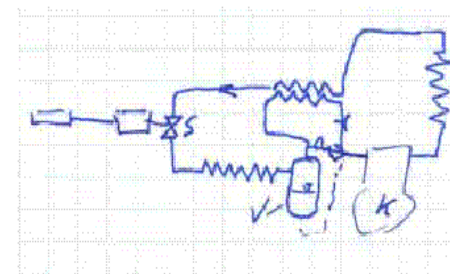
CO₂ refrigeration history



professor
Gustav Lorentzen
1915-1995

First draft of patent
application on transcritical
CO₂ system **November 1988**

- Phase 1 – 1850 to - ~1960
 - Patent in 1850 to phase out in the 60s
- Phase 2 -~1988 -?!
 - Lorentzents work





Phase 2 History



United States Patent [19]
Lorentzen et al.

US005245836A
[11] Patent Number: 5,245,836
[45] Date of Patent: Sep. 21, 1993

Revival of carbon dioxide as a refrigerant

Gustav Lorentzen
NTH, N-7034, Trondheim, Norway
Received 14 December 1993; revised 15 January 1994

In the present situation it seems appropriate to avoid as far as possible the use in large quantities of substances that are foreign to nature and will unavoidably be lost into the biosphere. A much safer philosophy must be to revert to 'natural' refrigerants: substances that are already present in our environment and which are known to be harmless. One such possibility is carbon dioxide (CO₂), which comes very close to being the ideal working medium, provided that a process to give competitive energy performance can be designed. The paper presents some examples of how this can be done.

(Keywords: refrigerant; substitute; R12; carbon dioxide; cycle; air conditioning; automobile; heat pump; district heating)

- Phase 2 - Lorentzen's work:
 - Articles
 - Patents

- [54] METHOD AND DEVICE FOR HIGH SIDE PRESSURE REGULATION IN TRANSCRITICAL VAPOR COMPRESSION CYCLE
- [75] Inventors: Gustav Lorentzen; Jostein Pettersen; Roar R. Bang, all of Trondheim, Norway
- [73] Assignee: Sinvent AS, Trondheim, Norway
- [21] Appl. No.: 728,902
- [22] Filed: Jul. 2, 1991

Related U.S. Application Data

[63] Continuation-in-part of Ser. No. 571,630, Sep. 6, 1990.

Foreign Application Priority Data

Jan. 9, 1989 [NO] Norway 890076

[51] Int. Cl.⁵ F25B 1/00

[52] U.S. Cl. 62/174; 62/503

[58] Field of Search 62/503, 513, 174, 149

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4,679,403	7/1987	Yoshida et al.	62/114
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5,042,262	8/1991	Gyger et al.	

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278095	6/1912	Fed. Rep. of Germany	
1021868	10/1958	Fed. Rep. of Germany	
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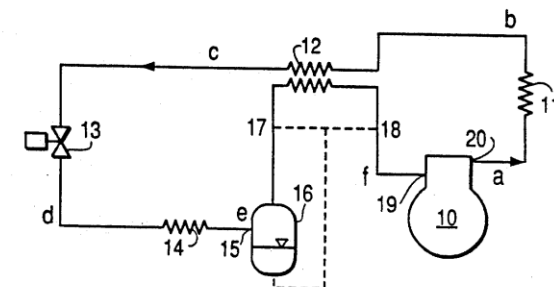
Refrigeration Engineering by H. J. MacIntire pp. 60-61 John Wiley & Sons Inc. 1937.
Patent Abstracts of Japan, vol. 13, No. 489, M888, abstract of JP 01-193561, publ. 1989-08-03.
"Cooling Machinery and Apparatuses", Gntimash, Moscow 1946, p. 4, FIGS. 28-29.
"Principles of Refrigeration": by W. B. Gosney; Cambridge University Press, 1982.
Kalteprozesse Dargestellt Mit Hilfe Der Entropietafel, by Dipl.-Ing. Prof. P. Ostertag, Berlin, Verlag Von Julius Springer, 1933 (w/translation).
Refrigeration Engineering, by H. J. MacIntire, 1937.

Primary Examiner—Albert J. Makay
Assistant Examiner—William C. Doerrler
Attorney, Agent, or Firm—Wenderoth, Lind & Ponack

[57] ABSTRACT

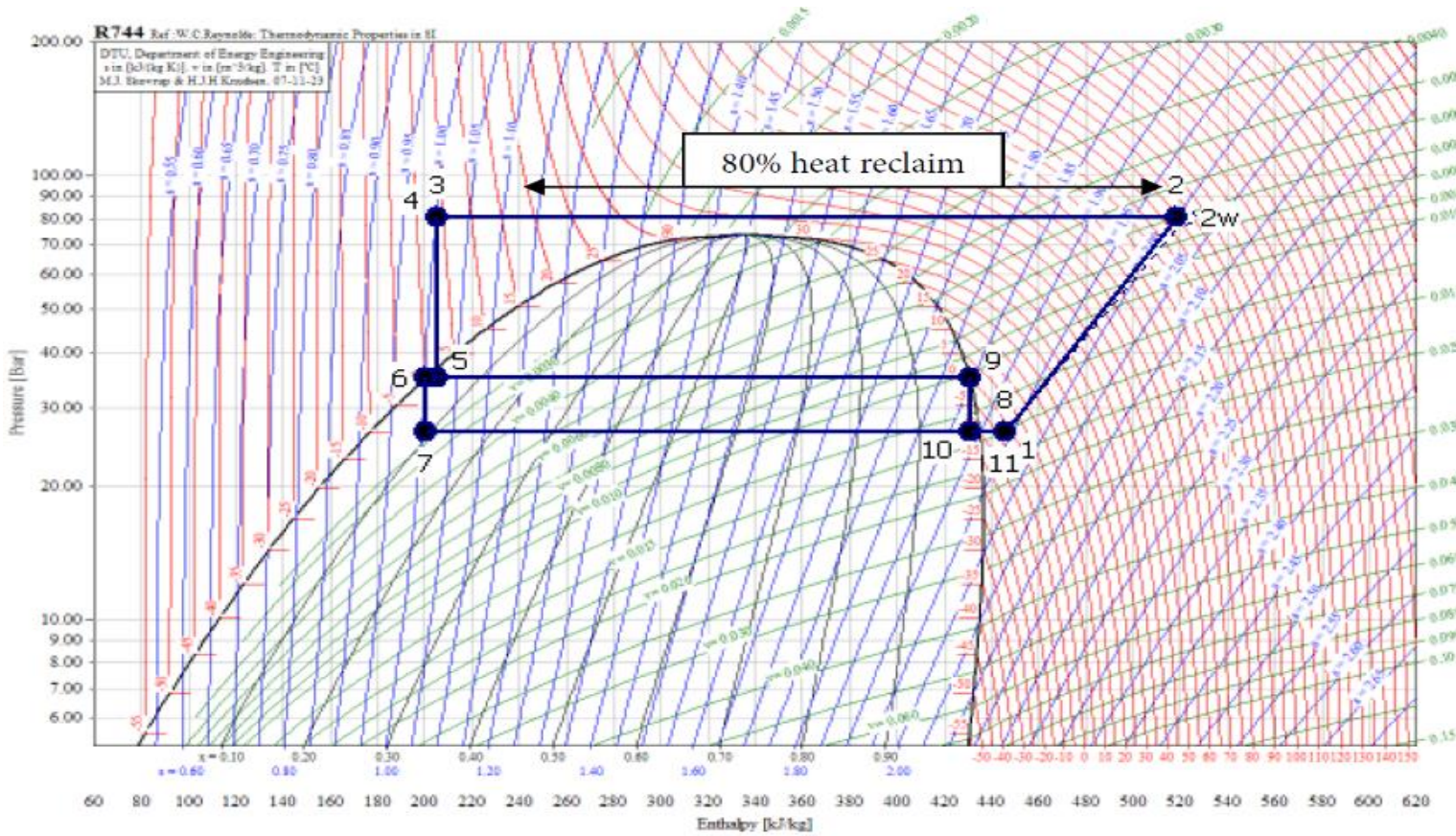
High side pressure in a transcritical vapor compression cycle system is regulated by varying a liquid inventory of a low pressure refrigerant receiver provided in a circuit of the system. The circuit includes a compressor, a gas cooler, a throttling valve, an evaporator and the receiver connected in series in a closed circuit operating at supercritical pressure in a high pressure side of the circuit. The degree of opening of the throttling valve is controlled to regulate the high side pressure in the circuit. It is possible to control capacity, and it also is possible to achieve minimum energy consumption for a given capacity requirement by regulating high side pressure.

26 Claims, 5 Drawing Sheets





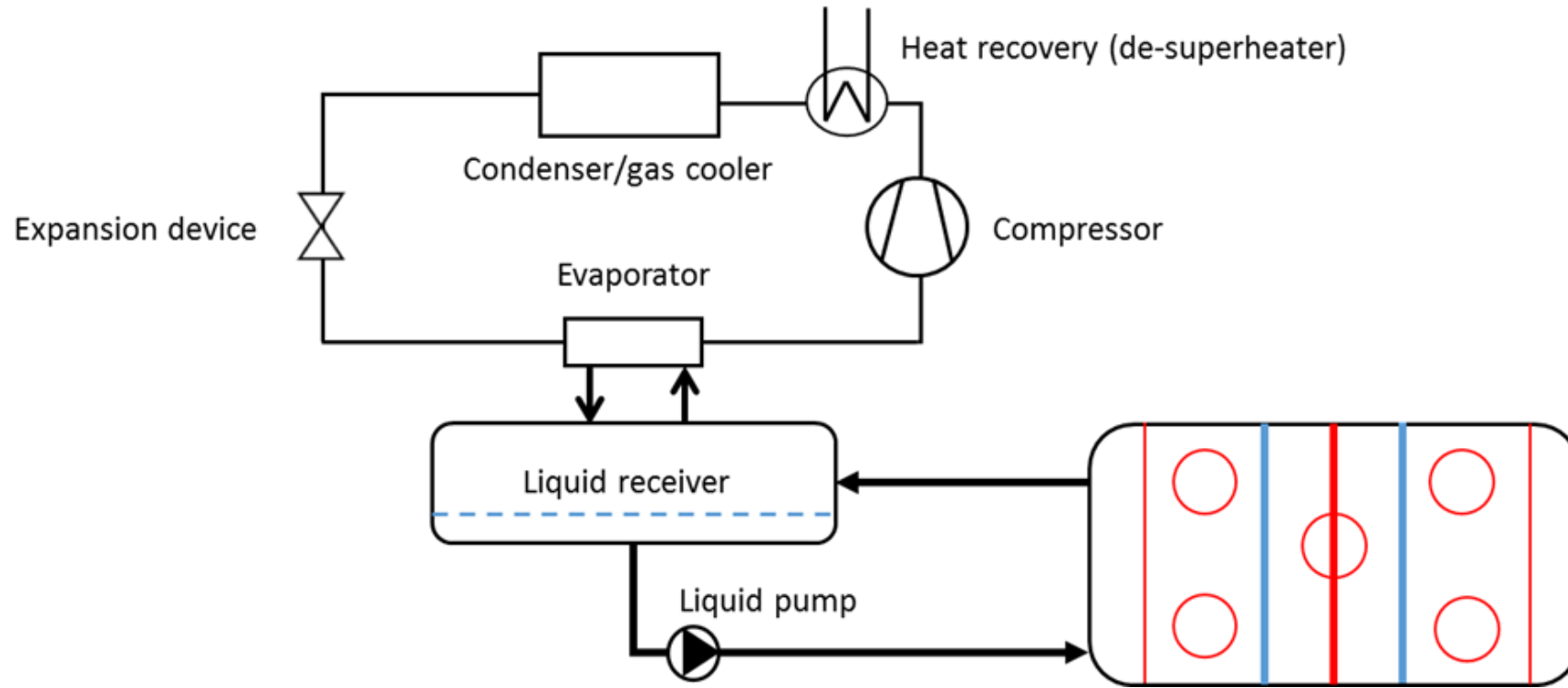
Properties – heat recovery



- CO2 can provide more heat at higher temperatures compared with other refrigerants



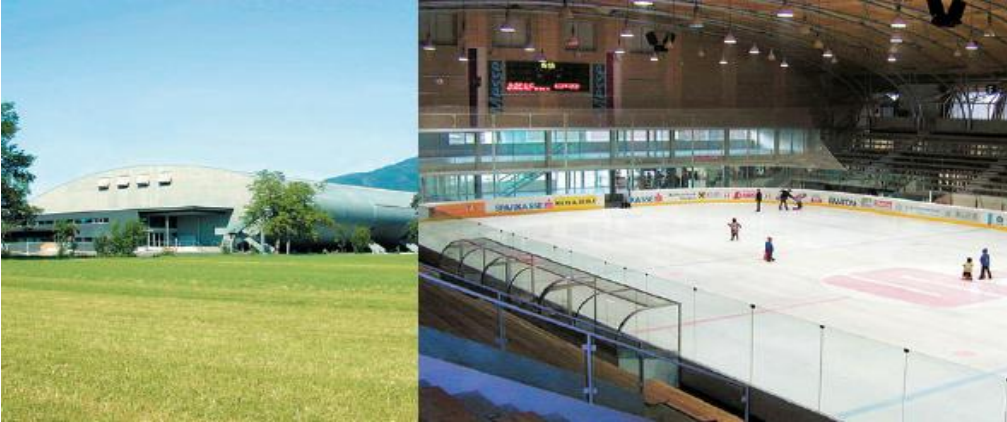
1st generation CO₂ ice rink



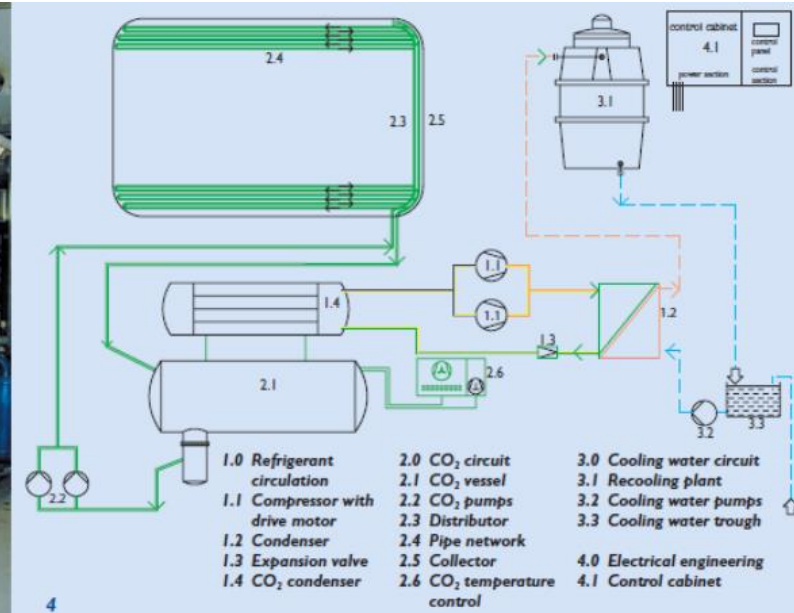
- CO₂ as secondary refrigerant
- Mainly ammonia as primary refrigerant
- About 56 ice sheets in the world - 2015



1st generation CO₂ ice rink



- Sulzer installs the first ice rink with CO₂ as secondary refrigerant in 1999 (Dornbirn, Austria)
- Ammonia as primary refrigerant





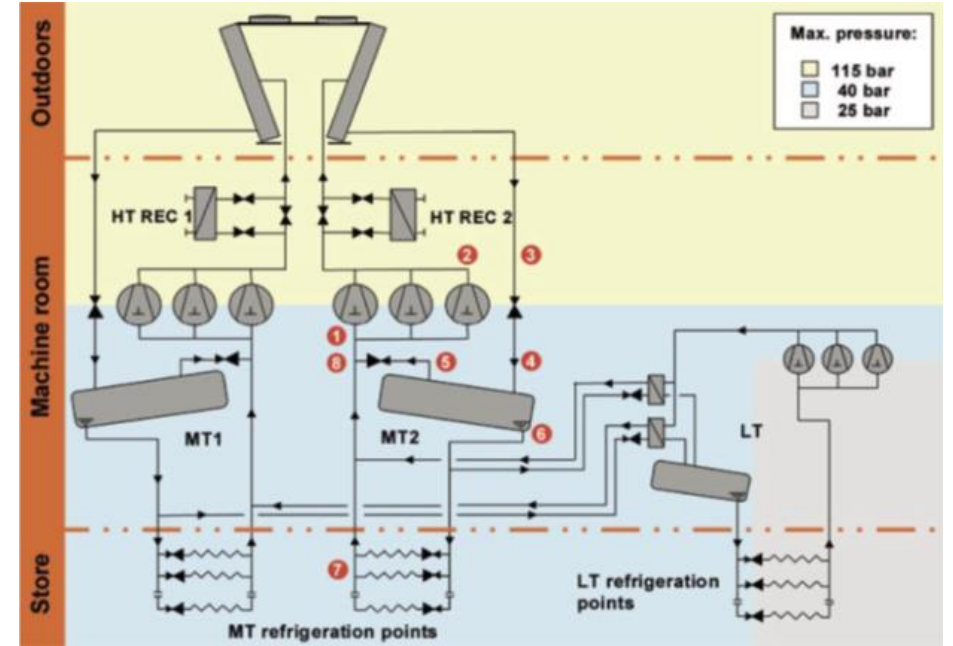
1st generation CO2 ice rink



- First ice rink with CO2 as secondary refrigerant and copper tubes in the rink floor (Katrineholm, Sweden, 2006)
- Ammonia as primary refrigerant



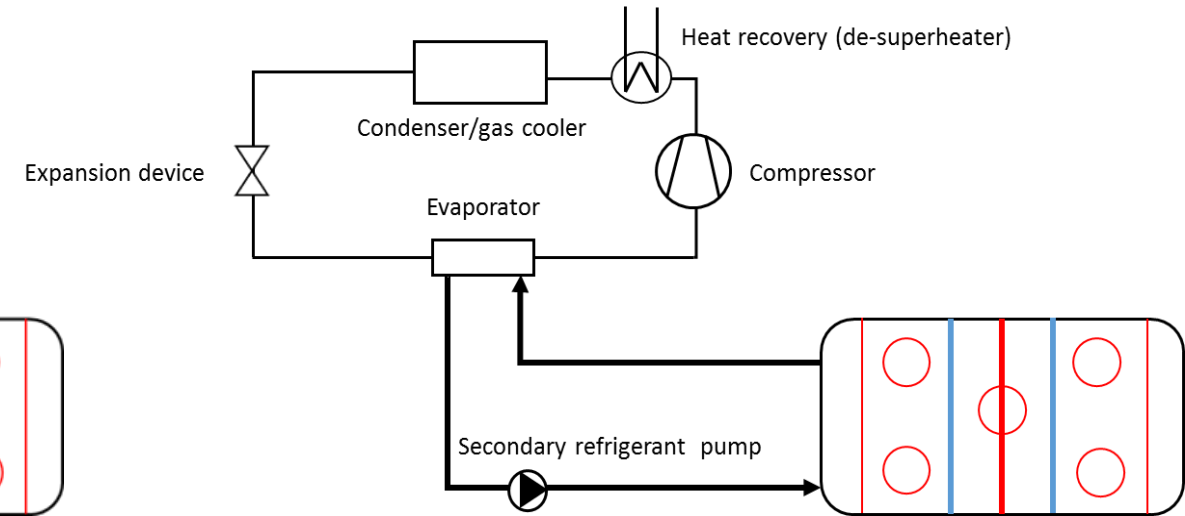
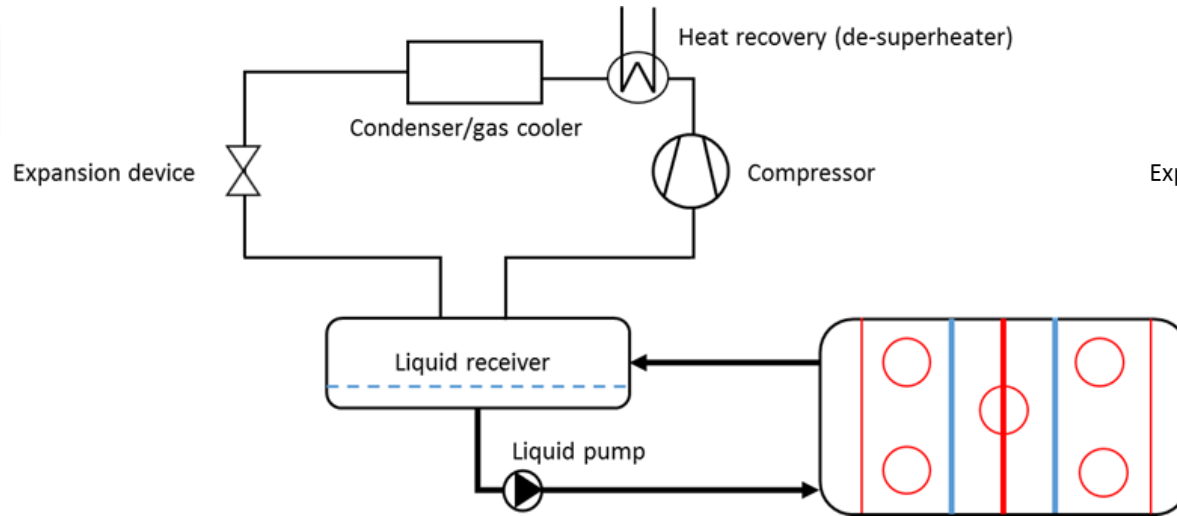
Supermarket – TC CO2 from ~2003



- Transcritical CO2 in supermarkets evolved from about 2003
- Example: Linde transcritical (TC) CO2 supermarket installation from 2005



2nd generation CO₂ ice rink



- CO₂ as primary refrigerant (transcritical design)
 - Direct – with CO₂ in the rink floor
 - Indirect – with a secondary refrigerant in the rink floor
- About 25-30 ice rinks in the world - 2016



2nd generation CO2 ice rink



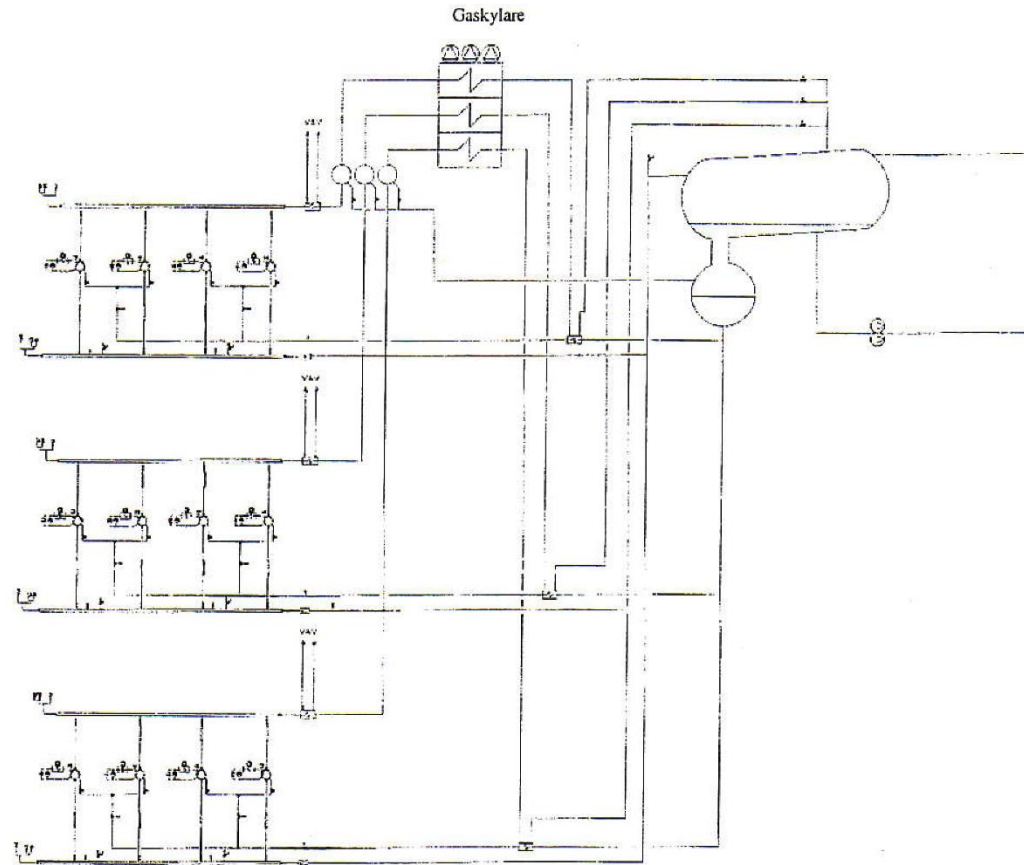
Ever thought of building an ice rink?

IHF Ice Rink Manual of the International Ice Hockey Federation

- International Ice Hockey Association handbook, 2002
- Proposed to use CO2 as refrigerant in 2002



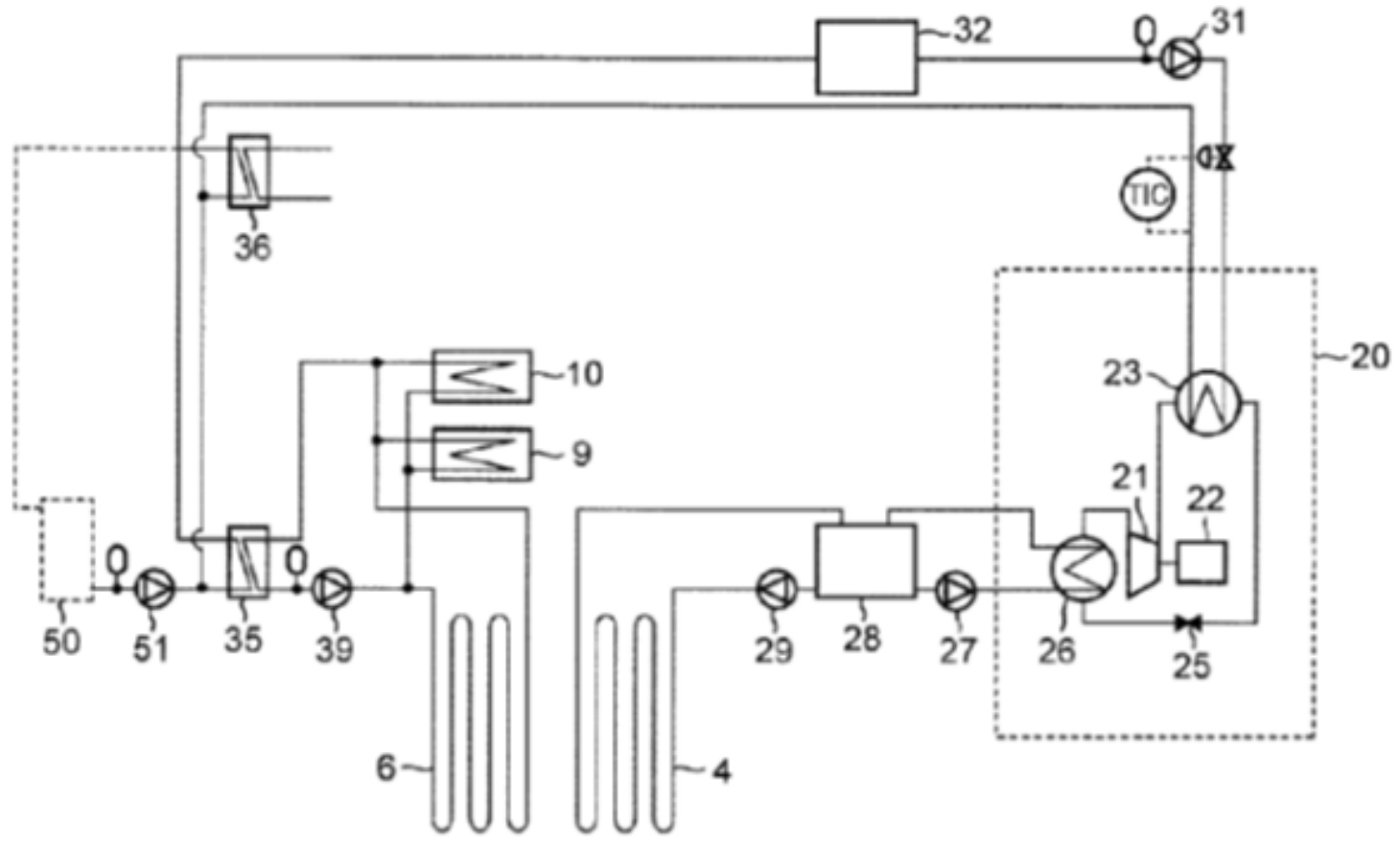
2nd generation CO₂ ice rink



- Proposed 2nd gen CO₂ ice rink in Sweden with CO₂ as primary refrigerant
- Alternate tender (Katrineholm, SE, 2006)



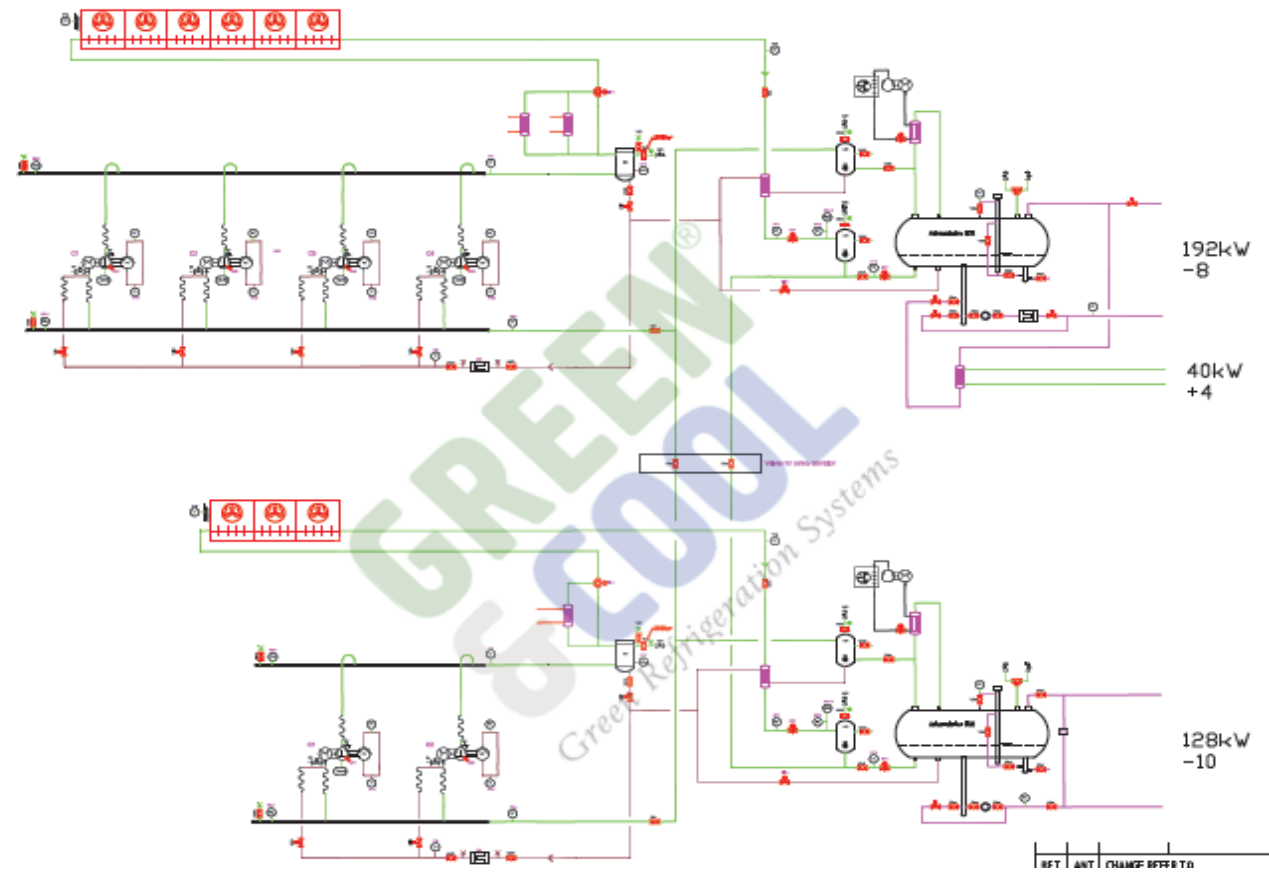
2nd generation CO₂ ice rink



- Proposed 2nd gen ice rink in Canada with CO₂ as primary refrigerant (Maykawa, CA, 2007)



2nd generation CO₂ ice rink



- Proposed 2nd gen CO₂ ice rink in Denmark with CO₂ as primary refrigerant
- Alternate tender (Gentofte, DK, 2010)



2nd generation CO₂ ice rink



- First 2nd gen ice rink to be realized in Canada with CO₂ as primary refrigerant (St Gedeon, CA/QC, 2010)
- Retrofit of a R22-system

First Place: Industrial Facilities or Processes, Existing

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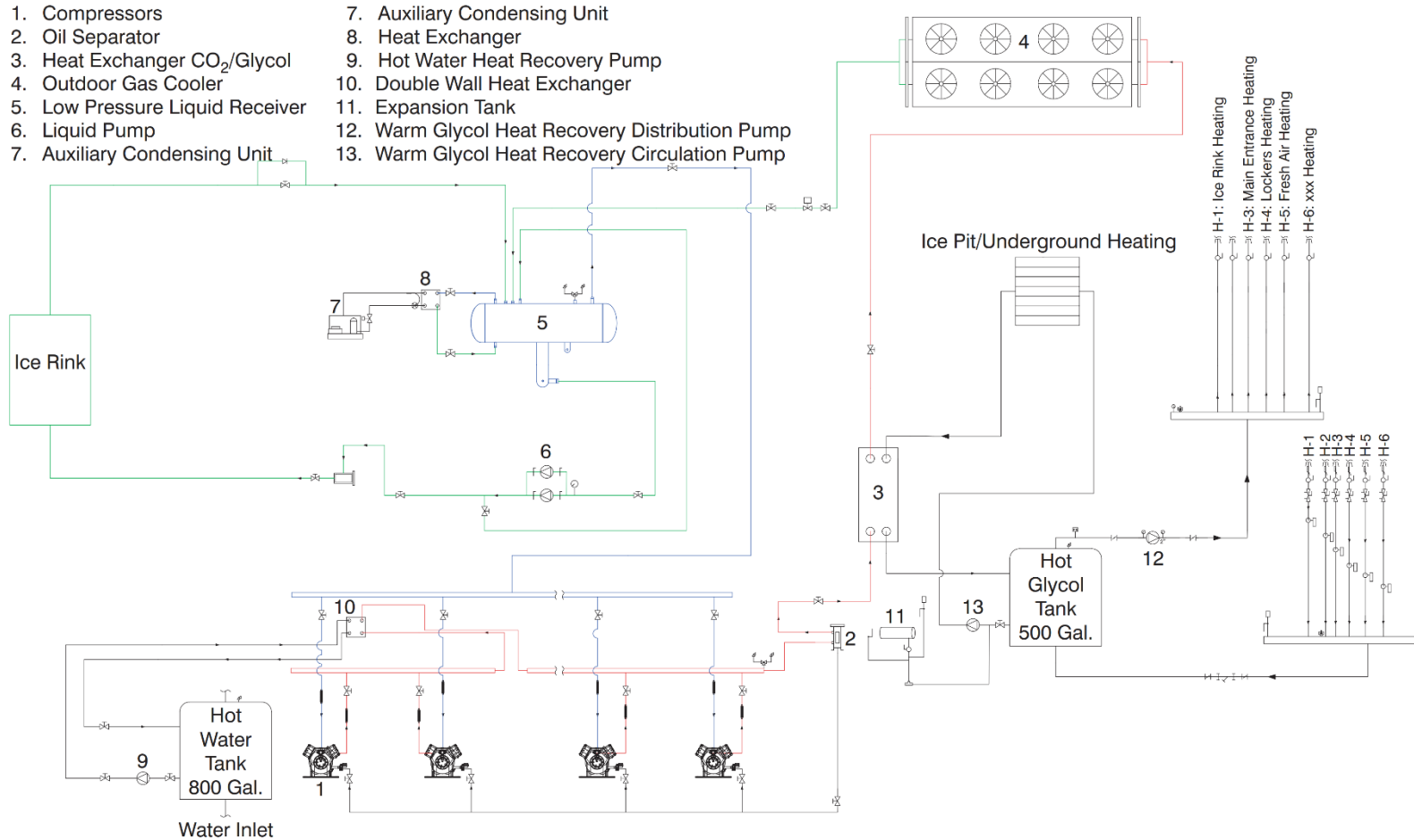
Arena Marcel Dutil, Les Coteaux, QC, Canada, is the first ice rink in the world to use a CO₂-based refrigeration system.

Ice Rink Uses CO₂ System

By Luc Simard, Associate Member ASHRAE



2nd generation CO₂ ice rink



- First ice rink with CO₂ as primary refrigerant in Canada (St Gedeon 2010)



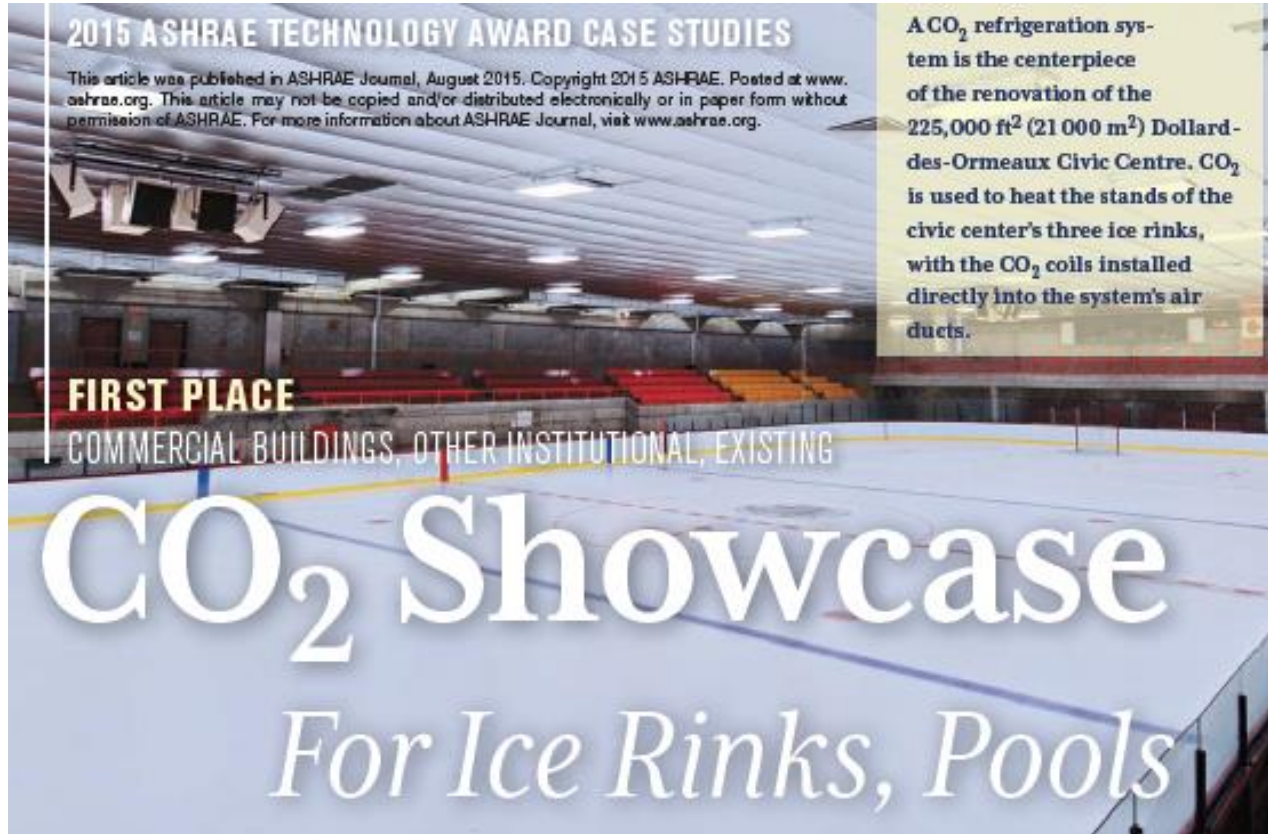
2nd generation CO₂ ice rink



- Skid with integrated receiver tank (3 m³), 7 compressors and heat recovery equipment



2nd generation CO₂ ice rink



- First realized indirect 2nd gen ice rink in Canada with CO₂ as primary refrigerant (DDO, CA/QC, 2012)

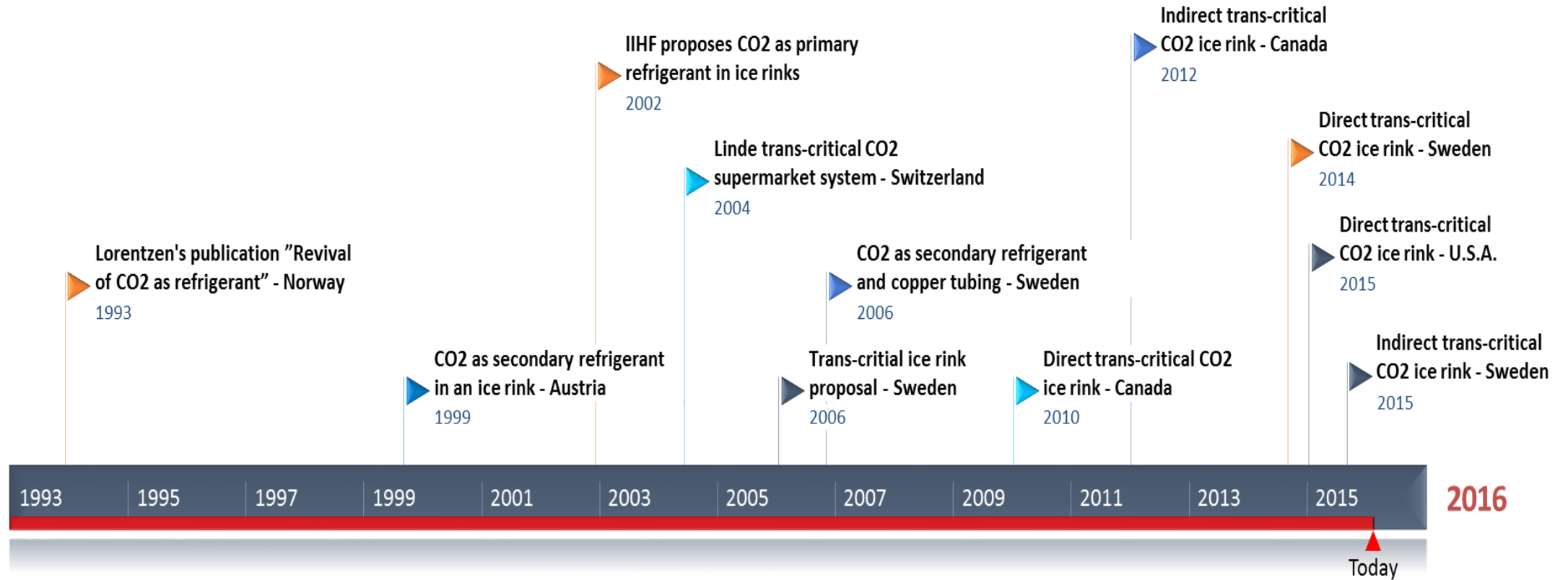


Why did it take so long.....?

- ...the advantages were demonstrated and proven in supermarkets...
- ...heat reclaim is even more important in ice rinks as in supermarkets...
- ...the system solution is the same as with ammonia and R22
- On the other hand:
 - ...the components were primarily developed for smaller systems..
 - ...in 2006 it took 12 compressors to achieve 300 kW (MT)
- So the answer is...
 - ..no ice rink customers were ready to take the risk....
 - ...and/or the somewhat higher cost for installing a trans-critical CO2 system.
- There was simply no demand for these systems until...
 -the confidence in the technology grew...
 -the cost of components/systems decreased which opened the market for the 2nd generation CO2 ice rink refrigeration systems



Time line - CO2 systems in ice rinks



- The steps contributing to the evolution of CO2 in ice rinks



Current status on 2nd generation CO2 ice rinks



- The total number of 2nd generation CO2 ice rinks in operation
 - 25-30 in the world
- Most in North America – 20-25
 - appr. 20 in Canada (most in Quebec)
 - 3 in the US (all in Alaska)
- Europe:
 - 5 in operation in Sweden - 2 more later this season
 - One project in process in Norway
 - "Interest" in Finland and UK



22/08/2016



Jörgen Rogstam





Conclusions



- Ice rinks represent combined cooling and heating demand
- CO₂ has favorable properties for heat reclaim
- Transcritical CO₂ systems primarily evolved in the supermarket industry
- CO₂ as secondary refrigerant has been in use in ice rinks since 1999
 - referred to as 1st generation
- Transcritical CO₂ systems in ice rinks were proposed as from 2002
 - and realized for the first time in 2010
- Today the number of CO₂ ice rinks is growing rapidly
 - Energy system integration with adjacent facilities is an interesting next step in utilizing the reclaimed heat
- Ice rinks will go CO₂ in the future.....!



Thank you for your attention!



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