Chillers for High Ambient Conditions: What Technologies and Fluids?

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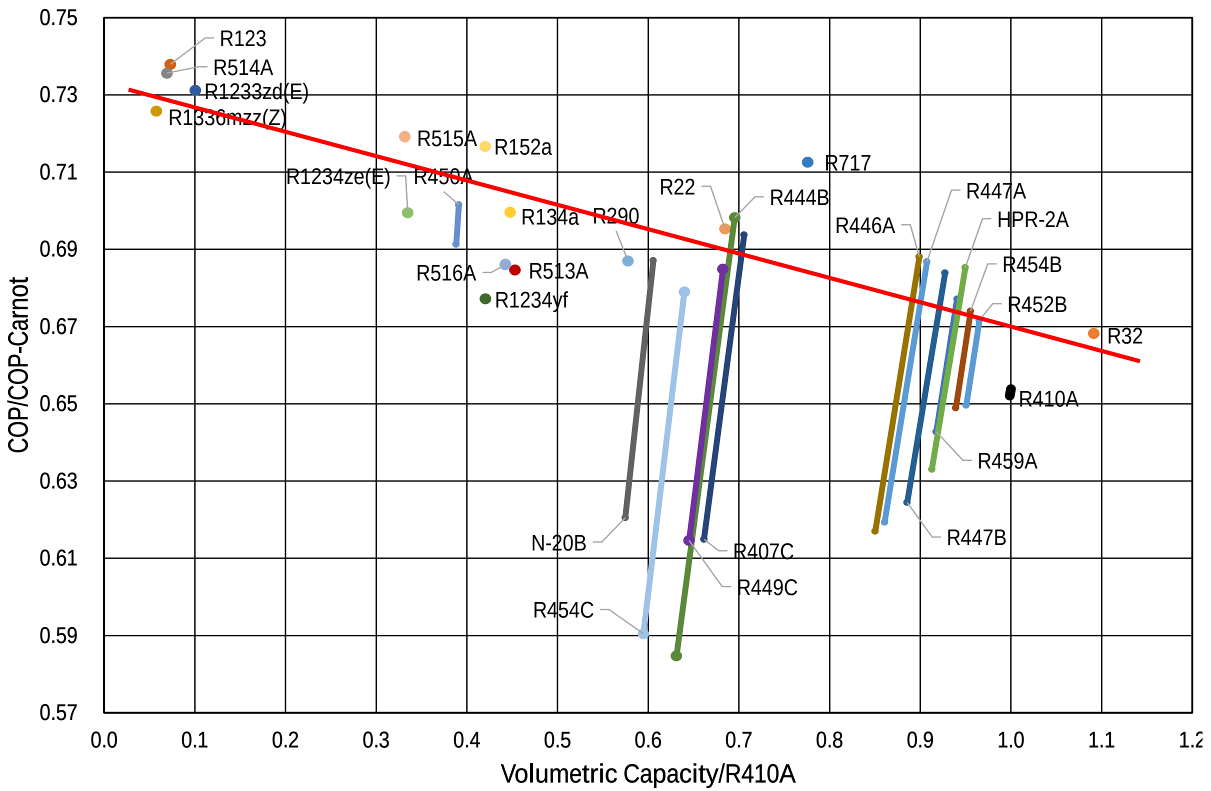
Current used Refrigerants and Chiller Technologies

Typical refrigerants and compressor types depending on cooling capacity				
kW	**R-22**	**R-123**	**R-410A**	**R-134a**
< 400	Scroll	/	Scroll	/
< 1500	Screw	Centri	Screw	Screw
< 6000	Centri	Centri	/	Centri
Up to 20000	Centri	/	/	Centri

Status of Refrigerants					
		R-22	**R-123**	**R-410A**	**R-134a**
		HCFC		**HFC**	
	ODS	**Yes**		**No**	
	GWP	1760	79	1900	1300
Use Today	**Art.2**			X	X
	Art.5	X	X	X	X
Future	**Global**	**Phase Out**		**Phase Down**	

Refrigerants: Cycle efficiency versus Volumetric capacity



Trade-off between initial cost and efficiency:
« Low pressure » fluids tend to have lobetter cycle effciency.
…but need higher volumtric flow, often more expensive.

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Impact of Condensing Mode & Ambient Temperature

Impact of condenser cooling technology →

- Air cooled condenser
- Water cooled condenser
  - Dry cooler
  - Evaporative cooling tower
  - River/Sea water

Condenser cooling	Water Cooling	Reference	
		Dry bulb	Wet bulb
Air	/	+10	/
Water	Dry	+15	/
	Evaporative	/	+12

Impact of:

- Higher ambient temperature.
- Difference between dry and wet bulb

Examples →

	Design conditions (°C) in hottest month (0.4%)			Typical design Condensing temperature (°C)		
	DB	WB	Delta	Air Cooled	Water +dry cooler	Water + Evaporative
Riyad	45.8	22	23.8	55.8	60.8	34
Djeddah	42.6	30.8	11.8	52.6	57.6	42.8
Singapore	33.9	28.2	5.7	43.9	48.9	40.2
Paris	34.0	22.8	11.2	44	49	34.8

Condensing temperature too high for single stage centrifugal compressor

10°C higher condensing temperature results in about 30% higher energy consumption !

Availability of water is critical.

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Safety issues - Specificities of chillers

- Some of the potential alternatives are flammable:
  - Mildly (2L class)
  - …or highly (hydrocarbons)
- Chillers are (relatively) less susceptible to safety issues than some other applications:
  - They are inherently "indirect" systems.
  - Installed in separate machine rooms
  - … or outdoor when air cooled.
- Yet, safety must always be assessed very carefully …and has a cost.

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Choice of Alternative fluids – Specificities of chillers

Heat exchanger technologies:

- Evaporators :
  - D-X evaporators no longer used: lower effciency
  - Mostly shell and tube, flooded or falling film.
- Condenser:
  - In-tube for air cooled
  - Shell and tube with external condensation for water cooled

→ Avoid blends with glide (large performance penalties)

Compact packages, factory built and tested. Low leaks.

High energy input, as cooling capacity is often very large.

Single stage centrifugals not suitable for high condensation (limit ~45°C). Adiabatic coolers can « shave » the hottest days.

Indirect emissions (from energy) highly dominant compared to direct emissions from fluid leaks. Importance of LCCP analysis.

Possible Alternatives

R-410A → R-32 sole alternative without glide. Relatively close, but A2L.

R-22: No single replacement

- o Some hydrocarbons are close, but highly flammable.
- o Ammonia also is close, but toxic, flammable… and rather expensive for chillers.
- o Much of the market likely to shitch to lower pressure fluids

R-134a has alternatives with fairly similar properties:

- o HFO 1234ze or blend 515A (near-zero GWB, but A2L)
- o Blend 513A or 516A (A1, GWP 400 to 600)

R-123 has non-flammable alternatives with near zero GWP and comparable properties:

- o HFO's 1233zd or M1336mzz
- o Blend R514A

Conclusions

- Solutions for chillers exist, even in hot climates.
- Higher ambient temperatures means lower efficiency.
- Not only the ambient « dry » temperature is important. When water is available for cooling, the key parameter is the « wet bulb » temperature.
- Water availability even more important than temperature.
- Life cycle analysis (LCCP) is especially important, at equivalent cost of ownership (initial cost, installation, safety, energy consumption…)

Thank you

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