Large Air Conditioning Plant using Ammonia

A Case Study

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- Description of conventional air conditioning plant
- Description of NH_3 based chiller plant
- Plant room design for NH_3
- System comparison – HFC versus NH_3
- Conclusion

Introduction

Ammonia

•Natural refrigerant (for over 130 years)

•Very favourable thermodynamic and transport properties

•ODP and GWP are zero

⇒ Ammonia has in recent years gradually and increasingly displaced CFC's, HCFC's and HFC's in applications traditionally thought unsuitable for NH_3

This case study provides a broad comparison between a conventional air conditioning system and an equivalent system using NH_3 as working fluid.

The building

•Typical inner city, multi-storey office building

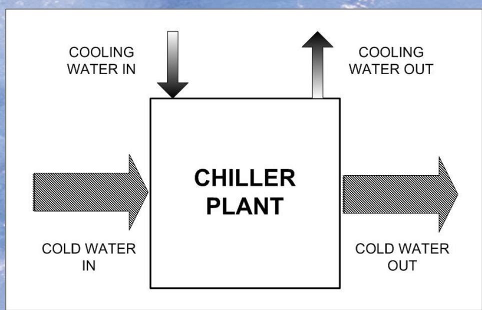
•Air conditioning concept is a reticulated chilled water plant

•The condenser is water cooled

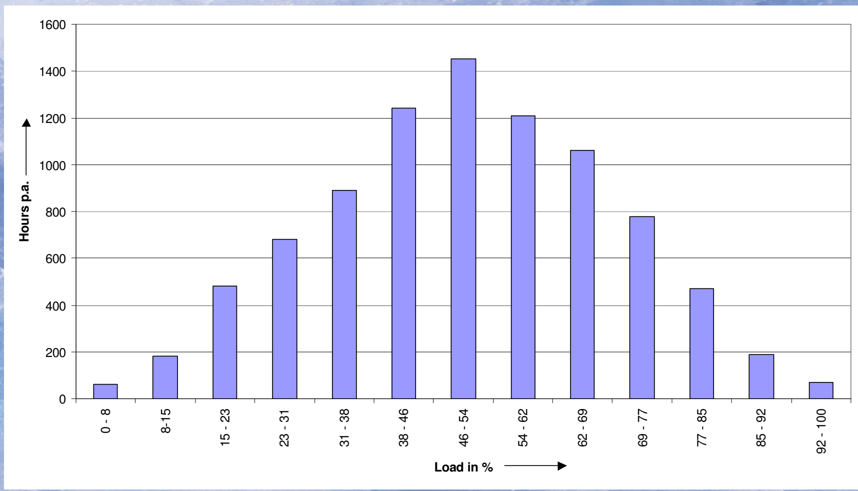
•The plant room is situated in the basement

•The calculated heat load is maximum 6500 kW

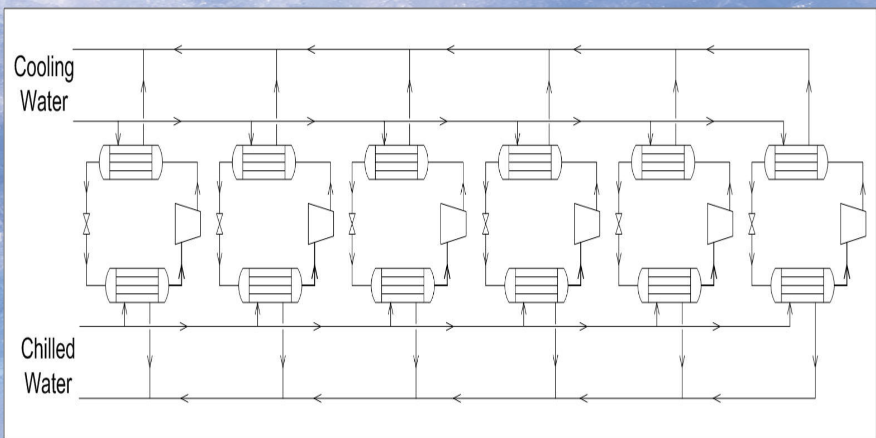
•Two thirds of the operating hours are in the capacity range 30 % to 70 %



Heat load profile



Conventional HFC air conditioning plant



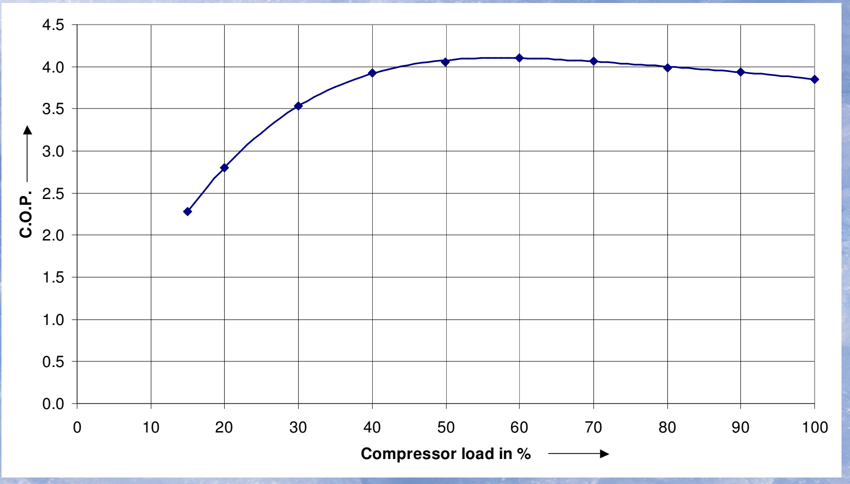
Full load HFC chiller unit performance data

Refrigerant	R404A
Chilled Water entering/leaving temperatures, °C	12.0/6.0
Chilled Water pressure drop, kPa	59
Cooling capacity, kW	1069.1
Compressor shaft power, kW	277.7
Evaporating temperature, °C	2.9
Evaporating fouling factor, m^2K/W	0.0002
Suction line temperature drop, K	0.5
Cooling Water entering/leaving temperatures, °C	29.5 / 35.0
Cooling Water pressure drop, kPa	51
Condensing temperature, °C	38.7
Condensing fouling factor, m^2K/W	0.0002
Discharge line temperature drop, K	0.2
Heat rejection, kW	1331.6
Coefficient of Performance	3.85

Full load HFC chiller unit performance data for unit selected for max. C.O.P.

Refrigerant	R404A
Chilled Water entering/leaving temperatures, °C	12.0/6.0
Chilled Water pressure drop, kPa	56
Cooling capacity, kW	1154
Compressor shaft power, kW	262.7
Evaporating temperature, °C	4.0
Evaporating fouling factor, m^2K/W	0.0002
Cooling Water entering/leaving temperatures, °C	29.5 / 35.0
Cooling Water pressure drop, kPa	38
Condensing temperature, °C	36.5
Condensing fouling factor, m^2K/W	0.0002
Heat rejection, kW	1411
Coefficient of Performance	4.39

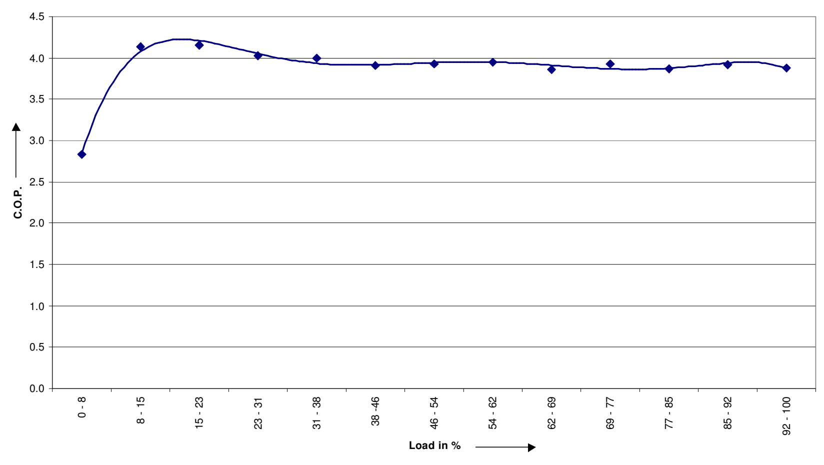
Part load HFC unit performance



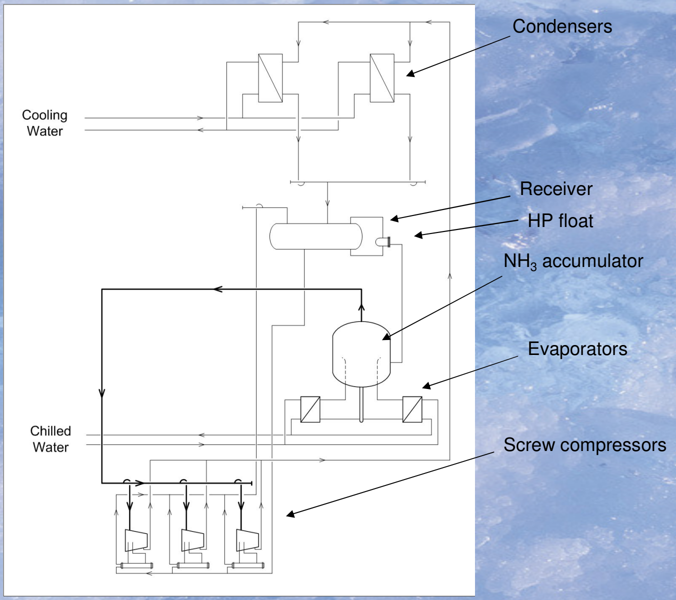
Overall HFC liquid chilling plant performance

Load [MW]	Hours p.a. [h]	Cooling Energy [MWh]	Compressor shaft power [MW]	Compressor shaft energy [MWh]
6.0 - 6.5	70	438	1.611	112.8
5.5 - 6.0	190	1093	1.466	278.5
5.0 - 5.5	470	2468	1.357	637.6
4.5 - 5.0	780	3705	1.208	942.2
4.0 - 4.5	1060	4505	1.100	1166.0
3.5 - 4.0	1210	4538	0.948	1148.0
3.0 - 3.5	1450	4713	0.826	1198.0
2.5 - 3.0	1240	3410	0.703	871.8
2.0 - 2.5	890	2003	0.563	501.0
1.5 - 2.0	680	1190	0.434	295.0
1.0 - 1.5	480	600	0.301	144.6
0.5 - 1.0	180	135	0.182	32.7
0.0 - 0.5	60	15	0.089	5.3
Σ	8760	28813	-	7334

Overall HFC plant C.O.P. as a function of load percentage



Chiller plant employing NH_3 refrigerant



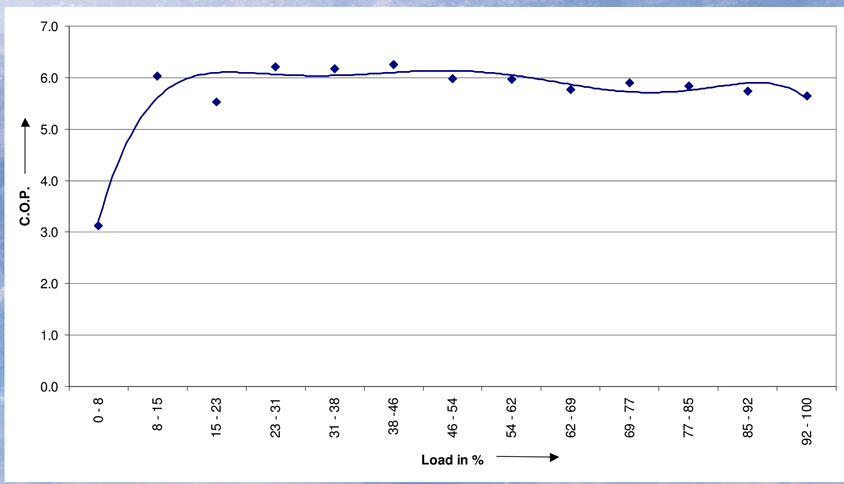
Full load NH_3 plant performance data

Refrigerant	R717
Chilled Water entering/leaving temperatures, °C	12.0/6.0
Chilled Water pressure drop, kPa	28
Cooling capacity, kW	6540
Compressor shaft power, kW	1156.8
Evaporating temperature, °C	3.0
Evaporating fouling factor, m^2K/W	0.000035
Suction line temperature drop, K	0.5
Cooling Water entering/leaving temperatures, °C	29.5 / 35.0
Cooling Water pressure drop, kPa	10
Condensing temperature, °C	36.6
Condensing fouling factor, m^2K/W	0.00002
Discharge line temperature drop, K	0.2
Heat rejection, kW	7576
Coefficient of Performance	5.65

Overall NH_3 liquid chilling plant performance

Load [MW]	Hours p.a. [h]	Cooling Energy [MWh]	Compressor shaft power [MW]	Compressor shaft energy [MWh]
6.0 - 6.5	70	438	1.108	77.6
5.5 - 6.0	190	1093	1.002	190.4
5.0 - 5.5	470	2468	0.9	423.0
4.5 - 5.0	780	3705	0.806	628.7
4.0 - 4.5	1060	4505	0.736	779.7
3.5 - 4.0	1210	4538	0.629	760.7
3.0 - 3.5	1450	4713	0.543	787.6
2.5 - 3.0	1240	3410	0.44	545.6
2.0 - 2.5	890	2003	0.365	324.5
1.5 - 2.0	680	1190	0.282	191.6
1.0 - 1.5	480	600	0.226	108.5
0.5 - 1.0	180	135	0.125	22.4
0.0 - 0.5	60	15	0.079	4.8
Σ	8760	28813	-	4845

Overall NH_3 plant C.O.P. as a function of load percentage



Plant room design

The preferred plant room location for the ammonia based liquid chiller is the roof top of the building. The reasons for this are:

- Access easily controlled by a key holder and an “access to work” system.
- Relatively easy to design chiller/condenser combination which will fit within the same footprint as the cooling tower.
- A release of ammonia including a major spill of ammonia liquid is easier to manage provided the building in question is taller than neighbouring buildings.

Plant room design

- Basement location as in this case probably the most difficult
- Self closing sealed doors
- Emergency escape to fresh air or to corridor leading to fresh air
- No other services than refrigeration plant in plant room
- No storage of combustible materials in plant room
- Electrical supply able to be isolated from outside the plant room
- Automatic gas detection
- Engine room ventilation – normal running and emergency
- Emergency exhaust duct termination
- Emergency discharge duct material

Plant room design

- Fan location – plant room air pressure
- Refrigerant charge minimization
- Water cooled oil coolers versus refrigerant cooled
- Emergency ventilation; 500 ppm ⇒ alarm; 30,000 ppm ⇒ isolation
- Emergency ventilation rate not for O H & S reasons
- Detection for long (25 ppm) and short term (35 ppm) exposure levels
- Normal practice for alarm levels in NH_3 plant rooms in Australia
- Rapid clearance of plant room NH_3 atmosphere in emergencies
- Containment of ammonia release; scrubbers, citric acid
- Percentage charge lost in the case of major liquid release

System comparison

System	Conventional system comprising six off HFC liquid chilling packages with screw compressors	NH_3 based liquid chilling system with three screw compressors
Full load C.O.P.	3.85	5.65
Annual C.O.P.	3.93	5.95
Annual electricity cost, k$	587 (1)	388 (1)
Capital cost, k$	1,380 (2)	1,450 (2)

1) Unit electricity cost $80/MWh
2) As of November 2005

Conclusion

- Plant room design – HFC versus NH_3
- Unobstructed escape routes – lack of same eliminates NH_3 option
- Charge cost of HFC plant 6-7 times higher than NH_3
- Change of image by factory packaging of NH_3 systems, automatic oil recovery systems, low NH_3 charges, reduced overall NH_3 plant dimensions, improvements in sealing technology, gas detection etc.
- Increased production numbers of factory assembled NH_3 packages ⇒ lower capital costs
- NH_3 cycle efficiency better than HFC due to more favourable refrigerant properties
- Barriers: toxicity, odour, image, capital costs, maintenance intensity