Trans-critical CO_2
an index of possibilities

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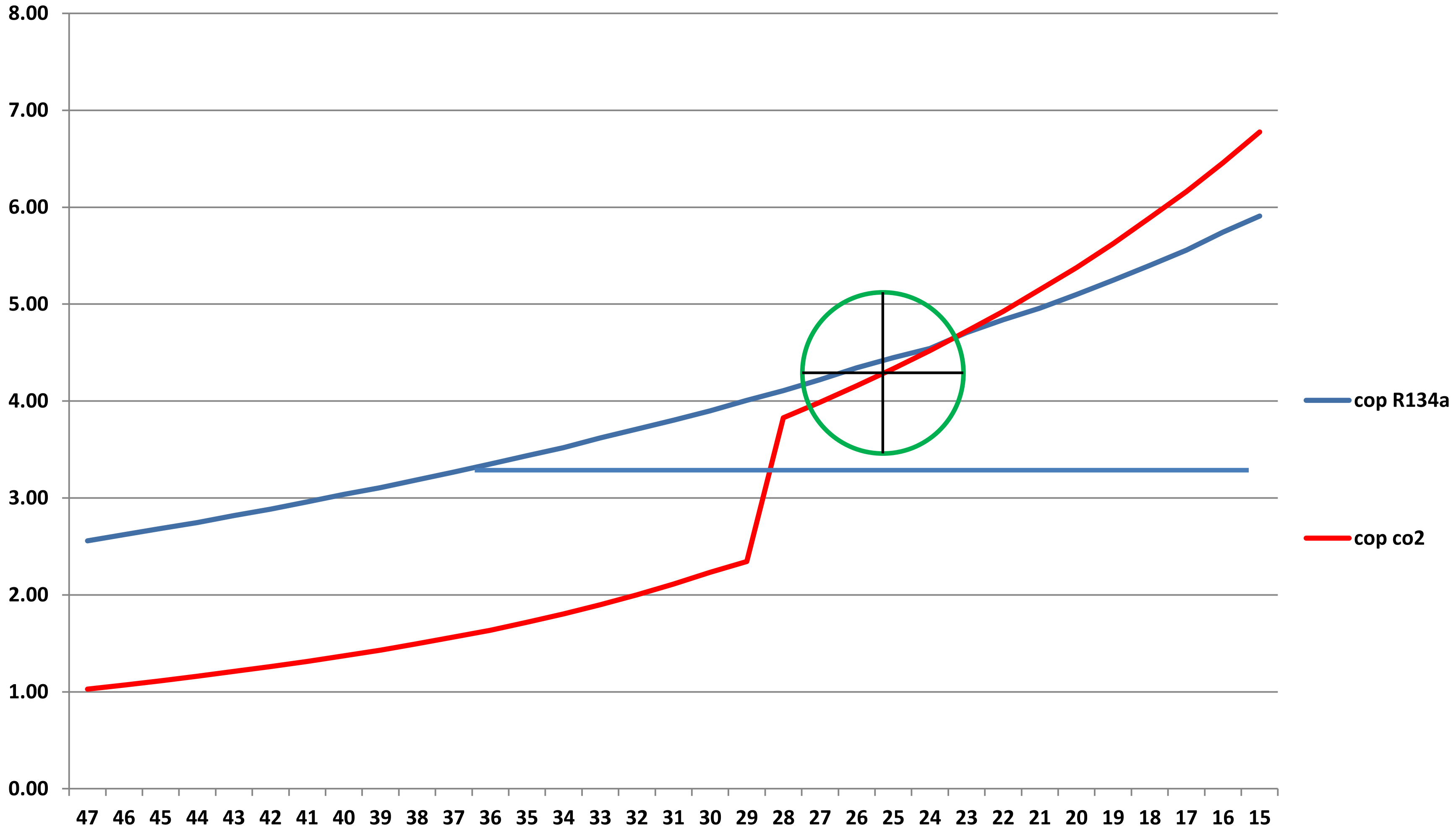
TODAYS TOPICS

- Performance comparison - R404a / cascade / trans-critical
- Trans critical compressor performance with seasonal change
- Two stage CO_2 System cascade v compound
- Parallel compression
- Ejector systems
- CO_2 direct expansion for air conditioning
- High demand cooling systems

Performance comparison – R134a -R404a / cascade / trans-critical

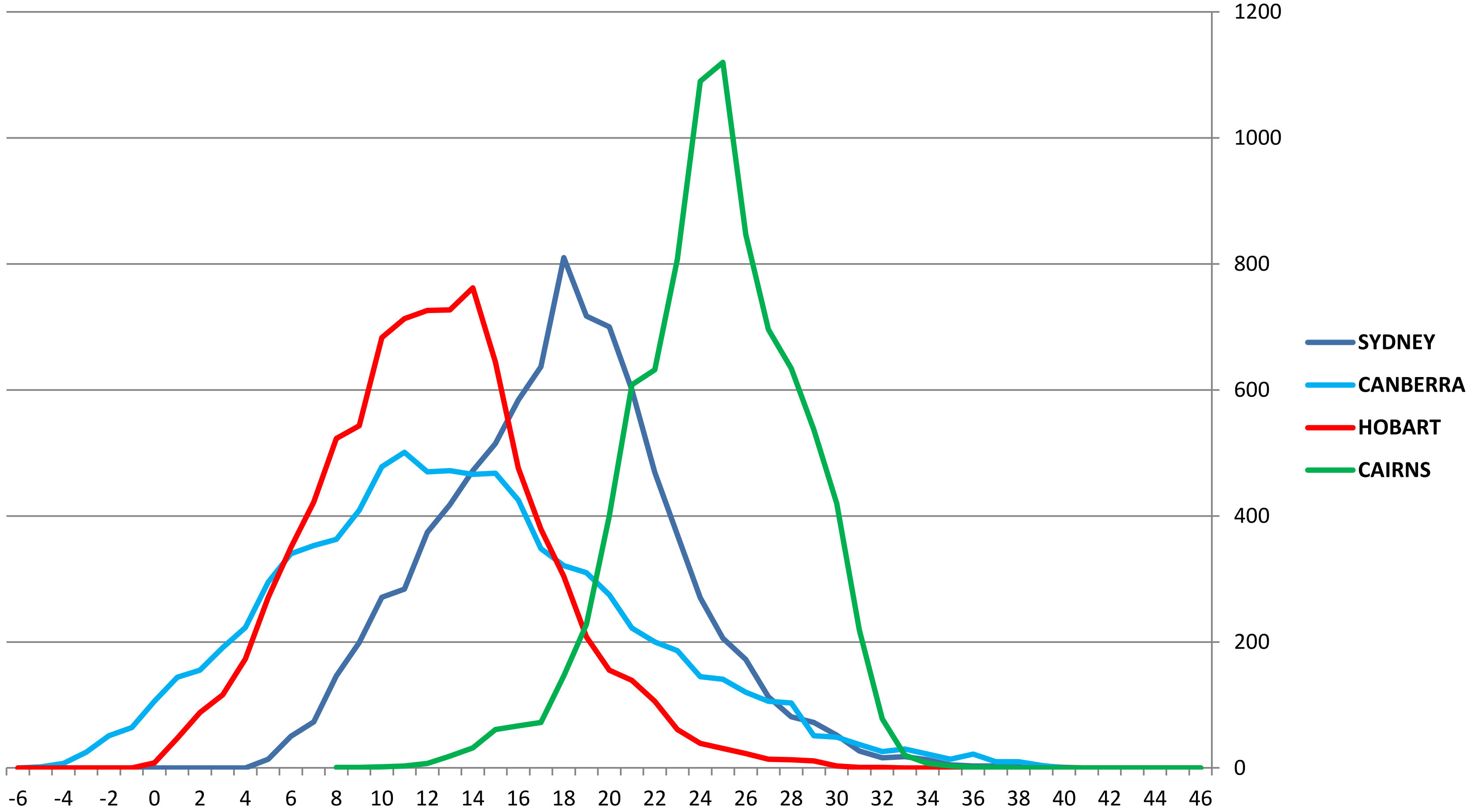
- straight R404a single stage DX system use 20.6% more power on a freezer then an R404a / CO_2 cascade systems (light & easy project 2006)
- R134a use 5% less power than R404a in cool room application
- R134a /CO_2 cascade freezer will use (approximately) 25% less power then R404a . (75% of the power is used by the high stage)
- CO_2 / CO_2 cascade freezer will use >40% less power than a R134a / CO_2 cascade freezer if the high stage CO_2 system never runs in the supercritical phase
- CO_2 cool room compressor will use 35% less power than R134a cool room if the CO_2 compressor never runs in the super critical phase
  (-4sst with 45deg C sct for R134a 25 deg C sct for CO_2)
- A CO_2 / CO_2 / NH_3 freezer / cool room system uses 50% less power than a conventional R404a system of the same capacity and duty, if it is done in the best possible way. (using multiple interconnected and optimized systems).

COP R134a v CO_2 with changing condensing temperatures



-7sst with decreasing condenser outlet temperatures

Trans-critical compressor performance @ different ambient conditions

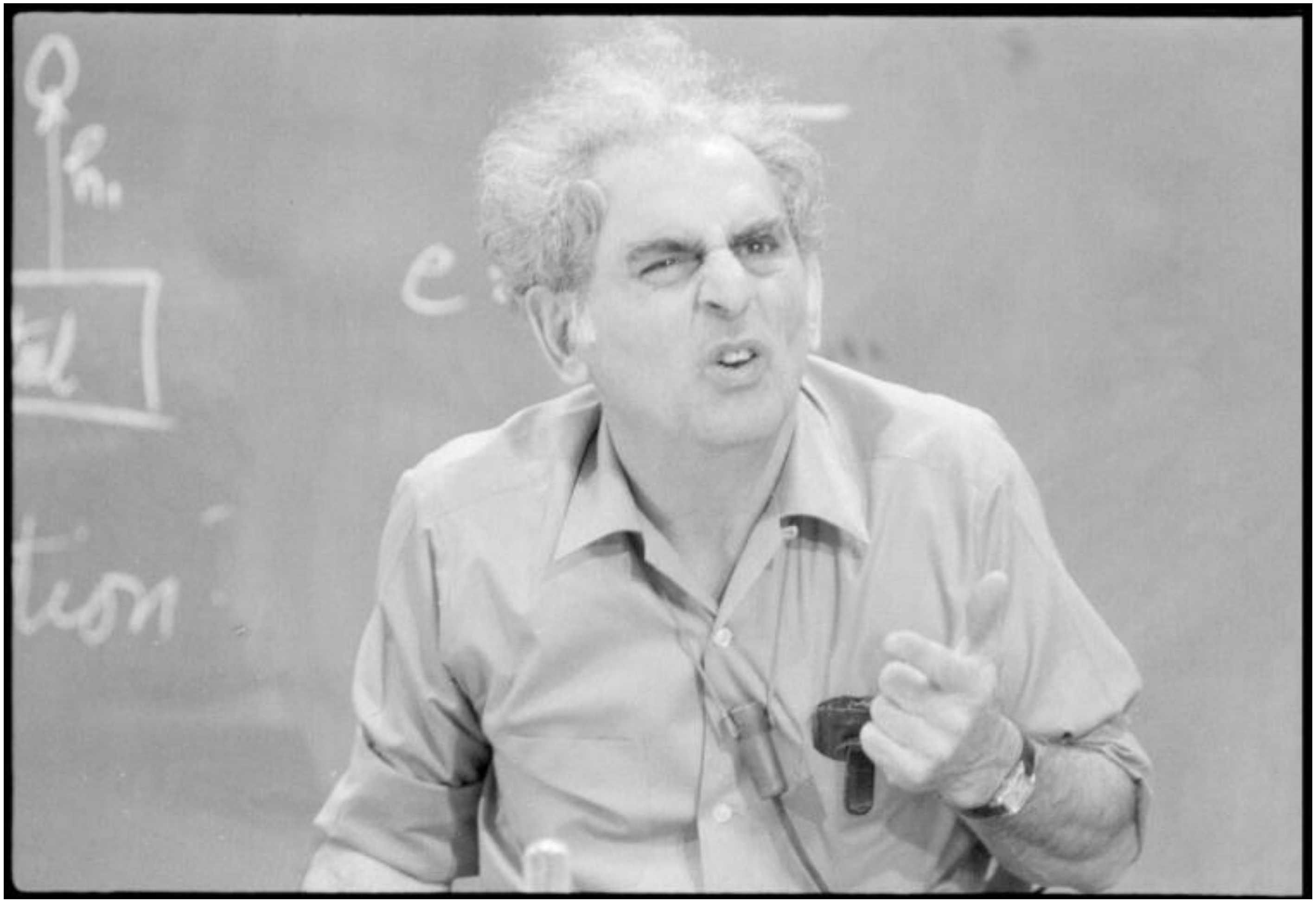


Total Hours in one year at each temperature for 4 Australian east coast cities @ Air port weather stations

Trans-critical compressor performance @ different ambient conditions

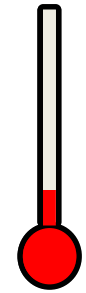
- Base line COP R134a 2.92 -4sst & 45 sct
- CO_2 compressor COP 4.73 -4sst & 20 sct
- CO_2 compressor COP 3.54 -4sct & 25 sct
- CO_2 compressor COP 2.47 -4sct & 30 sct ?
- CO_2 compressor COP 1.92 -4sst & 35 gas out
- CO_2 compressor COP 1.51 -4sst & 40 gas out
- CO_2 compressor COP 1.19 -4sst & 45 gas out
- CO_2 compressor COP 0.83 -4sst & 50 gas out

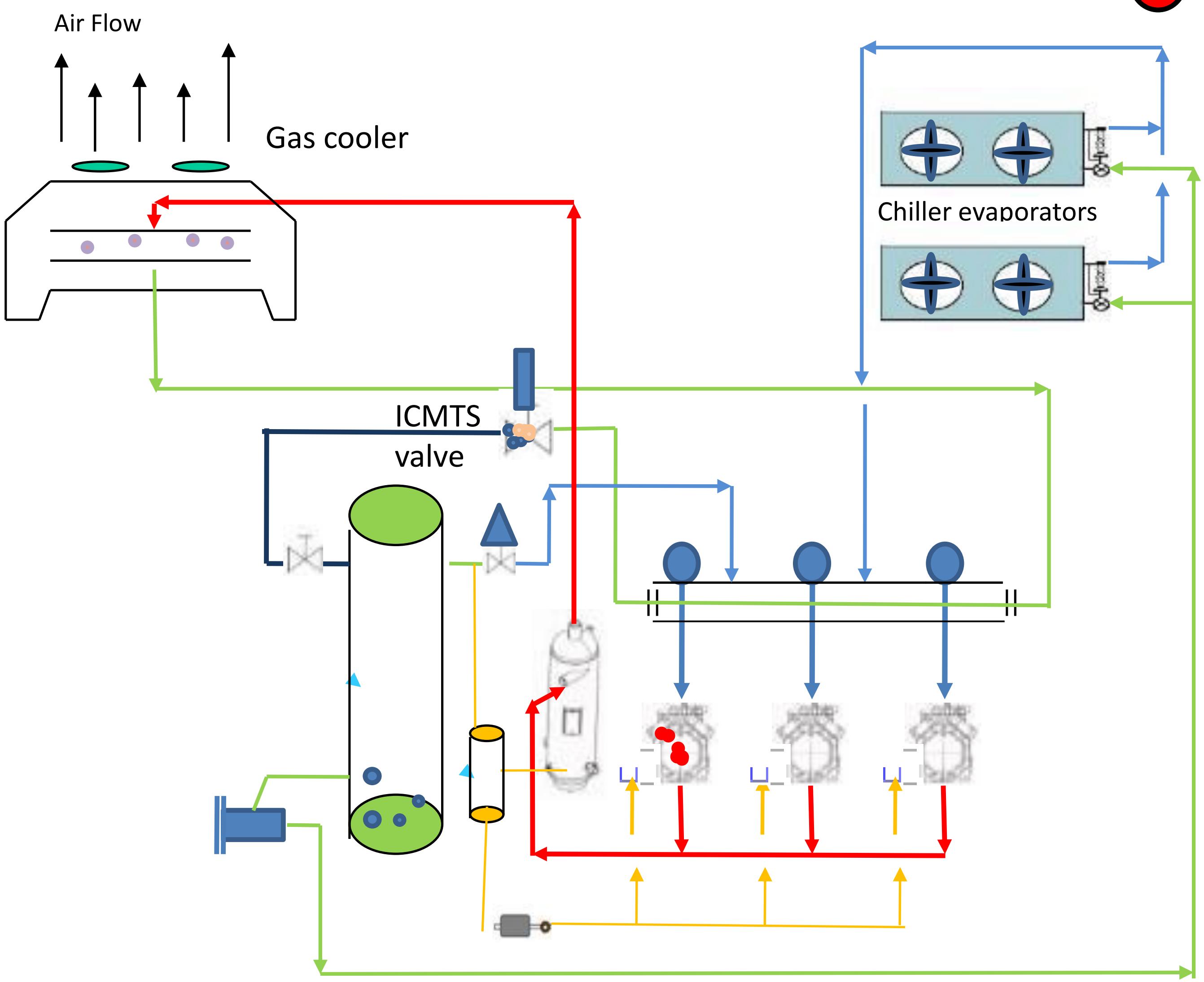
Why is it so



professor julius sumner miller

CO_2 system low ambient temp

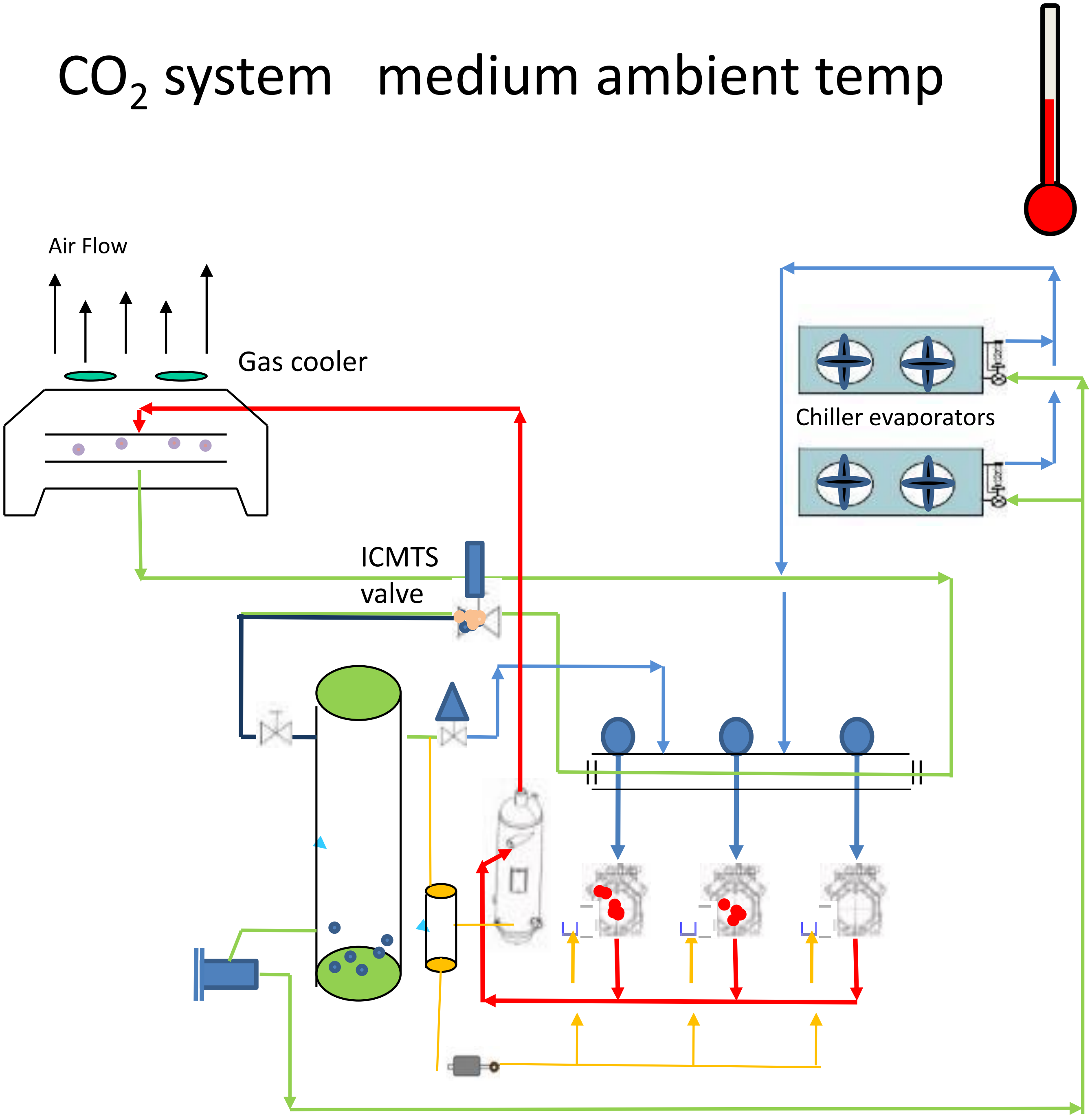




Control panel

Ambient temp	20 C
Gas cool exit temp	25 C
Gas cooler exit refrigerant	liquid
Gas cooler Fan speed %	60%
Discharge pressure	5800 kPa
Suction pressure	3000 kPa
Receiver pressure	3300 kPa
Receiver liquid level	50%
Discharge temp	60.2 c
Cool room temp	3 c
Comp 1 running	Yes
Cooling capacity	23.5 kw
Power consumption	4.7 kw
COP	5.01 : 1
Comp 2 running	no
Cooling capacity	
Power consumption	
COP	
Comp 3 running	no
Cooling capacity	
Power consumption	
COP	
Total amps	9.16
Total cooling capacity	23.5 kw
COP	5.01 : 1

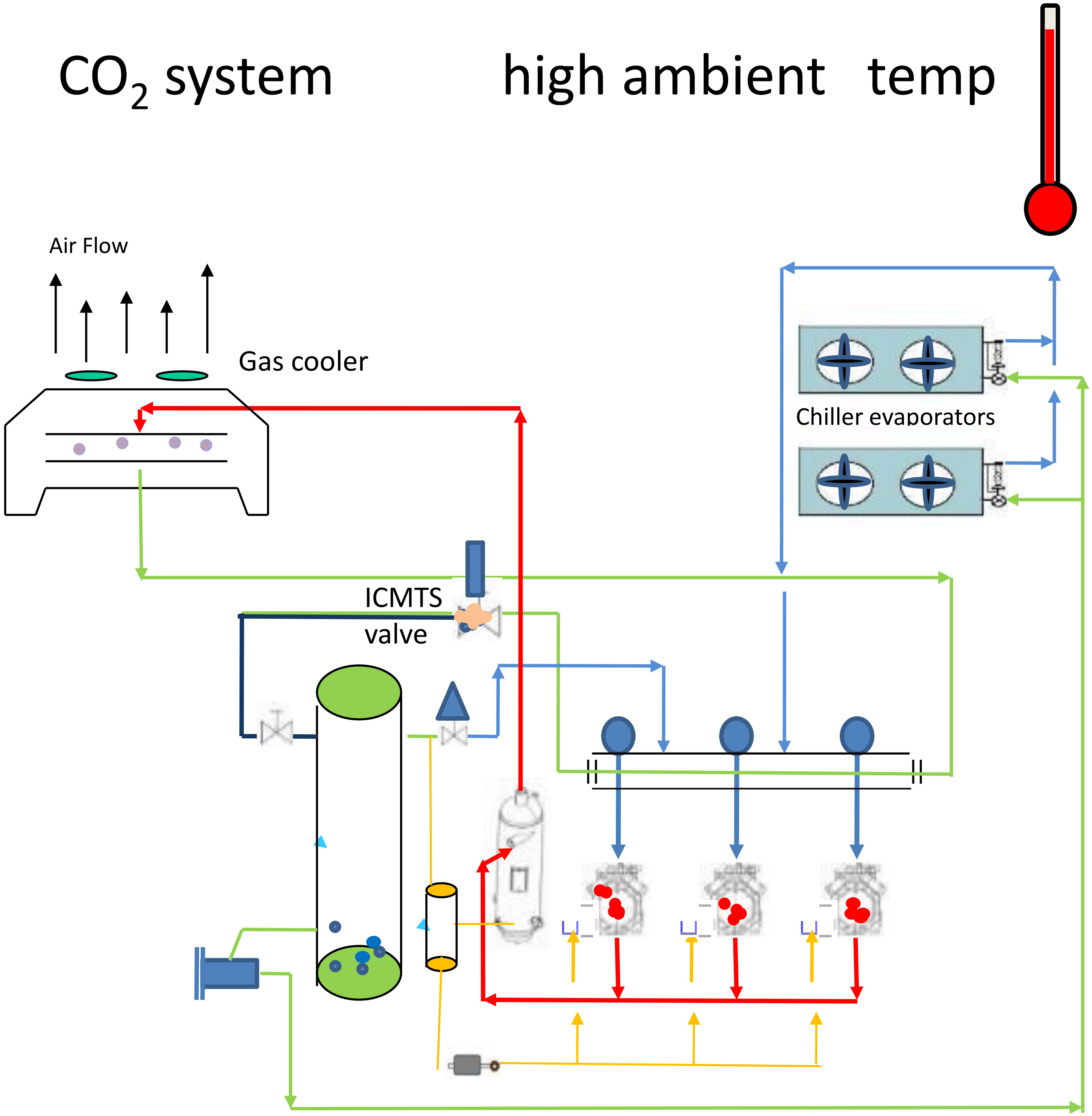
CO_2 system medium ambient temp



Control panel

Ambient temp	34 C
Gas cool exit temp	35 C
Gas cooler exit refrigerant	gas
Gas cooler Fan speed %	100%
Discharge pressure	8600kPa
Suction pressure	3000 kPa
Receiver pressure	3300 kPa
Receiver liquid level	30%
Discharge temp	102.6c
Cool room temp	3 c
Comp 1 running	Yes
Cooling capacity	15.2 kw
Power consumption	7.41kw
COP	2.05: 1
Comp 2 running	Yes
Cooling capacity	15.2 kw
Power consumption	7.41kw
COP	2.05: 1
Comp 3 running	no
Cooling capacity	
Power consumption	
COP	
Total amps	25.6
Total cooling capacity	30.2 kw

CO_2 system high ambient temp



Control panel

Ambient temp	49 C
Gas cool exit temp	50 C
Gas cooler exit refrigerant	gas
Gas cooler Fan speed %	100%
Discharge pressure	10400 kPa
Suction pressure	3000 kPa
Receiver pressure	3300 kPa
Receiver liquid level	10 %
Discharge temp	124.5 c
Cool room temp	3 c
Comp 1 running	Yes
Cooling capacity	7.67 kw
Power consumption	8.59 kw
COP	0.89 : 1
Comp 2 running	Yes
Cooling capacity	7.67 kw
Power consumption	8.59 kw
COP	0.89 : 1
Comp 3 running	Yes
Cooling capacity	7.67 kw
Power consumption	8.59 kw
COP	0.89 : 1
Total amps	43.65
Total cooling capacity	23.01 kw

Two stage CO_2 System cascade v compound

Compound system have more than one compression stage using the same refrigerant and oil, in a pipe network that will allow the gas and oil to travel to any part of the system.

Originally designed for optimal energy efficiency across multiple temperatures .

Slightly Better COP than cascade and potentially less expensive to build

More issues with oil systems .
low stage will generally circulate less oil than the high stage , so low stage compressors need to be modified by the manufacturer to increase the oil carry over so they don't fill up with oil. (otherwise they overfill with oil and smash up the piston rod assemblies)

This results in greater oil volume in circulation and high fowling factors in evaporators (drop in heat transfer)

If you have a leak you can loose the lot.

Two stage CO_2 System   cascade   v   compound

Cascade system use multiple refrigerants in separate refrigeration systems tied together with a heat exchanger to achieve the result.

The refrigerant can be optimized for the application so performance can be very good.   (CO_2 on both stages works well)

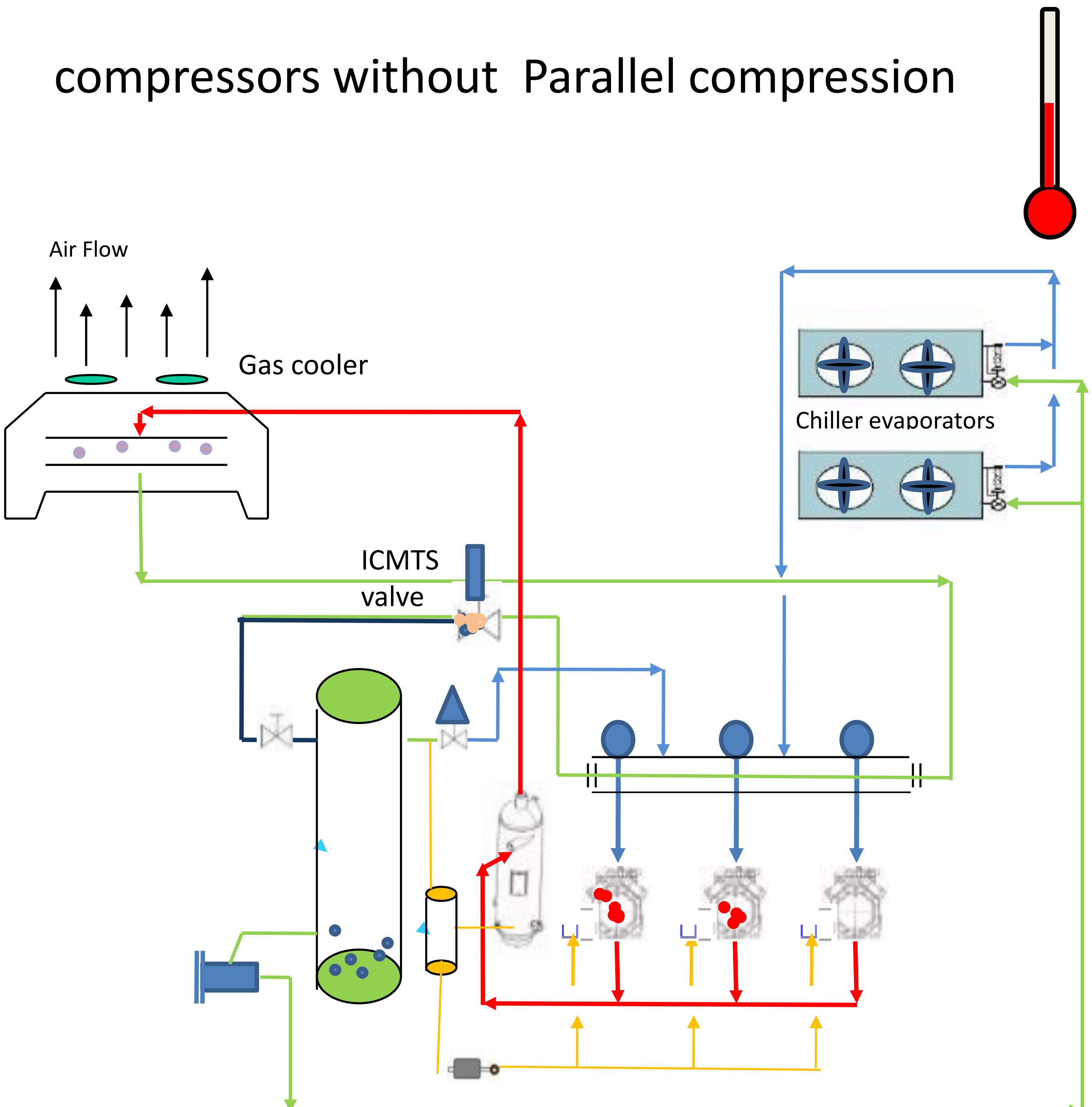
Easier to understand for service technicians

Slightly less efficient than compound systems due to the heat exchangers overlapping temperatures

Less problems with oil

Less exposure to gas loss with two separate gas charges

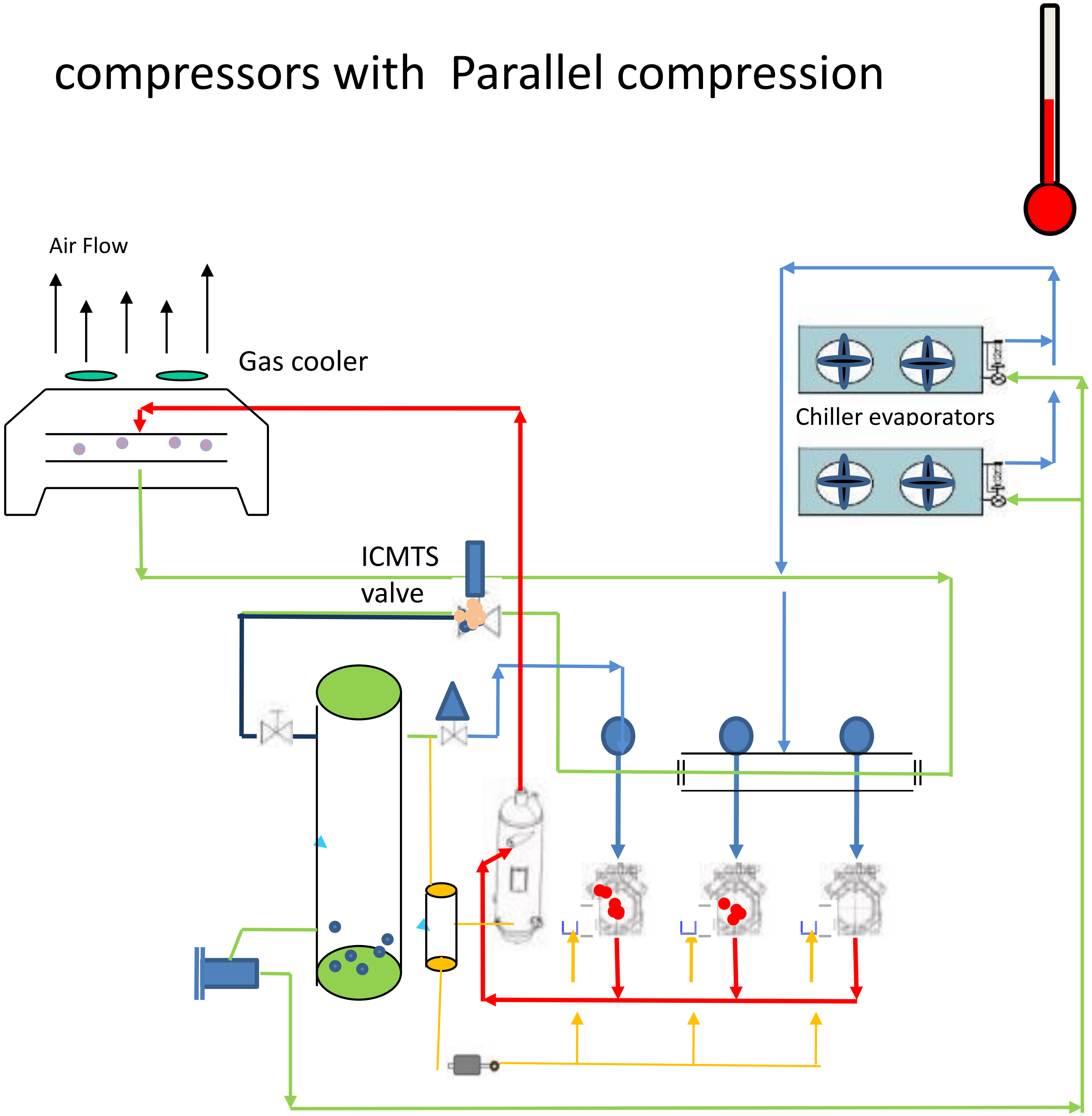
compressors without Parallel compression



Control panel

Ambient temp	39 C
Gas cool exit temp	40 C
Gas cooler exit refrigerant	gas
Gas cooler Fan speed %	100%
Discharge pressure	9000 kPa
Suction pressure	2800 kPa
Receiver pressure	3800 kPa
Receiver liquid level	20 %
Discharge temp	108 c
Cool room temp	3 c
Comp 1 running	Yes
Compressor capacity	27.92 kw
Power consumption	21.27kw
Evaporator capacity	14.7 kw
COP	1.31 : 1
Comp 2 running	Yes
Cooling capacity	27.92 kw
Power consumption	21.27kw
Evaporator capacity	14.7 kw
20 kw	
COP	1.31 : 1
Comp 3 running	no
Cooling capacity	0 kw
Power consumption	0 kw
Total amps	72.4
Total compressor capacity	55.84 kw
Total evaporator capacity	29.4 kw
Total COP	1.31 : 1

compressors with Parallel compression



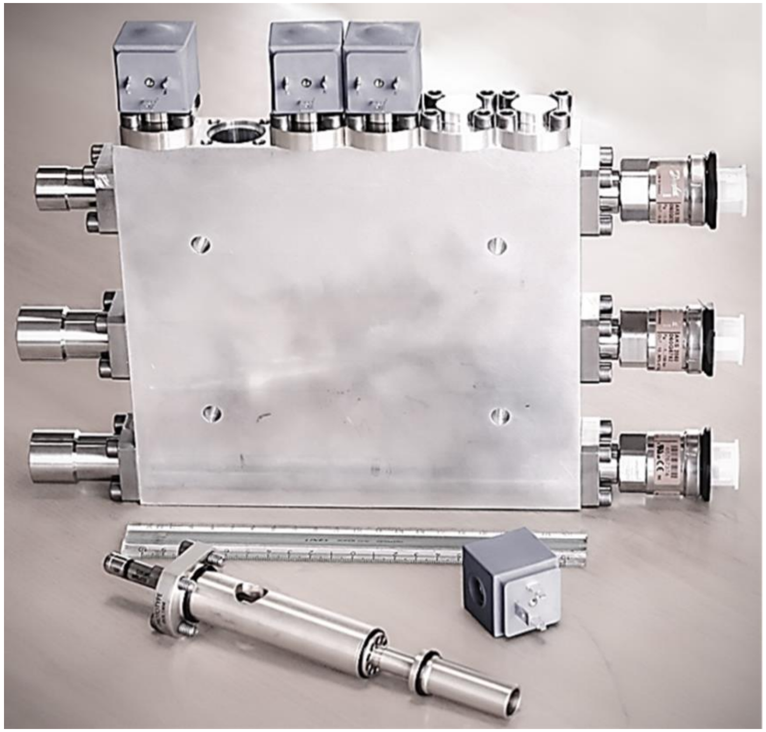
Control panel

Ambient temp	39 C
Gas cool exit temp	40 C
Gas cooler exit refrigerant	gas
Gas cooler Fan speed %	100%
Discharge pressure	9000 kPa
Suction pressure	2800 kPa
Receiver pressure	3800 kPa
Receiver liquid level	20 %
Discharge temp	108 c
Cool room temp	3 c
(smaller compressor selected)	
Comp 1 running	Yes
Compressor capacity	20.7 kw
Power consumption	11.1kw
COP	1.86 : 1
Comp 2 running	Yes
Cooling capacity	29.1kw
Power consumption	21.27kw
COP	1.37 : 1
Comp 3 running	no
Cooling capacity	0 kw
Power consumption	0 kw
Total amps	56.04
Total compressor capacity	49.8
Total evaporator capacity kw	29.1
Total cop	1.54 : 1

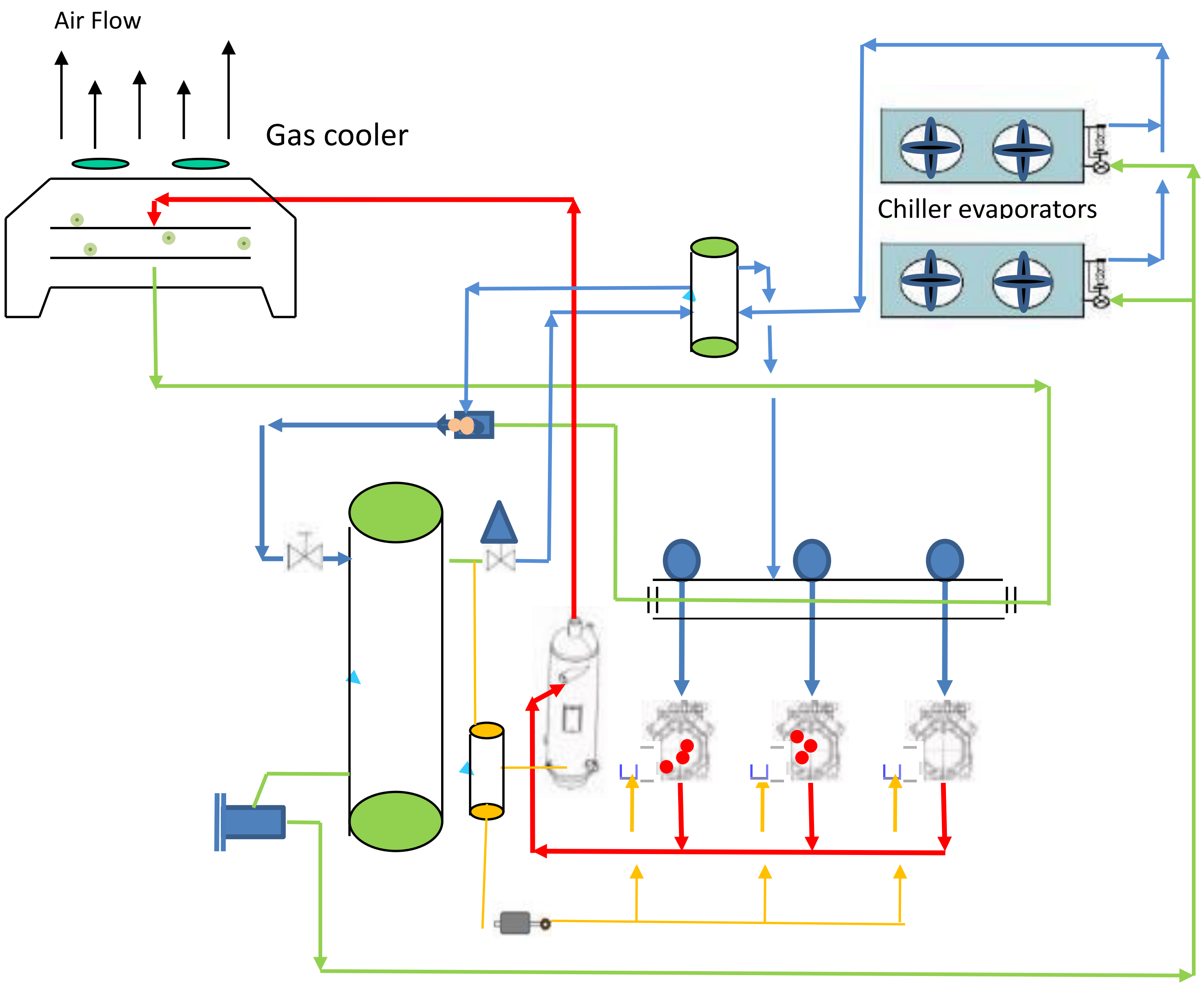
16.5% increase but still very poor

Ejector systems

Can we improve the operation and energy consumption of a CO_2 refrigeration system by including a ejector in place of the ICMTS valve ?



CO_2 system with ejector



Pros and cons

Increase in compressor performance due to slightly higher suction pressure (5%)

Possible to run a flooded evaporator which increases the evaporator performance

More complexity
More parts

many many design options

This technology is still evolving but will be a standard item in the future

Doesn't add to the performance when the condensing temperature is low

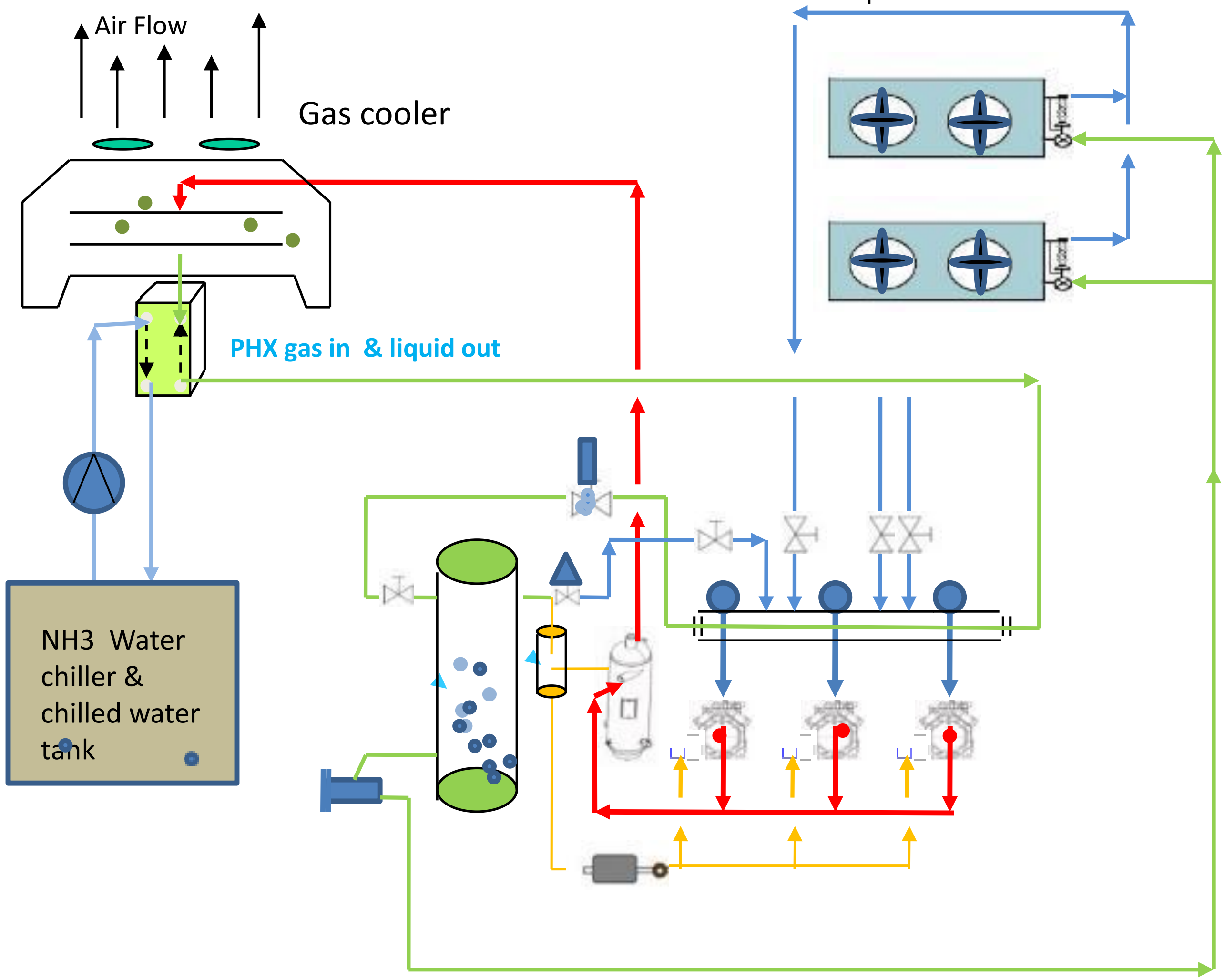
Air conditioning with Trans critical CO_2

- 40 year old R22 plants provide a COP OF 4:1
- We generally operate air conditioning in warm weather
- Trans critical CO2 compressor system with technology that allows it to run sub critical @ +5.5sst & +25 condensing have a COP of 5.65 :1
- evaporative condensers design for Sydney is 35 deg C outlet temperature which would be a COP of 3 :1
- At 45 deg gas cooler (air cooled) exit the COP is 1.8 :1
- Clearly it may be convenient to include the A/C system , but its not always the best solution to run a system that uses twice the power of the old one we left behind.
- An ammonia chiller with operating conditions of +1 sst / 35sct chilling water will have a COP OF 5.5 : 1 (Open drive piston compressor)

CO_2 into PHX
40 deg C as gas

CO_2 out of PHX
25 deg C liquid

CO_2 system with high demand cooling for hot weather



Control panel

Ambient temp	39 C
Gas cool exit temp	40 C
Gas cooler exit refrigerant	gas
Gas cooler Fan speed %	100%
Discharge pressure	5800 kPa
Suction pressure	3000 kPa
Receiver pressure	3300 kPa
Receiver liquid level	20 %
Discharge temp	65 c
Cool room temp	3 c
Comp 1 running	Yes
Compressor capacity	23.5 kw
Power consumption	4.7kw
COP	5.01: 1
Comp 2 running	Yes
Compressor capacity	23.5kw
Power consumption	4.7kw
COP	5.01 : 1
Comp 3 running	no
NH_3 Compressor with VSD	
Cooling capacity	18.85kw
Power consumption	1.77 kw
COP	10.64 : 1
(+15SST & +35SCT)	
Total compressor capacity	47 KW
Total power consumption	11.17kw
Total cop	4.2 : 1

Note - Ammonia chiller only runs in hot weather COP @ 20 Ambient 5 : 1

CO_2 system with high demand cooling for hot weather

F.MAYER IMPORTS PTY LTD
IMPORTER - FOOD SPECIALTIES

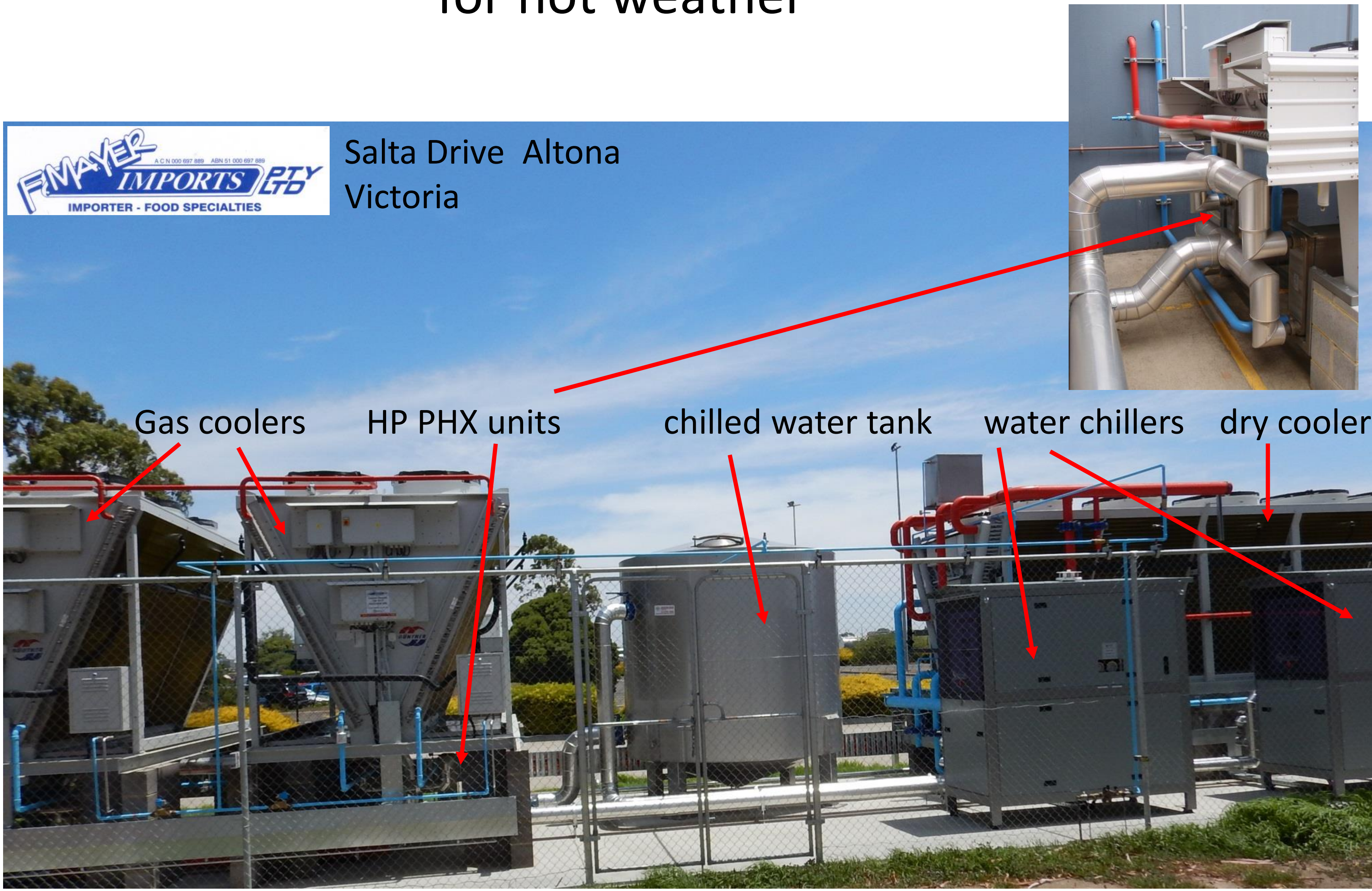
Salta Drive Altona
Victoria

EQUIPMENT
Designed & built by

Strathbrook
INDUSTRIAL SERVICES

Warm glycol defrosting
from low stage heat rejection

CO_2 system with high demand cooling for hot weather



CO_2 system with high demand cooling for hot weather

Ammonia chiller package

Designed and built by Strathbrook INDUSTRIAL SERVICES

weatherproof design , optional heat recovery , Danfoss controls, valves & VSD , self aliening coupling , fully safety system , easy to understand piping arrangement

250kW cooling capacity

+15 SST / +35 SCT

COP > 10 : 1

Refrigerant charge 4.9kg

Oil charge 7kg

52kW per kg of ammonia

- Automatic oil return
- Unloading plus VSD operation
- Ammonia gas sensor
- Anti freeze and flow safety controls

Thankyou for your attention