Indirect Evaporative Cooling (IEC) may have a major place in future air-conditioning

AIRAH

RENEWABLE HEATING AND COOLING FORUM 2019
December 3 • Canberra

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What is Indirect Evaporative Cooling?
Why is it important?

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1. What is Indirect Evaporative Cooling (IEC)? – IEC_R*
2. Energy efficient solution to air conditioning delivering high COP.
3. Eliminates the limitation of (*direct*) evaporative cooling - DEC.
4. Water is the refrigerant.
5. Compressor not necessarily required.
6. Simple concept - long life, low maintenance.
7. Small compressor added for humid conditions. – IEC_{VR}#
8. Mostly relies on the evaporation of water to provide cooling.
9. Great potential to reduce peak demand.
10. Sustainable system.

*IEC_R = indirect evaporative cooling with energy recovery.

IEC_{VR} = indirect evaporative cooling with vapour compression and energy recovery.

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The future of IEC in airconditioning and cooling

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1. The presentation will show that many people and organisations have contributed to the development of IEC.

2. Many ideas have been and are still emerging.

3. The interest in IEC is increasing exponentially

4. The future of IEC seems to be with mainstream airconditioning and cooling.

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Who are the Indirect Evaporative Cooling developers?

1. The researchers, developers, commercial risktakers are many.

2. Two pioneers are *Donald Pescod*, CSIRO, Hyett Victoria and *Dr Valeriy Maisotsenko*, a Ukranian professor of physics who moved to Colorado to continue his work. I have met and enjoyed some educational time with both pioneers.

3. An Australian developer is *John NcNab* of Adelaide, a cooling tower manufacturer who developed Pescod's experimental work and manufactured many early Australian IEC systems. John also developed patents and manufactured several hybrid (IEC_{VR}) systems.

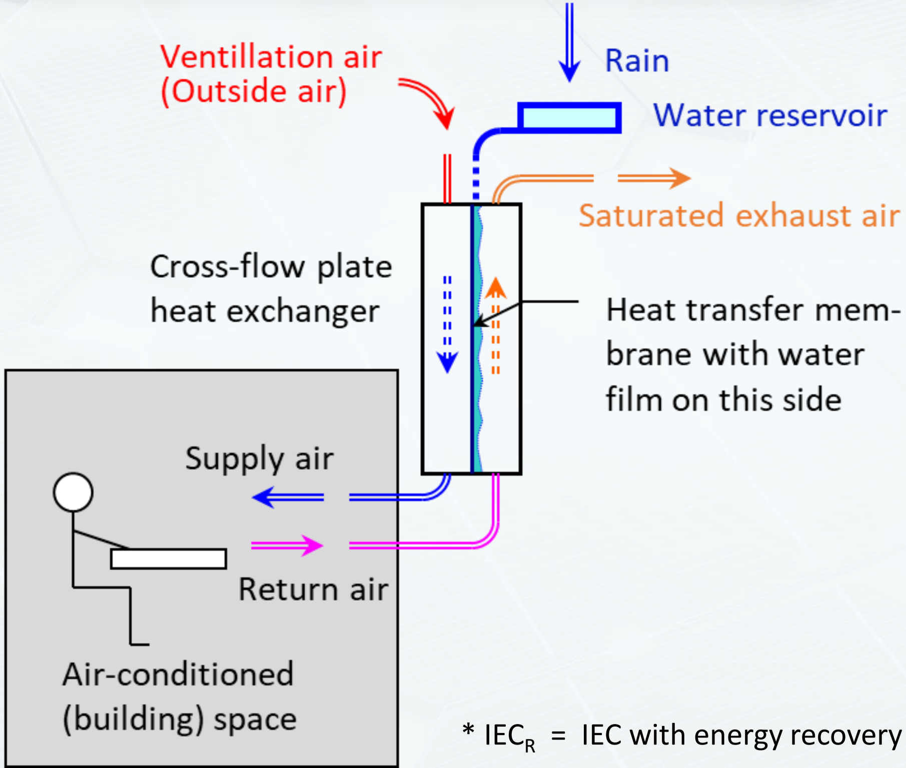
4. The researchers are numerous and seem to be increasing exponentially. Recently, I came to the conclusion that almost every mechanical engineering school has some IEC research project(s).

5. Research and development organisations include CSIRO, NREL, WCEC of UC Davis, Davis Energy Group of CA and others.

6. Early Commercial risktakers include Hydrothermal Adelaide, US companies: Coolerado, Munters-DeChamp, Spec-Air and others. In recent years a major player is Seeley International. Also several organisations involved in the cooling of data centres.

One scheme for Indirect Evaporative Cooling?

Atmospheric Cycle: Accepts saturated exhaust air and returns the condesed refrigerant as rain. This is primarily a solar driven system.



* IEC_R = IEC with energy recovery

A liquid is evaporated to provide cooling.

Heat is transferred from the air through a "wall" to the evaporating liquid. Familiar?

The refrigerant vapour passes through a cycle where it is condensed and returned for reuse. Familiar?

The refrigerant is water. Ultimately, water comes from rain.

Where is the refrigerant ***compressor***?

Where is the refrigerant ***condenser***?

Another scheme for Indirect Evaporative Cooling?

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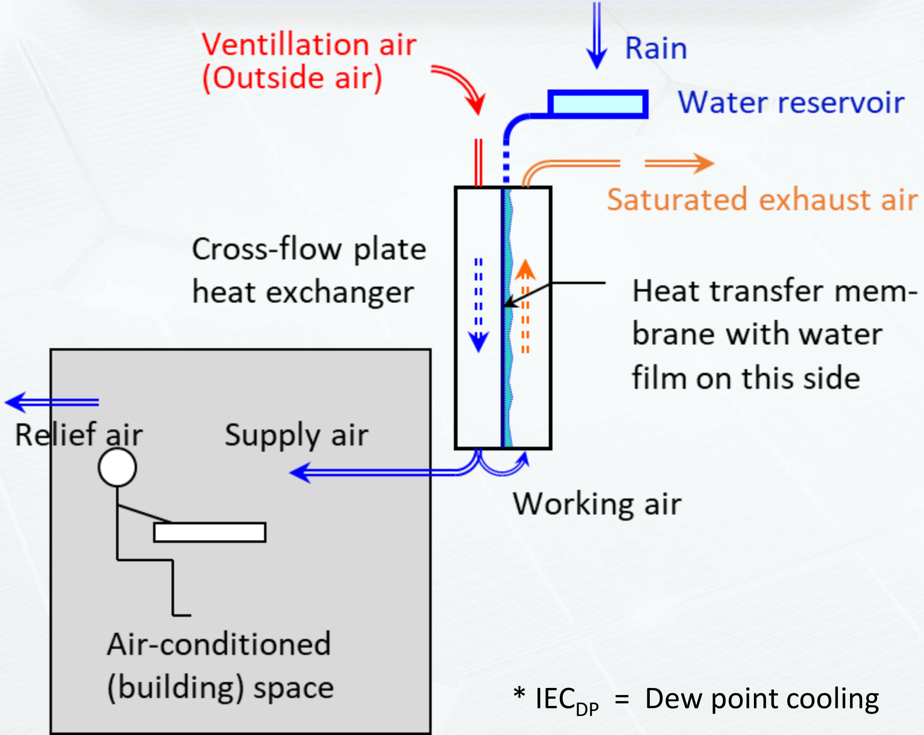


* IEC_{DP} = Dew point cooling

Where is the refrigerant *compressor*?

Where is the refrigerant *condenser*?

Atmospheric cycles that are driven by the sun condense the refrigerant.

This is a solar driven system.

Compressor-less cooling.

What is the IEC refrigeration cycle?

QUESTIONS

***Evaporating** refrigerant (R718) in exhaust*

air at 26 °C, 50% RH, $P_{partialR718}$ 1.7 kPa

*Where is the refrigerant **compressor?***

air in clouds, cool 4 °C, $P_{partial}$ 0.7 kPa

*Where is the refrigerant **condenser?***

***Energy to drive the cycle?** Atmospheric cycle that is driven by the sun: air rises, cools, partial pressure of steam in the air reduces, and the refrigerant condenses and returns. This is a solar driven system.*

***Compressor-less cooling**.*

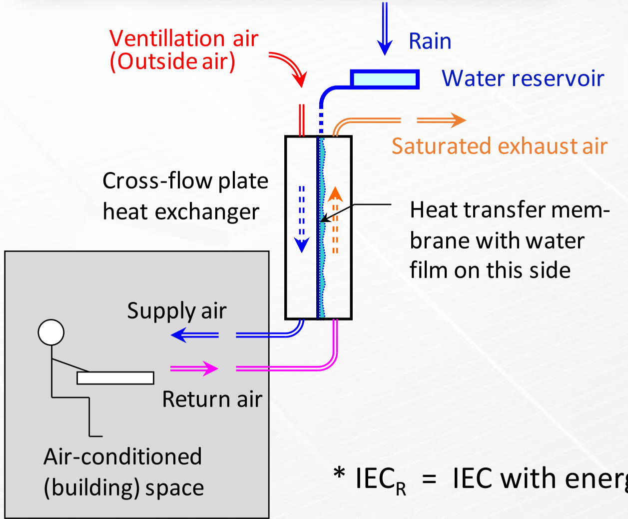
ANSWERS

At 15 °C, R718 evaporates at P = 1.7 kPa (steam tables)

at 26 °C, R718 evaporates at P = 3.4 kPa (steam tables)
at 36 °C, R718 evaporates at P = 6.2 kPa (steam tables)

***Unnecessary**! Moist air cools to condensation point as it rises to cloud height.*

*$P_{partial}$ reduced from 6.2 to 0.7: → **Rain (Condenser)***



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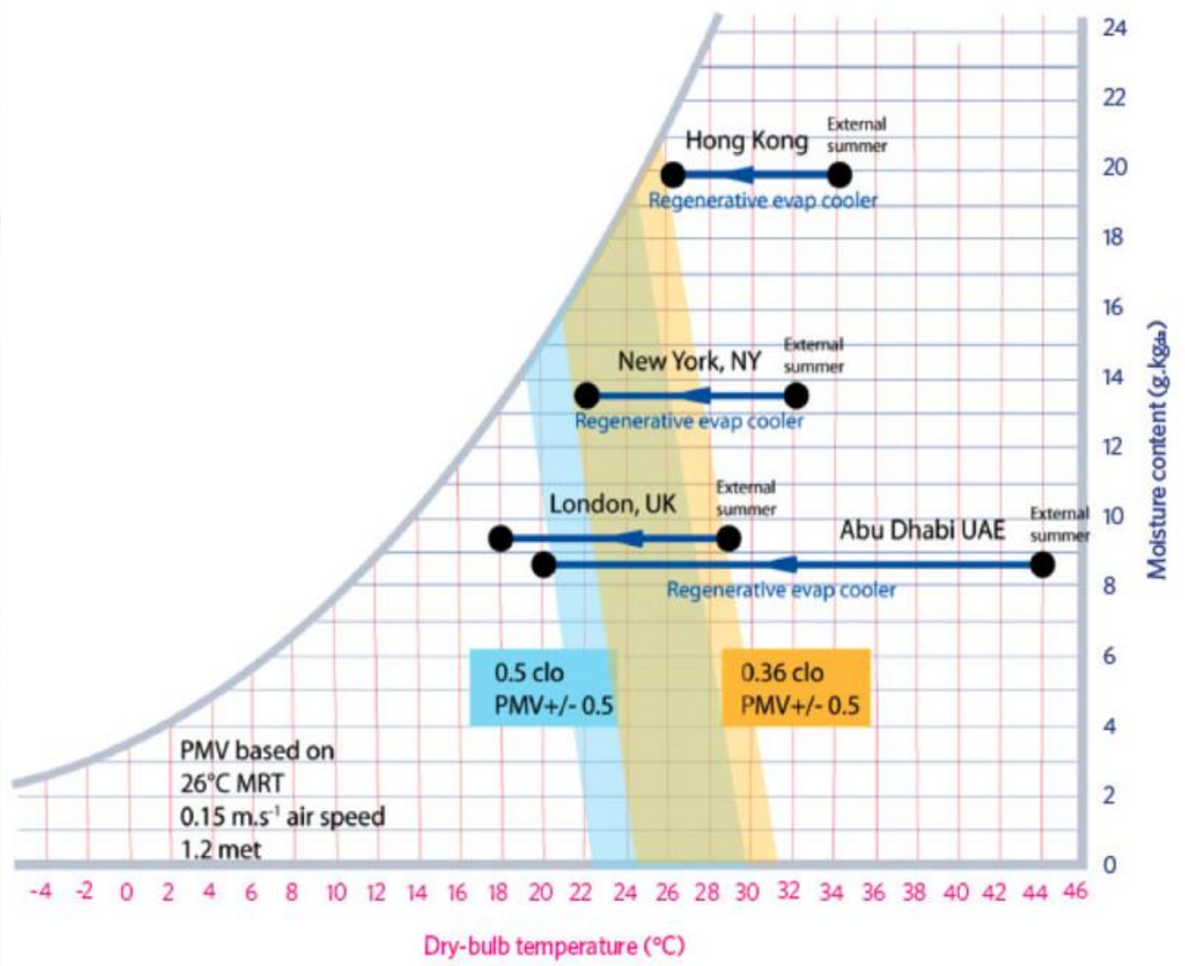
Locations for IEC

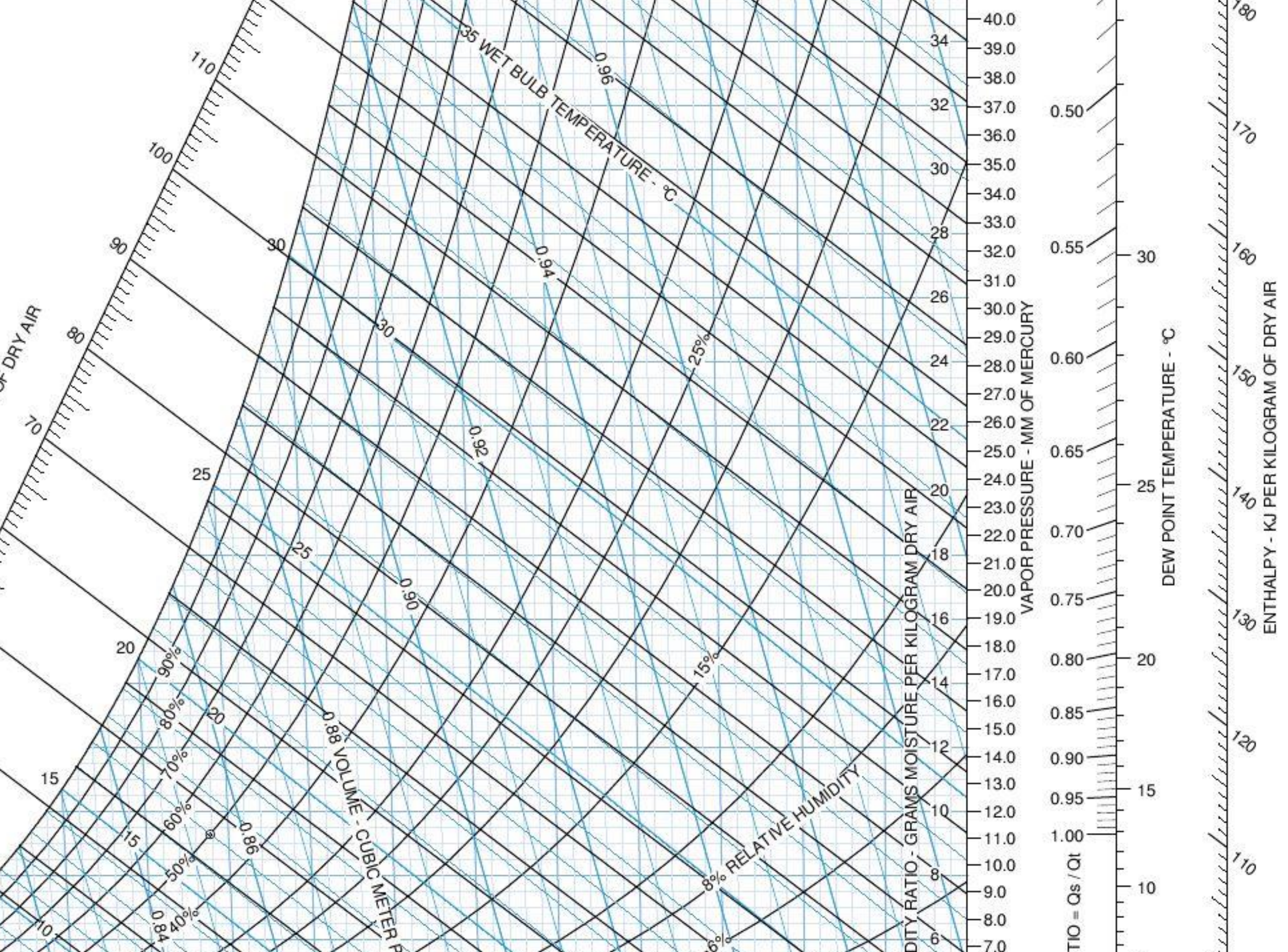


CIBSE article John Hammond, 2018.

Think Humidity ratio rather than relative humidity.

More relaxed dress code in the summer and IEC.

120% wet-bulb effective, indirect regenerative evaporative coolers, using 100% healthier outdoor air, recycled water and solar power.



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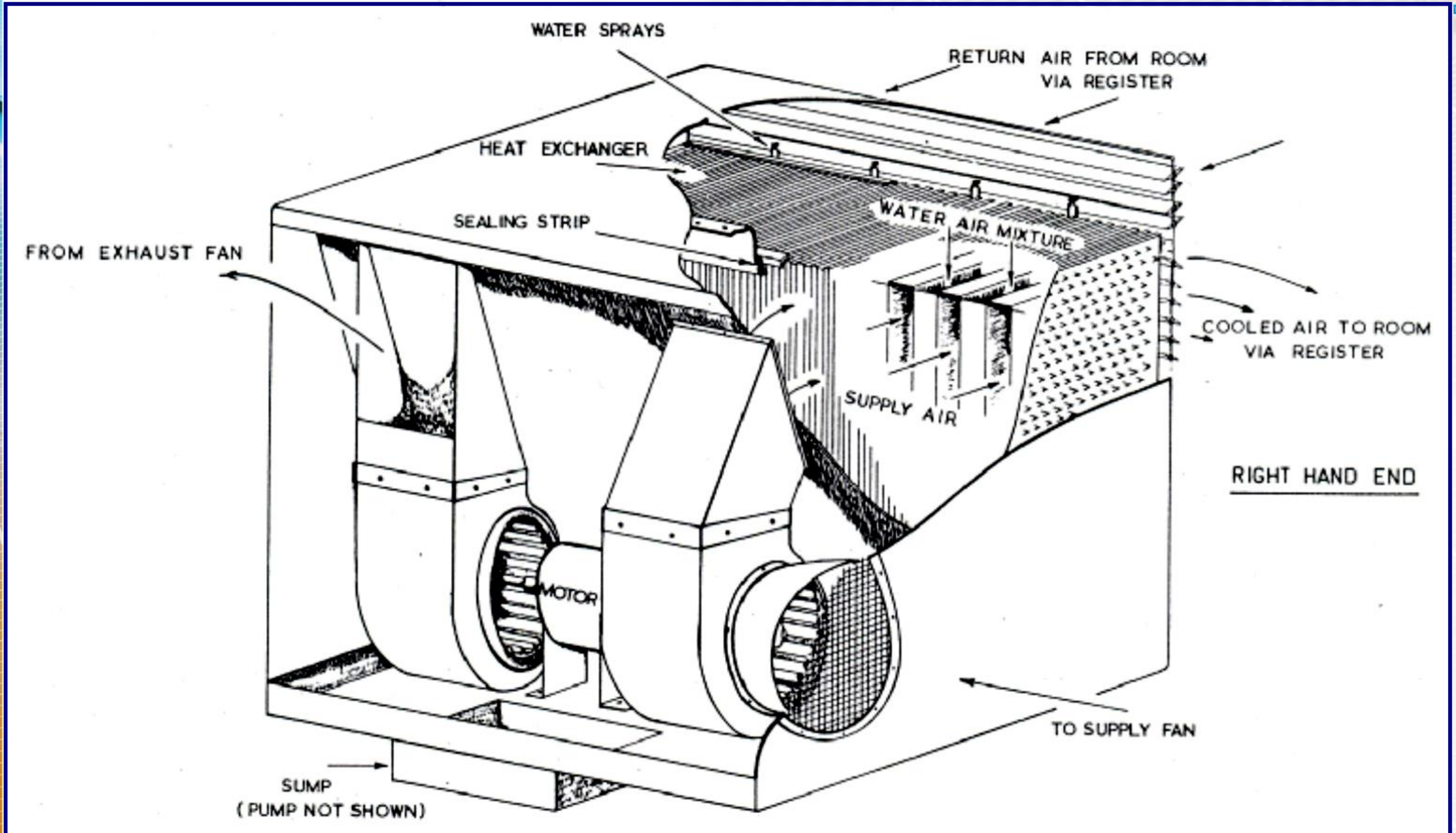
Rethinking how you use the psychro-metric chart

Donald Pescod of CSIRO developed a cross flow IEC_R system in 1960s.

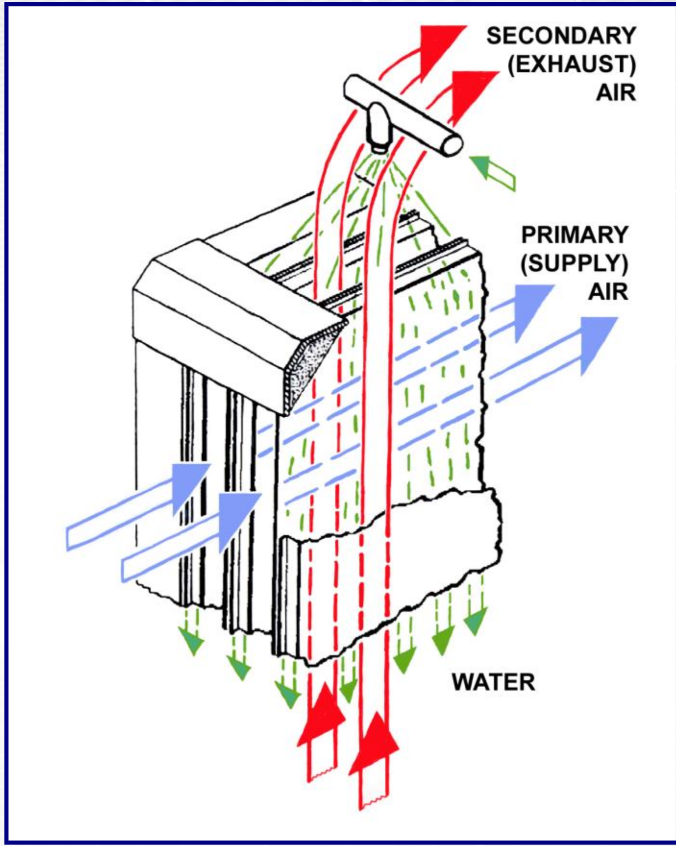


The CSIRO cross-flow heat exchanger was built by John McNab of Adelaide, whose company Hydrothermal Engineering manufactured a number of IEC systems including several in Telstra telephone exchangers.

1. The heart of the system is the polymer cross-flow plate heat exchanger – PPHE.

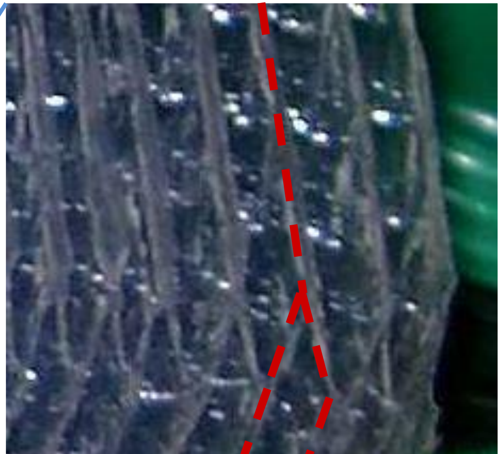
2. Spill air from the conditioned space (nominal condition: 24 ^{0}C, 50% RH) may be passed vertically upward (secondary stream) over wetted plates. The evaporating water cools the plates and the plates cool the incoming outdoor air.

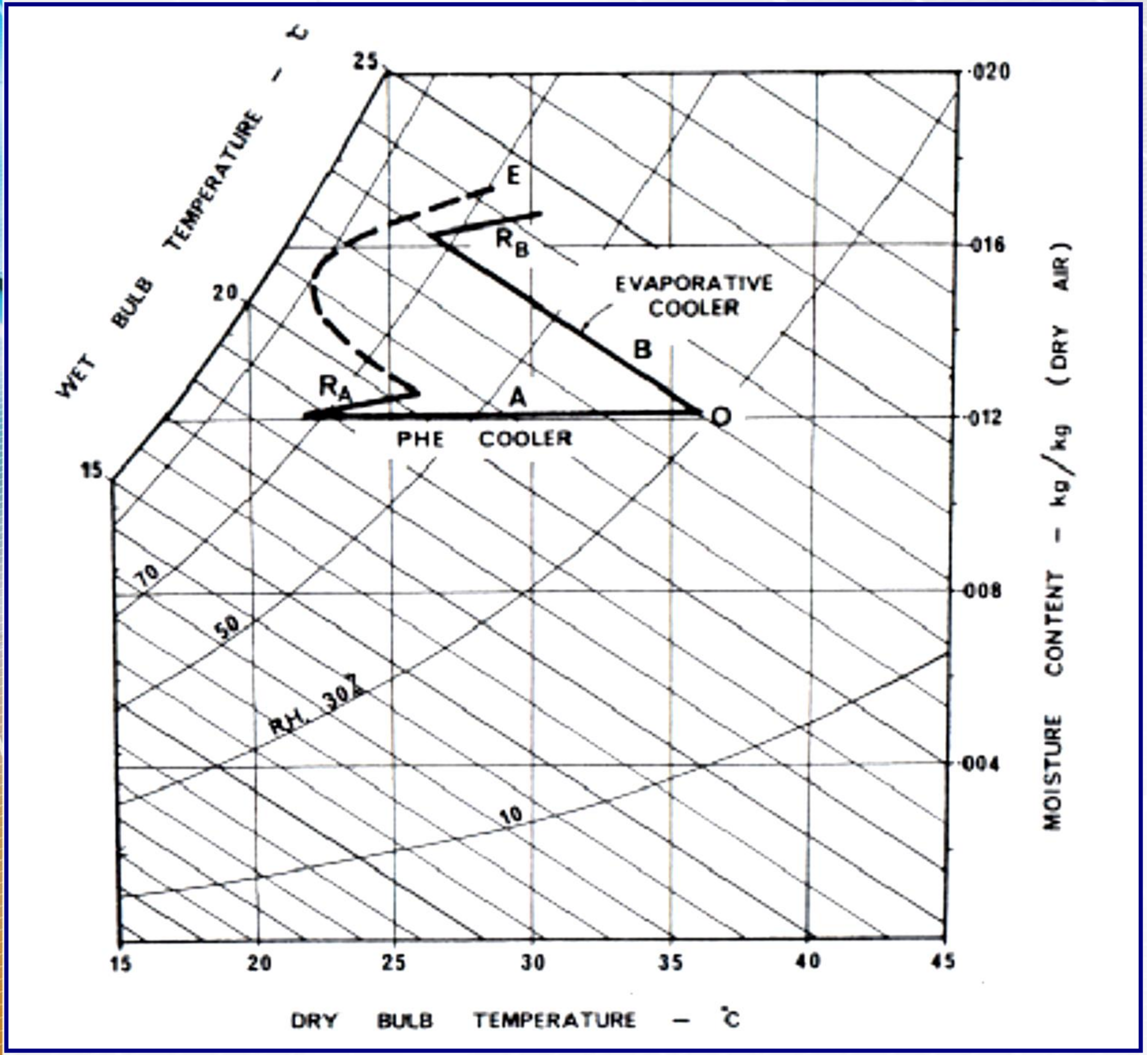
3. Outdoor air passes horizontally through the primary passages between heat exchanger plates where it is cooled as heat directly transfers through the plastic plates to the primary side.



An example of a polymer cross-flow heat exchanger block for Indirect Evaporative Cooling?

A plastic cross-flow heat exchanger block prior to corner-sealing and leak testing. Note the plate edge-welding. Note also, the flow roughening protrusions that assist in spacing the plates.





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Comparing DEC and IEC performance

Cooling process lines for IEC_R and DEC coolers. From an early publication of the CSIRO.

O: Outdoor air.

A and B: Cooling process lines.

R_A and R_B : Room lines.

E dashed line: Secondary side of heat exchanger.

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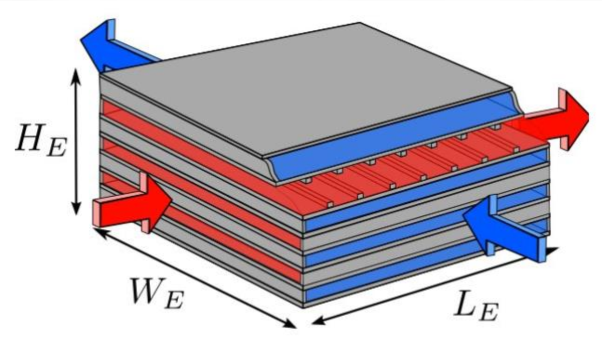
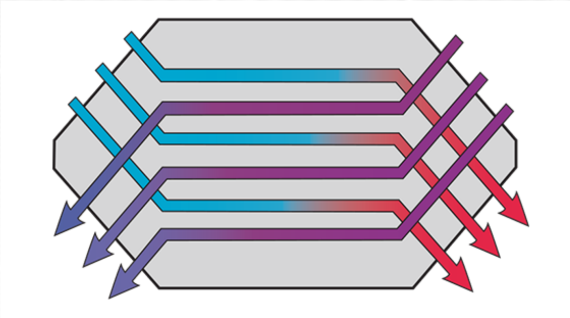
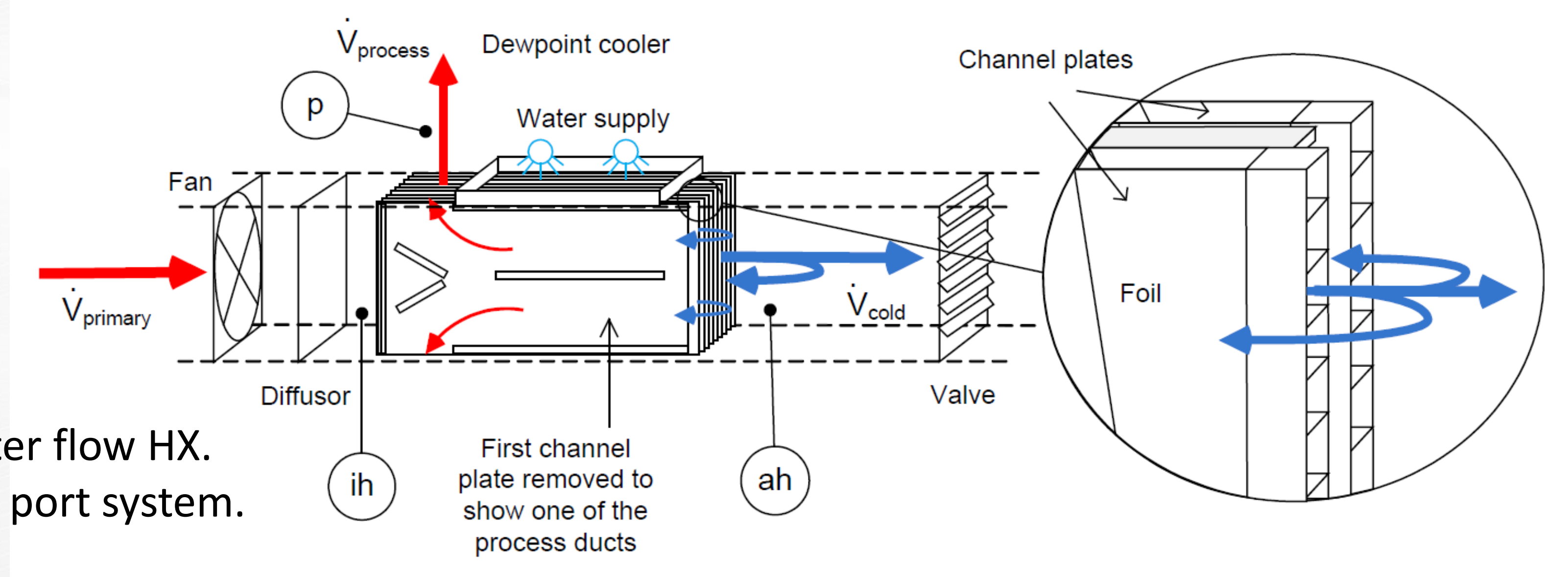
Cross flow versus counter flow heat exchanger



Cross flow HX

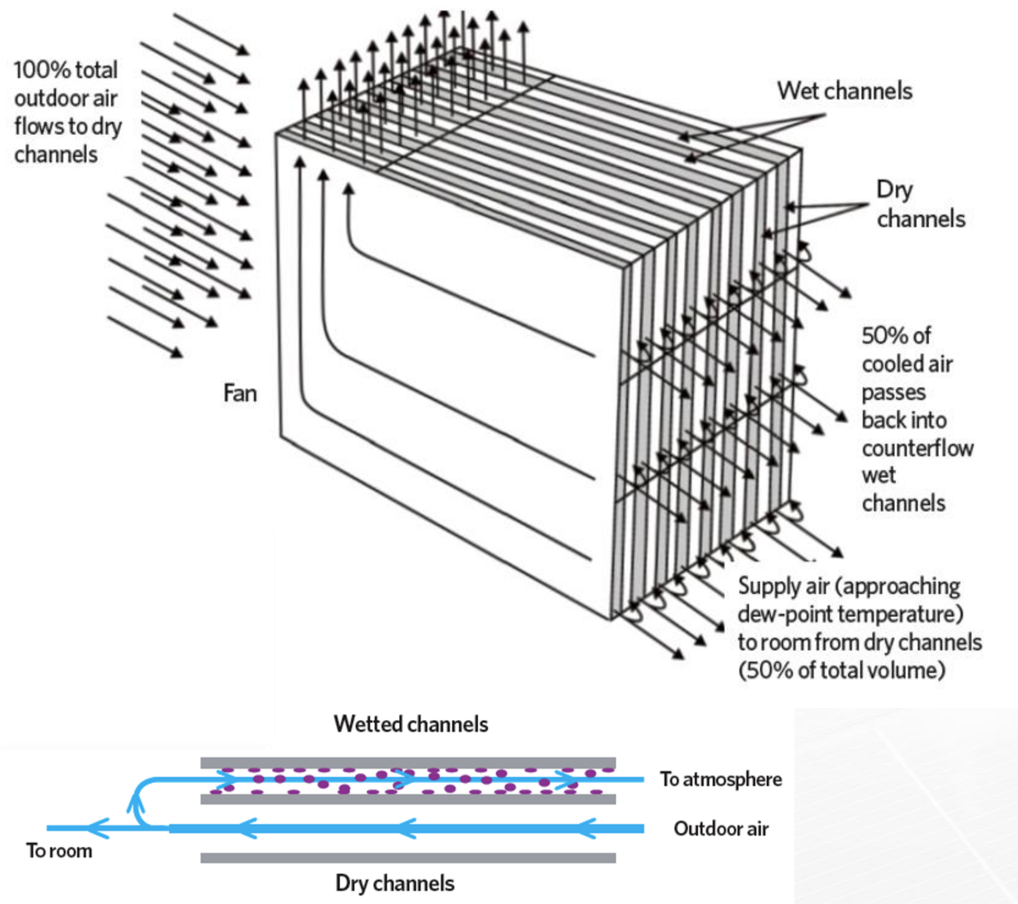


Mixed flow HX (moving towards counter flow)



Counter flow HX.
Three port system.

What is important about counter flow configuration? What are the challenges to designing /manufacturing the CF configuration?



CIBSE article John Hammond, 2018.

<u>Terminology</u>

120% wet-bulb effective, indirect regenerative evaporative coolers, using 100% healthier outdoor air, recycled water and solar power.

Dew point cooling.

The supply air can approach the dew point.

Water may be into into the wet channels which may have hydrophilic surfaces.

Manifolding can be tricky.

A McNab cross flow system under construction – 2004.

John McNab’s legacy?

Installation of IEC_{VR} system at Australian Army Simulator Building - Woodside, South Australia.

In a climate of low humidity ratio room temperatures of 22 ^{O}C are consistently maintained with outdoor conditions of 42 ^{O}C.

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McNab's patent for a hybrid system IEC and VC

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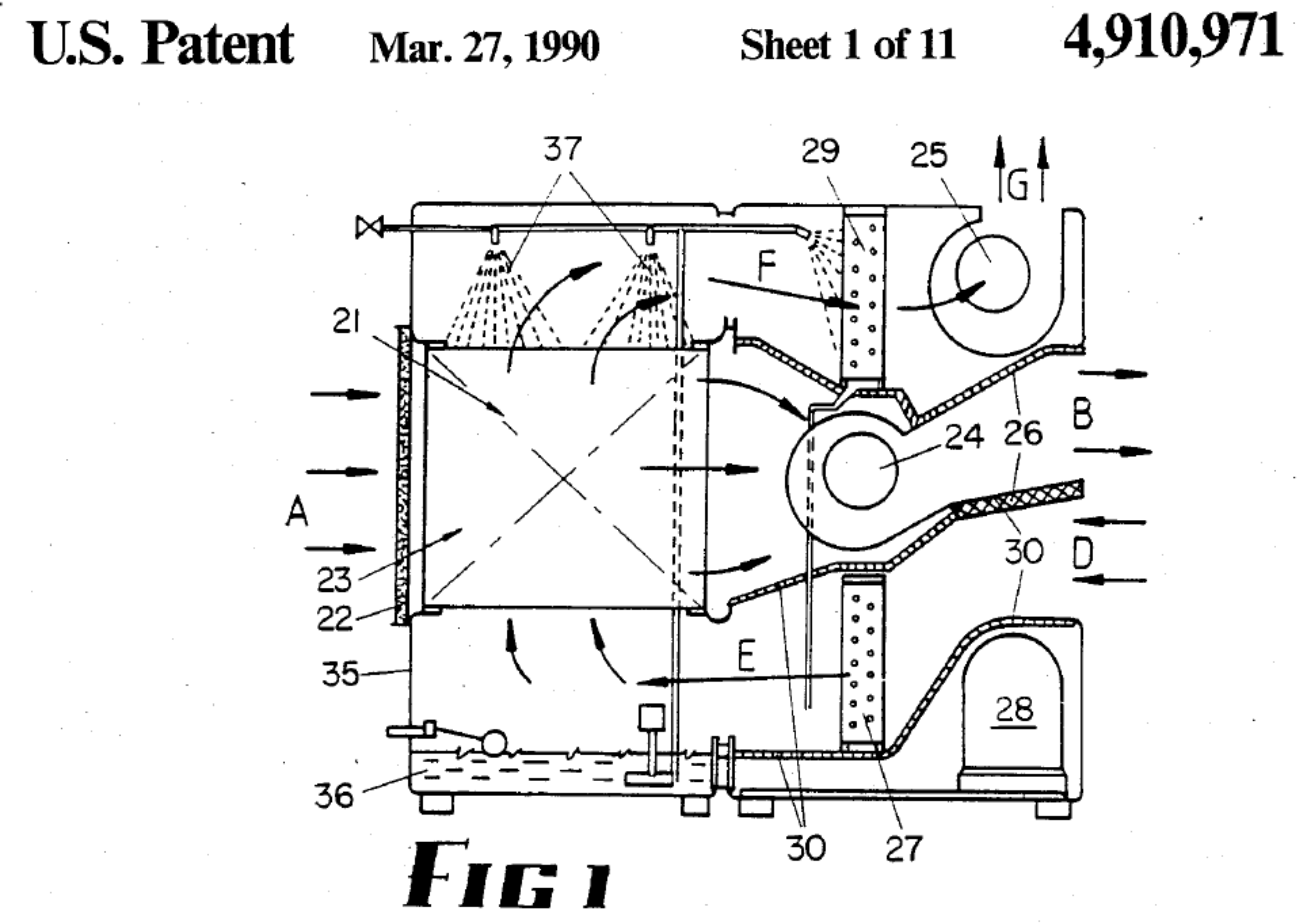


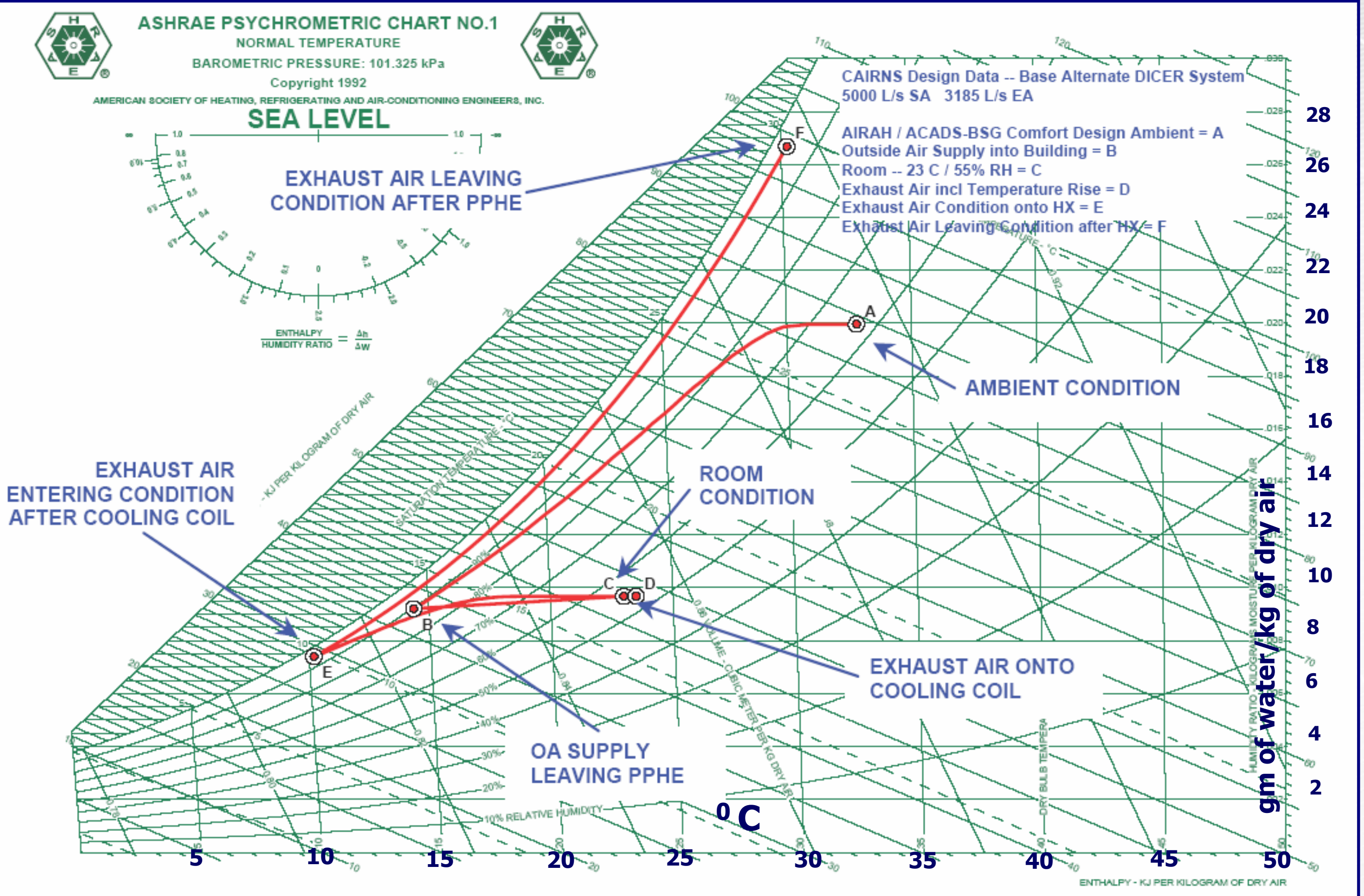
McNab patent

Vapour compression supporting IEC.

Evaporator cools room exhaust air before it enters wet side of IEC HX.

After rejection from wet side of, same air cools condenser coil.

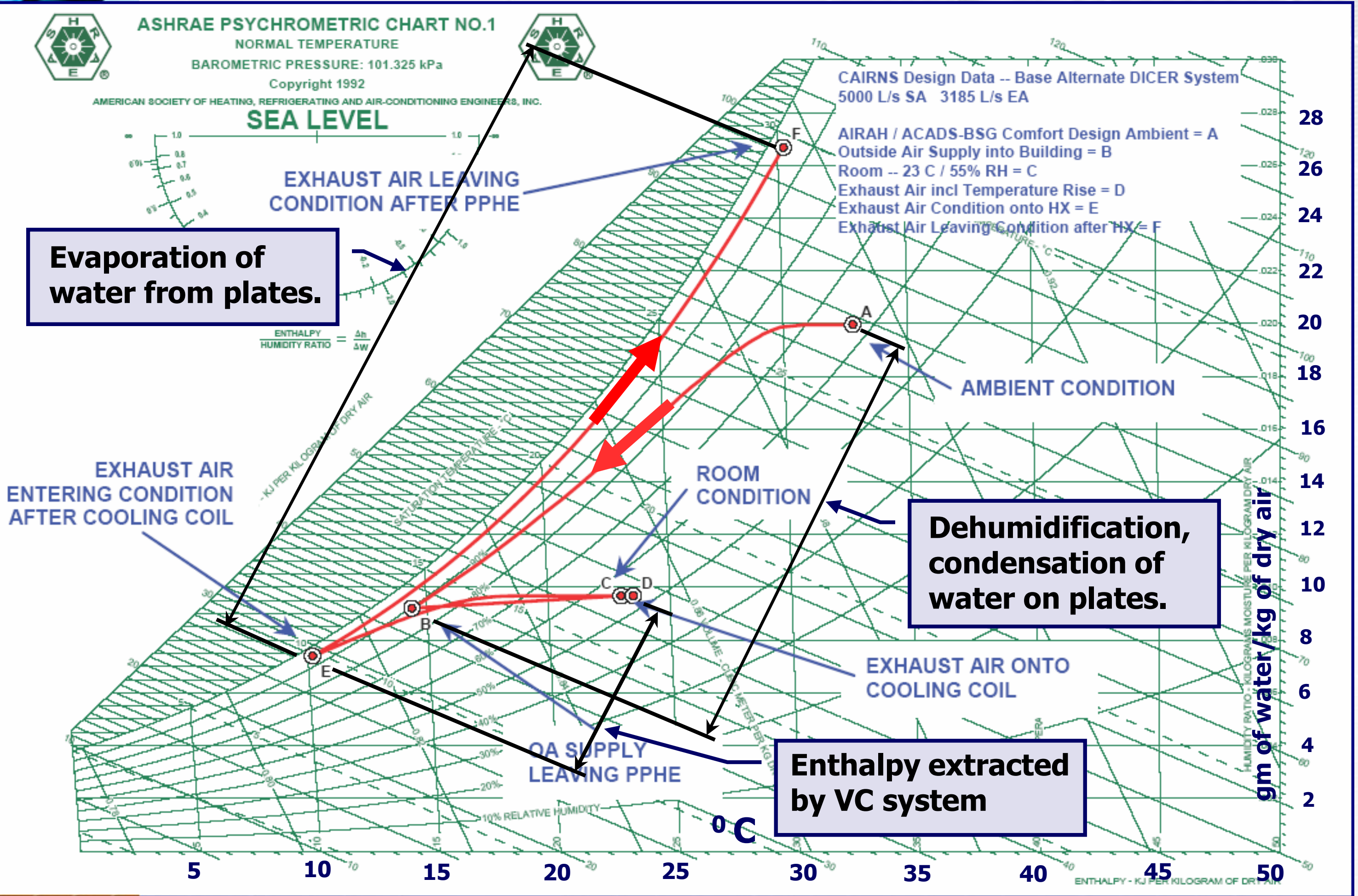
The McNab Hybrid process on the psychrometric chart



McNab cycle

IEC in humid climates.

The McNab Hybrid process showing enthalpies.

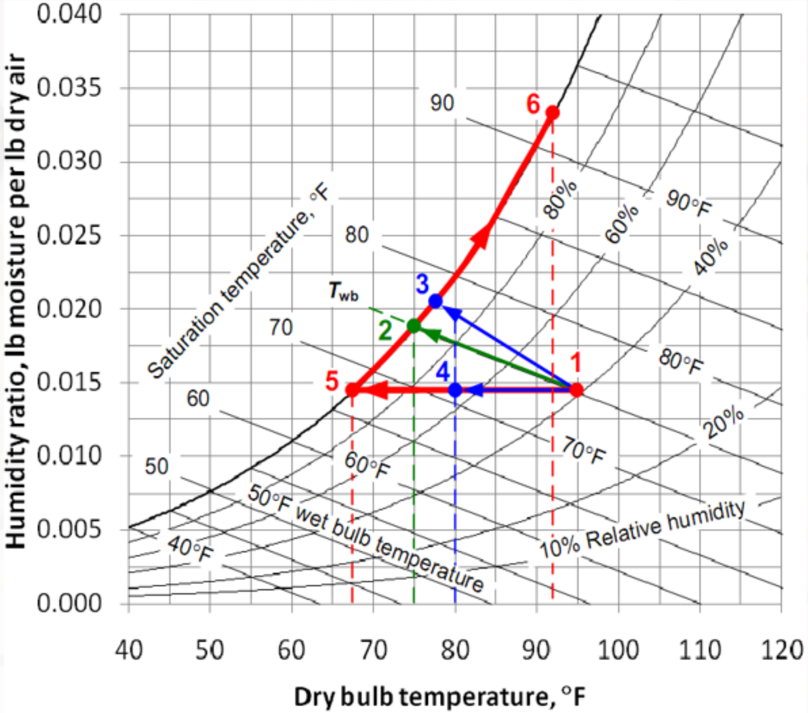


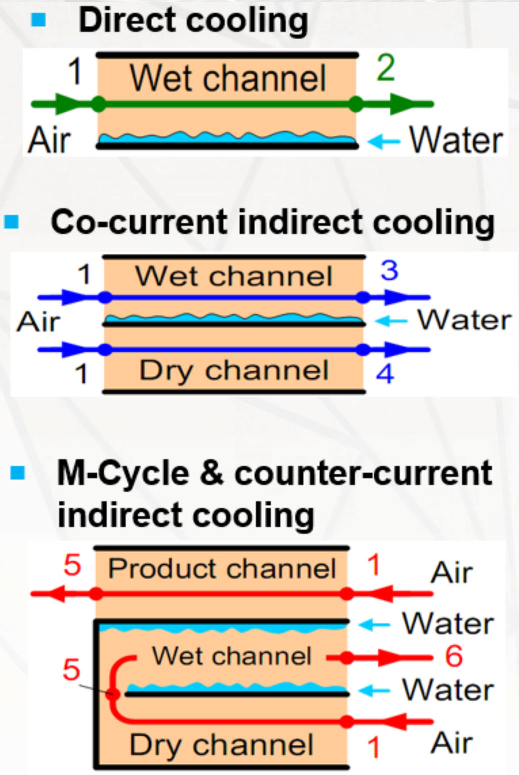
McNab cycle

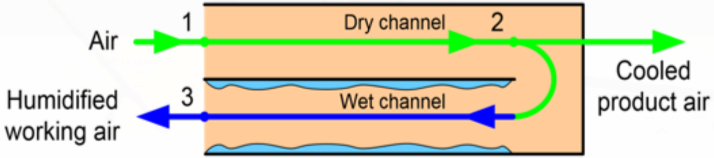
IEC in humid climates.

Enthalpies.

Maisotsenko's work







Progress towards Dew point cooling

- **Potential for > 100% wet bulb effectiveness**

Fast food application having high fresh air

The Challenge

Replace faulty 55 kWh traditional A/C unit, which was required to keep up with the heat loads in the kitchen and drive through locations

LOCATION

- South Africa

RESULTS

- 70% - 90% reduction of energy consumption in total restaurant cooling
- Payback 2.3 years

Data centre (free cooling in shoulder season)

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The Challenge
Achieve a significant reduction in GHG footprint

LOCATION

- Boulder, Colorado

RESULTS

- 85-97% reduction in energy use
- Drop in Power Usage Effectiveness (PUE) from 2 to 1.09

NSIDC Savings Website

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Schools and Gyms (100% fresh air)

Quick payback periods

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Case Study example: Las Vegas Data Centre ROI

(per 200 ton module, assuming $0.8/kWh)

	Conventional System	Coolerado System	Delta	Delta as %
Capital Expense	$390,000	$450,000	($60,000)	-15%
Annual Electricity Expense*	$72,000	$21,771	$50,299	70%
Annual Operating Expense**	$84,000	$37,769	$46,231	55%
Annual kWh Consumption	900,000	272,133	627,867	70%

Payback Period: **1.28 Years**, NPV: $289,701

* Does not include savings from reduced demand or peak charges

** Does not include service and maintenance costs

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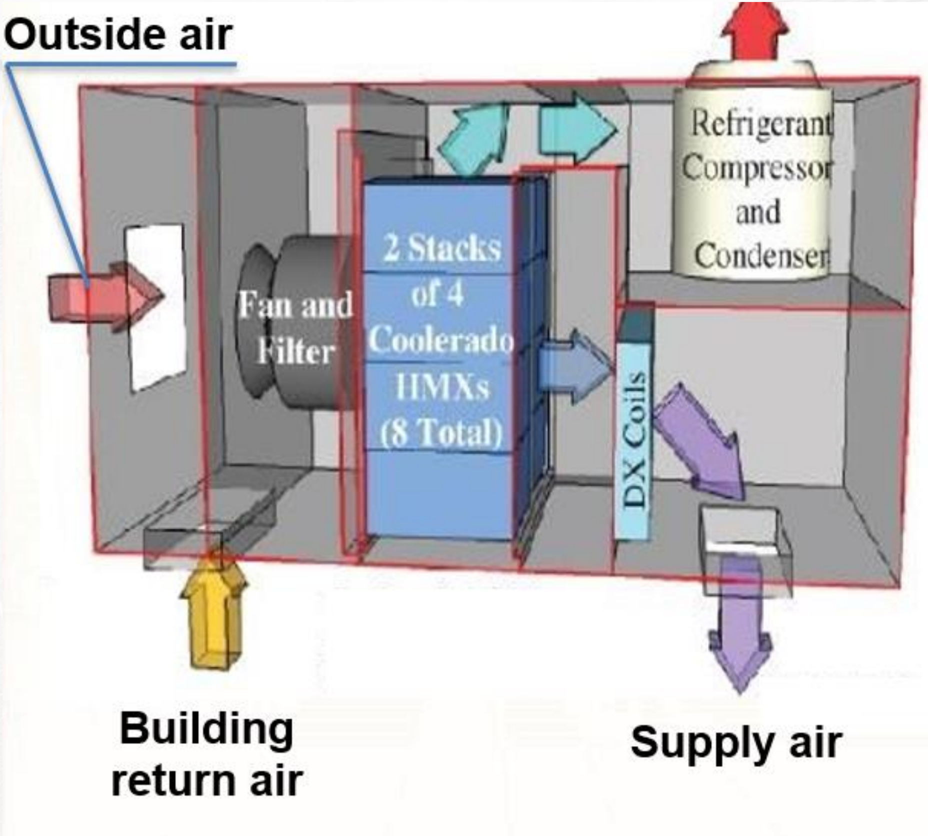
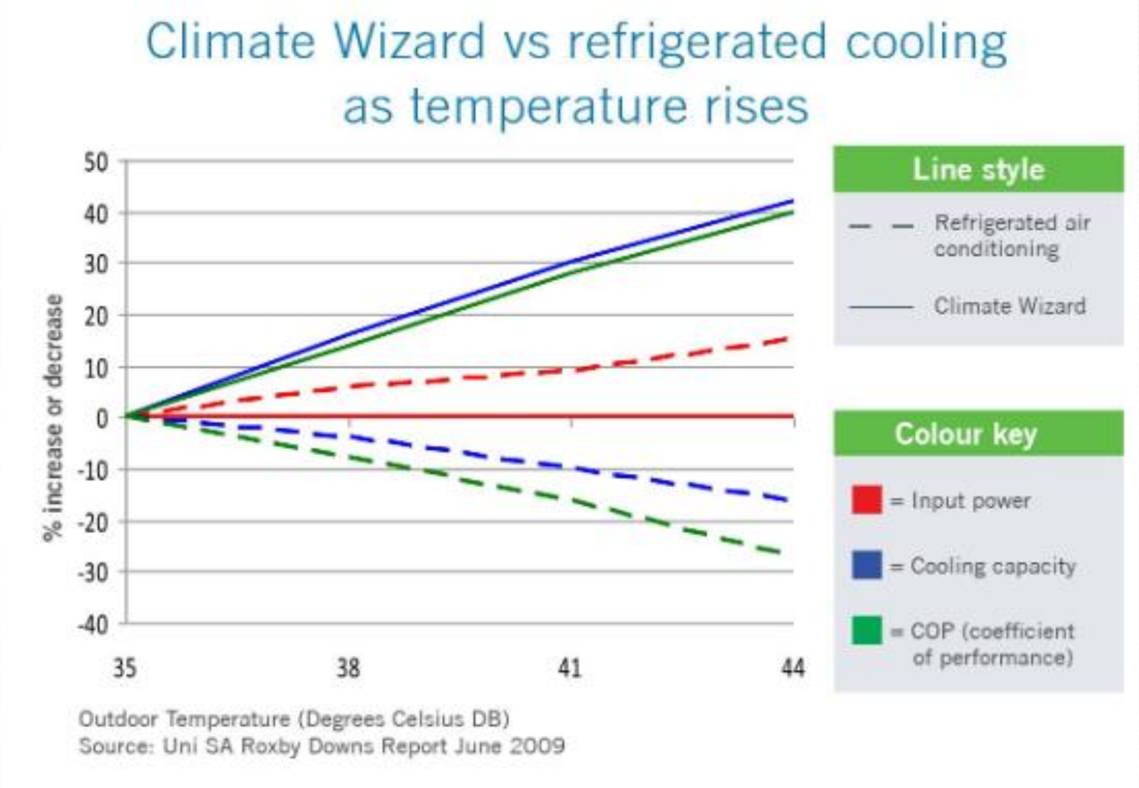
Hybrid with Coolerado system



HMX working air stream can be used to cool the refrigeration compressor & the air cooled condenser

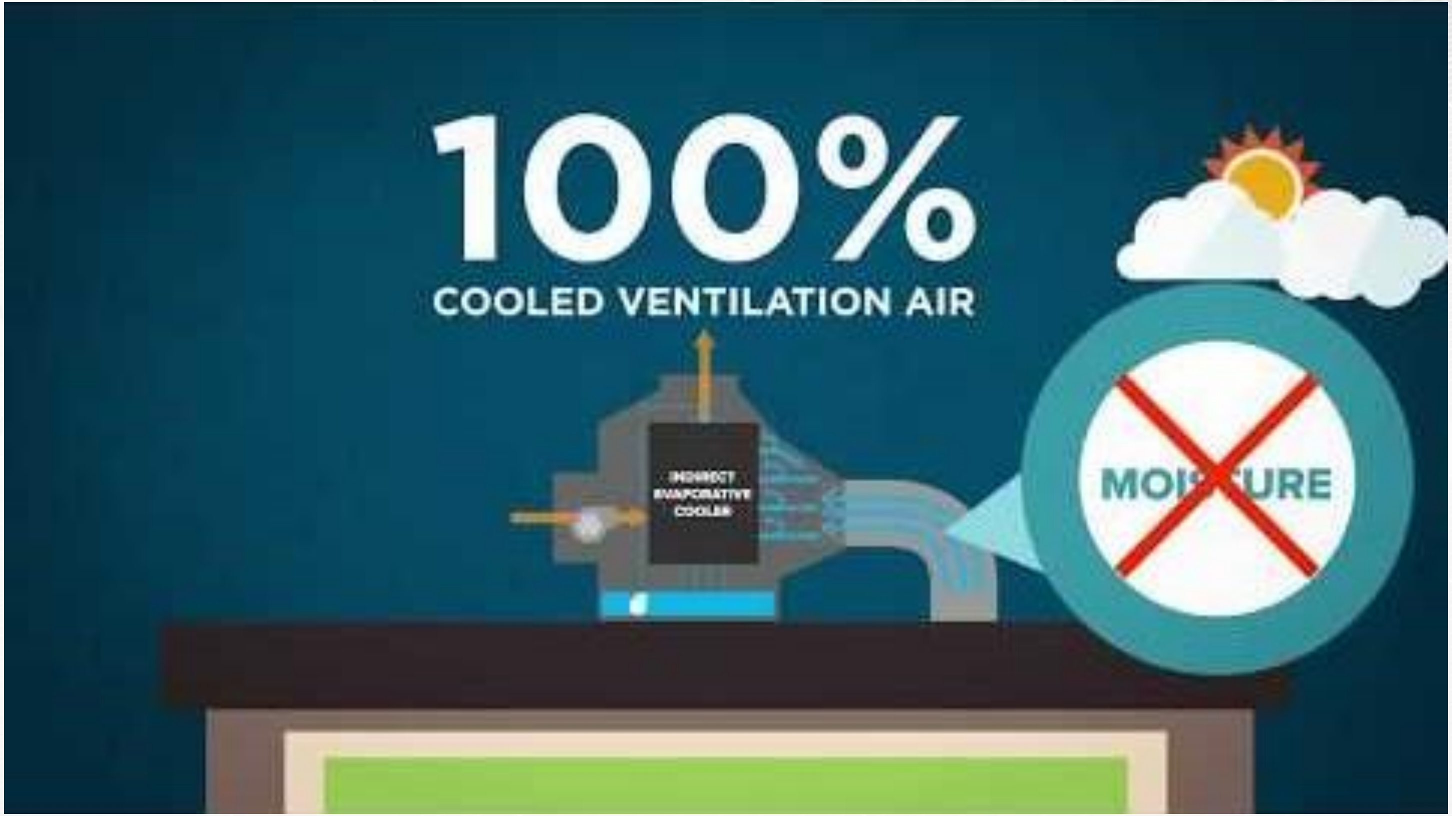
Refrigerant evaporator used for dehumidification and additional cooling when required.

WCEC video on Seeley International system.



WCEC UC Davis on Seeley:

https://www.youtube.com/watch?v=yjPb7PxmcQ0&feature=youtu.be


100%
COOLED VENTILATION AIR
INDIRECT EVAPORATIVE COOLER

The future?

Questions?

Thank you

Another scheme for Indirect Evaporative Cooling?