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KIVI Engineering Society

Kring Caribbean

"Cost Effective Ventilation in Hot & Humid Climates"

Jan van Haren

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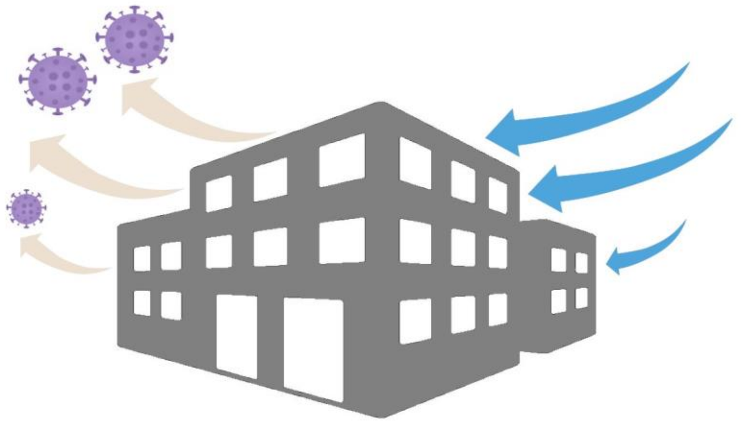
Graduated at 'MTS' in Mechanical Engineering, followed by 2 years of 'MIT' for all building service systems and 2 years of 'HIT' which covered the design and selections of air handling and ventilation.

" … Ventilation … "

While ventilation was already very important, the recent pandemic has brought it even more to the attention of the public.

Many different opinions and studies have been published about whether or not to ventilate air.

Ultimately, with or without a pandemic, most agree on removing ‘polluted' air and bring in 'clean' air.



That is called ventilation.

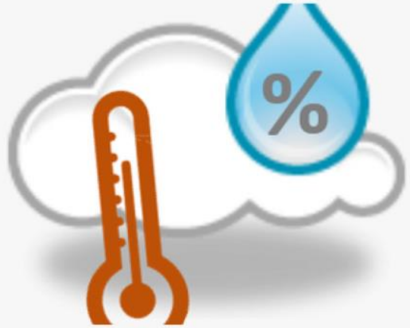
" … in Hot & Humid Climates"

… just bringing in 'clean' air also means bringing in heat and moisture. And we don't want that because that will create problems.

Nowadays we are very fond of thermal comfort, so the hot and humid air first needs to be preconditioned before we blow it into the space.

A little more about why pre-conditioning in a moment.

But preconditioning hot & humid air needs a process that requires energy.



" Cost Effective … "

https://www.healthworksnewcastle.org.uk/save-energy-save-money/

… and energy cost money.

And both energy and money is what we want to spend the less.

Therefore, some cost-effective and energy-saving solutions for ventilation purposes will be shown.

"   …   Ventilation   …   "

Ventilation already exists for centuries. It's not new.

Good ventilation maintains optimal health, saves lives and structures.

An ASHRAE journal from 1999 describes the history of ventilation:

- Publication of the first estimate of the minimum quantity of ventilating air needed.
- The creation and development of codes
- Why CO2 is a useful surrogate for vitiated air

The History of Ventilation and Temperature Control

The First Century of Air Conditioning

This is the eleventh article in a special series that commemorates a century of innovation in the HVAC&R arts and sciences.

By John E. Janssen
Fellow/Life Member ASHRAE

When man brought fire into his abode, he discovered the need to have an opening in the roof to let out the smoke and to supply air to keep the fire burning. Control of combustion provided the first incentive for the ventilation of a space. Because the fire warmed the space to a more comfortable temperature, thermal comfort was intimately linked to ventilation.

The ancient Egyptians observed that stone carvers working indoors had a higher incidence of respiratory distress than those working outdoors did. They attributed this to a higher level of dust in the indoor workspace. Thus, control of dust was the second recognized need for ventilation.[1]

The Romans negated the need for indoor fires when they invented radiant heating. Hollow tiles under the floors of their buildings ducted hot combustion products from "stoves" around the periphery of the buildings, through the floor tiles to a smokestack.

They developed a preferred ratio of window to floor area for daylighting. Oiled parchment over the window openings led to high infiltration. Later, the Venetians devised a method for making flat glass for windows.

In the Middle Ages, people began to realize that air in a building could somehow transmit disease among people in crowded rooms. Homes and small buildings were heated with open fires in fireplaces. Smoke often spilled into the room and poisoned the air. King Charles I of England in 1600 decreed that no building should be built with a ceiling height of less than 10 ft (3 m), and that windows had to be higher than they were wide. The objective was to improve smoke removal.

Research began to address the question, "What constitutes bad air?" In the 17th century, Mayow (cited by Michael Foster, 1902) placed small animals in a confined bottle with a burning candle.[3] The candle flame was extinguished before the animal was asphyxiated. An animal survived about half again as long without the candle. He concluded that the "igneo-aerial particles of the air" were the cause of the animals' demise.

The results of a 10-year study of schools in New York provided guidance on ventilation to schools throughout the United States.

One hundred years later (1775) Lavoisier, the father of gaseous chemistry, identified Mayow's igneo-aerial particles as carbon dioxide (CO_2). Lavoisier began his study of oxygen and carbon dioxide in the air of crowded rooms in 1777. He concluded that excess CO_2—rather than a reduction of oxygen—caused the sensations of stuffiness and bad air. The hypothesis was that excess CO_2 in the lungs interfered with their ability to absorb CO_2 from the blood. The argument as to whether "bad air" was caused by oxygen depletion or excess carbon dioxide continued for many years. Pettenkofer (1862) concluded that neither oxygen nor carbon dioxide were responsible for bad air. Rather, biological contaminants were responsible for vitiation of the air.[4] He believed, as did [illegible]eltzer (1872) and others, that CO_2 was a useful surrogate for vitiated air.[5]

About the Author

John E. Janssen chaired Standards Project Committee (SPC) 62, which developed ANSI/ASHRAE Standard 62–1989, *Ventilation for Acceptable Indoor Air Quality* and also served on the SPC that wrote Standard 62–1981. Until his retirement, he was a principal research fellow at Honeywell. Janssen has authored several Journal articles, including "The V in ASHRAE, An Historical Perspective" as part of ASHRAE's Centennial series.

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Minimum Ventilation

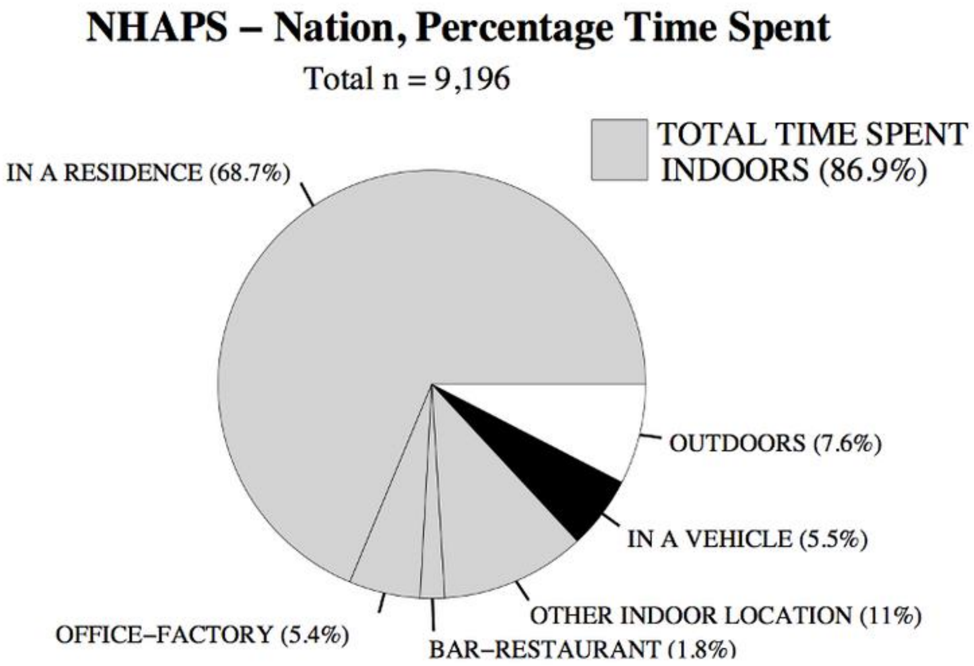
According to Klaus (1970), a Cornish mining engineer, T. Tredgold (1836) published the first estimate of the minimum quantity of ventilating air needed. He calculated from the breathing rate that a subject needed 800 in.^{3}/min. of unvitiated air to purge

" … Ventilation … "

Statistics show people (USA) spend 90% of their time indoors.

Backed by research:

https://www.buildinggreen.com/blog/we-spend-90-our-time-indoors-says-who



Adapted to local (hot & humid) conditions, this may be somewhere around 75%.

"   …   Ventilation   …   "

Buildings become more airtight and energy efficient. So actively managing indoor air quality becomes more important. Some air pollutants, like carbon monoxide and bacteria, can be highly dangerous. Others, like volatile organic compounds, can cause short-term health problems as well as chronic ones.

Adequate ventilation in combination with moisture management and selection of low-VOC products are some of the best ways to **ensure good IAQ.**

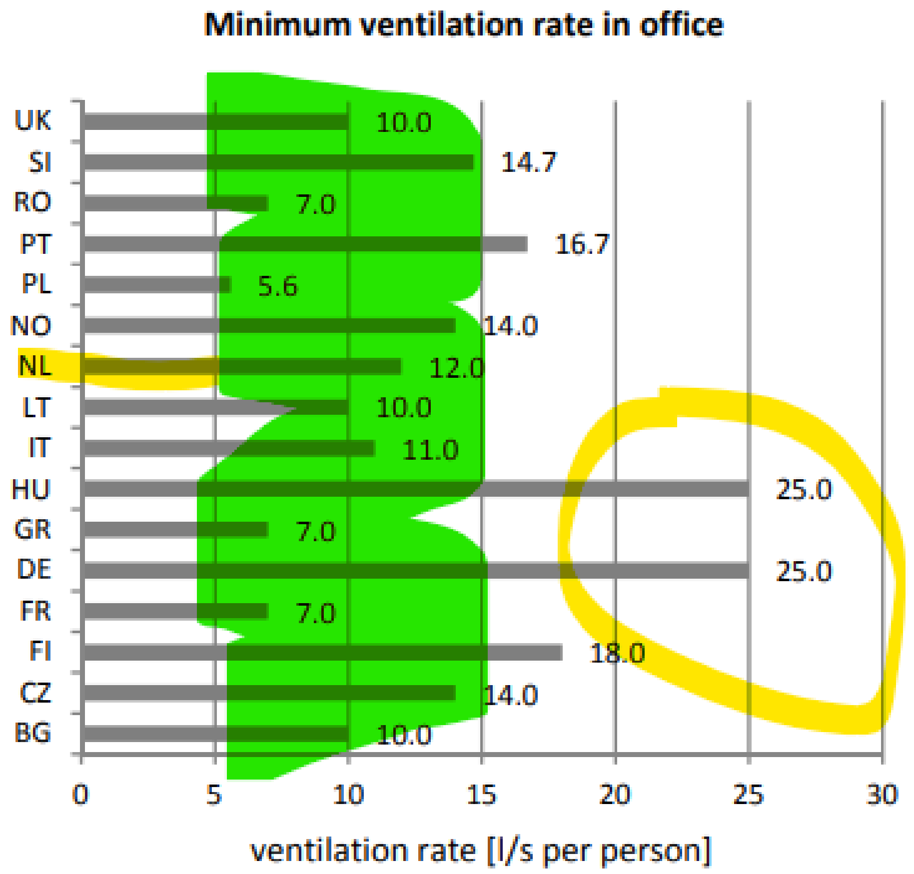
BUILD TIGHT, VENTILATE RIGHT

" … Ventilation … "

Over the years organizations all over the world have been working on developing standards for **adequate ventilation** requirements.

USA: ASHRAE 62.1

NL: NEN 1087 & Program of Requirements



" … Ventilation … "

Example for office spaces in USA:

USA: ASHRAE standard 62.1 - 2022;

Table 6-1 Minimum Ventilation Rates in Breathing Zone *(Continued)*

	People Outdoor Air Rate R_p		Area Outdoor Air Rate R_a		Default Values Occupant Density		
Occupancy Category	cfm/ person	L/s· person	cfm/ft^2	L/s·m^2	#/1000 ft^2 or #/100 m^2	Air Class	OS (6.2.6.1.4)
Occupiable storage rooms for dry materials	5	2.5	0.06	0.3	2	1	
Office space	5	2.5	0.06	0.3	5	1	✓
Reception areas	5	2.5	0.06	0.3	30	1	✓
Telephone/data entry	5	2.5	0.06	0.3	60	1	✓

2.5 l/s per person + 0.3 l/s per m2 (@10m2 pp) = 5.5 l/s

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" … Ventilation … "

Example for office spaces in the Netherlands:

NL: NEN1087 -> PvE healthy offices:

25 m3/h = 7 l/s (8 m2)

Or

3 m3/h/m2 = 30 m3/h = 8.3 l/s (10 m2)

LUCHT	Klasse C - VOLDOENDE	Klasse extra t.c
CO_2 concen-tratie & Luchtver-versing	De CO_2-concentratie in verblijfsruimten (in de ademzone) ligt tijdens gebruikstijd op maximaal **+ 750 ppm** boven de buiten-luchtconcentratie.	De CO_2-co (in de ade op maxim luchtconc
	Uitgaande van een normaal, gemiddeld metabolisme voor kantoorwerk (1,2 a 1,4 met) en een CO_2 productie van maximaal 0,005 L/s per persoon geldt dat aan de klasse C eis voldaan kan worden als er **25 m³/h per persoon** aan verse lucht toegevoerd wordt.	Uitgaande metabolis met) en e 0,005 L/s klasse B e **40 m³/h** toegevoer
	De genoemde verse luchttoevoer per persoon kan omgerekend worden naar benodigde verse luchttoevoer per m²: ga in een klasse C gebouw in kantoor-ruimten (op verblijfsruimteniveau) uit van minimaal **3 m³/h/m²** (uitgaande van minimaal 8 m² vloeroppervlak p.p.); in een bijeenkomstruimte is dit minimaal 8 m³/h/m² (uitgaande van minimaal 3 m² vloerop-pervlak p.p.).	De genoer persoon k benodigde in een kla uit van m van minim kamernive dit minim minimaal

PRO TEC

VAN DORP VOOR MORGEN

"   …   Ventilation   …   "

Example for office spaces:

USA: 5.5 l/s

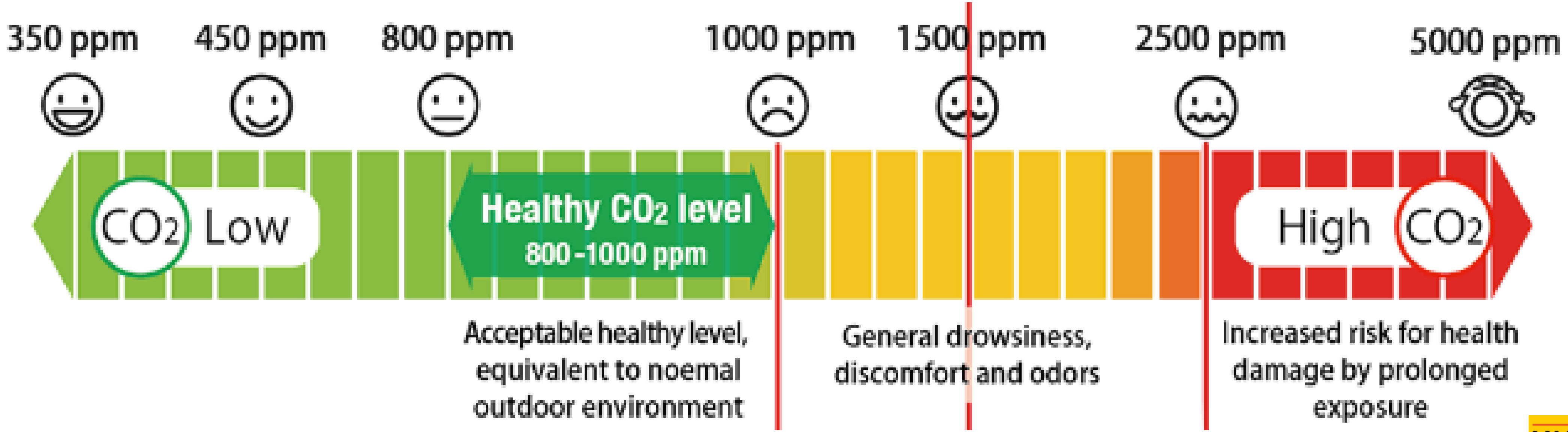
NL: 8.3 l/s

}

Average:

6.9 l/s = **24.84 m3/h** per person on 10 m2

To maintain a maximum CO2 level of **1200** ppm



" … Ventilation … "

Not to forget as buildings become more airtight and energy efficient,

- CO_2 is a useful surrogate for vitiated air
- Compensate extraction for removal of excessive moisture or kitchen ventilation systems
- Prevent health problems
- Maintain acceptable IAQ
- Over pressurize the building to prevent infiltration of unconditioned outside air

"   …   in Hot & Humid Climates"

Why over pressurize a building to prevent infiltration of unconditioned outside air?

To prevent bacterial growth !
(in hidden locations)

Aruba's Climatological Data 2020 shows a dewpoint temperature of outside air in a range between 22C-25C (71F-77F)

Condensation will occur on all surfaces colder than the dewpoint of that air.

Ventilating sufficient drier air will absorb the condensation.

" … in Hot & Humid Climates"
THIS SHOULD BE AVOIDED

Indoor

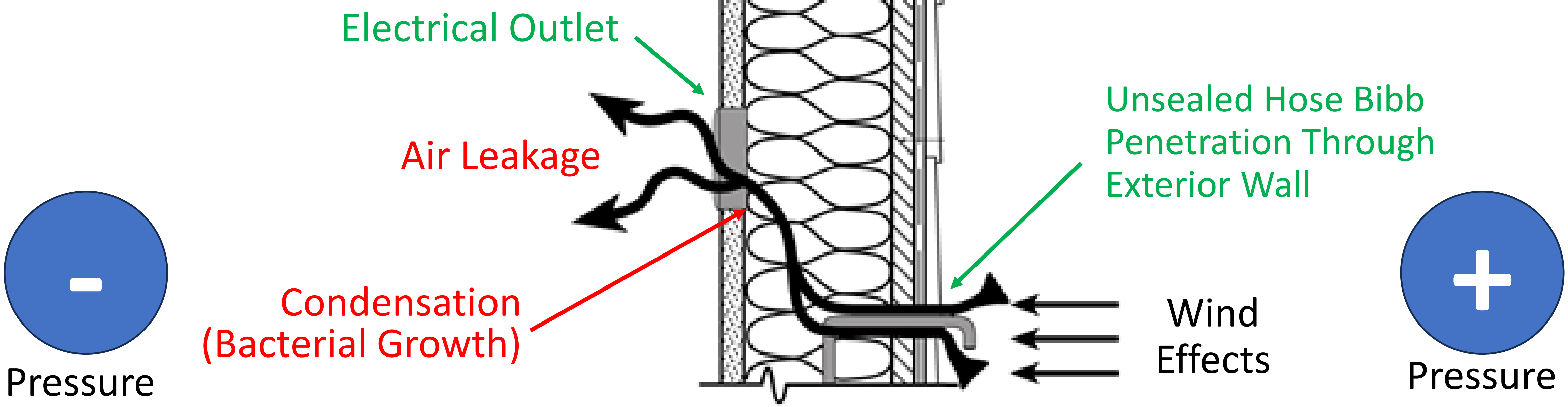
22C (71F) @ 55%

Dewpoint T = 12.6C (55F)

Outdoor

32C (90F) @ 65%

Dewpoint T = 24.6C (76F)



"   …   in Hot & Humid Climates"

THIS IS MUCH BETTER

Indoor

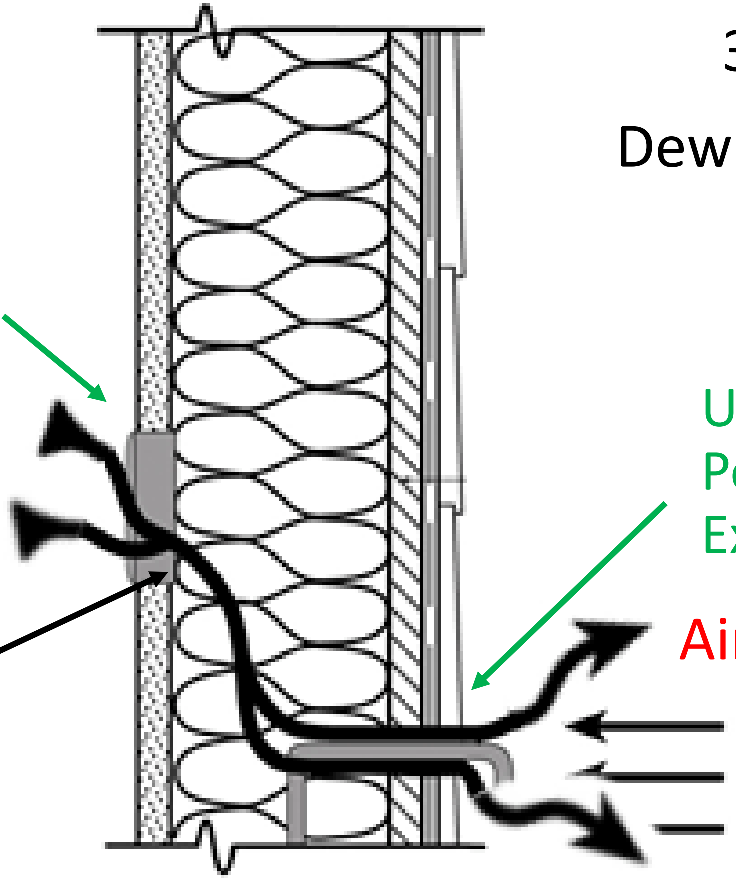
22C (71F) @ 55%

Dewpoint T = 12.6C (55F)

Outdoor

32C (90F) @ 65%

Dewpoint T = 24.6C (76F)



"   ...   in Hot & Humid Climates"

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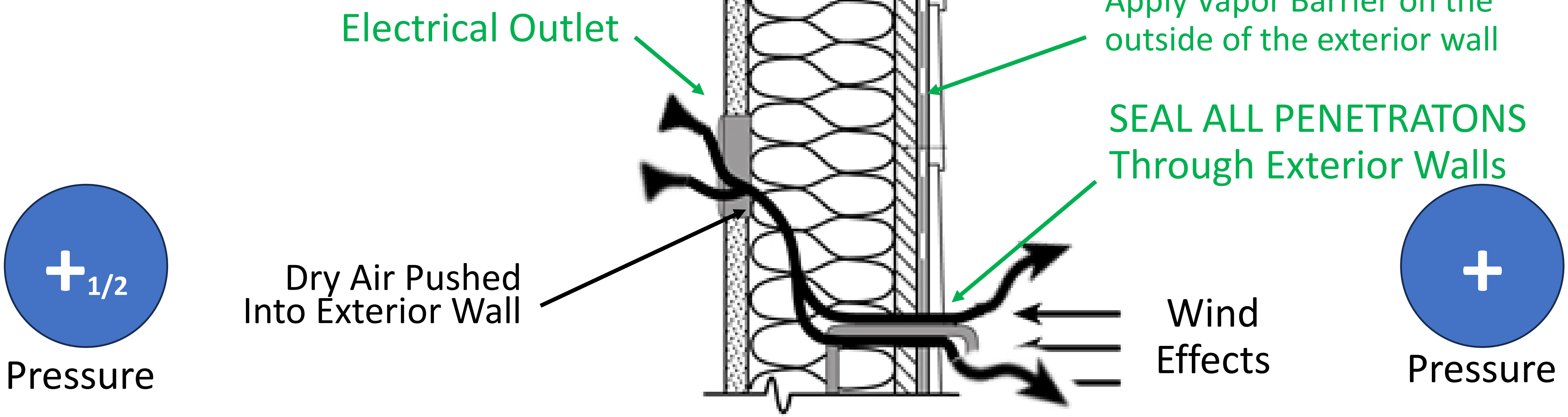
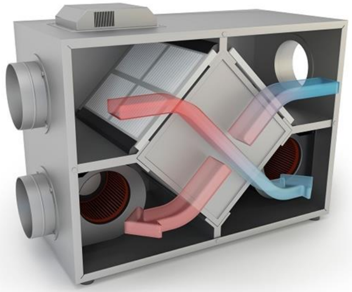


"   …   in Hot & Humid Climates"

Pressurize A Building

Balanced Air Ventilation System  &  Or 

DOAS (Dedicated Outside Air System)

"   …   In Hot & Humid Climates "

Example for office spaces:

USA: 5.5 l/s

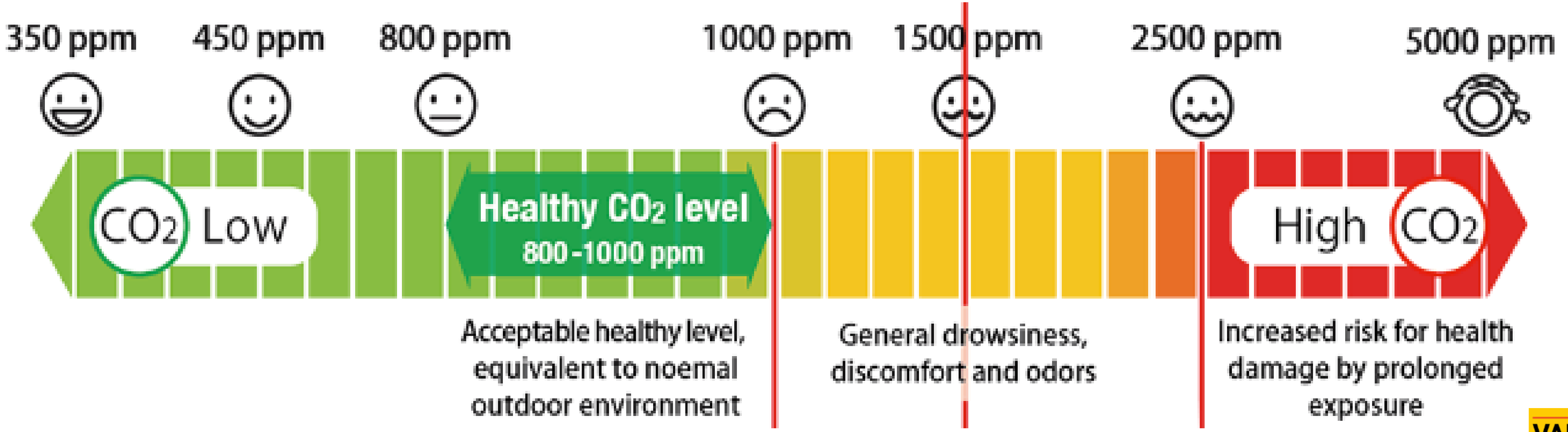
NL: 8.3 l/s

}

Average:

6.9 l/s = **24.84 m3/h** per person on 10 m2

To maintain a maximum CO2 level of **1200** ppm



"   …   in Hot & Humid Climates"

24.84 m3/h per person @ 20 people = **500 m3/h outdoor air intake**

Hot & Humid Outdoor Air Condition = 32C (90F) @ 65% RH

Dewpoint Temperature of 25C (77F) !

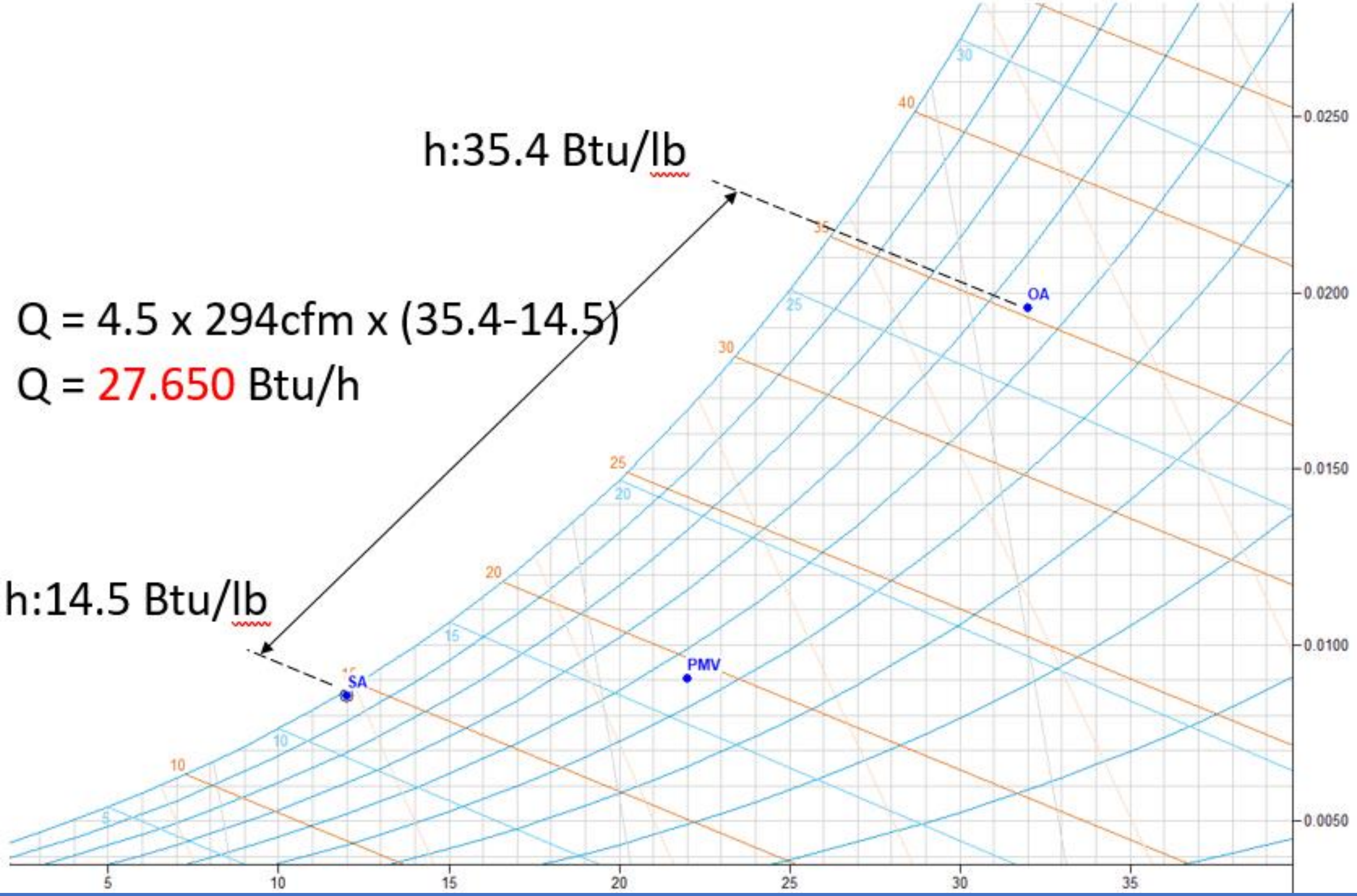
PMV Indoor Comfort Condition ~ 24C (75F) @ 50% RH

LOCAL Desired Indoor Conditions = 22C (71F) @ 55% RH

To condition 500 m3/h (294cfm) from 32C@65% to 22C@55%

A total cooling capacity of 27.650 Btu/hr is required

" … in Hot & Humid Climates"



Q = 4.5 x 294cfm x (35.4-14.5)

Q = 27.650 Btu/h

" … in Hot & Humid Climates"

27.650 Btu/h for 500 m3/h (294cfm)

For an office with 20 people

Air conditioning system efficiency of EER 11.0 Btuh/W

27.650 / 11.0 = **2.5 kWh**

Which is about **25%** of the total AC consumption

~ 540 kWh / Month @ 0.55 = **AWG 297,= / Month**

(Based on 10hrs AC operations, 5 days a week)

By just bringing it in to satisfy CO_2 levels

" Cost Effective … "

Spend less energy and save money by applying

Controls

Energy Recovery

Reduce Building Maintenance

Lower Sick Leave or Health Cost

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" Cost Effective … "

Controls based on:

Occupancy / Scheduling

Demand CO2 and/or VOC

sensor

controller

Balanced Ventilation

Pressure (also reduces motor power consumption)

PROTEC

VAN DORP
VOOR MORGEN

" Cost Effective … "

27.650 Btu/h for 500 m3/h (294cfm)

For an office with 20 people

Air conditioning system efficiency of EER 11.0 Btuh/W

27.650 / 11.0 = **2.5 kWh**

Which is about **25%** of the total AC consumption

BASED ON 8 HRS vs 10 HRS

~ 432 kWh / Month @ 0.55 = **AWG 237,= / Month**

(Based on 8hrs AC operations, 5 days a week)

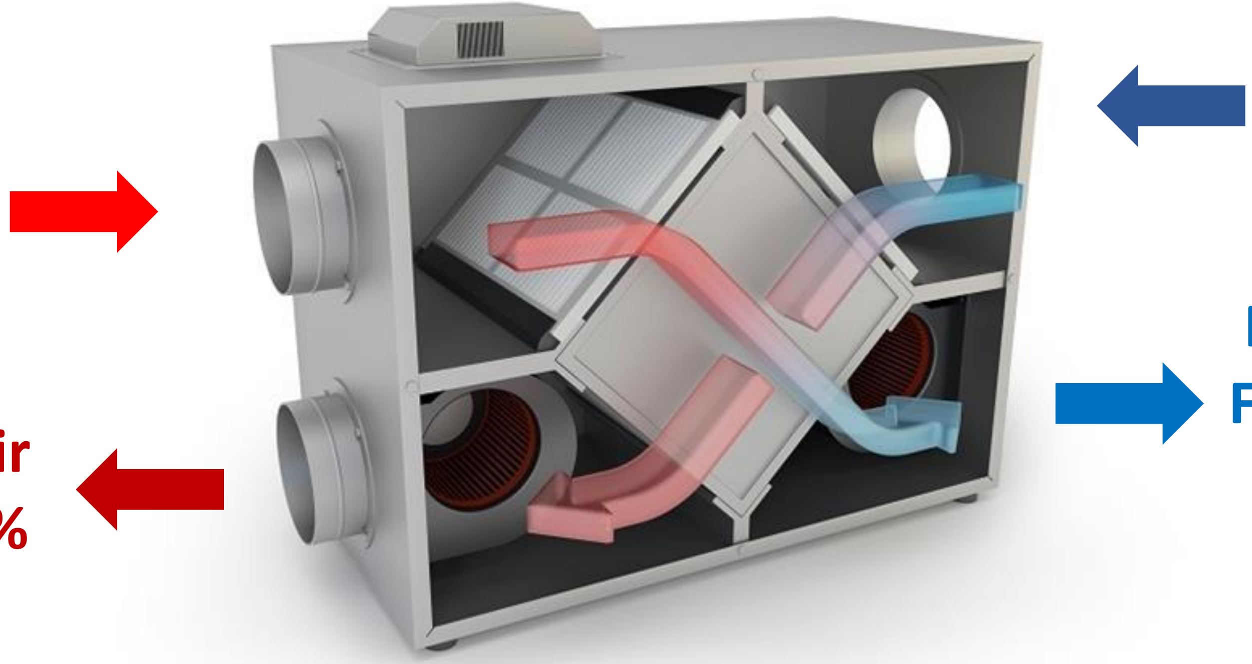
Saved AWG 60 / Month = AWG 720 / Year

By just SCHEDULING OCCUPANCY

" Cost Effective … "

Energy Recovery in a Balanced Ventilation System:

Pre-conditioning outdoor air intake



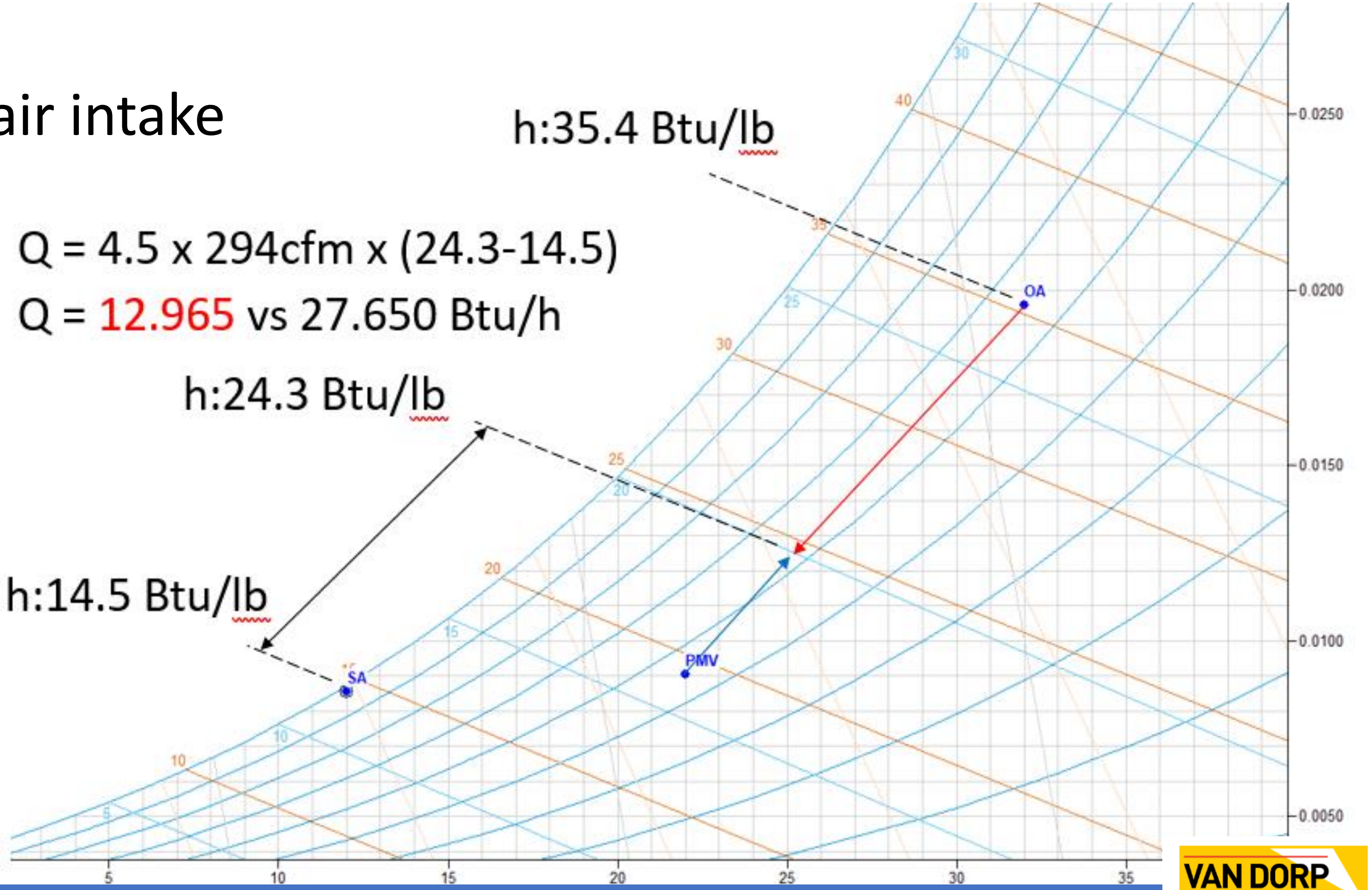
" Cost Effective … "

Energy Recovery:

Pre-conditioning outdoor air intake

Q = 4.5 x 294cfm x (24.3-14.5)

Q = 12.965 vs 27.650 Btu/h



" Cost Effective … "

12.965 Btu/h for 500 m3/h (294cfm)

For an office with 20 people

Air conditioning system efficiency of EER 11.0 Btuh/W

12.965 / 11.0 = **1.18 kWh** (vs 2.5)

Which is about **12%** (vs 25) of the total AC consumption

~ 255 kWh / Month @ 0.55 = **AWG 140,= / Month**

(Based on 10hrs AC operations, 5 days a week)

Saved AWG 157 / Month = AWG 1.884 / Year

By Applying Energy Recovery

" Cost Effective … "

Less Building Maintenance:

Less Sick Leave or Health Costs:

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"Cost Effective Ventilation in Hot & Humid Climates"

Is Feasable

Don't hesitate

It will improve IAQ and Occupant Satisfaction

PRO TEC

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