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Heating / Cooling Load Calculation: What we have and what we need

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Overview

Let's get started

1) Design heating load calculation
2) Peak dehumidification calculation
3) Peak load calculation for future climate

Issue 1 – Design Heating Load Calculation

Heating load calc

- Passive house peak / design heating load calculation is unusual.
  - With some justification, but there is some lack of transparency.
- Some credit for internal gains no one else does this
- Some credit for solar gains
  - Two solar gain scenarios – clear & colder, cloudy & less-cold
- Special design day conditions
  - Moderated outdoor temperatures
    - Builds in an assumption about the building time constant (problematic).

Known standards / methods:

- ACCA Manual J
- ASHRAE Handbook of Fundamentals 1989-2001
- ASHRAE HOF 2005-2017
- ASHRAE 183
- CAN/CSA F280
- EN 12831

Proposed Remedy

- Incorporate these ideas into a more open method
  - Design conditions should be a well-defined property of the climate data.

    And avoid assumptions about the building.
- Align with / Build on: previous work by ASHRAE
  - ASHRAE Handbook state-of-the-art for Nonresidential cooling load calculation is Heat Balance Method (Chapter 18 section 5)
    - Hourly "dynamic simulation" of a design day, zone-by-zone, 24-h steady periodic condition – iterates through all surfaces in each hour, and through the 24 h of a day.
  - It was extended to Residential cooling load in ASHRAE RP-1199 "ResHB"
    - Includes default values suitable for residential.

Proposed Remedy

Heating load calc

- Extend the 24-hour steady-periodic heat balance method to heating load calculation, for passive buildings.
  - The cooling load calc uses a hottest-month dry-bulb temperature daily range –> assemble analogous data for coldest month.
    - Use ASHRAE 99% dry-bulb design temperature
    - Adjust for clear/colder versus cloudy/milder?
  - Finite internal gains
    - Fixed - 1.6 W/m^2 (0.51 Btu/h.ft^2) ?
      - Gain from 1 person about every ~500 ft^2.
    - Variable - Gain from occupants or derated occupancy only?

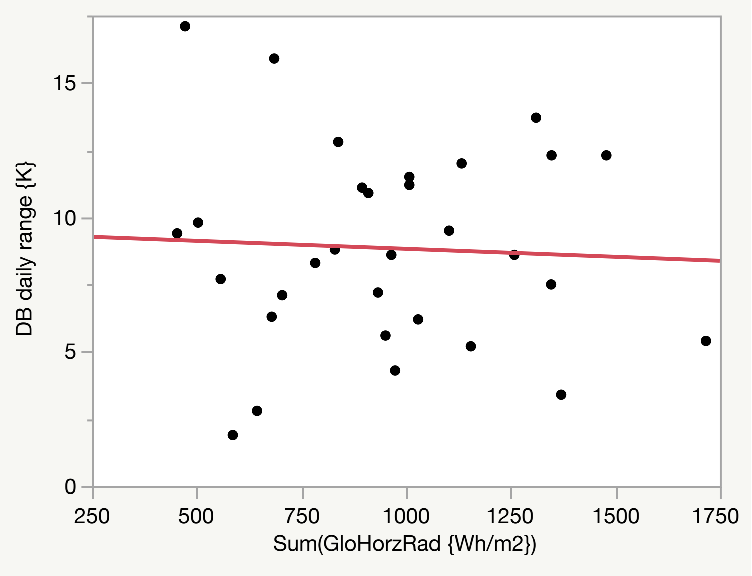
    - Technically allowed by ASHRAE 183. Clause 9.2:

"9.2 Credit for solar heat gains and for internal heat gains shall not be included as part of the calculation of the peak heating load. Exception: Where constant or permanent internal heat gains are known to be present in the zone to be heated, the peak heating load may be adjusted to account for these available heat gains."

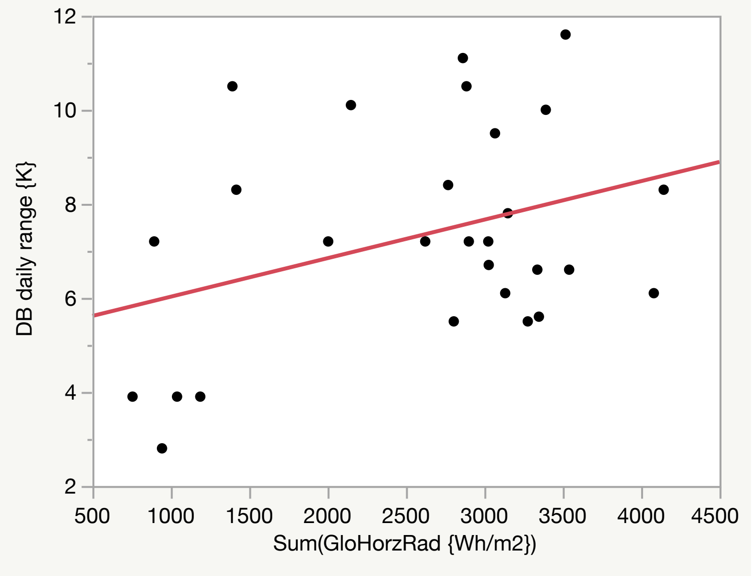
Example climate data – coldest month

Heating load design day info

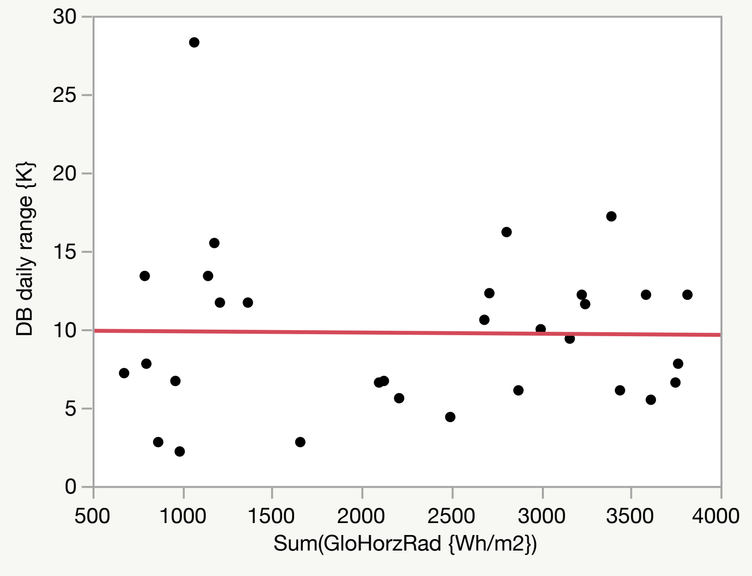
Edmonton, January



JFK, February



Memphis, January



Average daily range in the coldest month:	**9.8 K**	**7.3 K**	**9.8 K**

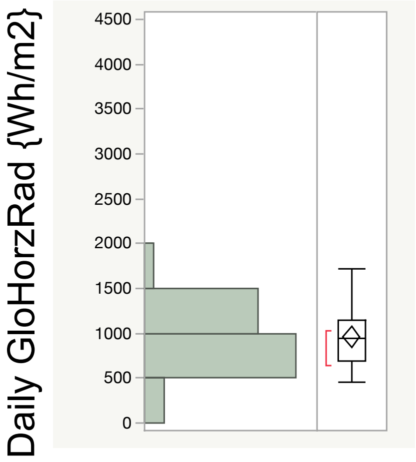
From CWEC, TMY3 climate data

- No significant correlation between daily temperature range and daily solar radiation.

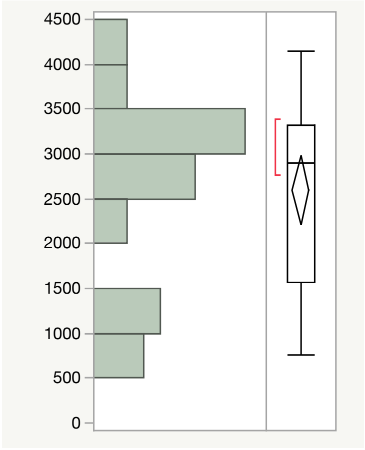
Example climate data – coldest month

Heating load design day info

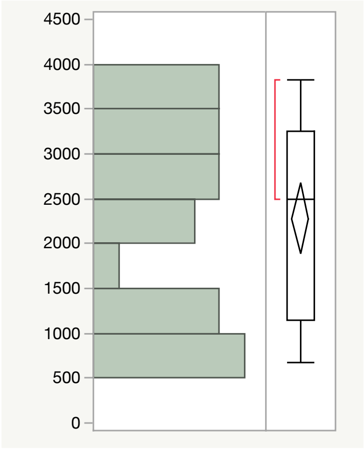
Edmonton, Jan



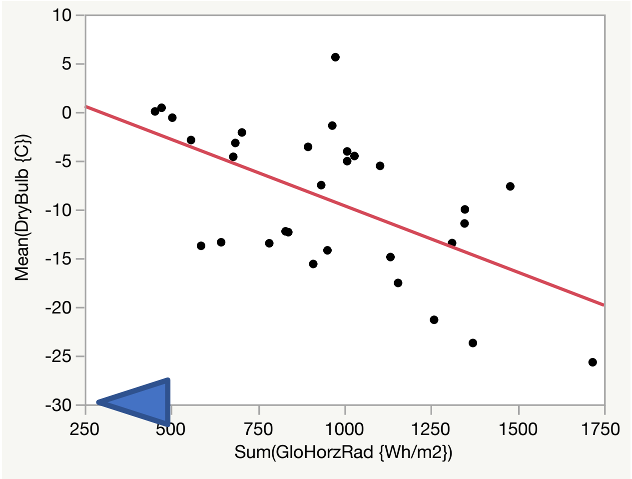
JFK, Feb

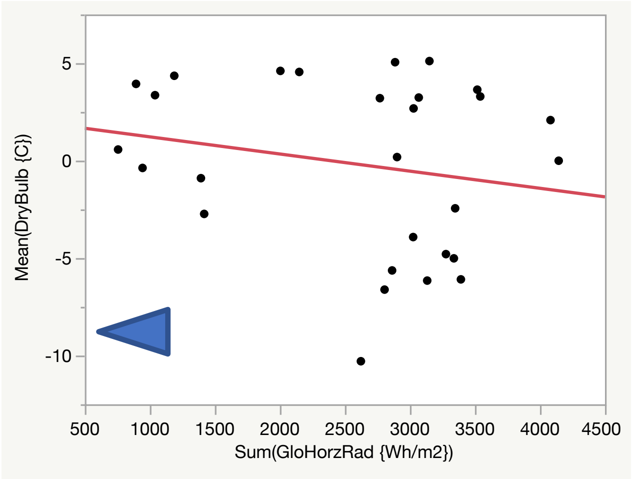


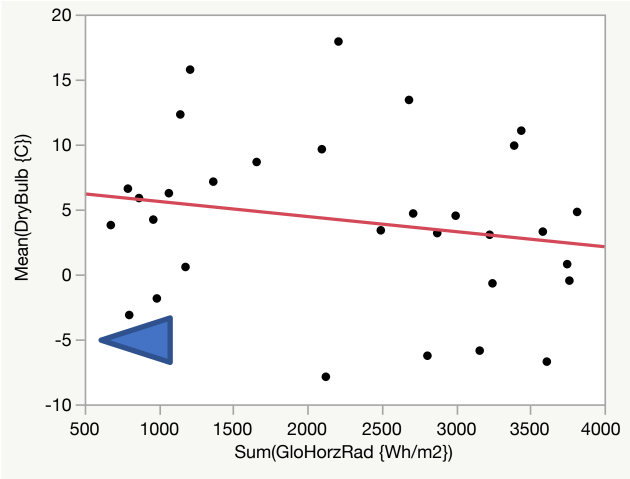
Memphis, Jan



High daily solar radiation (clear weather) does not always have a significant correlation with low daily average temperature.







99%

ASHRAE 99% temp is low enough that it probably always represents a clear sky condition.

Sensitivity -0.0136 K/(Wh/m2)

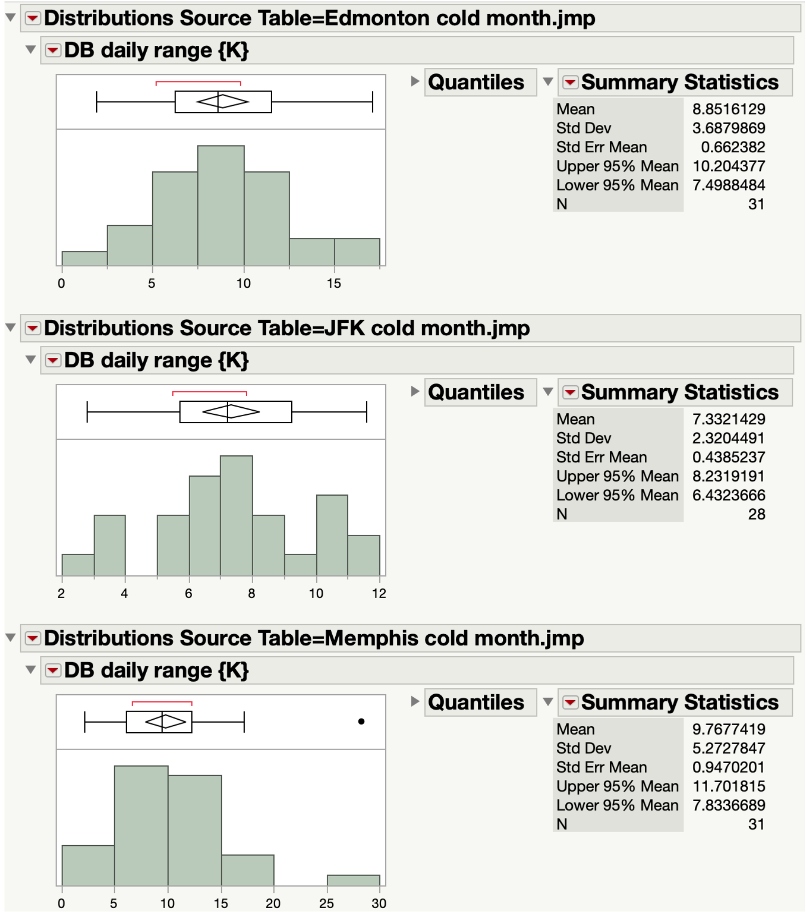
Proposed Protocol

Heating load calc

Extend the 24-hour steady-periodic heat balance method to <u>heating</u> load calculation, for passive buildings.

- Daily temperature swing – average daily range in the coldest month
  - From typical meteorological year climate files
- Clear/colder day
  - Solar radiation – ASHRAE HOF Chapter 14 section 2, clear-sky radiation
  - Temperature – ASHRAE 99% dry-bulb
- Wind speed – ASHRAE mean wind speed and direction coincident with 99.6% dry-bulb temperature
- Internal gains – From occupants only, at e.g. 70% of design occupancy for dwelling units and:
  - 220 Btu/person.h sensible, per BAHSP 2014 Table 48 (ASHRAE 2009).

About 1.3 W/m2 at 35 m2/person design occupancy.



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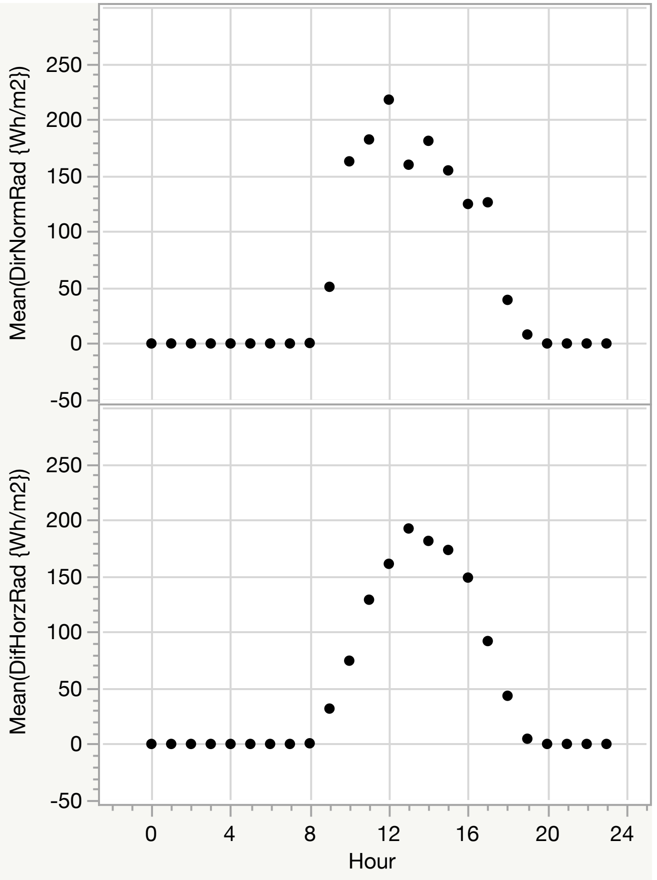
Proposed Protocol

Extend the 24-hour steady-periodic heat balance method to heating load calculation, for passive buildings.

- Cloudy/milder day
  - Only generate one if there is a statistically significant effect on daily mean temperature of the daily global horizontal radiation, over the days of the coldest month. (Of the 3 here, only Edmonton).
  - Solar radiation – average hourly profile over the days in the coldest month that are below-median for daily GloHorzRad.

Direct Normal and Diffuse solar radiation, JFK, February, days below median GloHorzRad



Proposed Protocol

Extend the 24-hour steady-periodic heat balance method to heating load calculation, for passive buildings.

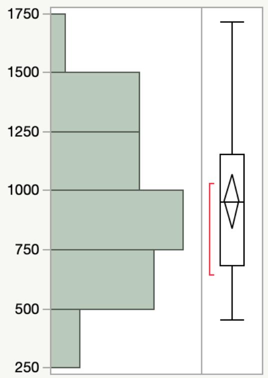
- Cloudy/milder day
  - Only calculate if there is a statistically significant effect on the daily mean temperature of the daily global horizontal radiation, over the days of the coldest month. (Of the 3 here, only Edmonton).
  - Solar radiation – average hourly profile over the days in the coldest month that are below-median for daily GloHorzRad.
  - Temperature – Using the sensitivity of daily mean temperature to daily GloHorzRad in the coldest month, calculate a temperature adjustment from the 99% temp, based on the difference between the top and bottom quartiles of daily GloHorzRad. **Here for Edmonton**:

Delta T = -0.0136 K/(Wh/m2) * (685-1155 Wh/m2) = 6.4 K

Temp = -29.2 C + 6.4 K = -22.8 C

Table=Edmonton cold month.jmp

Sum(GloHorzRad {Wh/m2})



Quantiles

100.0%	maximum	1717
99.5%		1717
97.5%		1717
90.0%		1366.4
75.0%	quartile	1155
50.0%	median	951
25.0%	quartile	685
10.0%		513.8
2.5%		453
0.5%		453
0.0%	minimum	453

Summary Statistics

Mean	955.80645
Std Dev	317.20902
Std Err Mean	56.972422
Upper 95% Mean	1072.1597
Lower 95% Mean	839.45324
N	31

Issue 2 – Peak dehumidification load

Result of applying passive building principles:

- Lower sensible cooling load
- Latent cooling load about the same or higher
- Lower sensible heat ratio

WUFI Passive <u>peak</u> cooling load calc is sensible only

- Arguably ok for regulating envelope design but incomplete for mechanical system sizing.

Proposed remedy

Dehumidification load

”What we need,” L. White 2017

1. An affordable, efficient, reliable, simple mechanical system solution that handles latent loads (ideally before introduced to the space).
2. Awareness and capability of AC systems to control latent loads.
3. Re-think ventilation strategies and requirements?
4. WUFI Passive integrated **calculation for latent cooling load and output of sensible heat ratio**.
5. Deeper understanding of potential of hygric buffering.

Proposed remedy

Dehumidification load

Winkler & Booten 2016, NREL/TP-5500-66515:

- 1. Calculation of peak cooling sensible and latent loads and sizing of primary cooling equipment (standard ACCA Manual J and S procedures using Building America House Simulation Protocols sensible and latent internal gains)
- 2. Calculation of part-load sensible and latent loads using the ASHRAE 2% dew point (DP) design condition with a slightly modified Manual J load calculation procedure (see Section 2.2.1)
- 3. Prediction of primary cooling equipment moisture removal at the DP design condition
- 4. Calculation of unmet moisture load at part-load cooling conditions and sizing of required supplemental dehumidification equipment (see Section 2.2.2).

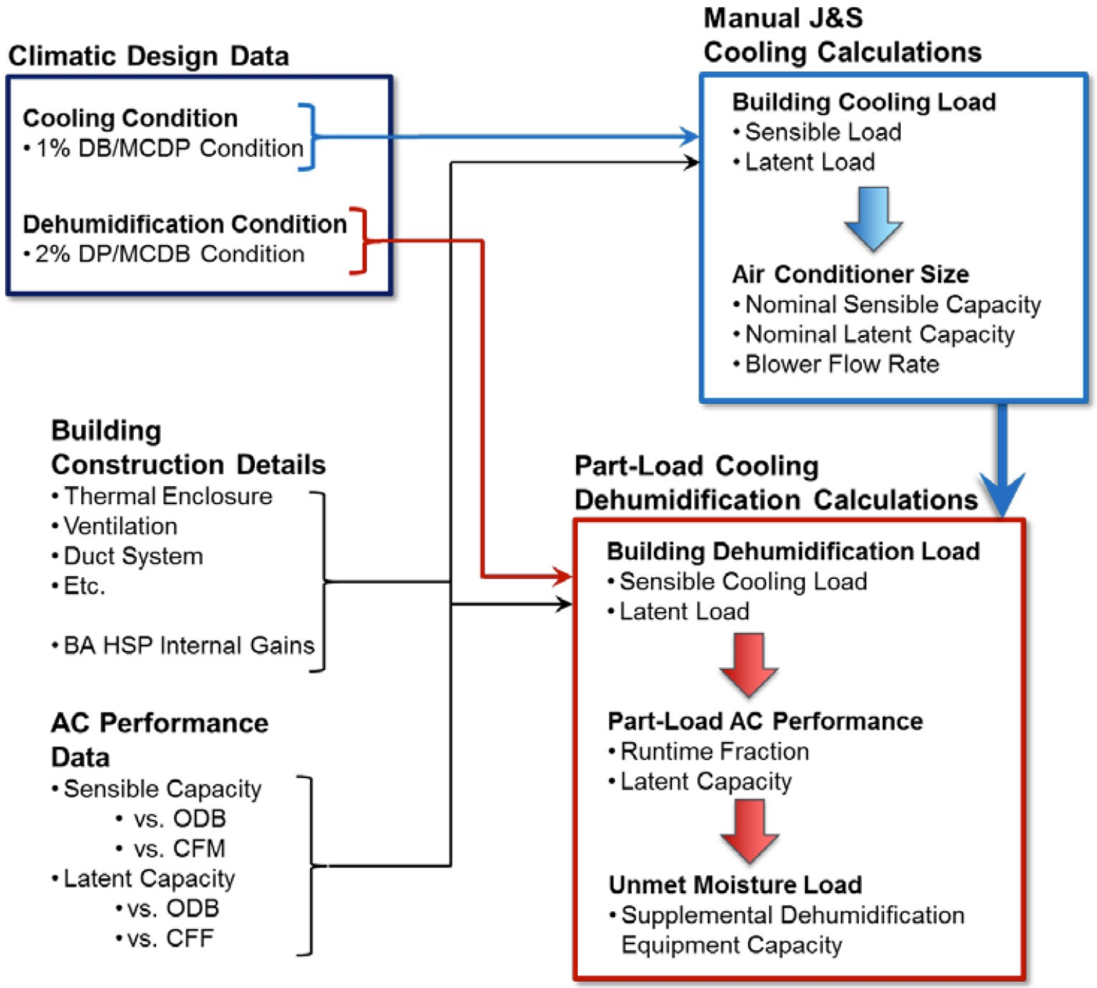


Figure ES-2. Overview of supplemental dehumidification equipment sizing proc re.

Proposed remedy

Dehumidification laod

- PHIUS has a calculator for the peak latent cooling load
- Based on ASHRAE Handbook of Fundamentals
  - Chapter 17, Equations 15-18, 31, 32
- It does not do 3) & 4) on the last slide – netting out the moisture removal by the main cooling device to get the supplemental, however:
  - It can do and it may be prudent to check the case of no sensible cooling, thus no removal by the main system, and 100% RH outside.
  - Using ~76 F and 100% RH (~135 grains/lb)

Latent Cooling Load Calculator v2.1

SOURCE: ASHRAE Fundamentals 2013		Default	
Chapter 17		Input	
		Calc'd value	

	Description	Value	Units	Source
	Location	Chicago, IL (Midway)		WUFI / Project Data
	Dehumidification design humidity ratio (0.4%)	134	grains/lb	ASHRAE
	Mean Coincident DB @ Design dehum ratio	84.1	F	ASHRAE
	Net Volume	63545	ft3	WUFI / Project Data
	Occupancy	24	people	WUFI / Project Data
	iCFA	9177	ft2	WUFI / Project Data
	Qvi (combined infiltration/ventilation flow rate, not including balanced component) - NATURAL infiltration rate	0.13	1/hr	WUFI / Project Data
	Qvi	137.6808333	cfm	Calc
	ERV? (YES/NO)	YES		WUFI / Project Data
	Es, ERV/HRV sensible effectiveness	0.84	% (0-1)	WUFI / Project Data
	Qbal, hr	480	cfm	WUFI / Project Data
	Qbal, oth	14.16	cfm	WUFI / Project Data
	Indoor Temp	77	F	Default
	Outdoor Temp (MCDB @ DDHR)	84.1	F	ASHRAE
	delta T	7.1	F	Calc
	Outdoor moisture	134	grains/lb	ASHRAE
	Outdoor moisture	0.019142857	lbw/lbda	Calc
	Indoor Moisture (default to 77F, 60% RH)	83.27342835	grains/lb	Default
	Indoor Moisture (default to 77F, 60% RH)	0.011896204	lbw/lbda	Default
	delta W	0.007246653	humidity ratio difference	Calc
	Et, ERV/HRV total effectiveness	0.64	% (0-1)	WUFI / Project Data ?
	Outdoor air enthalpy (with DB & Humidity Ratio)	41.5	BTU/lb	Psychometric Chart/Calc
	Indoor Air enthalpy (default to 77F, 60% RH)	31.50857992	BTU/lb	Default
	delta h	9.991420076	BTU/lb	Calc
	Cs (air sensible heat factor) default 1.1 @ sea level. Applicable up to 1000ft in elevation. More info in Chapter 18	1.1	BTU/hr.F.cfm	Default
	Cl (air latent heat factor)	4840	BTU/hr.cfm	Default
	Ct (air total heat factor)	4.5	BTU/hr.cfm/BTU/lb	Default
(15)	qvi,s (sensible ventilation/infiltration load)	1785.684908	BTU/hr	Calc
(17)	qvi,t	14596.30323	BTU/hr	Calc
(16)	qvi,l NO HRV/ERV	5325.635167	BTU/hr	Calc
	qvi,l with HRV/ERV	12810.61832	BTU/hr	Calc
(18)	**qvi, l (Ventilation/infiltration latent gain)**	**12,811**	**BTU/hr**	
(31)	**qig, l (intenal latent gain)**	**1,694**	**BTU/hr**	
(32)	**TOTAL LATENT COOLING LOAD**	**14,505**	**BTU/hr**	

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FYI

- "Depending on ventilation requirements and local climate conditions, peak cooling coil loads may occur at peak dehumidification or enthalpy conditions instead of design dry-bulb conditions. Coil loads should be checked against all those peak conditions."

  2017 ASHRAE Handbook of Fundamentals, Ch. 18, Section 8 System effects, 8.2 Ventilation

- That is, for the mechanical designer, four design conditions:
  - Peak heating
  - Peak sensible cooling
  - Peak dehumidification
  - Peak enthalpy

Issue 3 – Design-Day Parameters for Future

Future climate design conditions

- In addition to shifting the averages, climate change may alter the design-day extremes.
- Allegedly, the "morphing and downscaling" from coarse climate models to building-design climate data could address both however:
  - Meteonorm's future climate function doesn't change the design days.
  - ASHRAE Handbook, ashrae-meteo.info do not have any "future" modes.
  - The IPCC has a lot of possible future emission scenarios.
    - Meteonorm picked three (a low, medium, and high emission.)
- Workaround? Do a full hourly annual calculation and set a threshold on "unmet hours"

No remedy to propose, rather, a change of perspective

Future Climate Design Days

Future climate design conditions

- Proposed perspective – think about resilience instead of equipment sizing.
- Heating:
  - People do not really have a hard lower limit on ambient temperature, but pipes do. Design for:
    - Passive freeze protection (e.g. how deep is the sewer line)
    - Backup power to run heat recovery ventilation.
- Cooling:
  - Still resist temptation to oversize sensible capacity for normal operation.
  - Instead, design for outage:
    - On-site PV, dehumidifier, below-ground shelter, etc.

Heating/cooling load calculation – Key takeaways

1. Design heating load calculation
   - Passive house method is unusual and design-day generation is proprietary/nontransparent.
   - ➢ Proposal: extend ASHRAE 24-hour steady-periodic heat balance method from cooling load to also heating load.
2. Peak dehumidification calculation
   - WUFI Passive peak cooling load calc is sensible only, but buildings with low sensible cooling load still need at least as much dehumidification.
   - ➢ Proposal: At least do a ”pure dehumidification” load calculation at 77 F and 100% RH and provide enough supplemental capacity to handle that.
3. Peak load calculation for future climate
   - Info on design-day conditions not yet readily available.
   - ➢ Proposal: Ask a different question – consider how to design for outages caused by weather extremes instead of how to design for normal operation therein.

Questions?

Ok then

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