JRS ENGINEERING
BUILDING ENVELOPE CONSULTANTS

CONDENSATION ANALYSIS IN A COLD CLIMATE

Wesley Narciso, *P.Eng., CRP, PRA, LEED AP*

June 19, 2014

OUTLINE

- History and Background
- Visual Review
- Testing Methodology
- Results and Discussion
  - Psychrometric and Thermal Analysis
  - Ventilation Conditions (ASHRAE, Thermal Comfort and CONTAM Modeling)
- Conclusion
- Recommendations

HISTORY AND BACKGROUND

Property and Climate info

Location: Whistler, BC (between Highway 99 and Whistler/Blackcomb Mountains)

Construction Date: Circa 1999

Management Structure: Stratified property with private hotel management and original developer on strata council

Whistler:	Vancouver (YVR):
Temps (Nov to Feb): -3.2°C to 0.6°C	Temps (Nov to Feb): 3.3°C to 6°C
Days under 0°C: 152 days	Days under 0°C: 46 days

*Environment Canada (Climate Services)

HISTORY AND BACKGROUND

Building description:

- 1 building (2 towers), over 380,000 ft^2 (gross floor area)
- 10 stories, 419 units, 19 staff units
- Multiple amenities (restaurants, lounges, ballroom, conference rooms, spa, child care, business centre, commercial/retail units etc.) with strict and unpredictable occupancy limitations

Structure and Building Envelope:

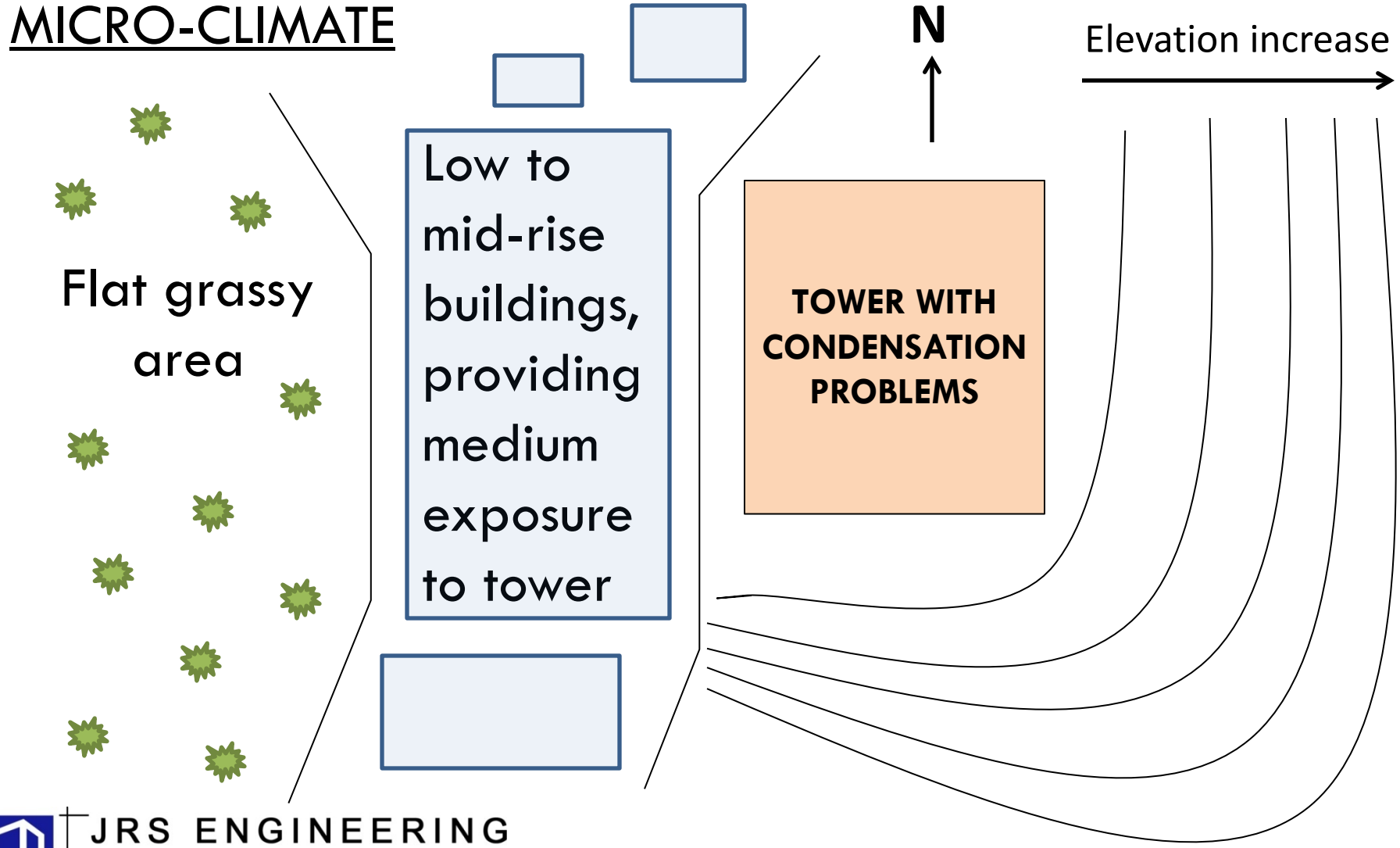
- Concrete tower with steel stud infill walls
- Exterior Insulated Finishing System (EIFS) with sloped metal shingle roof
- Aluminum framed, thermally broken glazing (window wall, punched windows and sliding doors)

HISTORY AND BACKGROUND

Macro Climate

HISTORY AND BACKGROUND

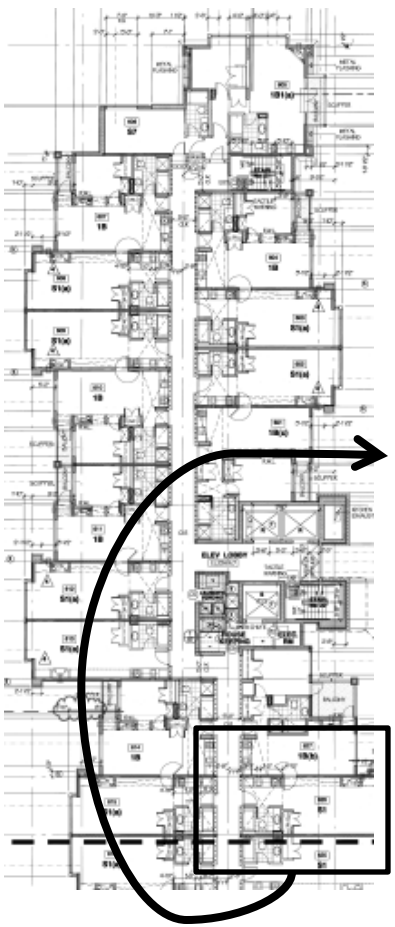
MICRO-CLIMATE

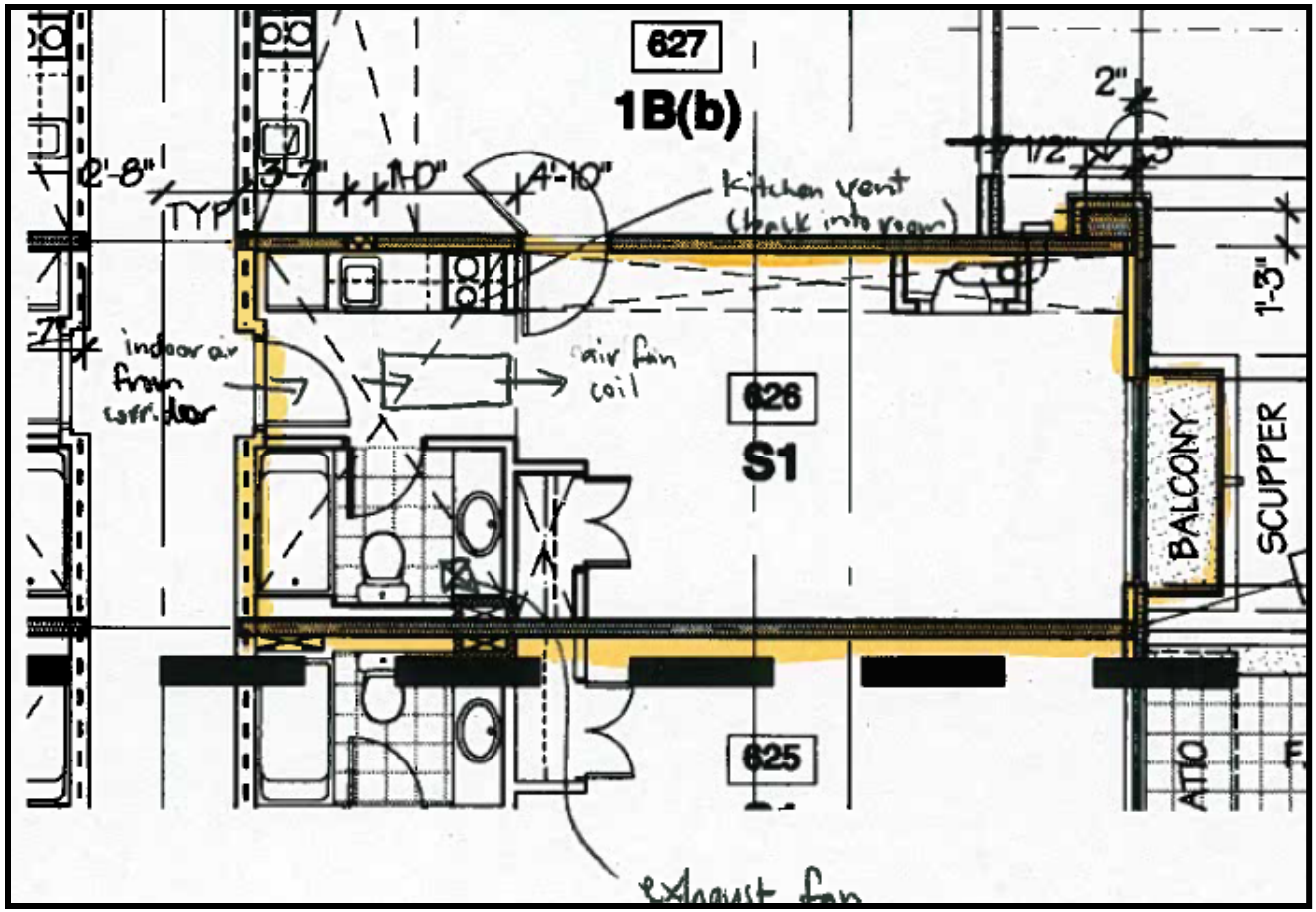


JRS ENGINEERING
BUILDING ENVELOPE CONSULTANTS

HISTORY AND BACKGROUND

Floor Plan and Room Configuration

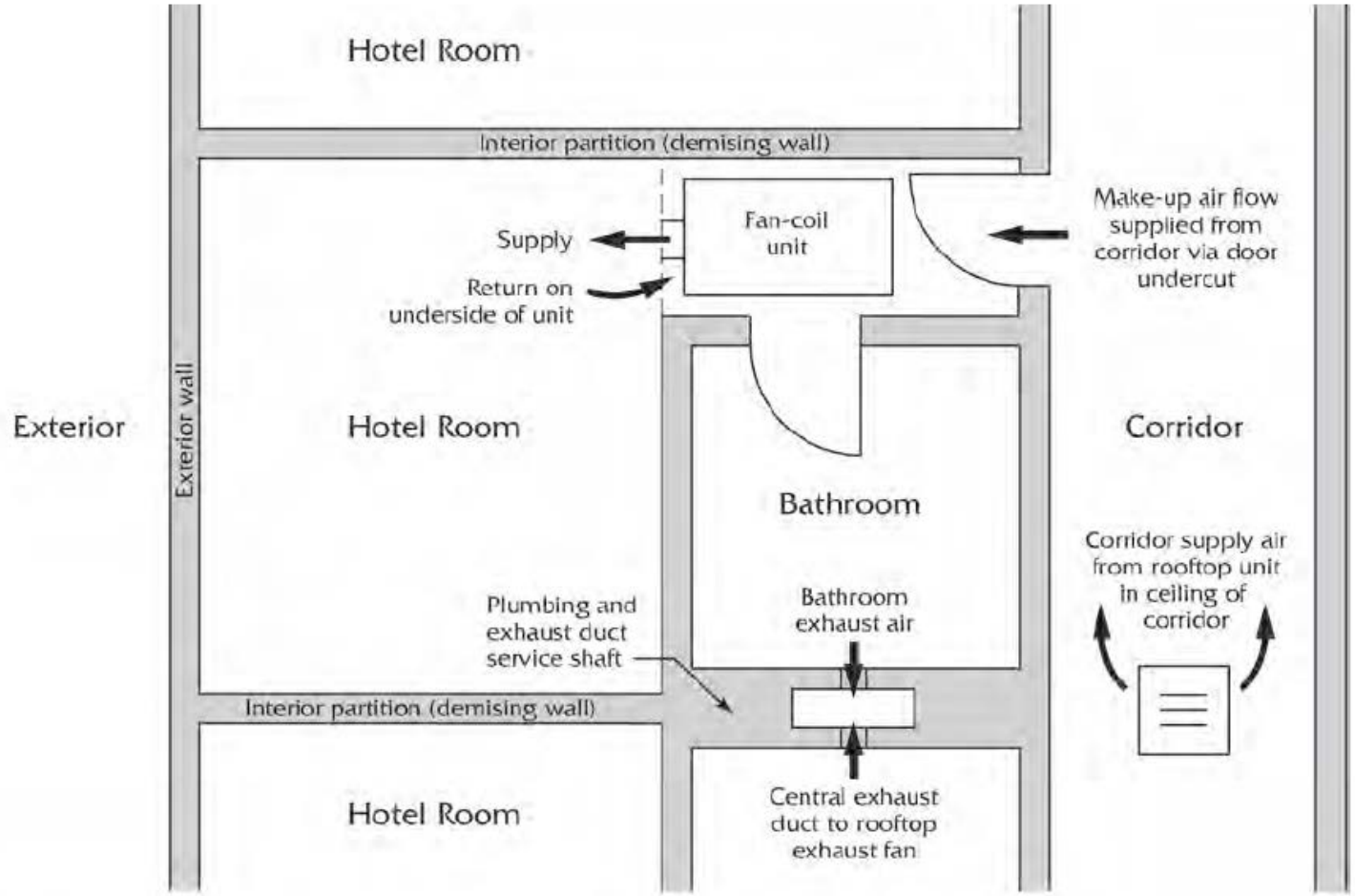




JRS ENGINEERING
BUILDING ENVELOPE CONSULTANTS

HISTORY AND BACKGROUND

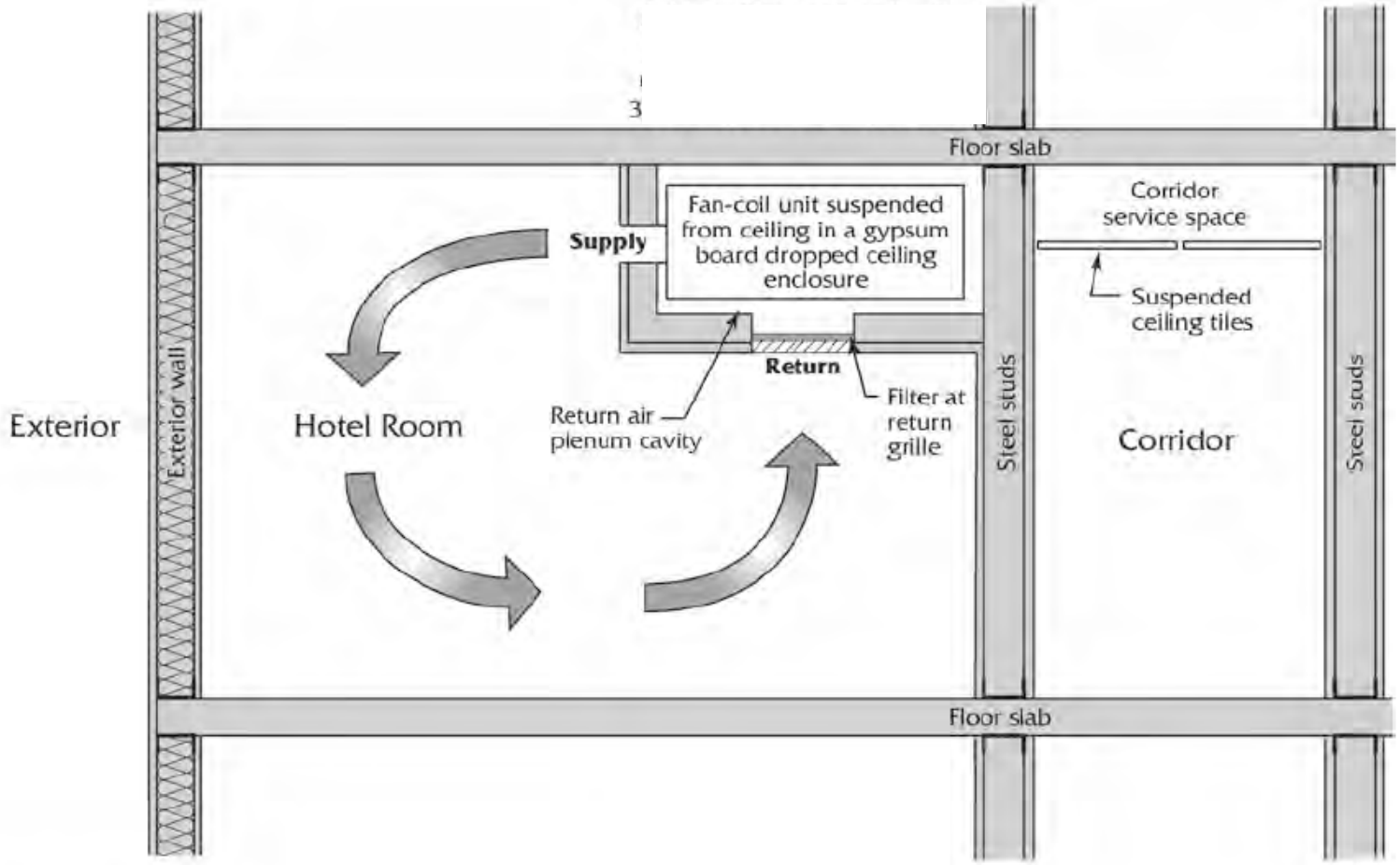
Hotel Room/Bath Suite (Plan View)



Dr. Joseph Lstiburek, PhD Thesis, University of Toronto

HISTORY AND BACKGROUND

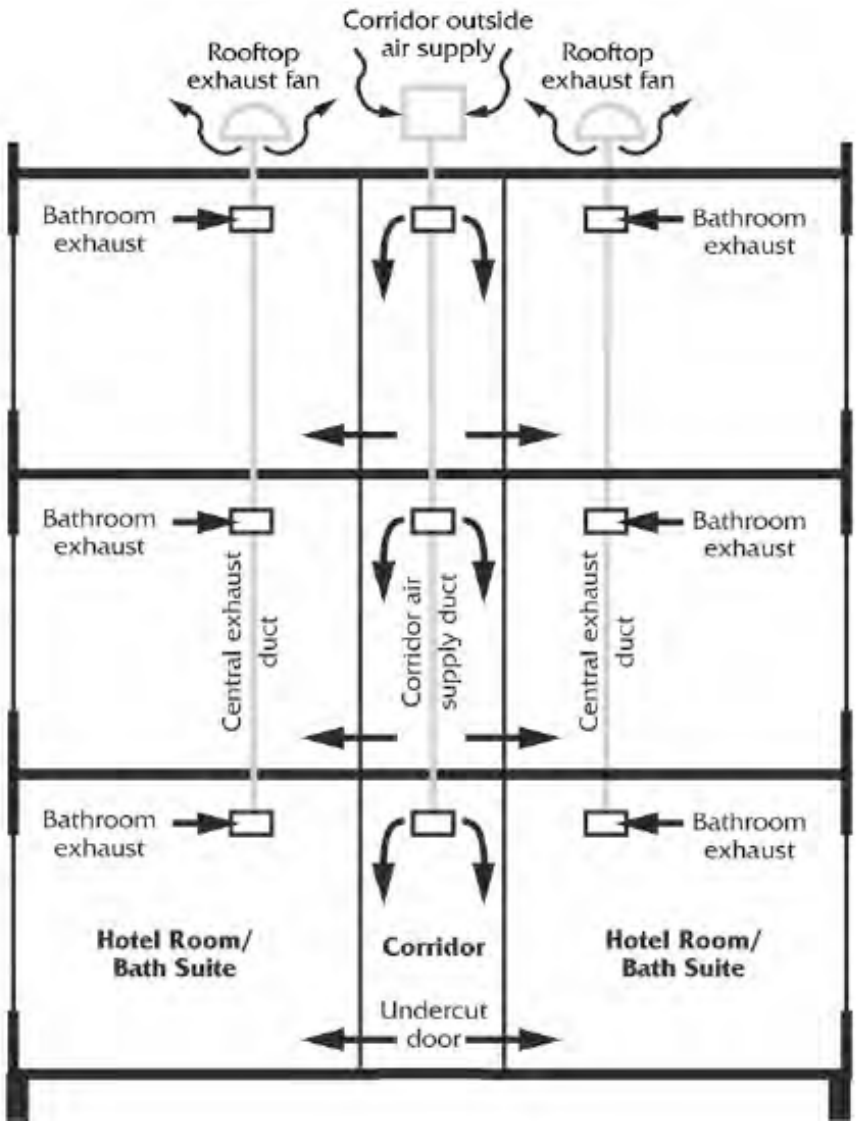
Hotel Room/Bath Suite (Section View)



Dr. Joseph Lstiburek, PhD Thesis, University of Toronto

HISTORY AND BACKGROUND

Hotel HVAC System



Dr. Joseph Lstiburek, PhD Thesis, University of Toronto

JRS ENGINEERING
BUILDING ENVELOPE CONSULTANTS

HISTORY AND BACKGROUND

Room Layout

VISUAL REVIEW

JRS ENGINEERING
BUILDING ENVELOPE CONSULTANTS

VISUAL REVIEW

VISUAL REVIEW

VISUAL REVIEW

JRS ENGINEERING
BUILDING ENVELOPE CONSULTANTS

VISUAL REVIEW

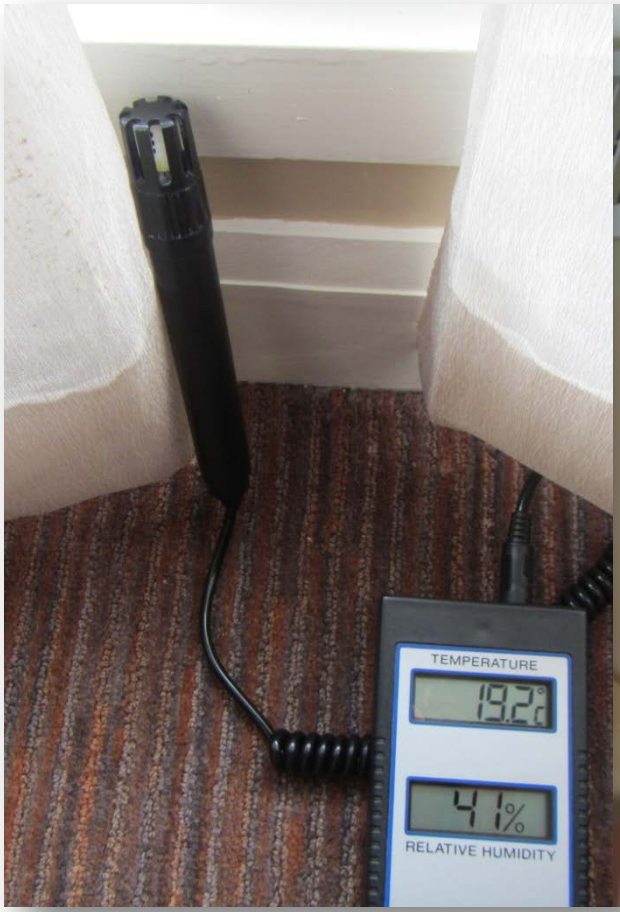
JRS ENGINEERING
BUILDING ENVELOPE CONSULTANTS

VISUAL REVIEW

JRS ENGINEERING
BUILDING ENVELOPE CONSULTANTS

TESTING METHODOLOGY

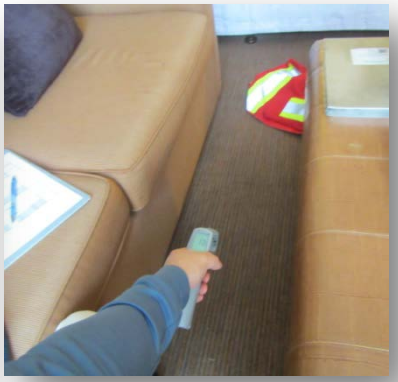
Air Temperature and Humidity Measurements (Interior and Exterior, High and Low)

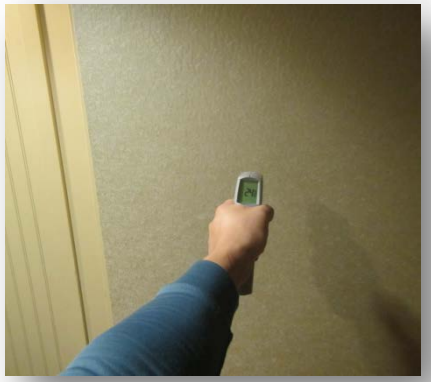


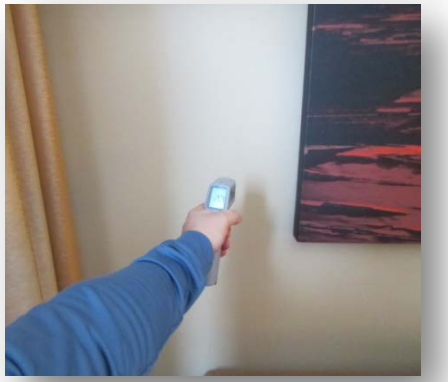
TESTING METHODOLOGY

Surface Temperature Measurements (Interior and Exterior, High and Low)







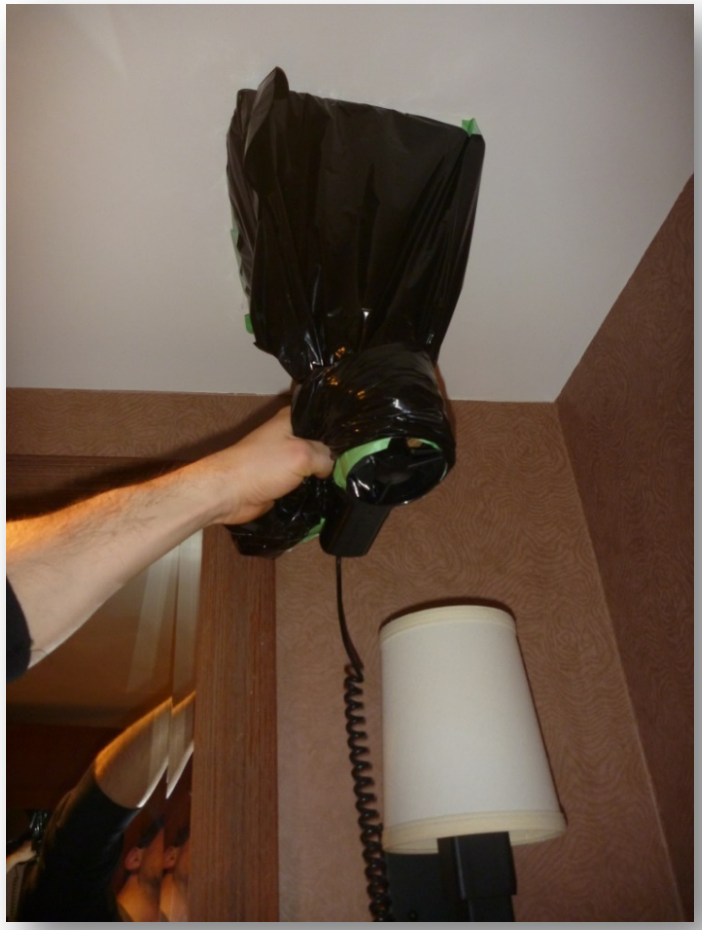



TESTING METHODOLOGY

Smoke Pencil Video

TESTING METHODOLOGY

Airflow rates (Under door, bathroom fan, FCU)



TESTING METHODOLOGY

Moisture Loaded Scenario

RESULTS AND DISCUSSION

Psychrometric Analysis of Sliding Door

- Dew point calculations
- Simplified conductance heat flow
- Heat flow modeling (THERM)

Ventilation Conditions

- ASHRAE calculations (Supply/Exhaust Air)
- FCUs and other fans
- Thermal comfort (Fanger Model)
- CONTAM modeling

PSYCHROMETRIC ANALYSIS OF SLIDING DOOR

Dew Point Calculations

Location	Average Temp (C)	Average RH (%)	Dew Point Temp (C)
FEBRUARY 10, 2014			
	Semi-Vacant		
Living Room/Kitchen (Air)	21	47	9.3
Near Sliding Door (Air)	19	45	6.7
Sliding Door Surface (Surface)	3		
	Moisture Loaded		
Living Room/Kitchen (Air)	25	82	21.4
Near Sliding Door (Air)	23	67	16.6
Sliding Door Surface (Surface)	9		
MARCH 29, 2014			
	Semi-Vacant		
Living Room/Kitchen (Air)	21	42	7.4
Near Sliding Door (Air)	18	50	7.4
Sliding Door Surface (Surface)	8.5		

PSYCHROMETRIC ANALYSIS OF SLIDING DOOR

Typical semi-vacant scenario (average conditions):

Temp: **21˚C** & RH: **45 %** Dew Point Temp: **8.7˚C**

To avoid condensation, the coolest surface in the room (sliding door frame) must be above **8.7˚C**.

Air Leakage: Observed air leakage with use of smoke pencil at joints in the frame. This air leakage reduces the interior surface temperature of frame due to wind washing.

Convection: Heating fan coil intended to provide air circulation at sliding door. Heavy floor to ceiling curtains impeded the convection currents.

PSYCHROMETRIC ANALYSIS OF SLIDING DOOR

Conductance Heat Flow (Current door vs. New Door)

$$\mathbf{Q = Area \times U\text{-}Value \times (T_{Inside} - T_{Outside})} \qquad \text{(Watts)}$$

Interior surface of existing door (U-value of 2.8 $W/m^{2o}C$) = **3°C**

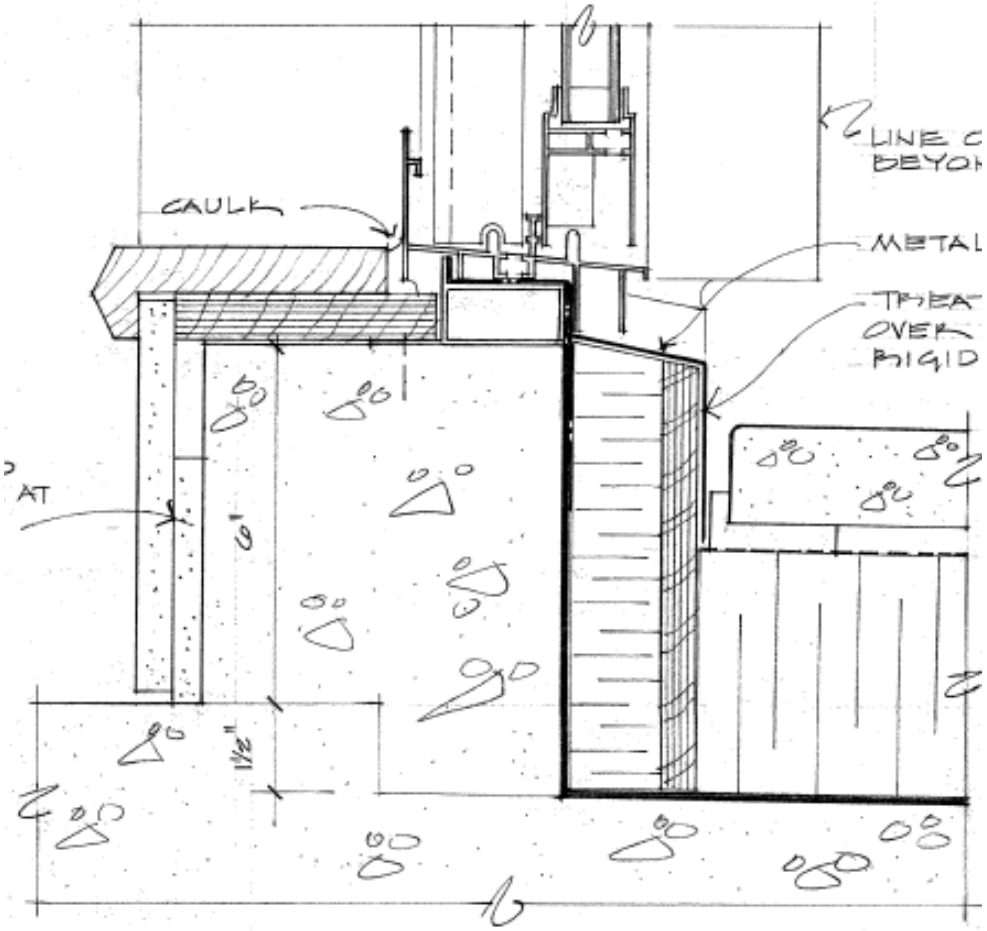
Interior surface of a new, better insulated door (e.g. 1.6 $W/m^{2o}C$) = **9.5°C**

**Assuming constant area and heat flow*

Interior surface temp **9.5°C > 8.7°C** (Dew point temp). Therefore, less likely to condense on new slider.

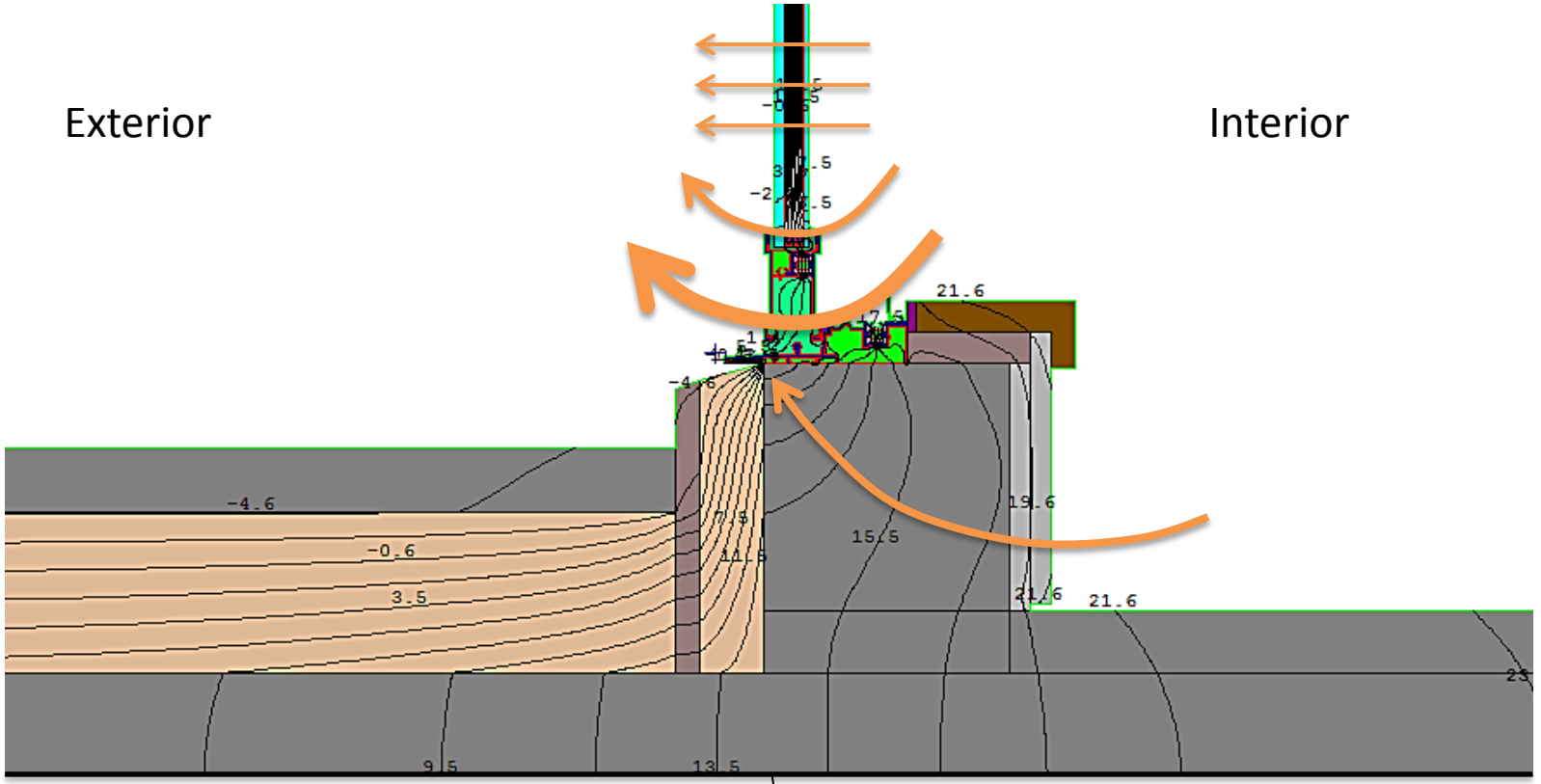
PSYCHROMETRIC ANALYSIS OF SLIDING DOOR

THERM Modeling – Set up



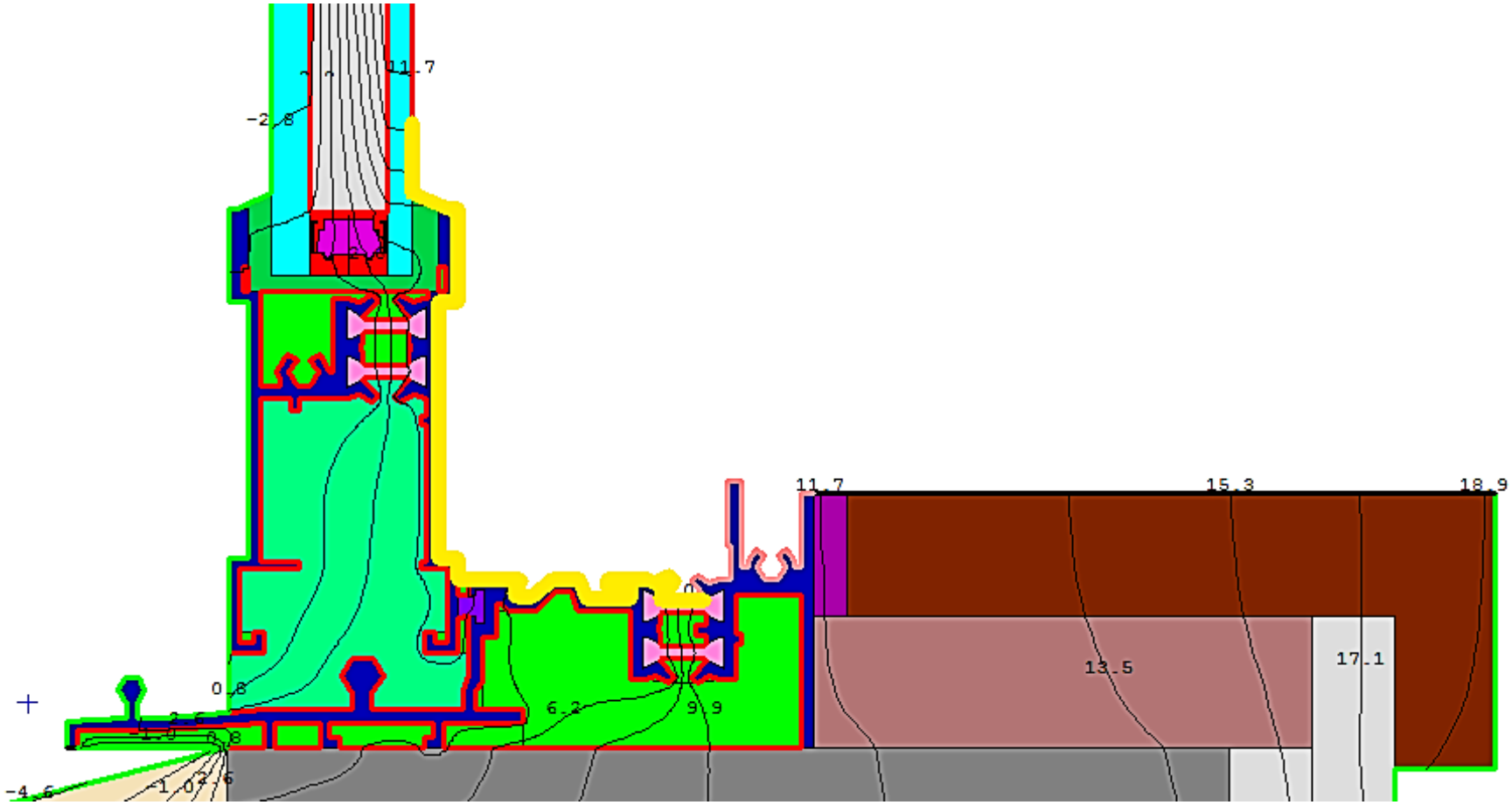
PSYCHROMETRIC ANALYSIS OF SLIDING DOOR

THERM Modeling - Variance In Heat Flow



PSYCHROMETRIC ANALYSIS OF SLIDING DOOR

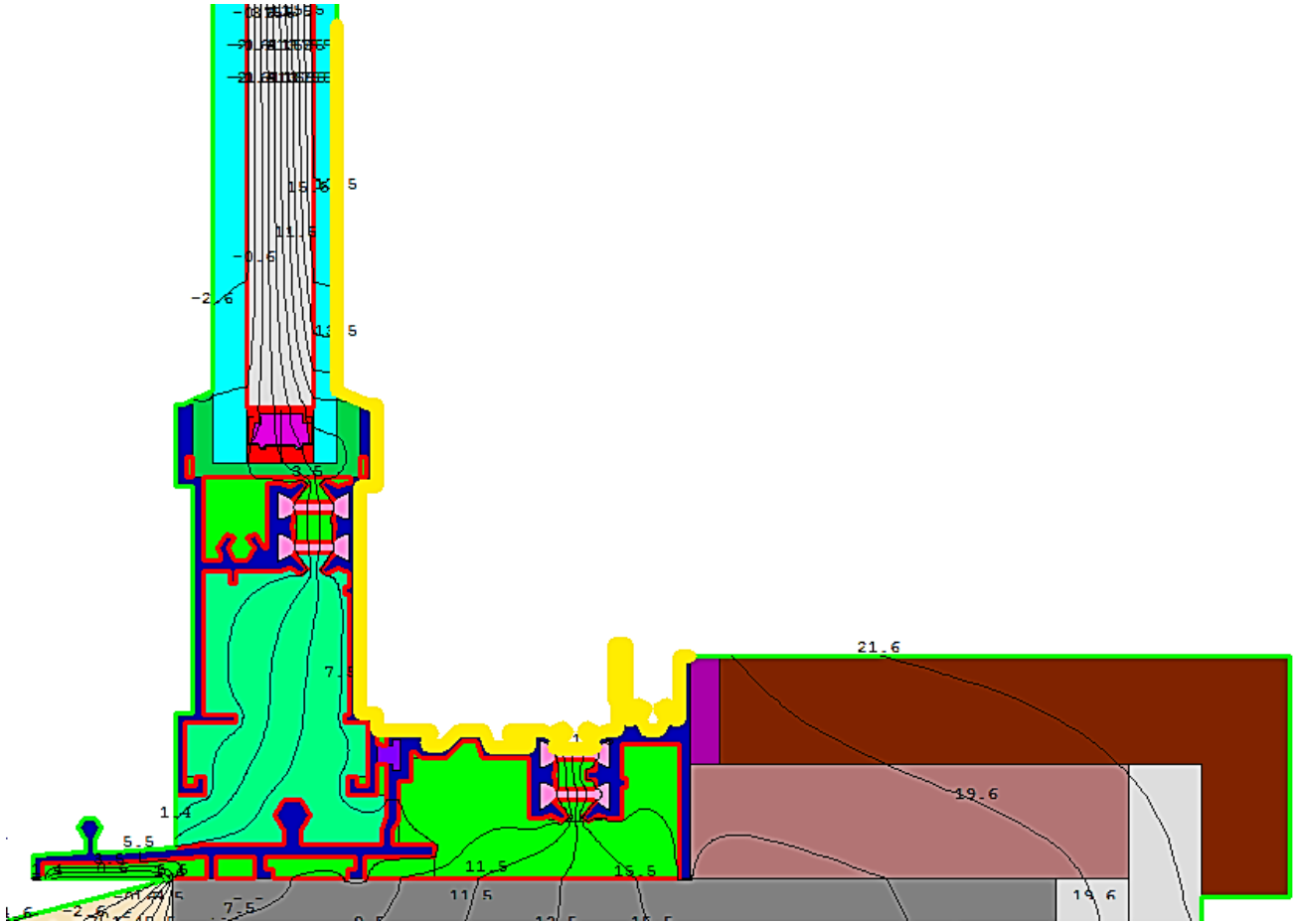
THERM Modeling – Condensation Potential (Semi-Vacant)



JRS ENGINEERING
BUILDING ENVELOPE CONSULTANTS

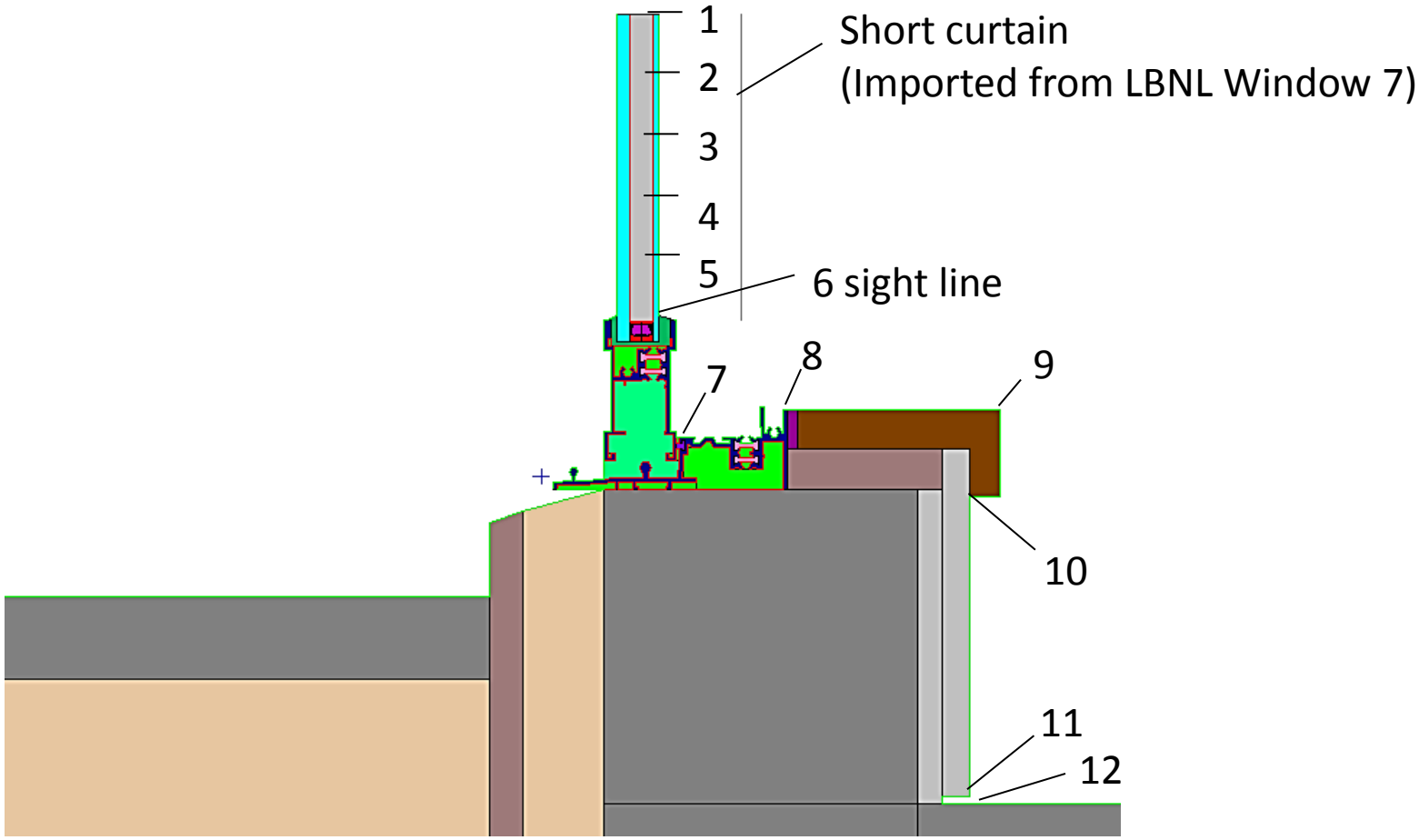
PSYCHROMETRIC ANALYSIS OF SLIDING DOOR

THERM Modeling – Condensation Potential (Moisture Loaded)



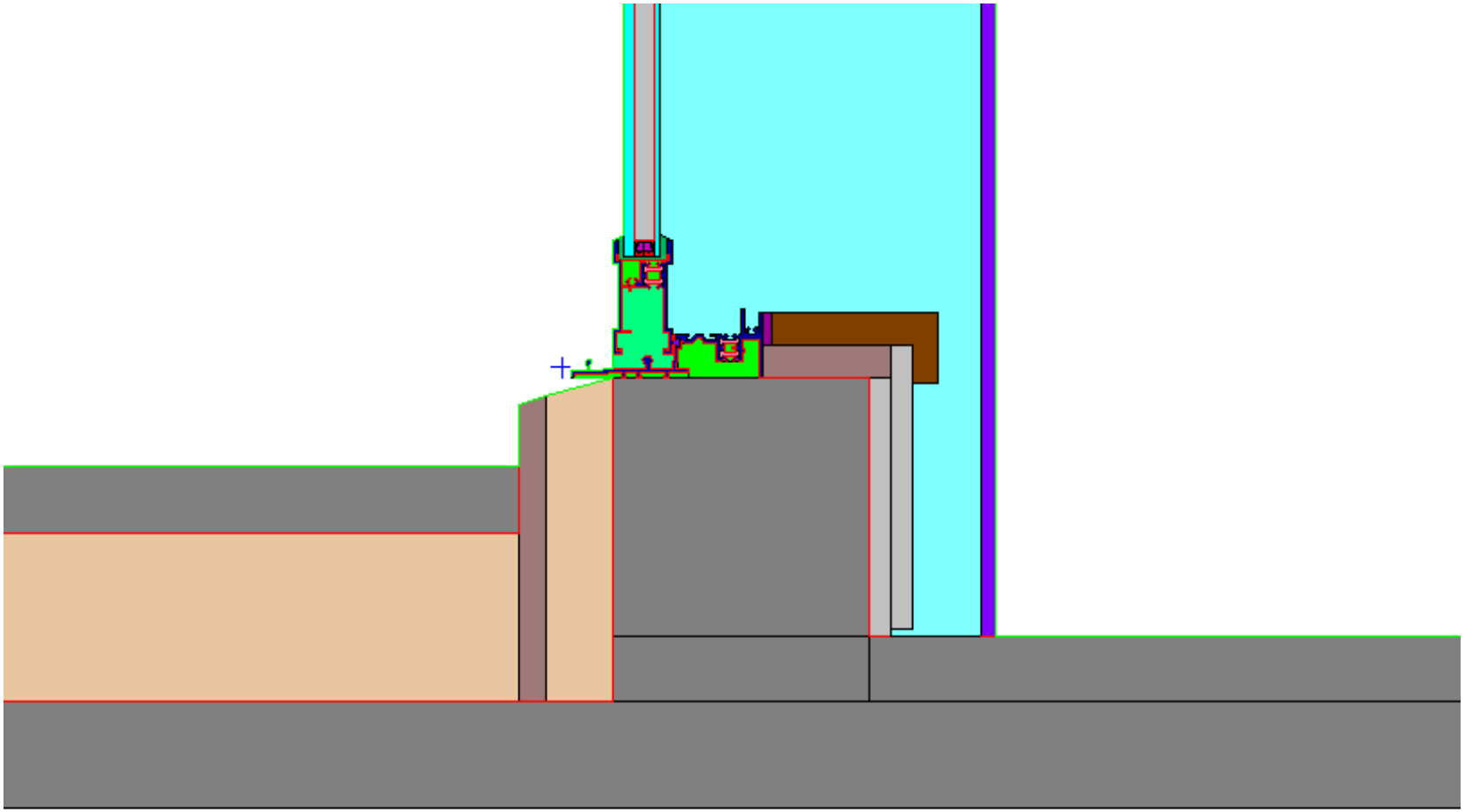
PSYCHROMETRIC ANALYSIS OF SLIDING DOOR

THERM Modeling – Short Curtain and Data Points



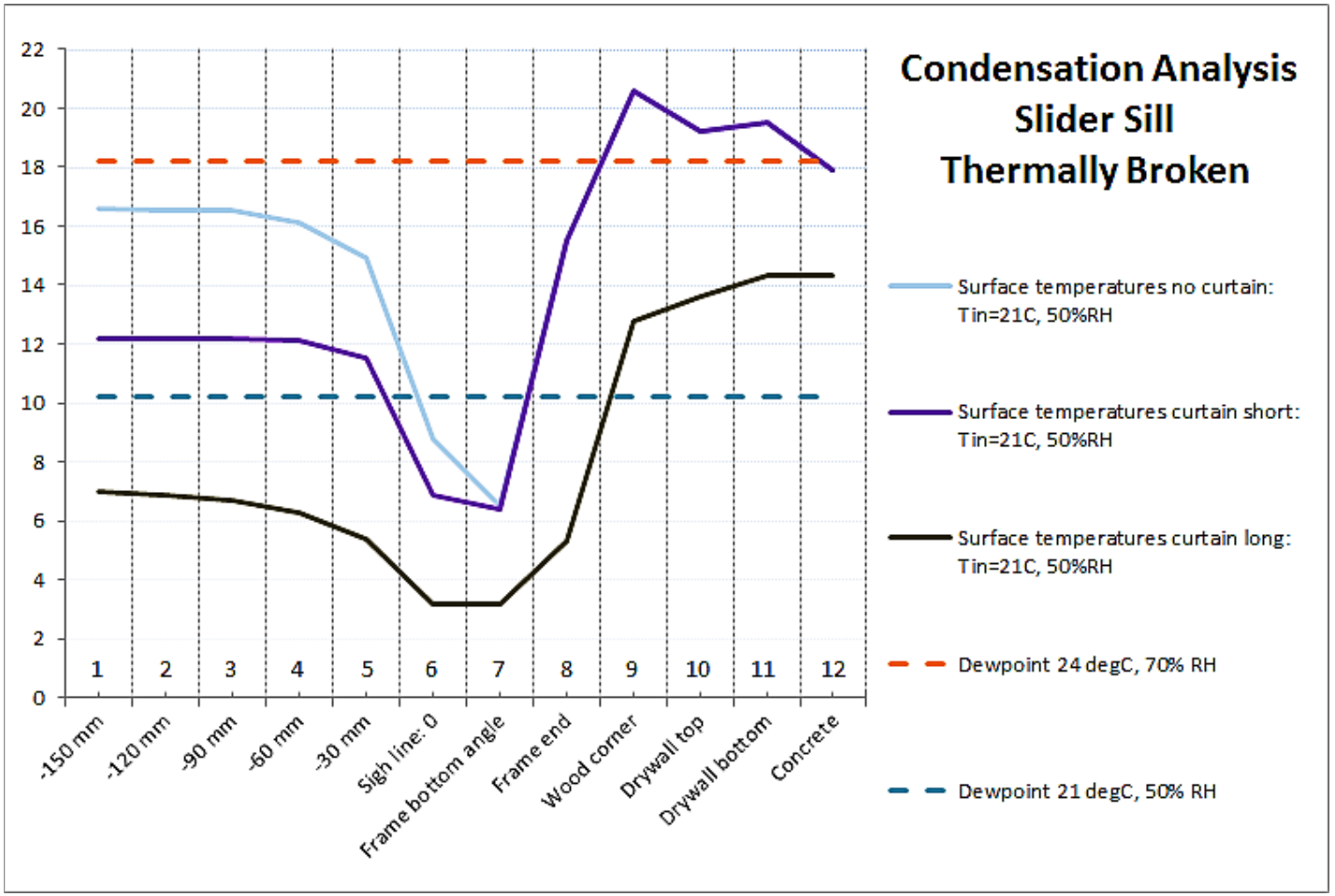
PSYCHROMETRIC ANALYSIS OF SLIDING DOOR

THERM Modeling - Long Curtain



PSYCHROMETRIC ANALYSIS OF SLIDING DOOR

THERM Modeling - Graphical Results



PSYCHROMETRIC ANALYSIS OF SLIDING DOOR

THERM Modeling - Tabulated Results

	Semi-vacant	Moisture loaded	Semi-vacant	Semi-vacant
Outdoor Temperature	-5 degC	-5 degC	-5 degC	-5 degC
Indoor Temperature	21 degC	24 degC	21 degC	21 degC
Indoor RH	50%	70%	50%	50%
Curtain	open	open	Short closed	Long closed
Indoor dewpoint	10.2 degC	18.2 degC	10.2 degC	10.2 degC
-150 mm	16.6	19.1	12.2	7
-120 mm	16.5	19	12.2	6.9
-90 mm	16.5	19	12.2	6.7
-60 mm	16.1	18.8	12.1	6.3
-30 mm	14.9	17.6	11.5	5.4
Sigh line: 0	8.8	10.4	6.9	3.2
Frame bottom angle	6.5	7.8	6.4	3.2
Frame end	15.5	17.9	15.5	5.3
Wood corner	20.6	23.5	20.6	12.8
Drywall top	19.2	22	19.2	13.6
Drywall bottom	19.5	22.4	19.5	14.3
Concrete	17.9	20.5	17.9	14.3

VENTILATION CONDITIONS OF HOTEL ROOM

ASHRAE 62.1 -2010

Breathing Zone (Supply) Airflow:

$V_{bz-}=(R_p x P_z) + (R_a x A_z)$; R_p= 5 cfm/person R_a= 0.06cfm/ft^2

V_{bz}= (5cfm/p x 2p) + (0.06cfm/ft^2 x 424ft^2) = 35cfm

$V_{oz}=V_{bz}/E_z$: E_z=0.7 (Warm floor supply and ceiling return)

V_{oz}=35cfm/0.7 = 50 cfm

Measured Supply Air **36cfm < 50 cfm**

Exhaust Airflow:

Measured at **27 cfm < 50 cfm** requirement

Both outdoor and exhaust airflow **do not** meet ASHRAE 62.1 requirements.

VENTILATION CONDITIONS OF HOTEL ROOM

Fan Coil Unit

Exterior Wall

Kitchen Fan

JRS ENGINEERING
BUILDING ENVELOPE CONSULTANTS

VENTILATION CONDITIONS OF HOTEL ROOM

Prediction of Thermal Comfort

- Hotel Management increased FCU air flow to warm slider; but how is human comfort affected?
- **Povl Ole Fanger** (July 16, 1934 – September 20, 2006): expert in the field of thermal comfort and perception of indoor environments
  - Fanger's model relates thermal sensation to physiological variables.
  - The model was developed & calibrated with hundreds of individuals that were instrumented & surveyed.

Dr. Rodrigo Mora, P.Eng., BCIT, Building Science Centre of Excellence

VENTILATION CONDITIONS OF HOTEL ROOM

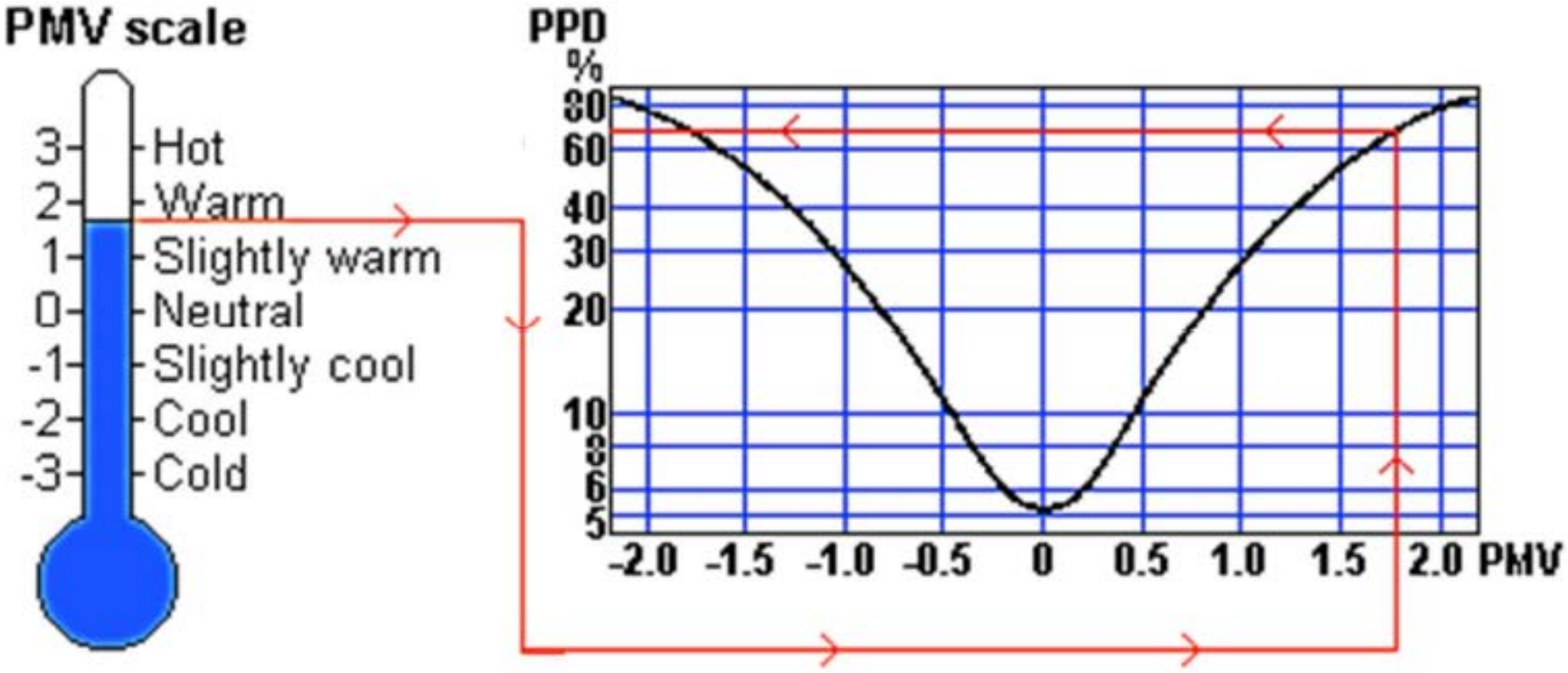
Fanger Model Assumptions

- Uniform airflow; no drafts or spatially localized currents
- Applies to sedentary or moderately elevated activities
- Assumes the whole body is at a uniform temperature (one ball or node)
- Assumes all sweat generated is evaporated
- Applies to indoor spaces that are not naturally conditioned/ventilated)
- Does not distinguish between clothed and unclothed portions of the body (clothing asymmetries) - uncovered skin is more sensitive

Dr. Rodrigo Mora, P.Eng., BCIT, Building Science Centre of Excellence

VENTILATION CONDITIONS OF HOTEL ROOM

Fanger Model – Output



Dr. Rodrigo Mora, P.Eng., BCIT, Building Science Centre of Excellence

VENTILATION CONDITIONS OF HOTEL ROOM

Fanger Model Inputs

- Relative Humidity: 47%
- Mean Radiant Temperature (MRT): 20°C
- Clothing Insulation (Icl): 0.75 clo (sweatpants and a long sleeve shirt) – per ASHRAE 55
- Metabolic Rate: 1.1 met (sitting, reading, typing on a laptop) – per ASHRAE 55
- Input parameters: Air temperature and air velocity (however air flow assumes cooling effect)

VENTILATION CONDITIONS OF HOTEL ROOM

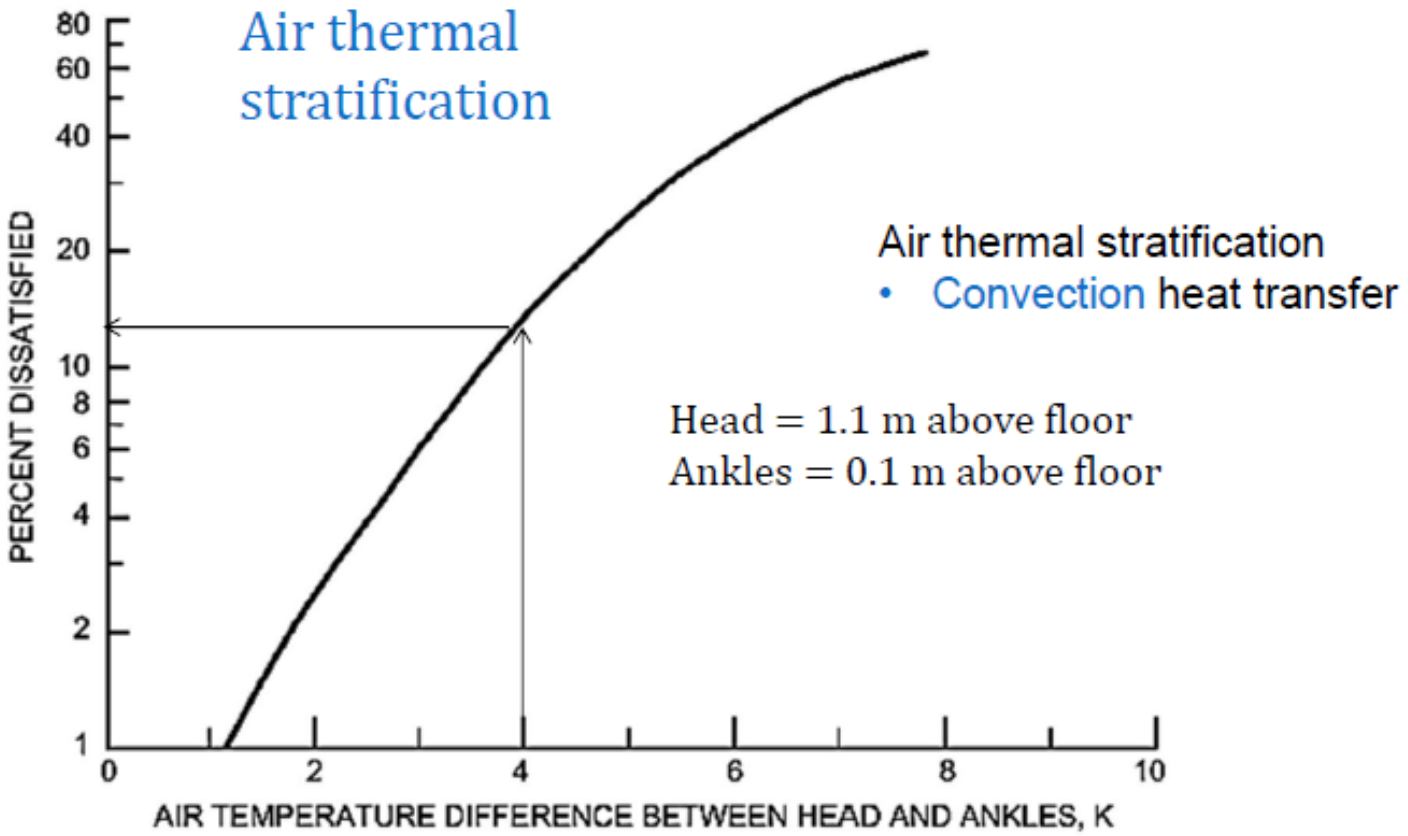
Fanger Model - Thermal Comfort Results

Scenario	Air Temp (°C)	PPD	Commentary
Semi-vacant	21	24	Usually a little cool
Fan Coil	25	11	More comfortable but comes with increased air flow

- Fan coil units have three settings, with the highest setting having the most impact on the sliding door
- Unfortunately, local air velocities were > 1 m/s
- Therefore, use of fan coil may assist in warming the sliding door but may create annoyingly drafty conditions

VENTILATION CONDITIONS OF HOTEL ROOM

Fanger Model – Limitations (assumes uniform air temperature)



Dr. Rodrigo Mora, P.Eng., BCIT, Building Science Centre of Excellence

VENTILATION CONDITIONS OF HOTEL ROOM

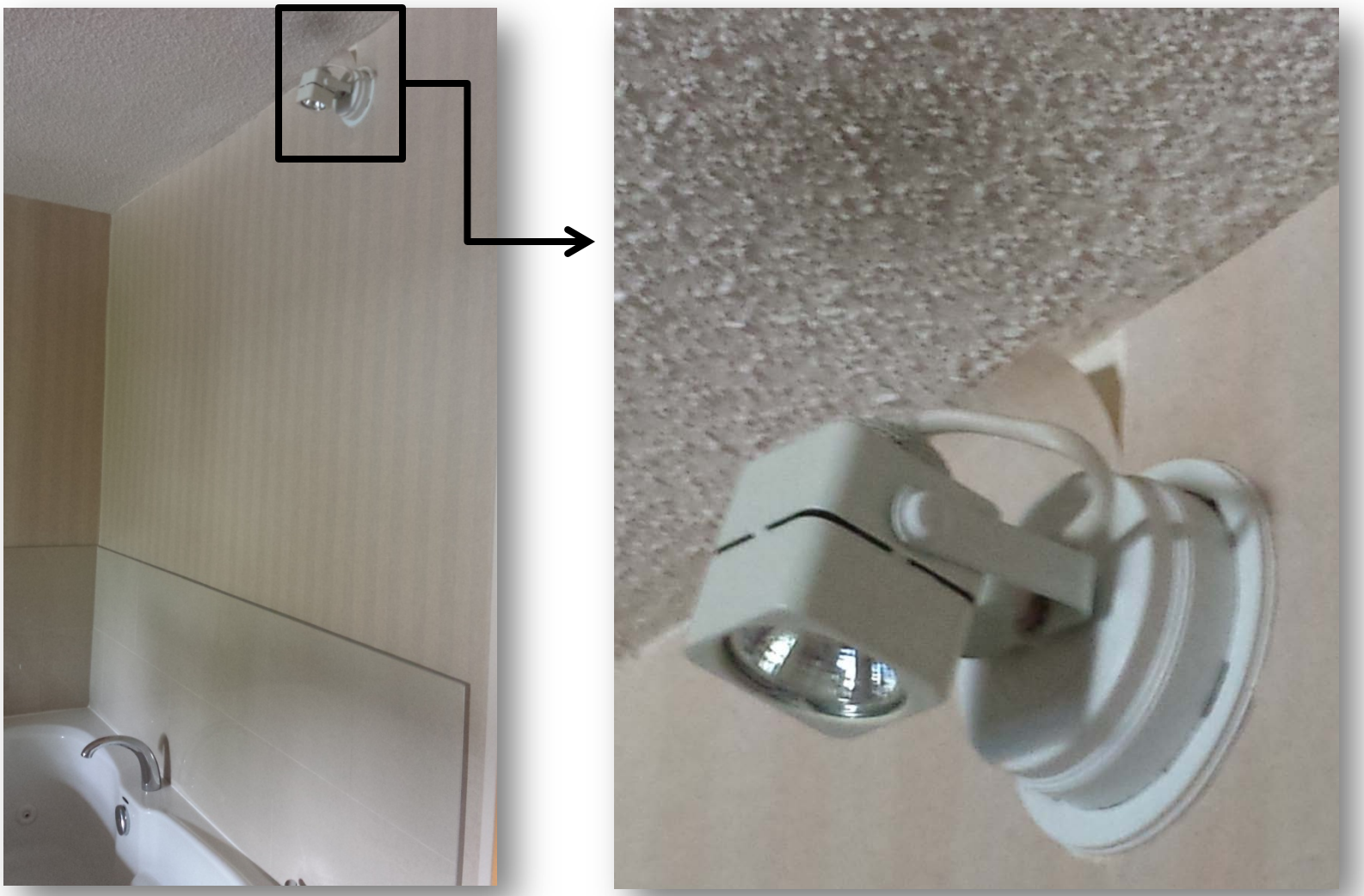
Inherent challenge with hotel units

- Glazing
- Curtains
- Heating
- Size
- Layout

VENTILATION CONDITIONS OF HOTEL ROOM

Really?

VENTILATION CONDITIONS OF HOTEL ROOM



JRS ENGINEERING
BUILDING ENVELOPE CONSULTANTS

VENTILATION CONDITIONS OF HOTEL ROOM

Multi-tasking

VENTILATION CONDITIONS - CONTAM

CONTAM is multi-zone airflow and contaminant transport analysis software.

Major Model/Software Assumptions

- Air flow, temperature and pressure is uniform and constant throughout – well mixed with no localized air flow
- Air leakage is uniformly distributed
- Does not consider heat transfer – temperature is only considered as it relates to air movement (e.g. pressure differences, stack effect)

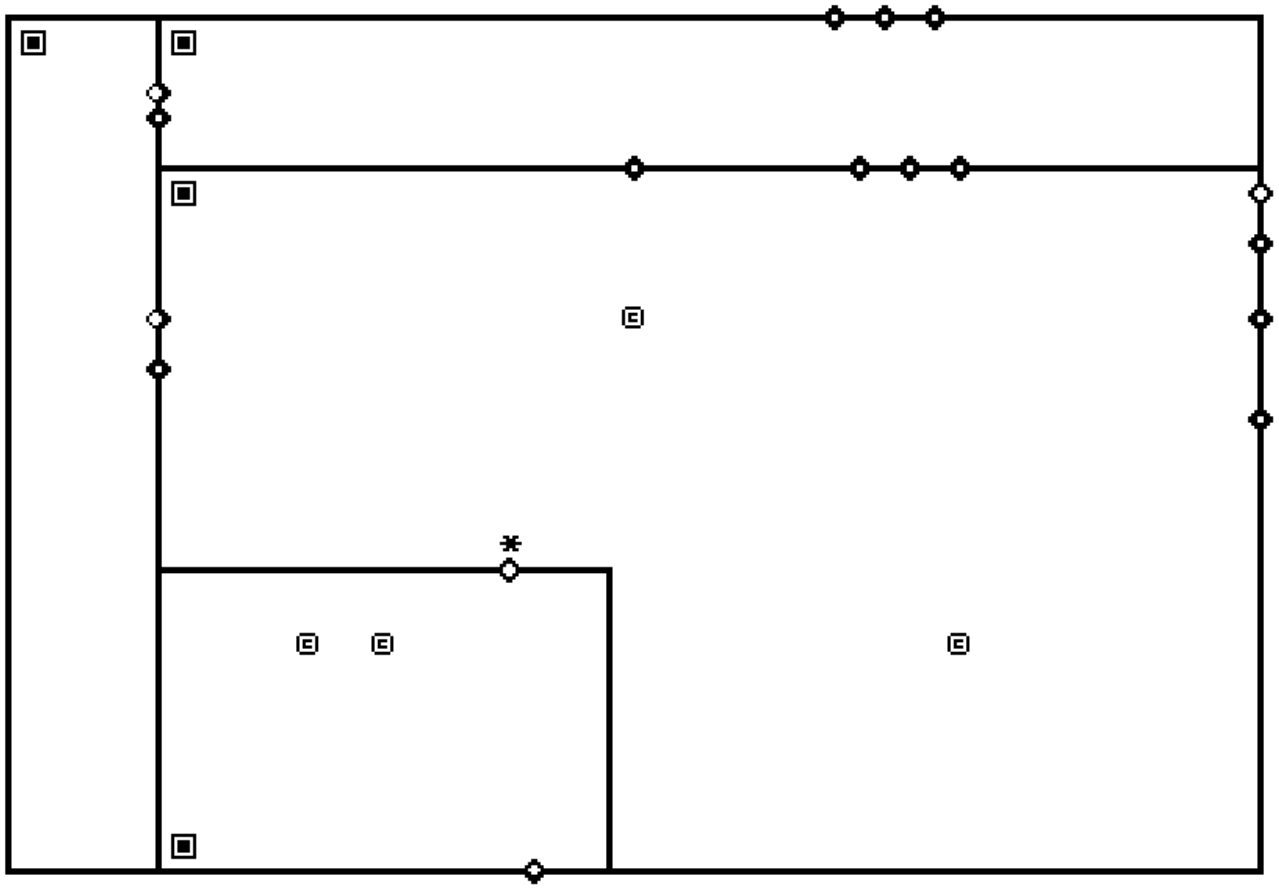
VENTILATION CONDITIONS - CONTAM

Objective

Quantitatively comment on if the humidity problem can be mitigated by increasing the supply air and/or increasing the capacity of the bathroom exhaust fan.

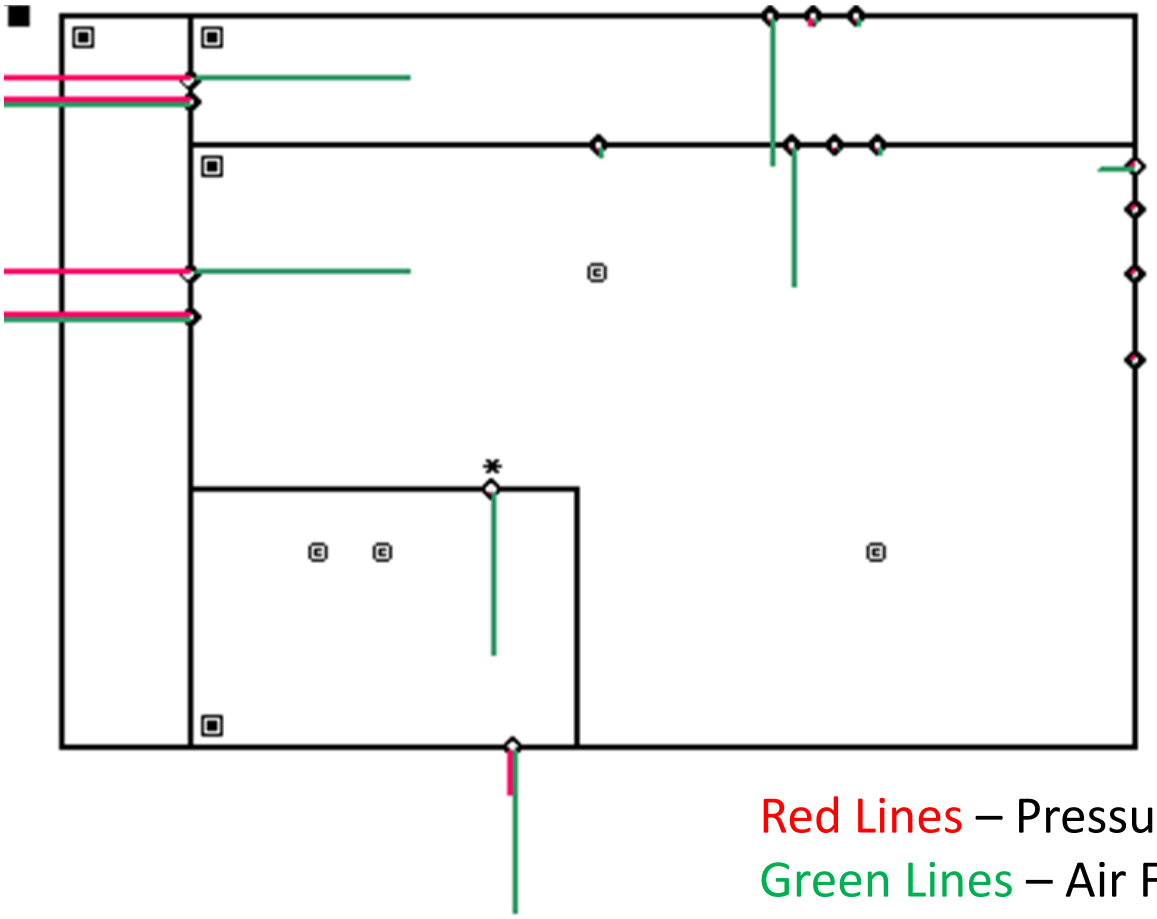
VENTILATION CONDITIONS - CONTAM

Model Set Up



VENTILATION CONDITIONS - CONTAM

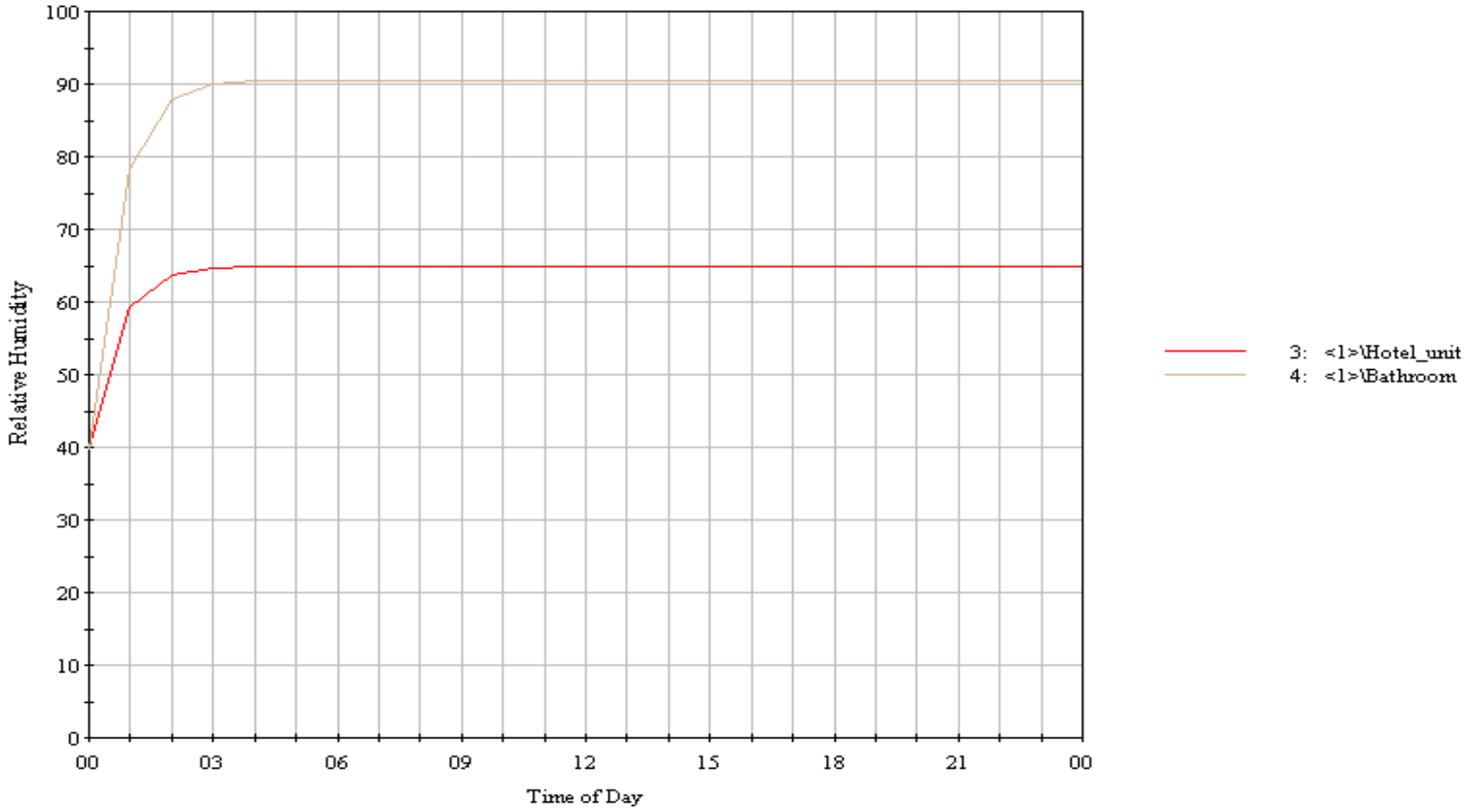
Moisture Loading (Stressed Scenario)



Red Lines – Pressure Difference
Green Lines – Air Flow

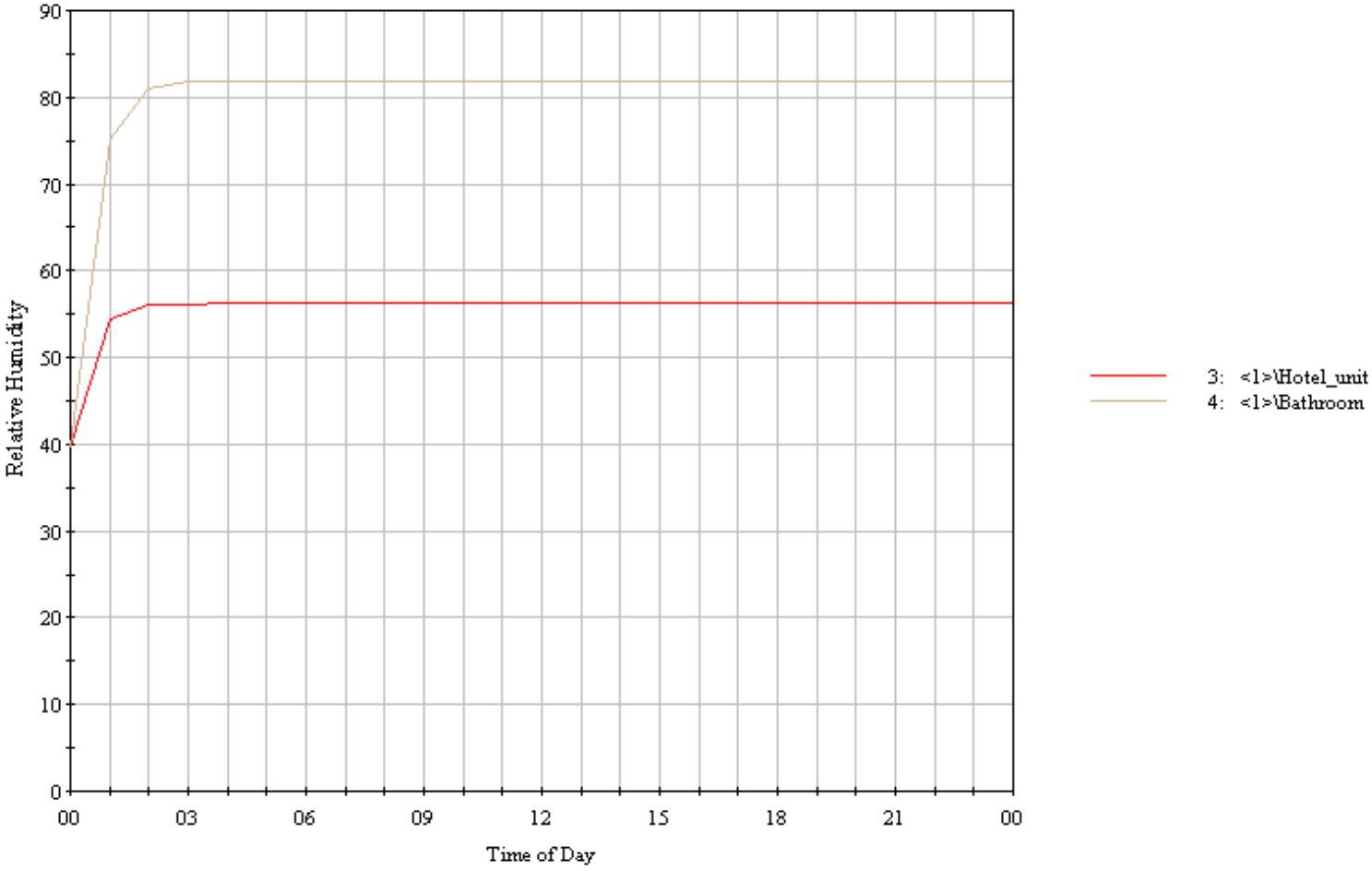
VENTILATION CONDITIONS - CONTAM

Stressed Condition at Existing Flow Rates



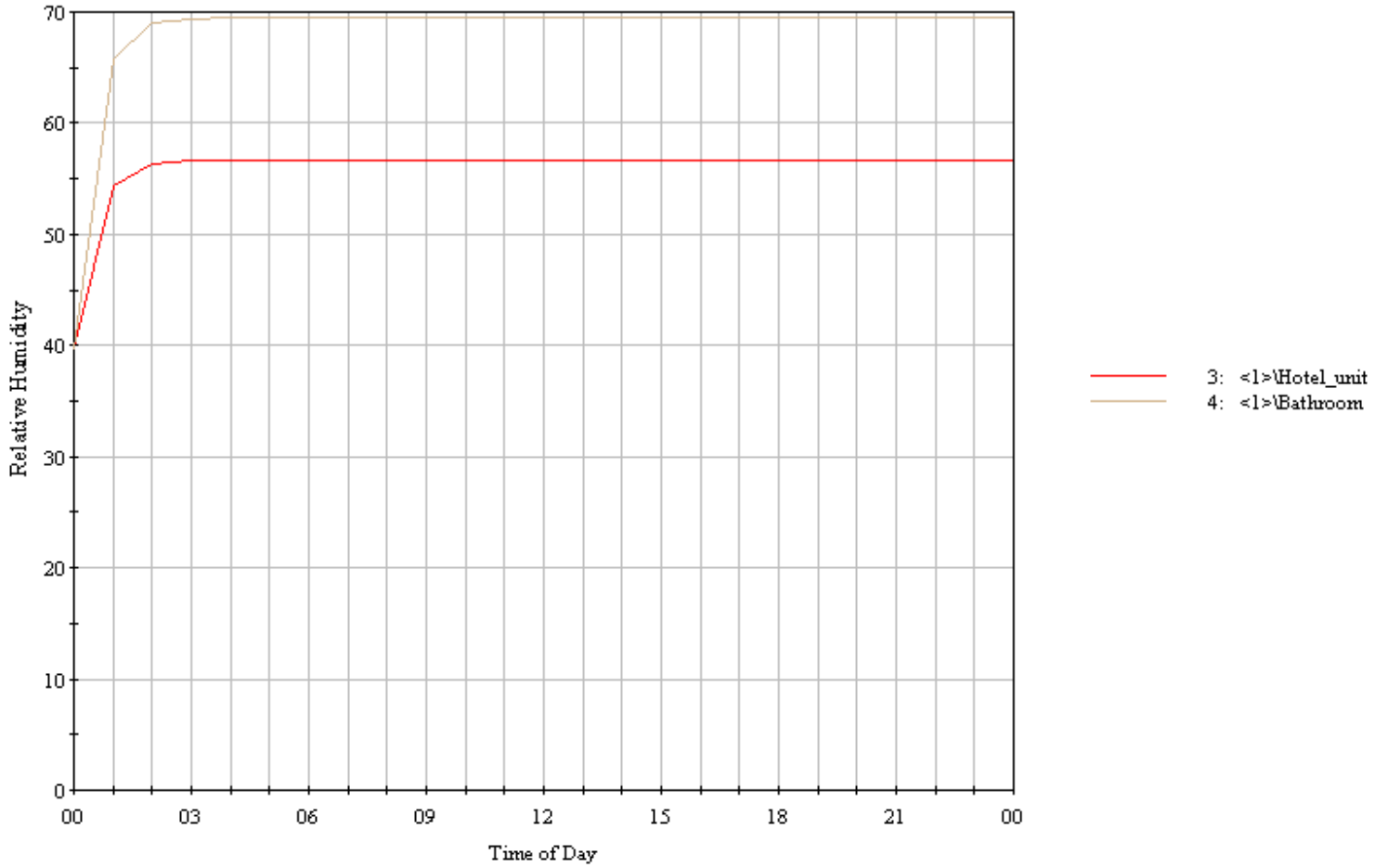
VENTILATION CONDITIONS - CONTAM

Double Supply Air



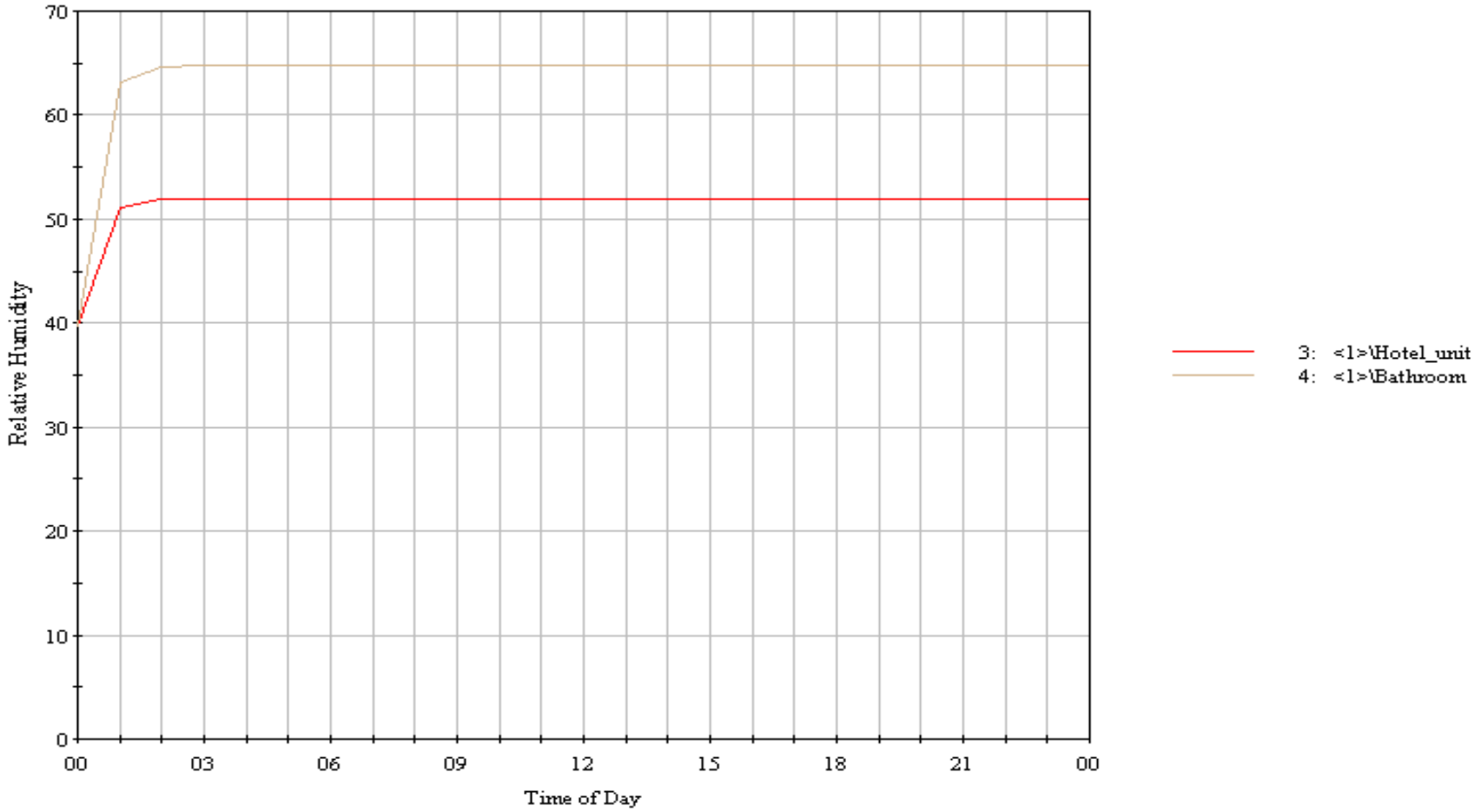
VENTILATION CONDITIONS - CONTAM

Double Exhaust Flow



VENTILATION CONDITIONS - CONTAM

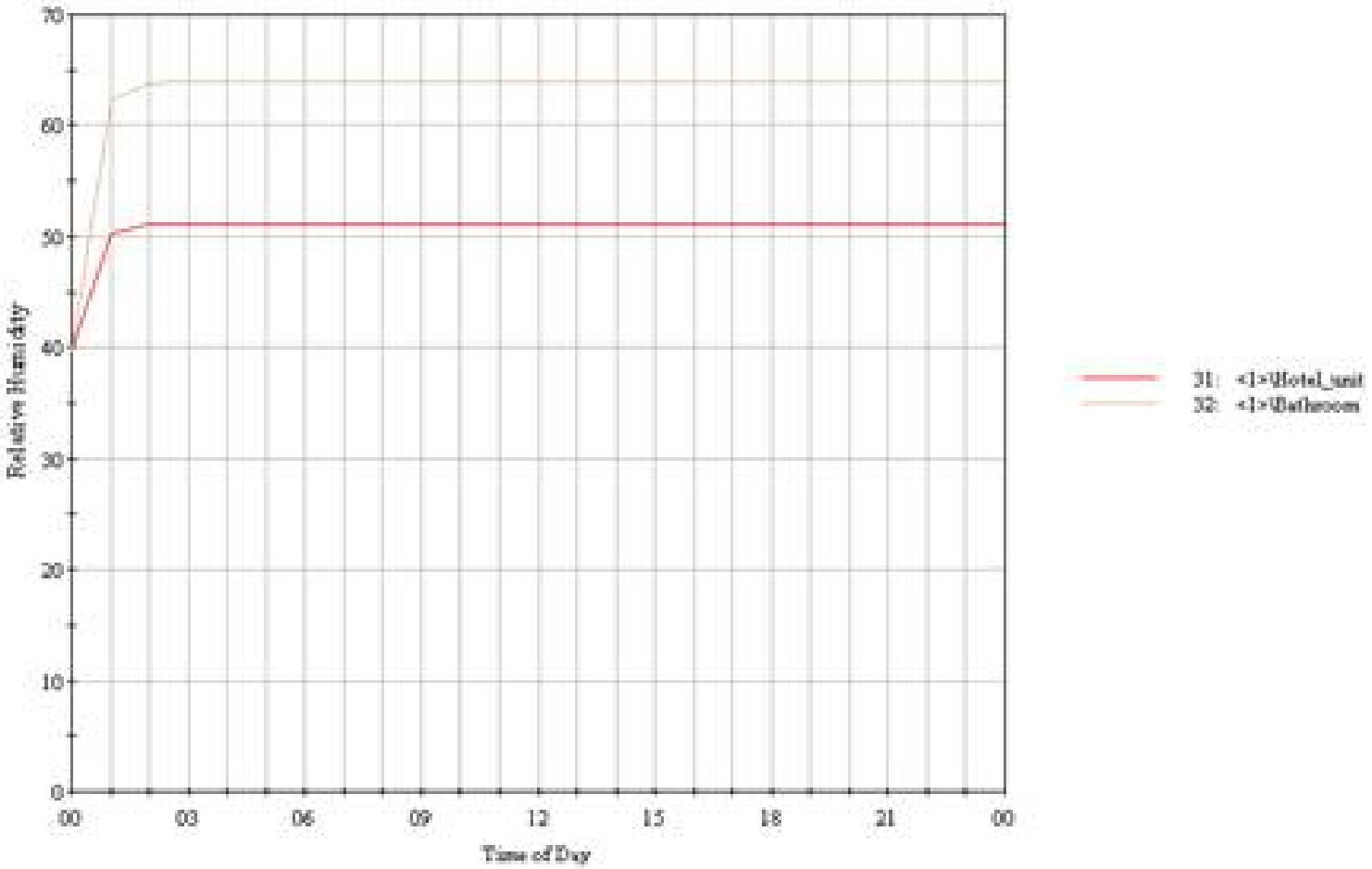
Doubled Supply and Exhaust Flow Rates



JRS ENGINEERING
BUILDING ENVELOPE CONSULTANTS

VENTILATION CONDITIONS - CONTAM

Stack Effect



VENTILATION CONDITIONS - CONTAM

Summary Table

Condition	Relative Humidity (%)	
	Hotel Unit	Bathroom
Moisture Loaded	65	91
Supply Air Doubled	57	82
Exhaust Flow Doubled	57	69
Supply and Exhaust Doubled	52	65
With Stack Effect	51	64

CONCLUSION

The problem has multiple origins, each of which is periodic, seasonal and not independently significant.

<u>Therefore, the solution must also multi-faceted:</u>

1) Ventilation – Reduce humidity levels in the general vicinity of condensing surfaces.

2) Temperature – Increase temperature of condensing surfaces.

RECOMMENDATIONS

1) Keep heavy drapes open when not in use.
2) Trim bottom of curtains.
3) Replace weather-stripping gaskets.
4) Increase air speed of fan coil unit.
5) Balance the HVAC system.
6) Install new exhaust fans in bathrooms with an option to increase airflow (e.g. humidistat, movement sensor, on-demand, etc.).
7) Install baseboard heaters and with new slider design.

Thanks to the following who helped contribute to this work:

Adam Jarolim, EIT
Dr. Rodrigo Mora, P.Eng.

QUESTIONS?