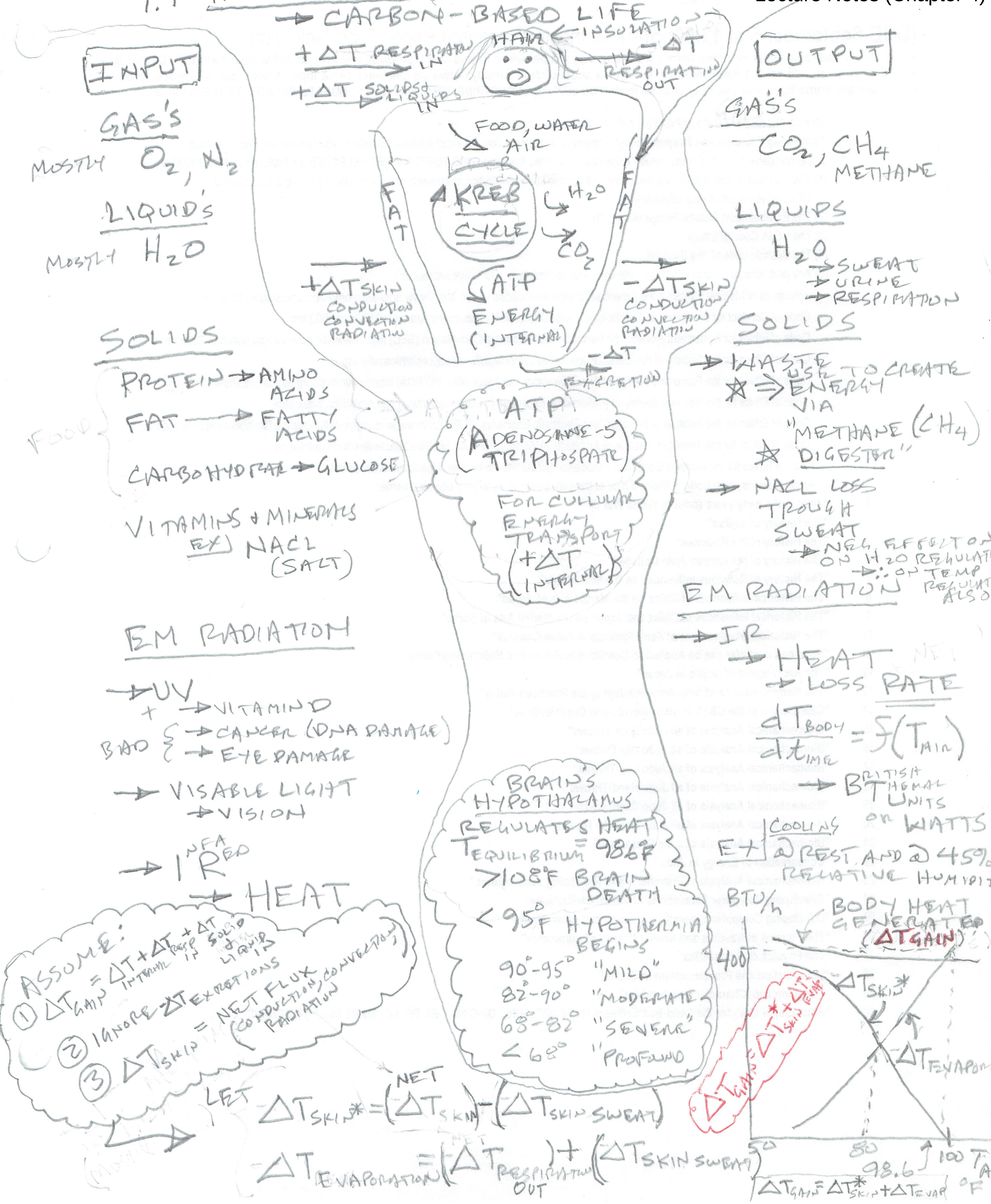
J. WUNDERLICH PhD

EGR343 Green
Architectural Engineering
Lecture Notes (Chapter 4)

CH 4 THERMAL COMFORT

4.1 HUMAN "BIOLOGICAL MACHINE"



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4.2 "THERMAL BARRIERS"

- → CLOTHES
- → CANOPY BED'S, BLANKETS
- ☆ → BUILDINGS, GEODESIC DOMES
  - ☆ → CREATE MICROCLIMATE

4.3 "METABOLIC RATE" $\frac{dT_{BODY}}{dtime} = \frac{dT_{GAIN}}{dt}$

BODY HEAT GENERATION (HEAT GAIN)

ACTIVITY	AVE BTU/h
SLEEPING	~340
LIGHTWORK	~680
WALKING	~1020
JOGGING	~2720

SANJAY GUPTA, MD:

☆ "MOST FIT CULTURES ALWAYS MOVING AROUND; BODY NOT DESIGNED TO SIT 23 HOURS, THEN EXERCISE HARD FOR 1 HOUR"

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4.4 "THERMAL CONDITIONS OF ENVIRONMENT"

① AMBIENT AIR TEMP T_{AIR}

$$\frac{dT_{BODY}}{dt_{TIME}} = f(T_{AIR})$$

② RELATIVE HUMIDITY RH

$$\frac{dT_{BODY}}{dt} = f(RH)$$

EVAPORATION

~ COMFORT @: ☆

RH_{SUMMER} = ~20 TO 60

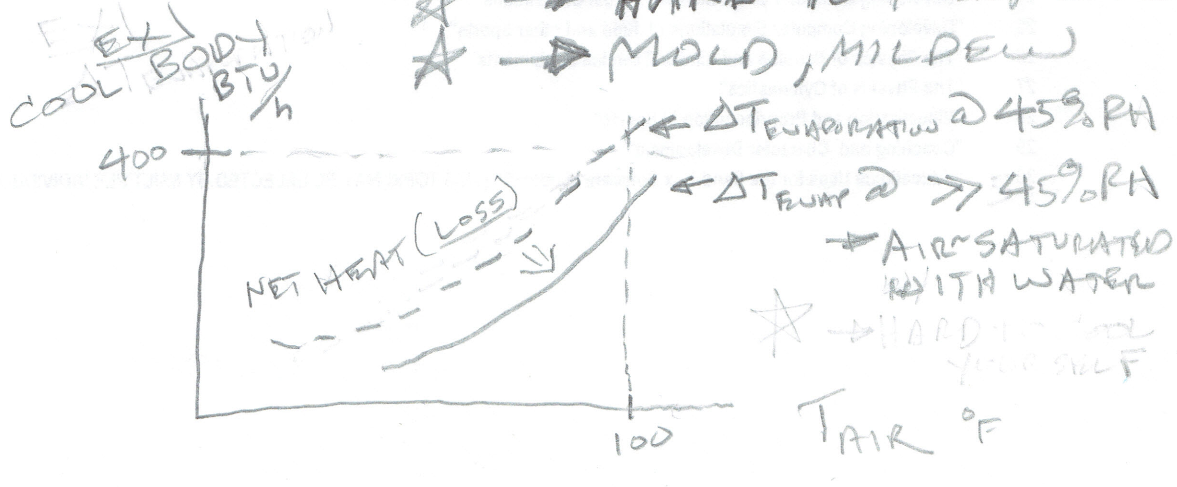
RH_{WINTER} = ~20 TO 80 ☆

@ LOW RH:

- ★ → DRY NOSE, MOUTH, SKIN, EYES
- ☆ → RESPIRATORY ILLNESS
- → STATIC ELECTRICITY
- ☆ → WOOD SHRINKAGE

@ HIGH RH:

- ☆ → HARD TO KEEP COOL
- ☆ → MOLD, MILDEW



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③ "AIR MOVEMENT"

$\Delta T_{BODY} = f(\text{CONVECTION, EVAPORATION})$

→ GOOD IN SUMMER

→ BAD IN WINTER

☆ → DRAFTS → DON'T PUT BED IN DRAFT

☆ → "WIND CHILL FACTOR"

④ MRT (MEAN RADIANT TEMP)

SEE CHAPTER 3 →

COMFORT = f(PROXIMATY TO SOURCES)

☆ → BEST IF HEAT SOURCE ALLOWS EVEN DISTRIBUTION THROUGHOUT HOUSE

☆ {
→ HOT-WATER-LOOP RADIATORS
→ RADIANT FLOOR HEATING
→ NOT POT-BELLY STOVES OR ELECTRIC WIRE HEATERS

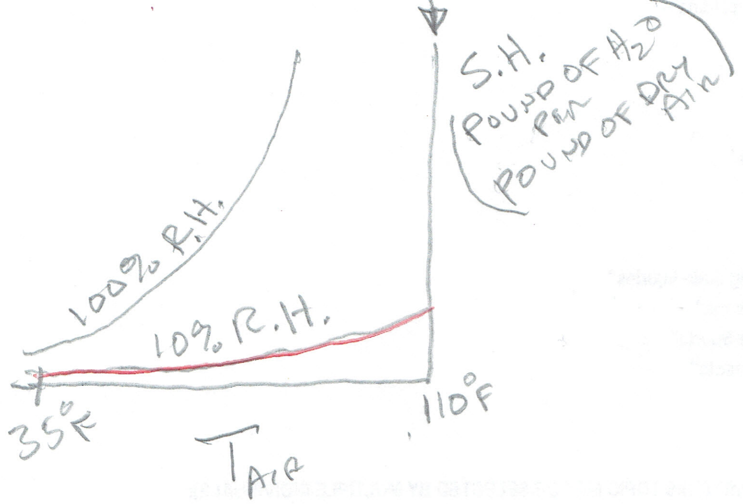
☆ → DON'T PUT BED UNDER WINDOW IN COLD CLIMATES

4.5 "PSYCHOMETRIC CHART"

SPECIFIC HUMIDITY (HUMIDITY RATIO)

☆ → ACTUAL AMOUNT OF WATER IN AIR

= f(TEMP)



RELATIVE HUMIDITY (RH)

= f(TEMP, MAX H_2O AIR CAN HOLD AT THAT TEMP)

☆ → @ 100% RH SWEAT CAN'T EVAPORATE

From: https://www.eva-dry.com/blog/dehumidifiers/humidity-the-difference-between-absolute-relative-and-specific/

Humidity

– The Difference Between Absolute, Relative, and Specific

Posted on February 25, 2011 by DeHughMidify

We've all heard of humidity. Plenty of homeowners have invested in dehumidifiers to prevent the damage it can cause. Most people who live with humidity don't enjoy it too much. And those who don't live with it are thankful for that fact! Humidity refers to how much water vapor is in the air. Generally, the more water vapor there is, the more humid that area is. But did you know that there are different kinds of humidity? Absolute, relative, and specific humidity are all terms that represent different aspects of humidity.

Absolute humidity

This term is used to describe the actual amount of water vapor that is saturating the air. Absolute humidity is calculated by finding the mass of water vapor in an area and dividing it by the mass of air in the same area.

Relative humidity

This is the type of humidity that meteorologists are typically referring to on their weather reports. Relative humidity describes the amount of water vapor in the area as opposed to how much water vapor could be in the area. This type of humidity is basically a ratio of the absolute humidity and the potential amount of water saturation that the air could possibly hold.

Specific Humidity

This term is used as a ratio of the amount of water vapor in the air to the amount of dry air in the area.

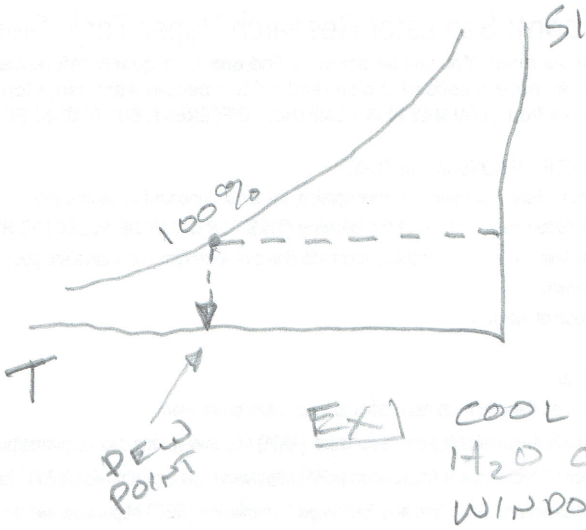
No matter what name you call it by, humidity is a natural part of our climate that we have to adapt to. If we don't, then we'll have to settle for being uncomfortably warm and sweaty. Luckily, we have dehumidifiers to help us fight back against the damaging effects of moisture in the air.

4.6.

"DEW POINT"

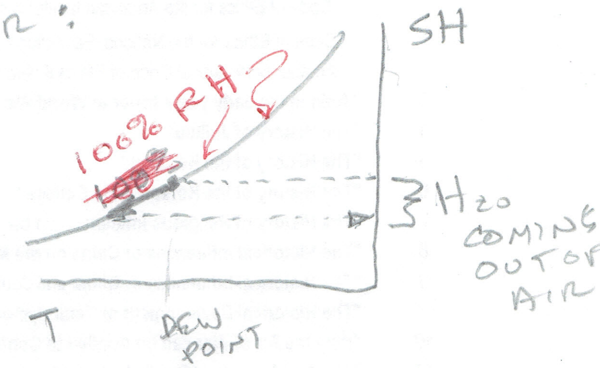
TEMP AT RH=100% FOR A FIXED S.H.

(i.e., THE TEMP AT WHICH WATER WILL CONDENSE OUT OF THE AIR)



EX) COOL HOUSE UNTIL H_2O CONDENSES ON WINDOW INTERIORS

☆ "DEHUMIDIFIER" IF ΔT↓ PAST DEW POINT, H_2O COMES OUT OF AIR:



TWO THERMOMETERS IN HERE

MEASURE RELATIVE HUMIDITY

☆ WATCH YOUTUBE VIDEO

"WET BULB TEMP" T_{WB} AND "DRY BULB" T_{DB}

→ SPECIAL TEST USING SLING PSYCHROMETER

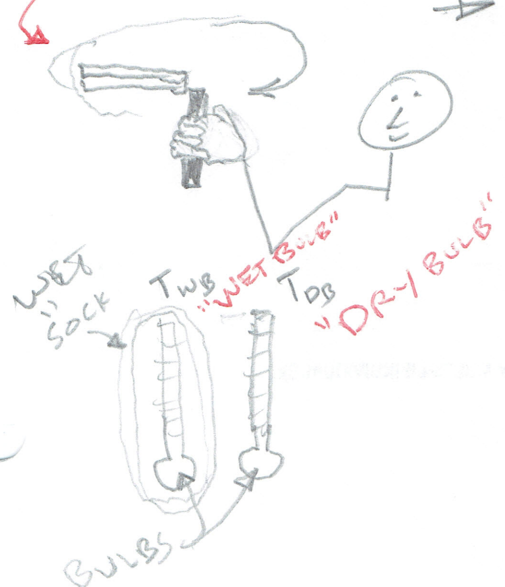
→ SPIN IT IN CIRCLE

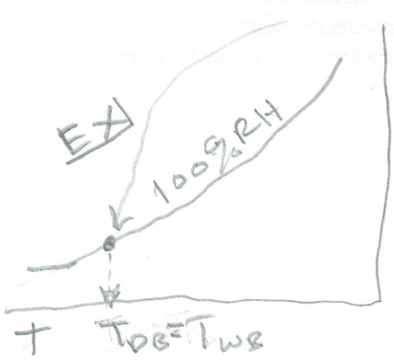
→ CONTAINS 2 THERMOMETERS

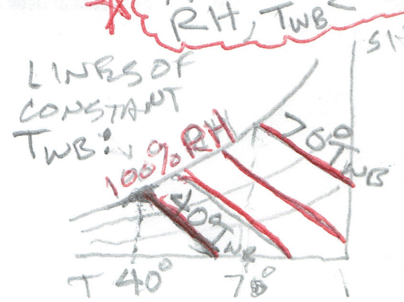
→ ONE COVERED WITH A WET "SOCK" T_{WB}, OTHER OPEN TO AIR

☆ @100% RH, $T_{WB}=T_{DB}$ BECAUSE AIR IS NOW AS SATURATED AS WET SOCK

☆ AT LESSER RH, $T_{WB}<T_{DB}$







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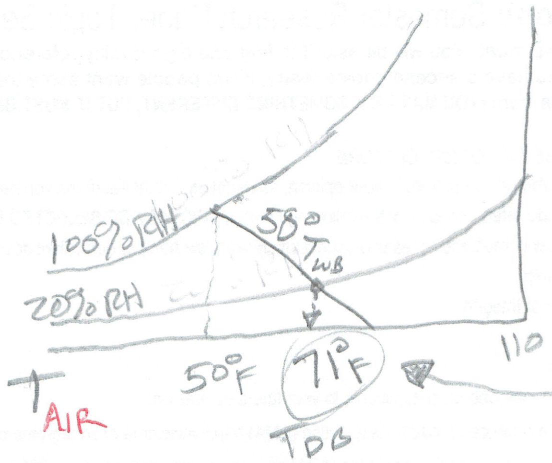
★ EX | VERY DRY DAY,
RH = 20%, T_{WB} MEASURES AT 50°F

→ GUESS WHAT T_{DB} SHOULD BE.



ANSWER

$T_{DB} >> T_{WB}$ BECAUSE OF LARGE EVAPORATIVE COOLING OF SPINNING THERMOMETER IN WET "SOCK" BUT NOT DRY THERMOMETER WITH LOW THERMAL CONDUCTIVITY DUE TO DRY AIR

4.7 "HEAT CONTENT OF AIR"

"TOTAL HEAT (ENTHALPY)"

= SENSIBLE HEAT + LATENT HEAT

RECALL "HEAT STORED" $= f(\Delta T_{AIR})$

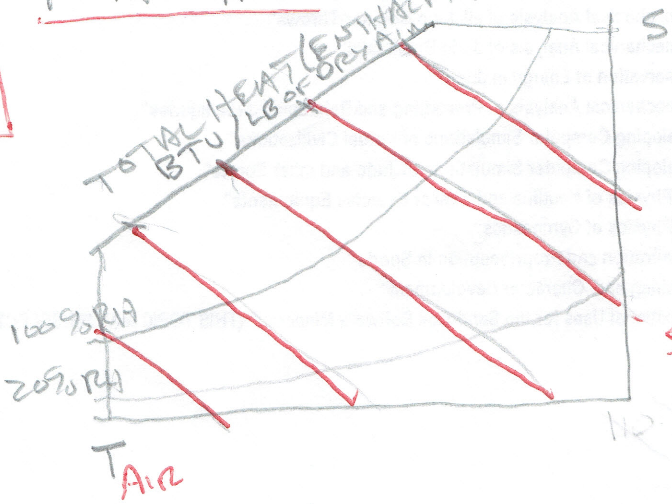
RECALL "HEAT NEEDED TO Δ STATE" $= f(\Delta H_2O)$

∴ MOISTURE IN AIR

SO PLOT LINES OF CONSTANT TOTAL HEAT

PSYCHROMETRIC CHART

YOUTUBE "PSYCHROMETRIC CHART - AIR CONDITIONING PROCESS"



Δ LATENT HEAT

Δ SENSIBLE HEAT

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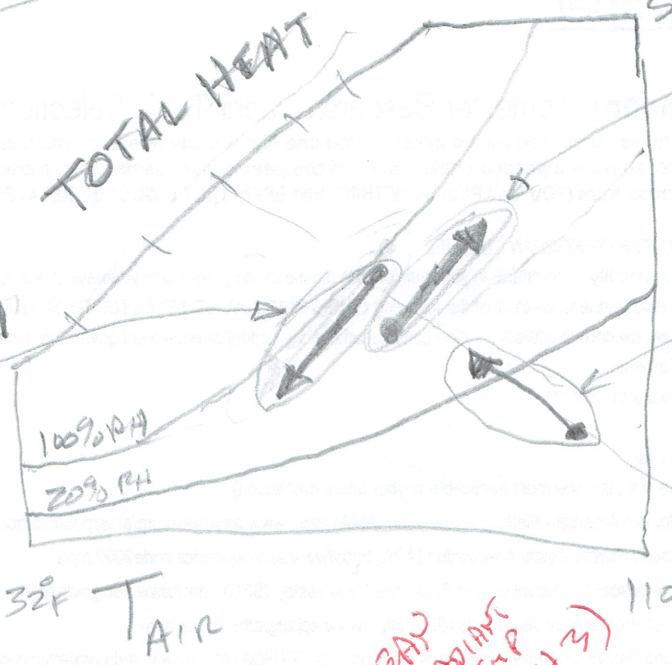
EX'S

★ WHEN WE HEAT & HUMIDIFING AIR.

★ WHEN WE COOL AND DEHUMIDIFY AIR



WHEN WE USE ONLY A FAN TO COOL PEOPLE
• PURE EVAPORATIVE COOLING

(−Δ SENSIBLE HEAT) = (+Δ LATENT HEAT)

AIR GETS WETTER

SO NO Δ IN TOTAL HEAT

I.E. "ADIABATIC CHANGE"

MEAN RADIANT TEMP (CH 3)

★ 4.8 "THERMAL COMFORT" ★

INITIALLY
→ ASSUME AIR MOTION MINIMAL
→ " MRT CONSTANT
→ " FOR NOW MINIMAL VARIATIONS IN:

★

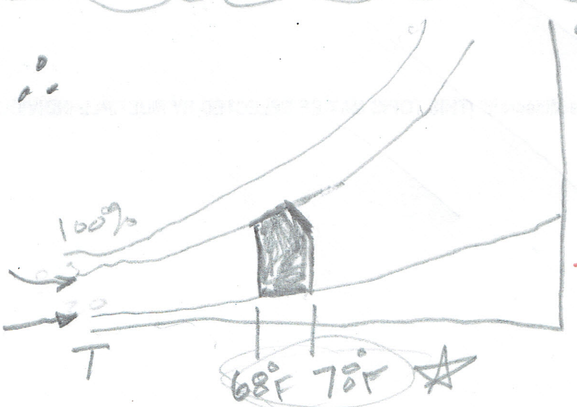
1. CULTURE
2. FAT ON PEOPLE
3. CLOTHES
4. PHYSICAL ACTIVITY
5. AGE / OVERALL HEALTH
6. ADAPTATION TO SEASONS

★ ★ IF PEOPLE UNCOMFORTABLE:

1. PEOPLE WASTE MORE ENERGY
2. ARCHITECTURE MAY FAIL!

∴

★



80% RH →
20% RH →

68°F 78°F ★

★ TOO HUMID
★ TOO HOT

★ TOO COLD
★ TOO DRY

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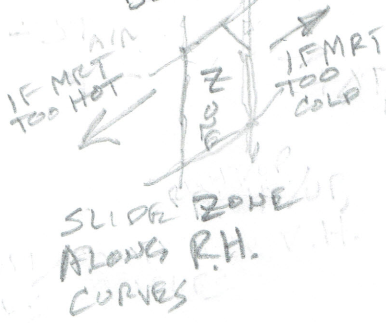
4.9 "SHIFTING OF COMFORT ZONE"

NOW ADRESS ASSUMPTIONS IN 4.8

DESIGN RULES!

☆ (A) FOR EVERY [M.R.T.] ± 3°F ⇒ ADJUST AIR TEMP IN OPPOSITE DIRECTION
BECAUSE ZONE SHIFTS



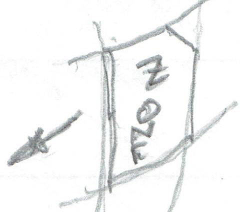
I.E., COMPENSATING FOR OVERLY INTENSE SOURCES OF HOT OR COLD, LIKE:
→ BIG WINDOWS
→ FIRE PLACES

☆☆ CAN MITIGATE WITH
→ THERMAL DRAPES ON WINDOWS
→ GLASS SCREEN ON FIRE PLACE

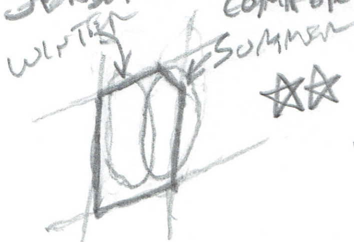
☆ (B) FOR EVERY [AIR SPEED (fpm) (feet per minute)] + 15 fpm (FEET PER MINUTE), COMFORT DROPS 1°F

☆☆ SO ADJUST AIR TEMP UP 1°F

☆ (C) FOR INCREASE IN PHYSICAL ACTIVITY (GYMS ETC.), ☆☆ MORE COMFORT IF T_{AIR} ↓



☆ (D) SEASONAL VARIATIONS
COMFORT ZONE = ∫ (SUMMER ZONE, WINTER ZONE)



☆☆ SO, GET VERY LOCATION SPECIFIC TO COMPENSATE .... CH.5 "BIOCLIMATIC CHARTS"
(CH 4.11 MOVED THERE & INTO CASE STU...

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