TruTech Technical Training

Understanding Equipment Operation

The rest of the story….

Part IV

Going where no technician has gone before

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There are no theories in HVAC/R!

- Air conditioning is made of scientific facts
  - Repeatable
  - Universal
  - Well proven
  - Understandable
  - Provable
  - And you can do it!
- Measurements are made to prove facts!

The Basics of the Basics

- Heat is a form of energy
- Temperature is a measure of the heat intensity.
  - Does not quantify how much work is being done!
- Btu's are a measure of the heat quantity.
  - **Sensible heat** causes a change in temperature
  - **Latent heat** is heat added or removed without a change in temperature due to a change in state.
  - Total heat is a combination of sensible and latent heat added or removed.

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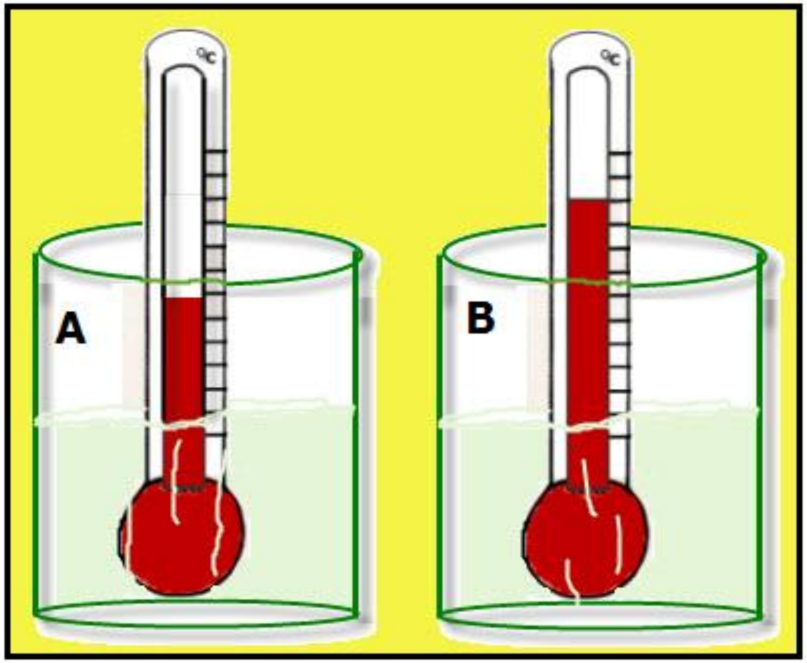
Heat is measured in BTUs or BTUH

- 1 BTU is the amount of heat required to raise 1 lbs of water 1°F



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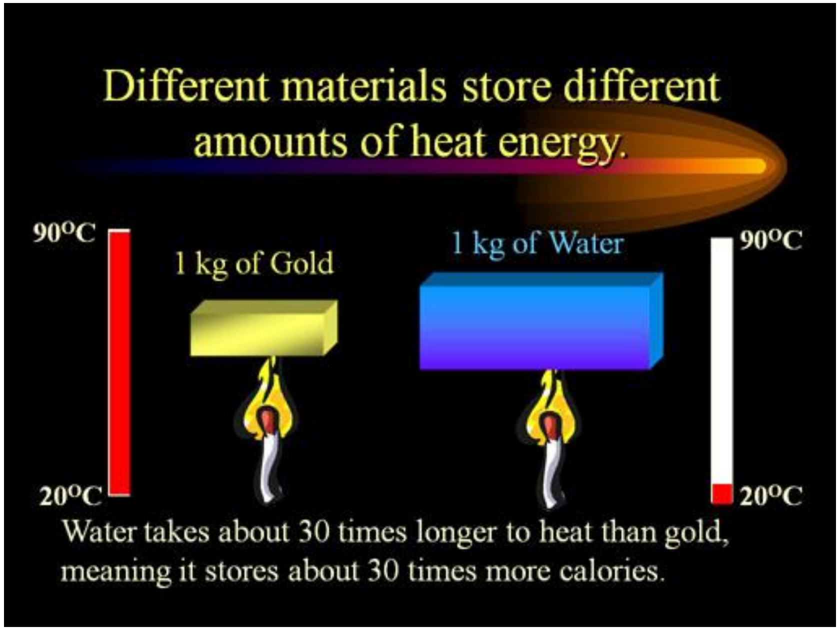
Specific Heat

Specific heat is the quantity of heat required to raise 1 lb of a substance 1°F

The specific heat of water is 1 Btu
The specific heat of air is .24 Btu
Units of specific heat are Btu/lb/°F



Heat Quantity Formula

- Q=weight x specific heat x ΔT
- $Q = (x)\ \text{lbs} \times \frac{(x)\text{btu}}{\text{lbs}/°\text{F}} \times \Delta T°\text{F}$

Q=BTU’s

If we have a mass flow rate instead of a mass only…..

Q(dot)=BTUh

Total Heat Formula
Heating or Cooling

BTU/hr = specific density x 60 min/hr x ΔH

= 0.075 x 60 x CFM x ΔH

= 4.5 x CFM x ΔH

ΔH (Enthalpy) takes into account total heat both latent and sensible

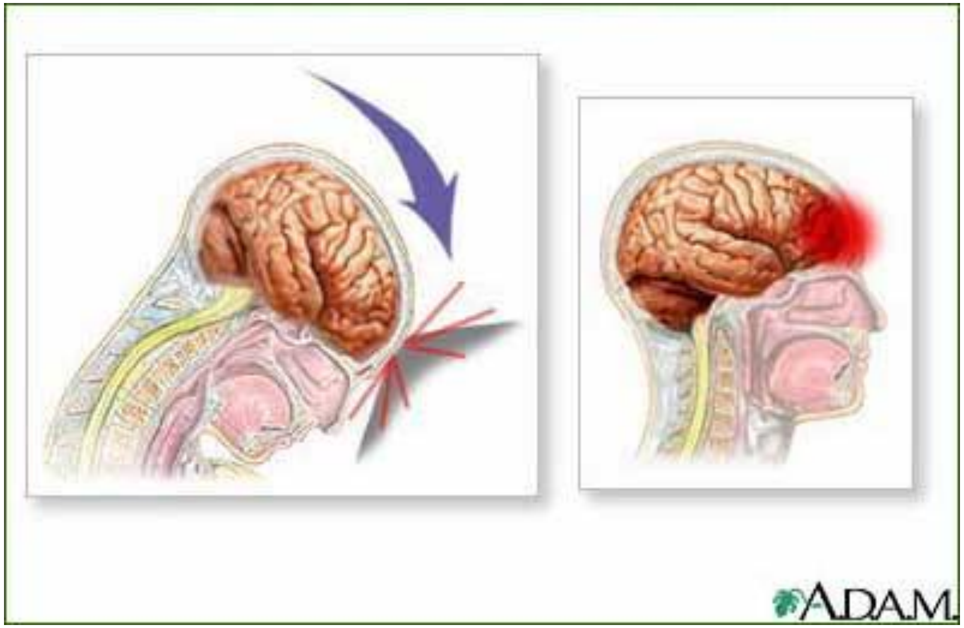
Air Conditioning

When was the last time you quantified how much you *conditioned* the air?

– Temperature drop won’t tell you……
– Electrical measurements won’t tell you…..
– Gauge pressures won’t tell you……
– Superheat and sub-cooling won’t tell you….

Yet that is what technicians measure to quantify performance!

Insanity: Doing the same thing over and over, and each time expecting a different result.



There is a better way to:

- Make correct measurements the right way without hurting your frontal lobe.
- Get lab accurate results in the field.
- Get the job done right the first time in *less* time.
- Guarantee the efficiency and capacity you have been selling.

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Simply Put!

If you are going to sell BTU's Learn to Measure Them!

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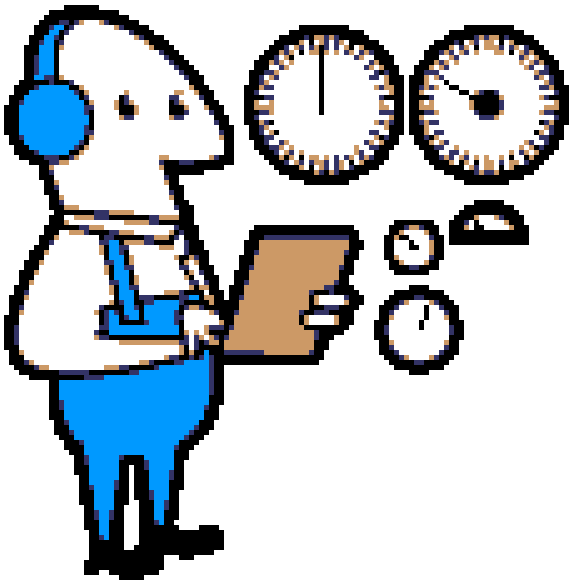
It all comes down to one thing….

Making measurements

- In any work that involves:
  - Engineering
  - Design verification
  - Installation
  - Service
  - Factory support



- The goal is to deliver
  - the designed efficiency and capacity
  - the performance that the customer purchased (13+ SEER)
  - the reliability promised (manufacturer & dealer)

10 Steps to Proper Performance

1. Perform a load calculation
2. Select a matching A/C of proper size
3. Select an A/C with the proper features for your climate
4. Select a furnace (air handler) and duct design together
5. Install the outside unit with adequate clearance to any obstacles
6. Braze the lineset while purging with dry nitrogen
7. Evacuate the system using a micron gauge
8. Measure and adjust airflow
9. Adjust using subcooling and superheat
10. Performance test the equipment

Capacity & Efficiency

- Capacity and efficiency are directly related
- With low efficiency you have low capacity
- Verification of rated capacity guarantees performance.
- A quick determination can be made where the problem lies.
  - The equipment
  - The duct system
  - Or both!

Appliance and System Performance

If the airflow is correct…….

And the refrigerant charge is correct……

The system capacity should be correct……..

Benchmarking system performance assures your customer is getting the designed BTUh!!!

If you don’t measure, how can you ever know???

Appliance Commissioning vs. System Commissioning

- Too often technicians repair the appliance instead of the system.
- Symptoms at the appliance often indicate problems elsewhere in the system.
- It is imperative we teach system commissioning and not just appliance start-up.
- Airflow and refrigerant charge are two of the most common misunderstood and improperly adjusted parameters in our industry
- **How are you addressing the problem?**

Remember

Think clean

Look for the obvious

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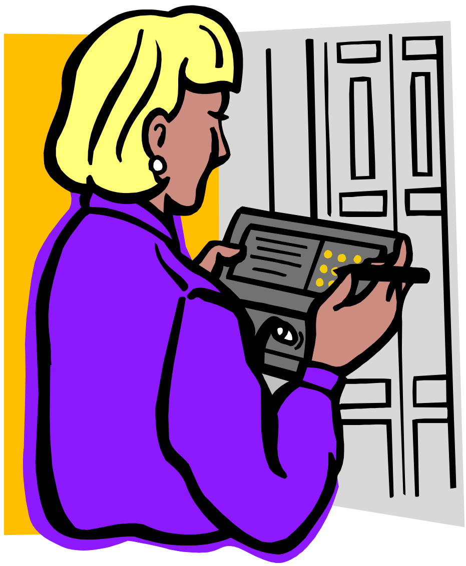
Performance testing

- Think clean
  - Filter, blower & coils
- Verify appliance operation
  - Cooling/Heating capacity
- Verify system operation
  - BTUH Delivery to the space



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So, what can we do?

1. **Visual inspection of duct inadequacies**
2. **Verify airflow:** digital vane anemometer or other airflow measurement device
3. **Verify static pressure** is within range
4. **Use digital refrigerant gauges** for better accuracy
5. **Measure** return and supply wet-bulb and dry-bulb, **calculate delivered capacity,** compare to rated capacity
6. **Recommend corrective actions**

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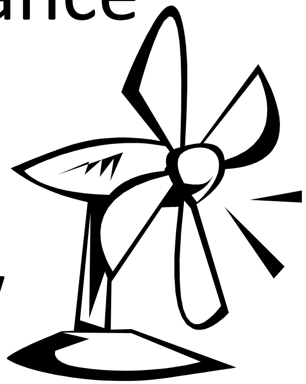
Airflow

- Airflow must ALWAYS be set at the appliance first!
  - Airflow is critical to system performance
  - Refrigerant charging requires proper airflow
  - Set to a nominal 400 CFM/Ton for A/C
  - Set to 450 CFM/Ton for heat pumps

  Always refer to manufacturer's specific instructions



After the airflow has been set at the appliance <u>NEVER</u> adjust it to change system characteristics!

Vane Anemometers

inherently have

- High accuracy
- Excellent repeatability
- Excellent measurement repeatability using different measurement devices and techniques
- Have excellent repeatability even from user to user

The Large Vane Advantage

- True velocity measurement
- No air density correction required
- Simple one hand operation
- Easy to carry and operate
- Required for proper commissioning of residential systems
- Low battery consumption
- Averages true flow over a sample area, not just responding to local stray eddie

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Measure CFM

Recommended Testo 416 Mini Vane

- Airflow in under 3 minutes
- Full duct traverse assures accuracy
- Ultra Low mass rotating vane
- Precision jewel bearings
  - the thrust of a fruit fly
- Excellent durability and chemical resistance.
- No air density correction required.

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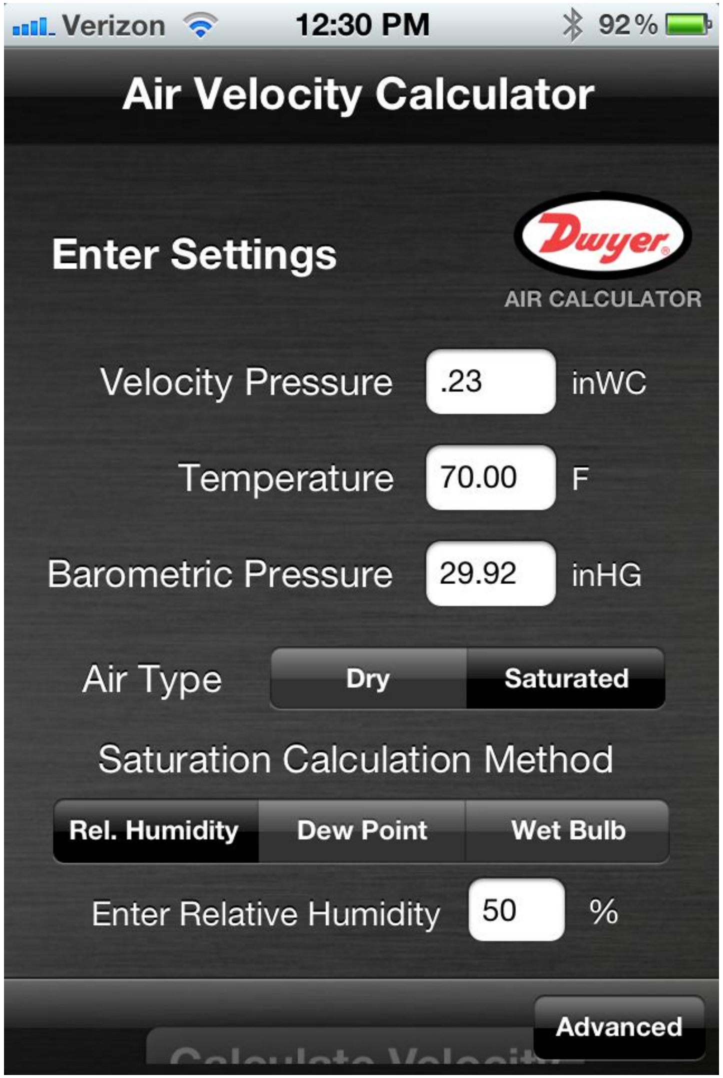
testo 416 Mini Vane

- Non-invasive measurement
- Excellent repeatability
- Forgiving to operator error
- Guaranteed performance with a

  Two year warranty

Pitot Tube



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Measuring Wet Bulb

Recommended Testo 605 H2

- Accurate measure of initial and final wet-bulb is required with 10th of a degree resolution
- 605 uses a high accuracy reliable sensor
- Only instrument designed to make measurements in the duct
- Low cost and easy to use
  - Single button operation

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Accurate Instruments are Important!

- 0.1 F Wetbulb Temperature difference results in 0.1 ton cooling difference
- Problems inherent with instrumentation lead to misdiagnoses.
- Technician after technician should get the same measured results.
  - Technicians should be able to make equipment operate in the field as well as it did in the lab!!! (You need lab accurate instruments to do it!!!)

Achieving Proper Charge:
500 series Refrigeration System Analyzer

- A digital window into AC/R systems
  - Superior accuracy
  - Greater speed
  - Real-time calculations
  - All-in-one tool
  - Confidently charge at low ambient temps
  - Graphic capabilities on Testo 570

EasyKool software monitors refrigerant levels and makes it possible to download new refrigerant profiles to the 570 as they become available.

Refrigerant Charge

System charge is critical

Charging by superheat and subcooling is the most accurate method of charging.

- Superheat (Fixed) verifies evaporator performance
- Subcooling (TXV) assures adequate refrigerant for proper metering device operation with a TXV.

Any charge other than the correct charge will negatively affect system performance.

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Calculating cooling capacity

$$x = -\frac{b}{2a} \pm \sqrt{\frac{b^2 - 4ac}{4a^2}}$$

$$x = -\frac{b}{2a} \pm \frac{\sqrt{b^2 - 4ac}}{\sqrt{4a^2}}$$

$$x = -\frac{b}{2a} \pm \frac{\sqrt{b^2 - 4ac}}{2a}$$

$$\frac{1-X}{X} = \frac{X}{1}$$

$$X^2 = 1-X$$

$$1X^2 + 1X - 1 = 0$$

$$\frac{-1 \pm \sqrt{1-(-4)}}{2}$$

bx + c = 0)

$$\left(\frac{-b \pm \sqrt{b^2 - 4ac}}{2a}\right)$$

$$\begin{aligned} \text{LHS} = I_{k+1} &= \frac{2k+1}{2(k+1)} \times \frac{(2k)!}{(k!)^2} \times \frac{\pi}{2^{2k}} \\ &= \frac{2k+2}{2(k+1)} \times \frac{2k+1}{2(k+1)} \times \frac{(2k)!}{(k!)^2} \times \frac{\pi}{2^{2k}} \\ &= \frac{(2k+2)!}{((k+1)!)^2} \times \frac{\pi}{2^{2(k+1)}}, \end{aligned}$$

Calculating cooling capacity

Don’t Panic

It’s as easy as

1-2-3

3 Step test

Even a kid can do it!!

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Manual calculation performance

1 Measure

2 Look up

3 Calculate

~$750

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Manual: STEP 1: Measure

- Airflow - CFM
  - in the return

- Entering and leaving wet bulb
  - Around the heat exchanger or A-coil
  - Allows you to get the enthalpy change (total energy change)

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Manual: STEP 2: Look up

- Find change in enthalpy (Δh) from wet bulb measurements
- Using a table, chart or program

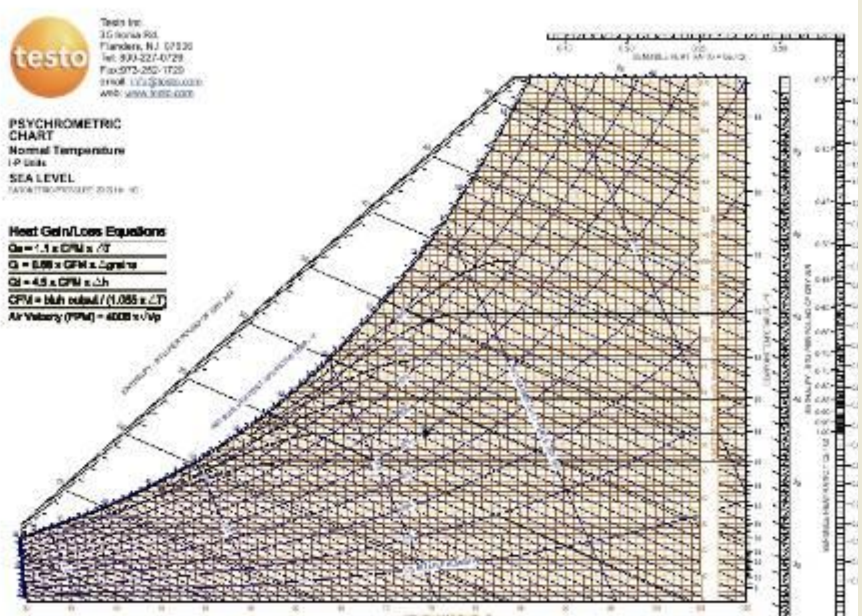
ET BULB EMPER-ATURE

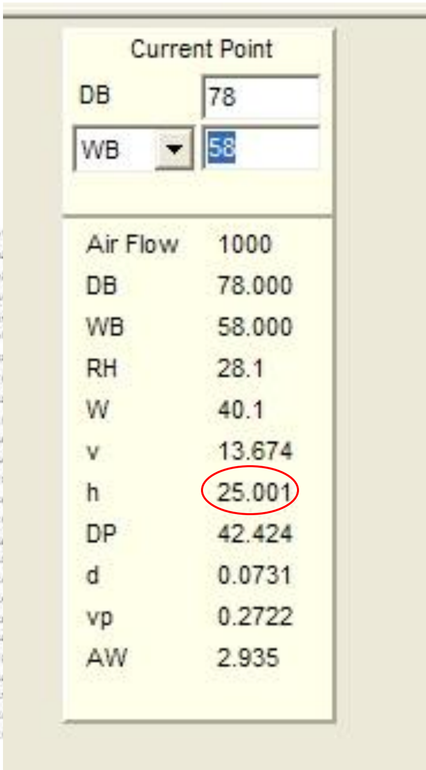
ENTHALPY CHART

WET BULB TO ENTHALPY CONVERSION

Wet bulb temperature in tenths of a degree Fahren

	.0	0.1	0.2	0.3	0.4	0.5	0.6
35	12.97	13.01	13.05	13.10	13.14	13.18	13.23
36	13.40	13.45	13.49	13.53	13.58	13.62	13.67
37	13.85	13.89	13.93	13.98	14.02	14.07	14.11
38	14.30	14.34	14.39	14.43	14.48	14.52	14.57
39	14.75	14.80	14.84	14.89	14.94	14.98	15.03
40	15.21	15.26	15.31	15.36	15.40	15.45	15.50
41	15.68	15.73	15.78	15.83	15.88	15.92	15.97
42	16.16	16.21	16.26	16.31	16.36	16.41	16.45
43	16.65	16.70	16.75	16.80	16.85	16.90	16.95
44	17.14	17.19	17.24	17.29	17.34	17.39	17.45
45	17.65	17.70	17.75	17.80	17.85	17.90	17.95
46	18.16	18.21	18.26	18.31	18.37	18.42	18.47
47	18.68	18.73	18.79	18.84	18.89	18.94	19.00
48	19.21	19.26	19.32	19.37	19.43	19.48	19.53
49	19.75	19.81	19.86	19.92	19.97	20.03	20.08
50	20.30	20.36	20.41	20.47	20.53	20.58	20.64
51	20.86	20.92	20.98	21.04	21.09	21.15	21.21
52	21.44	21.49	21.55	21.60	21.66	21.72	21.78
53	22.02	22.06	22.12	22.09	22.24	22.30	22.36
54	22.62	22.68	22.74	22.80	22.86	22.92	22.98
55	23.22	23.28	23.34	23.40	23.46	23.52	23.58
56	23.84	23.90	23.96	24.03	24.09	24.15	24.21
57	24.48	24.53	24.59	24.66	24.72	24.79	24.85
58	25.12	25.18	25.25	25.32	25.38	25.45	25.51
59	25.78	25.85	25.91	25.99	26.06	26.12	26.19
60	26.46	26.53	26.60	26.67	26.74	26.81	26.88





Determining Enthalpy from Wet Bulb

Enthalpy in BTU per Pound of Dry Air

Wet Bulb Temperature F	Tenths of a Degree F									
	0.0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9
35	13.01	13.05	13.10	13.14	13.18	13.23	13.27	13.31	13.35	13.40
36	13.44	13.48	13.53	13.57	13.61	13.66	13.70	13.75	13.79	13.83
37	13.87	13.91	13.96	14.00	14.05	14.09	14.14	14.18	14.23	14.27
38	14.32	14.37	14.41	14.46	14.50	14.55	14.59	14.64	14.68	14.73
39	14.77	14.82	14.86	14.91	14.95	15.00	15.05	15.09	15.14	15.18
40	15.23	15.28	15.32	15.37	15.42	15.46	15.51	15.56	15.60	15.65
41	15.70	15.75	15.80	15.84	15.89	15.94	15.99	16.03	16.08	16.13
42	16.17	16.22	16.27	16.32	16.36	16.41	16.46	16.51	16.56	16.61
43	16.66	16.71	16.76	16.81	16.86	16.91	16.96	17.00	17.05	17.10
44	17.15	17.20	17.25	17.30	17.35	17.40	17.45	17.50	17.55	17.60
45	17.65	17.70	17.75	17.80	17.85	17.91	17.96	18.01	18.06	18.11
46	18.16	18.21	18.26	18.32	18.37	18.42	18.47	18.52	18.58	18.63
47	18.68	18.73	18.79	18.84	18.89	18.95	19.00	19.05	19.10	19.16
48	19.21	19.26	19.32	19.37	19.43	19.48	19.53	16.59	19.64	19.70
49	19.75	19.81	19.86	19.92	19.97	20.03	20.08	20.14	20.19	20.25
50	20.30	20.36	20.41	20.47	20.52	20.58	20.64	20.69	20.75	20.80
51	20.86	20.92	20.97	21.03	21.09	21.15	21.20	21.26	21.32	21.38
52	21.44	21.50	21.56	21.62	21.67	21.73	21.79	21.85	21.91	21.97
53	22.02	22.08	22.14	22.20	22.26	22.32	22.38	22.44	22.50	22.56
54	22.62	22.68	22.74	22.80	22.86	22.92	22.98	23.04	23.10	23.16
55	23.22	23.28	23.34	23.41	23.47	23.53	23.59	23.65	23.72	23.78
56	23.84	23.90	23.97	24.03	24.10	24.16	24.22	24.29	24.35	24.42
57	24.48	24.54	24.61	24.67	24.74	24.80	24.86	24.93	24.99	25.06
58	25.12	25.19	25.25	25.32	25.38	25.45	25.52	25.58	25.65	25.71
59	25.78	25.85	25.92	25.98	26.05	26.12	26.19	26.26	26.32	26.39

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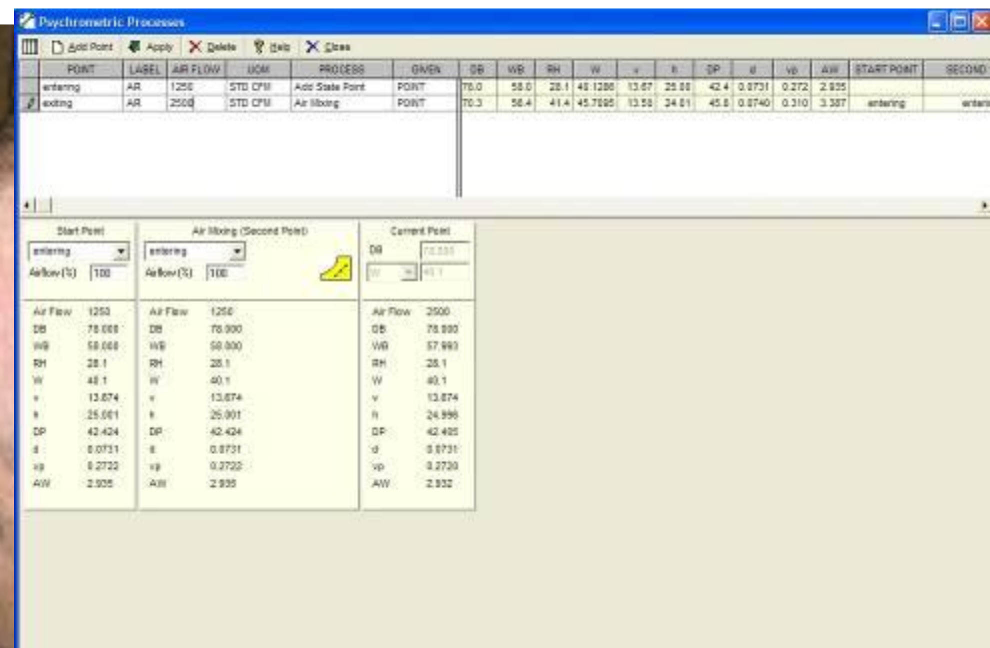
Manual: STEP 3: Calculate

- Manual capacity calculation using total heat equation
  - BTUh = 4.5 x CFM x Δh (field calculation)
  - Tons = BTUh/12,000
- or with program
  - Program corrects for air density



The Total Heat Formula

BTUh=	0.075 lbs	60 min	400 ft³	6.66 BTU
	ft^3	hr	min	lbs

0.075 x 60 x 400 x 6.66 = 12,000 BTUh

Total Heat Equation

- Capacity calculation using total heat equation
  - BTUh = 4.5 x CFM x Δh (field calculation)
  - Tons = BTUh/12,000
- Some programs correct (4.5) for air density

Testo Inc.
35 Ironia Rd.
Flanders, NJ 07836
Tel: 800-227-0729
Fax:973-252-1729
email: info@testo.com
web: www.testo.com

0.068 lbs/ft^3

PSYCHROMETRIC CHART

Normal Temperature

I-P Units

1500 FEET

BAROMETRIC PRESSURE: 28.335 in. HG

Heat Gain/Loss Equations

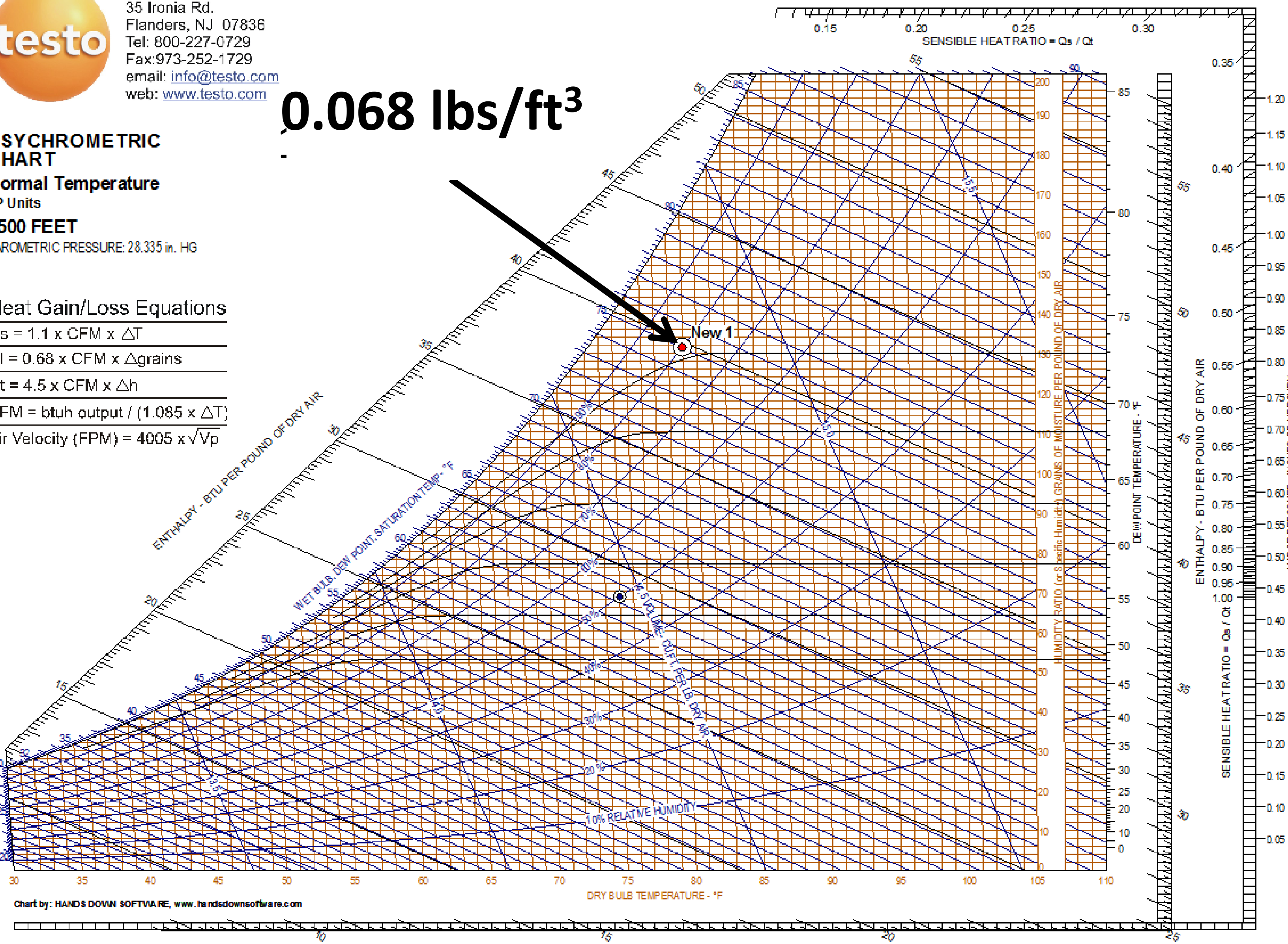
$Qs = 1.1 \times CFM \times \Delta T$

$Ql = 0.68 \times CFM \times \Delta grains$

$Qt = 4.5 \times CFM \times \Delta h$

$CFM = btuh\ output / (1.085 \times \Delta T)$

Air Velocity (FPM) $= 4005 \times \sqrt{Vp}$



How much airflow is required for my A/C unit?
It depends....

If we are at 1500’ feet and 80º at 80% Rh

Like a new start up in Ohio

The air density is about 0.067 lbs/ft^3

SO……..

30 lbs/min / 0.067 lbs/ft^3 = 448 ft3/min

It matters anywhere above sea-level

The Total Heat Formula Corrected for Ohio 80º at 80%Rh

BTUh=	0.067 lbs	60 min	448 ft^3	6.66 BTU
	ft^3	hr	min	lbs

0.067 x 60 x 448 x 6.66 = 11,994 BTUh

Why density really matters

If the air density is low, more CFM is required to keep the mass flow rate the same!!!

If air density is not considered, many systems will have very low airflow.

Real-time System Performance

- Process
  - Calculate real-time heating and cooling capacity
    - Using ASHRAE calculations
    - Compensates for air density changes
      - Humidity
      - Pressure (elevation)
      - Temperature
  - Can average, log, print, stream or download the data
- Cost: <$2000

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Real-time System Performance

- Equipment:
  - multifunction HVAC meter
    - Mini-vane anemometer probe in return
  - 2 humidity probes
    - Before and after cooling coil/heat exchanger

wireless humidity probe

Mini-vane anemometer

a multifunction HVAC meter

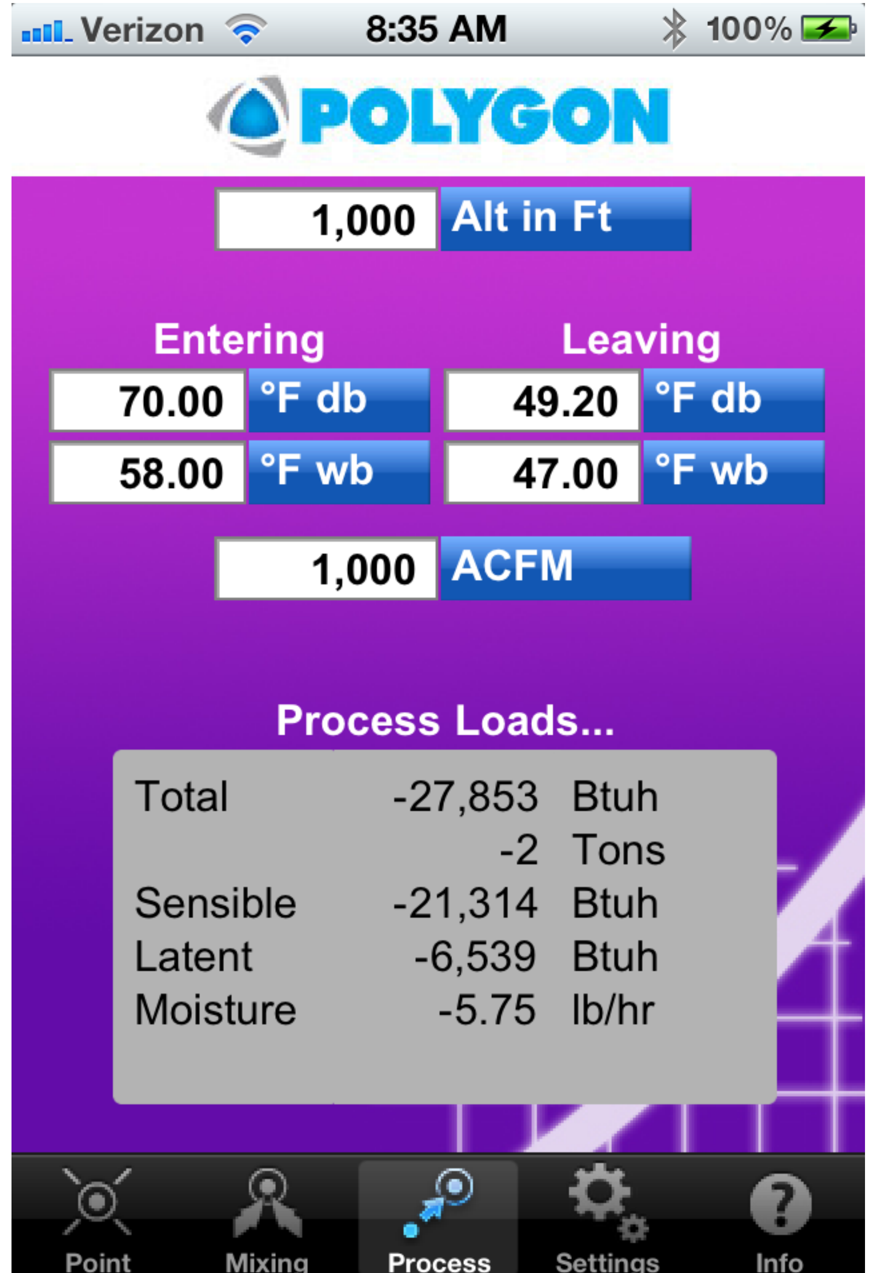
wireless humidity probe

Hate Math?
There is an app for that!

PSYC IT (Either very low cost or Free)

Corrects for:

- **Air Density (via altitude)**
- **Relative Humidity**
- **Temperature**



We need to use modern technology

- Benchmarking equipment requires lab accurate tools
- Field instruments are available with lab accuracy
- With new technology, and tools comes new and **quicker** and methods

System Design

- Measurements on their own mean nothing without knowledge of the design operation
- ARI Design conditions
  - What’s your “design temperature”?

Operating Conditions and Installation both have an Impact on Capacity!

EXTENDED REFRIGERANT LINE CORRECTION FACTORS

Varying Line Length in Feet (m) vs. Total Capacity Multiplier					
25 (8)	50 (15)	75 (23)	100 (30)	125 (38)	150 (46)
1.00	.99	.98	.96	.94	.92

REFRIGERANT CHARGE DATA

All models are factory charged with R–22 for outdoor unit, 25' (8m) of refrigerant line and matching indoor section.
Refrigerant charge correction per foot (305mm) of line:
1/4″ O.D. = .25 oz.; 5/16″ O.D. = .45 oz.; 3/8″ O.D. = .60 oz.; 1/2″ O.D. = 1.2 oz.

VOLTAGE CORRECTION FACTORS

Volts	Capacity	Watts
208	.98	.99

INDOOR AIRFLOW CORRECTION TABLE

% Rated Air	90	95	100	105	110
Total Cap. Mult.	.98	.99	1.00	1.01	1.03
Sens Cap. Mult.	.95	.98	1.00	1.03	1.05

INDOOR TEMPERATURE CORRECTION TABLE
(Based on 95°F Ambient)

Indoor D.B. °F (°C).	Correction Factor	Entering Indoor Wet Bulb °F (°C). 59 (15)	61 (16)	63 (17)	65 (18)	67 (19)	69 (20)	71 (21)
70 (21)	Total Cap. Mult.	**.90**	.93	.96	.99	1.02	-	-
	Sens Cap. Mult.	**.86**	.85	.82	.77	.70	-	-
75 (24)	Total Cap. Mult.	.89	.92	**.95**	.98	1.01	1.04	-
	Sens Cap. Mult.	1.04	1.03	**1.00**	.95	.88	.78	-
80 (26)	Total Cap. Mult.	.88	.91	.94	.97	**1.00**	1.03	1.06
	Sens Cap. Mult.	1.18	1.17	1.14	1.08	**1.00**	.89	.73
85 (29)	Total Cap. Mult.	-	.90	.93	.96	.99	1.02	**1.05**
	Sens Cap. Mult.	-	1.29	1.26	1.20	1.11	.98	**.81**

Bold Type = approximately 50% Relative Humidity

10+ SEER - AIR CONDITIONER

.98 x .98 x .99 x .95 = .90 Typical field conditions you will encounter

24,000 x .90 = 21,678 Btuh (Reality Bites)

90%+ of Rated capacity is typically a good goal!

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Tune up Analysis Results
Example Pre- and Post test of a System

- Pre-test: 44% of system rated capacity
- Post-test:100% of system rated capacity
- **HOW DID IT HAPPEN?**
- **LET'S TAKE A LOOK:**

ls

Selected Pre-test Data

- **1112 CFM for a 5-ton system (56% of design)**
- **Static Pressure: Ret = 0.54” Supply = 0.52”**
- **Delivered Capacity = 26,521 Btu (44%)**
- **Superheat = 42.1 deg.; target = 20 deg.**
- **Delta-T across evaporator = 4.9 deg.**
- **Delta-h = 5.3**

HOW MANY TECHS HAVE THIS INFORMATION BEFORE MAKING A DECISION ON A COURSE OF ACTION??

With practice, it only takes about 20 minutes to get ALL this info

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Selected Post-test data

- **2014 CFM for a 5-ton system (100% of design)**
- **Static Pressure: Ret = 0.53” Supply = 0.47”**
- **Delivered Capacity = 59,997 Btu (100%)**
- **Superheat = 18.0 deg.; target = 20 deg.**
- **Delta-T across evaporator = 20.6 deg.**
- **Delta-h = 6.62**

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Tune up Analysis Results
Example Pre- and Post test of System

So, HOW do we get from

Pre-test: 44% of system rated capacity… TO:

Post-test:100% of system rated capacity

Improvements performed:

- **Cleaned blower**
- ***Increased flex duct size from 6 to 7”***
- **Increased blower speed to proper setting**
- **Added 2 lbs. of R-22 on a 5-ton system**
- **Digitally-accurate charge to superheat on correct airflow**

Typical Results

- Average increase in Delivered Cooling:

27.2%!

- Hundreds of $ savings per system
- Often less than a 1- year payback per system
- Less trouble-calls and maintenance costs
- Fewer replaced parts
- Less "Guessing;" Get it right the first time!

THE AC-TUNE-UP

- Includes the entire system
- Focusing on:
  - Proper airflow
  - Correct refrigerant charge
  - Delivering conditioned air
- Ultimately proper AIR CONDITIONING
  - By quantifying performance

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Results

- Average reduction of 0.127 kW/ton in peak demand (res. & comm.)
- (99% confidence from a 7500-TU sample)
- Average of 500 – 1500 kwh savings annually (A/Cs only; Heat pumps higher)

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Now…

How do we turn this into a new profit center in our business?

INGREDIENTS of a Successful Testing

- *AND– it doesn't happen by itself!*
- Educate customers
- Test in and Test out on your jobs
- Interested contractors
  - Business training
  - Mindset change
  - Technical Training
  - Proper tools

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Contractor Success Stories

- Higher customer satisfaction
- Better profits
  - More profitable service contracts
  - Fewer call backs
  - Increased sales
- Excited technicians
- Better reputation
- More confidence from equipment manufacturers
- More confidence from technicians
- Improved reputation
- Business Impact for contractors and Utilities

CONCLUSIONS:

- So Therefore….
- Training need
- Contractors don’t know what they should know. Measure what you sell!
- Business model changes

Thank you!

More info: 888-224-3437
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The A/C System Performance Series