Calculation of AC System Performance ***Without Gauges***

Presented at the RESNET Conference
San Diego, CA
February 21, 2007

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testo worldwide

- **Largest manufacturer of portable instrumentation in the world**
- **1350 employees worldwide, 110 R&D Engineers**
- **testo AG - Headquartered in Black Forest Germany**
- **testo inc. - Headquartered in Flanders, NJ**
- **25 subsidiaries worldwide (USA, Japan, Australia, China, India, Russia, Europe, …)**
- **ISO 9001 Quality Standards**
- **Service and repair facilities worldwide**
- **50 years of experience**

Gauges

- Gauges = Refrigerant gauges
- Used for charging
- Omnipresent
- Only a part of the answer
  - Superheat or subcooling
  - airflow
- Limited accuracy

System Performance

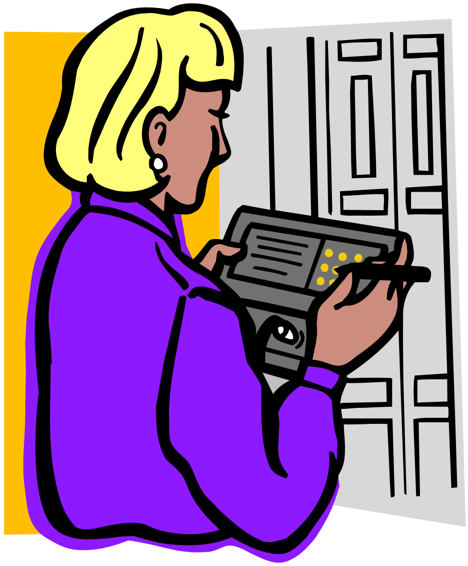
- Performance (BTU/hr)
  - …as designed by the manufacturer
  - …as specified by the dealer/installer
  - …as purchased by the customer
- In Heating mode
  - Heating output in BTUh or KW
- In cooling mode
  - Cooling in tons
  - BTUh or KW
    - 1ton =12,000 BTU/hr

How do you do that?

- Energy conversion rate at the box
- Mass flow rate
  – Airflow over the coil
- The change in latent heat
  – Change in enthalpy

Why measure?

- Verify appliance operation
  - Heating capacity
  - Cooling capacity
- Verify system operation
  - Delivery (ducts)
  - Throw (mixing-comfort)



System Performance

- Performance cannot be assumed!!!
  - Performance varies with load conditions
  - Equipment performance does not assure delivered performance
  - Systems are field installed and require a field commissioning procedure
- Efficiency and performance go hand in hand

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!

Benefits

- AC
  - Better humidity removal and comfort resulting in higher thermostat settings
  - Increased cooling capacity resulting in shorter run times
  - Equipment will cycle off during peak demand periods
  - Reduced electrical energy consumption
- Heating
  - Reduced short cycling
  - Extend equipment life
  - Reduced fuel usage

Who should measure

- Contractors
  - Troubleshoot customer complaints
  - Proper installation and set up
  - System commissioning
- Energy/program auditors
  - Test-out
  - Verify performance
  - Virtual VSP

What happens today

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Estimating vs. measuring

- Air flow estimates
  - Pressure drop across the dry evaporator coil
  - Total external static pressure method
  - The temperature rise method (Sensible heat formula)
  - RPM and manufacturers’ fan curves (Belt or VF Drive)
- Airflow measurements
  - Pitot tube and digital manometer
  - Hot Wire Anemometer
  - Mini-vane Anemometer

Limitations today

- Estimations
- Surrogate indicators
- Understanding measurements are possible and helpful
- The Holy Grail
  - An accurate and reliable way to measure **airflow** in the field
  - That doesn't cost and arm and a leg
  - And will be used more often than not

The Sensible Heat Formula

BTUh = SPECIFIC HEAT x SPECIFIC DENSITY x

60 MIN/HR x CFM X ΔT

Or

= 0.24 x 0.75 x 60 x CFM x ΔT

=1.08 x CFM x ΔT

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

Standard Air

- 0.075 lbs./ft^3 at
  - 68 degrees F
  - 0% rH
  - 14.7 psia

But……

Air is never standard!!!

- – The constants 1.08 & 4.5 are derived from standard air density at 0.075 pounds/ft^3
- – If we want accurate calculations, we must correct our measurements for **actual** air density!!!
- – Pitot tube and hot wire anemometers are density dependent

Off-line calculation of heating & cooling capacity

Don't Panic

It's as easy as

1 Measure

2 Look up

3 Calculate

Off-line: 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)

Off-line: STEP 2: Look up

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

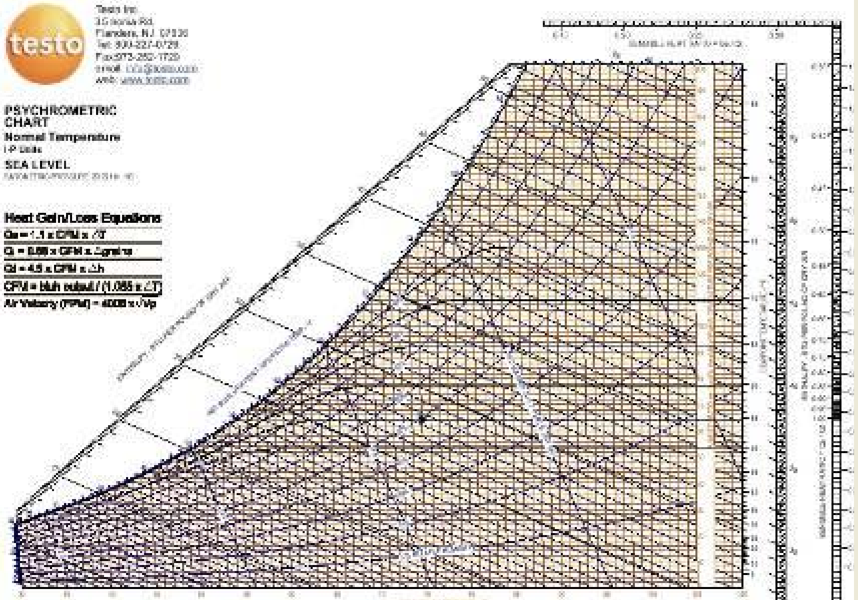
ET BULB EMPER- ATURE

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



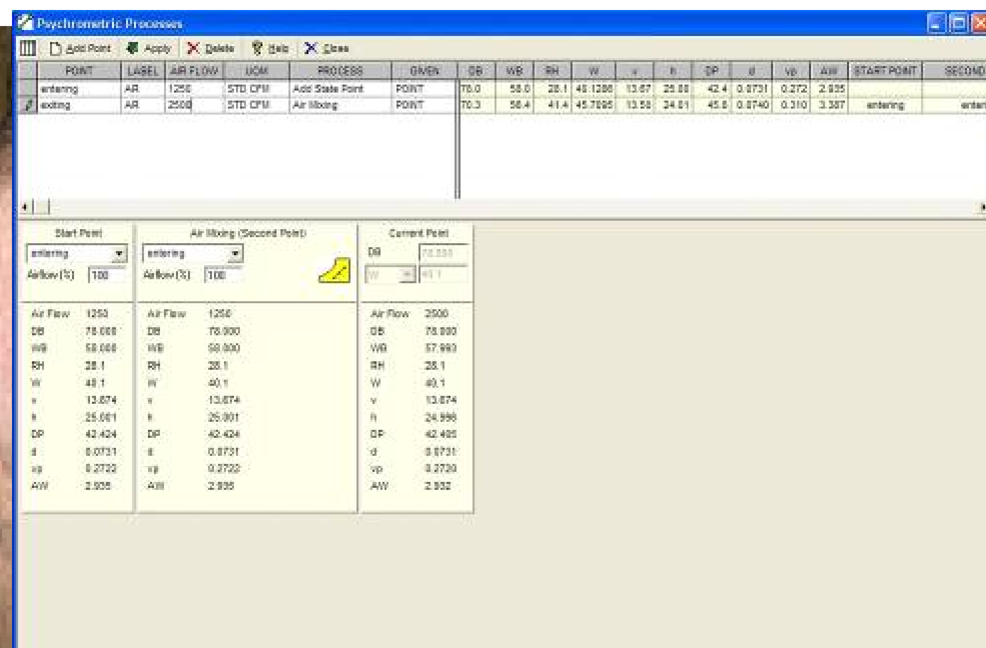
Current Point

DB	78
WB	58

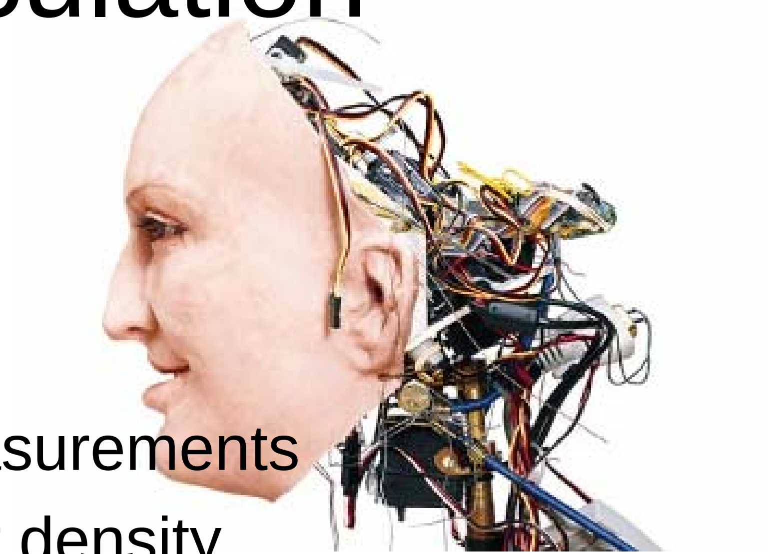
Air Flow	1000
DB	78.000
WB	58.000
RH	28.1
W	40.1
v	13.674
h	25.001
DP	42.424
d	0.0731
vp	0.2722
AW	2.935

Off-line: 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



Real-time calculation



Advantages:

- Very high accuracy
- Quick set up, real-time measurements
- Automatically adjusts for air density
- No charts or forms required
- All data used for calculation can be printed on site
- Trend and log data
- Download or Slave mode to PC via USB

Real-time system performance

- Process
  - The 435 calculates real time heating and cooling capacity
    - Using total heat equation
    - Compensates for air density changes
    - Humidity
    - Pressure (elevation)
    - Temperature
  - Can average, log, print or download the data
- Cost: ~$1800

Integrated - Multifunction

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

wireless humidity probe

Mini-vane anemometer

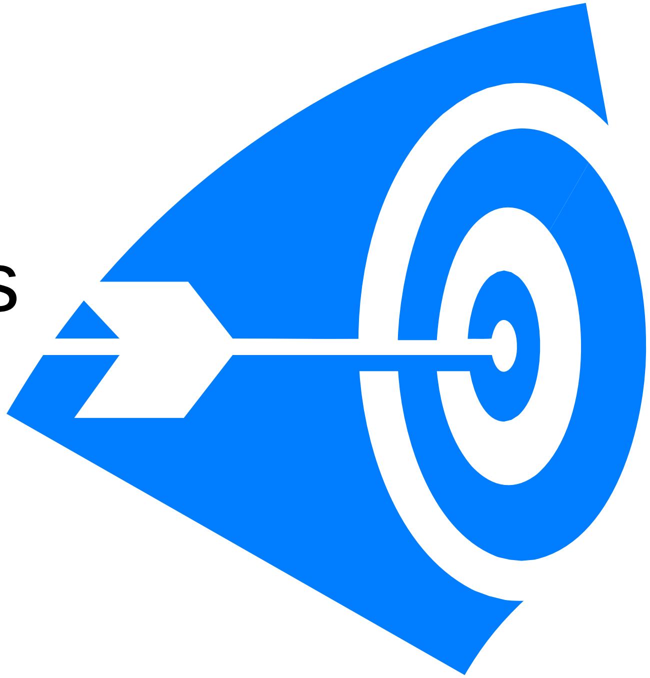
testo 435 multifunction HVAC meter

Accurate Measurements are Critical!

- 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!!!)

Impact of inaccuracy

- An error of ~1 ºF wet bulb yields an error of 1/4 ton of cooling (3,000 BTU/hr)
- An error of 62.5 CFM yields an error of 1/4 ton of cooling (3,000 BTU/hr)

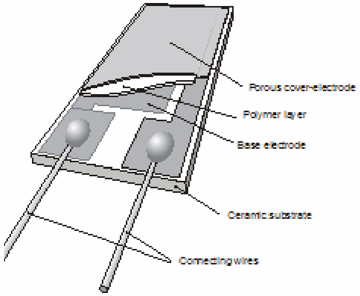


Thermometers and Psychrometers

- Thermometers
  - Sensor tolerances
  - Measurement technique
  - Sensor drift
- Sling Psychrometers
  - Proper air velocity
  - Distilled water
  - Low resolution
  - “Speed reading”
  - Sling in a duct?

Enabling technology

- Mini-Vane Airflow
  - Easy and fast
  - Accurate
  - No density compensation
  - Minimally invasive
- Humidity sensor
  - Accurate
  - Responsive
- Wireless probes
  - Real-time
  - Minimally invasive



Think clean

- Don't neglect the performance impact of dirt
  Filters
  - A-coils
  - blower wheels
  - (secondary) heat exchangers
  - Burners
- And other unwanted stuff
- LBL report (2002)
  – Evaporator pressure drop doubles in 7.5 years
  – Siegel, Walker, Sherman

Contractor Study

- Wisconsin: 1 contractor co., 5 technicians
- Average summer temps like Philadelphia
- 85 tests: 37 TXV systems, 49 fixed orifice
- Capacity ranges
  - 1.5 tons 6 systems
  - 2.0 tons 52 systems
  - 3.0 tons 23 systems
  - 3.5 tons 1 system
  - 4.0 tons 1 system
  - 5.0 tons 2 systems

90% 2-3 tons

Energy Star on Air Flow

- Essential for comfort
  - 70% of systems tested are operating at less than 350 cfm/ton (ideal is 400 cfm/ton)
  - Annual savings of 8% possible
- Technician verifies system is flowing at 400cfm/ton (or cfm specified by manufacturer) during full-speed testing
  - Systems incapable of 350 cfm/ton or greater must be corrected by improving ducts or would not qualify

US Southwest/California study

Considering an ENERGY STAR CAC/ASHP Specification for 2006

Study results

(CFM/ton)

	289-350	351-475	476-890
Pre test	5%	20%	76%
Post test	7%	65%	28%

Wisconsin study

Study results
(CFM)

	3-9	10-99	100-299	300-499	500-985
decreased	3	2	17	4	2
increased	1				

57 systems left unchanged

Energy Star on proper charge.

Refrigerant Charge

- Essential to maintain capacity
  - Improper charge can lead to premature compressor failure
  - Up to 41% systems undercharged, 33% overcharged
  - Average savings of 12.5% with proper charge
- Adjusted by technician in accordance with manufacturer's instructions
  - Systems with more than ±3° deviation in subcooling from manufacturer's spec would not qualify

Considering an ENERGY STAR
CAC/ASHP Specification
for 2006

Study results
(refrigerant charge)

	UNDER	GOOD	OVER
Pre-service	35%	35%	30%
Post-service	19%	53%	12%

65% wrong charge

Study results
(Watts)

	0.1-9	10-99	100-299	300-499	500-699	700-916
saved		15	8	5	2	1
increased	3	4	2			

33% of systems saved from 10 to 500 watts
53% of systems left unchanged

Delivery

- Insure proper delivery at register
  - Volume flow & velocity (throw)
    - Large vane with CFM and averaging
  - Humidity
    - Accurate and responsive
  - Air Temperature
    - Large vane
    - With humidity

Assessment → Repair

- Heating & Cooling
  - Set air flow: using mini-vane
- Cooling
  - Correct refrigeration charge Heating
- Correct combustion set ups
  - Tuning
  - Fuel pressure
  - Venting
  - Safety

Resources

- Integrated Psychrometric program
  - http://www.handsdownsoftware.com/downloads/testo-HDPsyChart-STUDENT.exe
- testo A/C Applications Guide
  - Request PDF: bspohn@testo.com
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Thank you!

· 50 years of Testo
· More innovative than ever
· 50 innovations in the anniversary year
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