Welcome to TruTech Training!

We'll be starting in just a few moments……

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Making Measurement Science Work!

If you are having trouble connecting, please email:
Jim2@TruTechTools.com

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TruTech Technical Training

Gauging your performance

Part III

The Next Generation

Energy Star on proper charge.

Refrigerant Charge

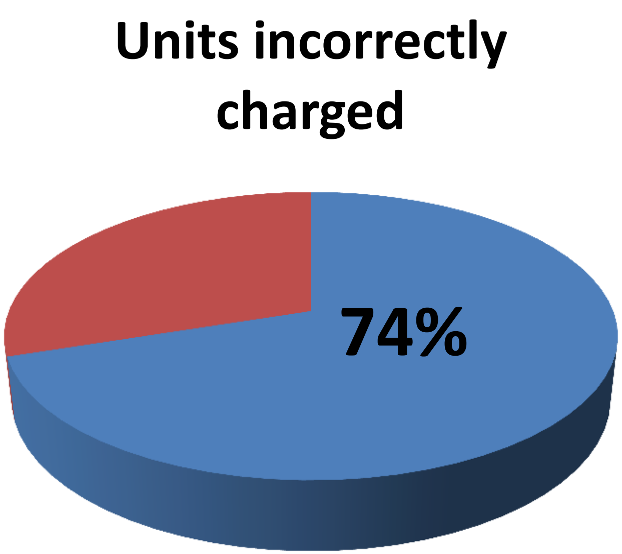
- Essential to maintain capacity
  - Improper charge can lead to premature compressor failure
  - Up to 41% systems undercharged, 33% overcharged
  - Average savings of 12.5% with proper charge
- Charge is adjusted by the technician in accordance with manufacturer's instructions
  - Systems with more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

Up to 41% systems undercharged, 33% overcharged

74% of systems have improper charge

California PUC analysis of 13,000 residential and commercial units

- Most off by ½ to 5 pounds of refrigerant
- A/C units off by more than 8 ounces will potentially fail within 5 years
- In cap tube or short orifice systems even one or two ounces can have a serious impact on performance



74% of systems are improperly charged

Causes

- Improperly calibrated measurement equipment
- Human errors during commissioning

SOURCE: The California refrigerant and airflow verification program

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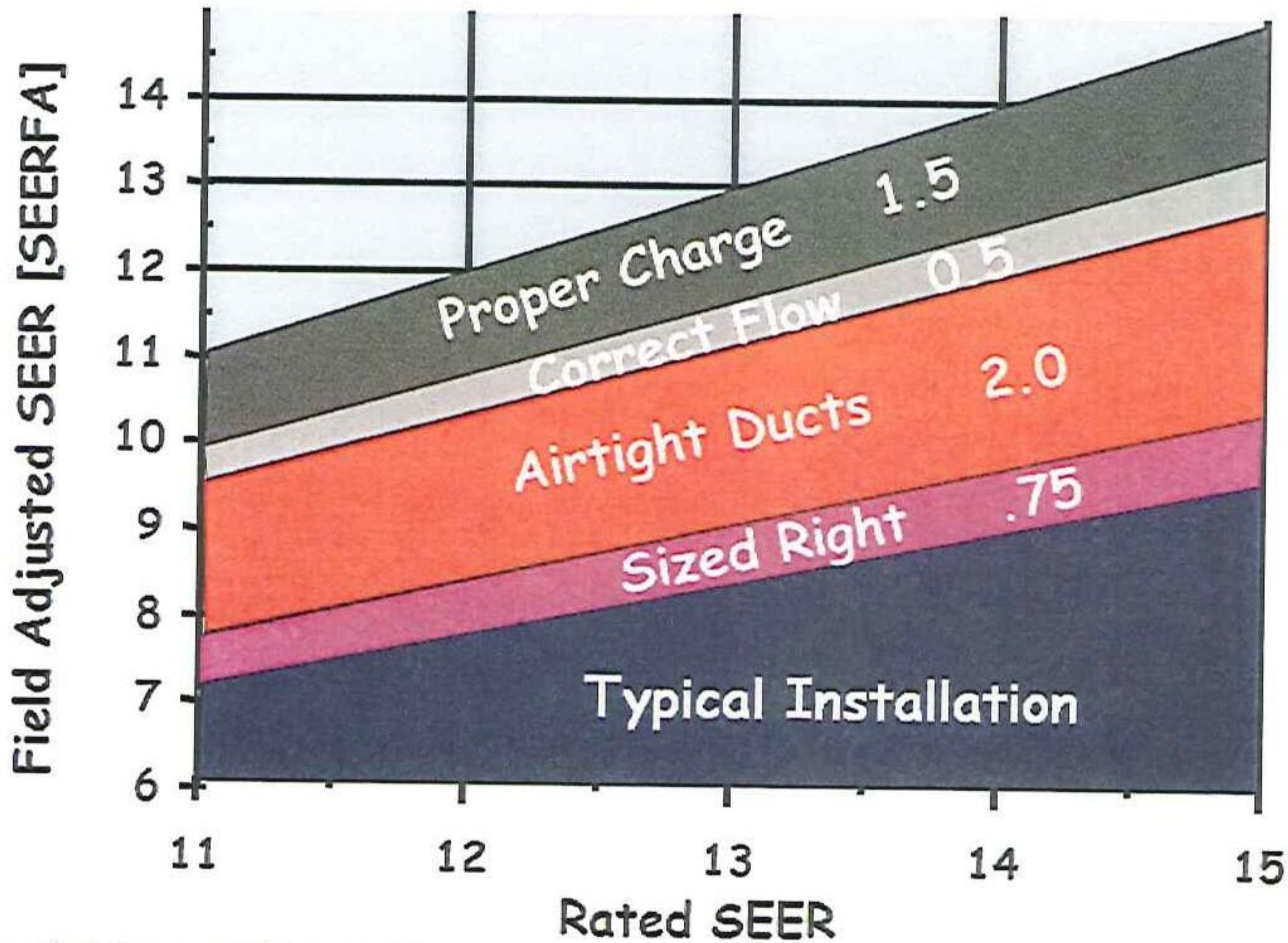
ENERGY STAR INDOOR AIR PACKAGE
HVAC BEST PRACTICE INSTALLATION

ENERGY STAR



Commissioning the system

Getting the Charge Correct

- Set airflow
- ID metering device
- Charge by superheat or subcooling
- Check the split across the evaporator
- Document the operation

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Matched components:

–Systems must be listed in the ARI directory

Increased importance of charging:

–Proper charge is imperative to get guaranteed energy efficiency, capacity, and system reliability.

–A few ounces of refrigerant changes everything!!!!!

Critical airflows:

–Airflow directly effects efficiency, capacity, and creature comfort.

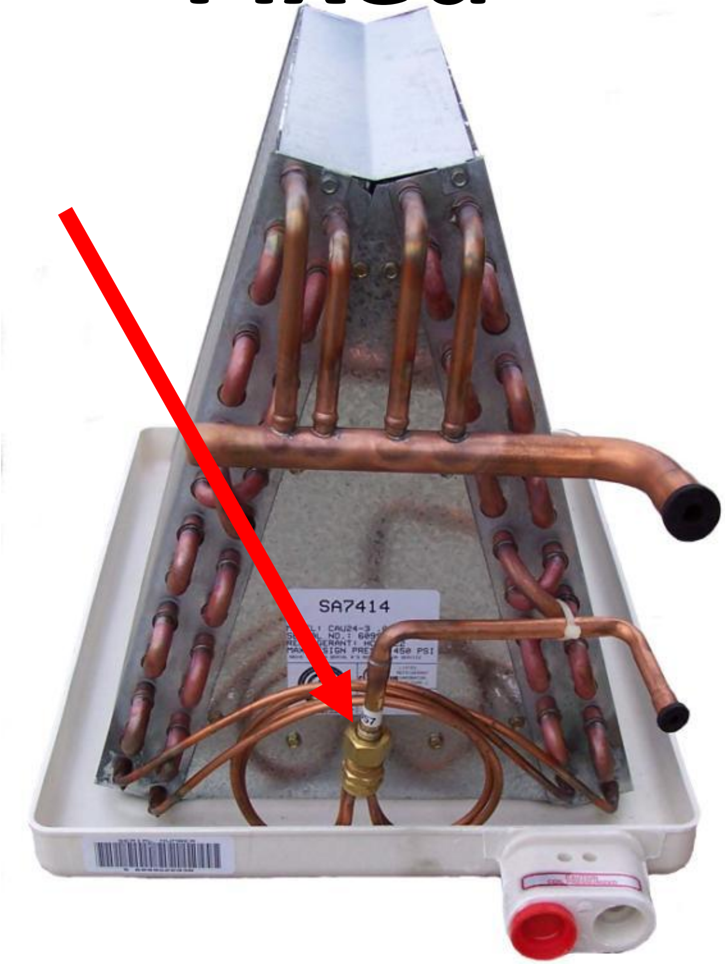
–Proper airflow across the evaporator is critical to achieve efficiency ratings.

Set Airflow (nominal)

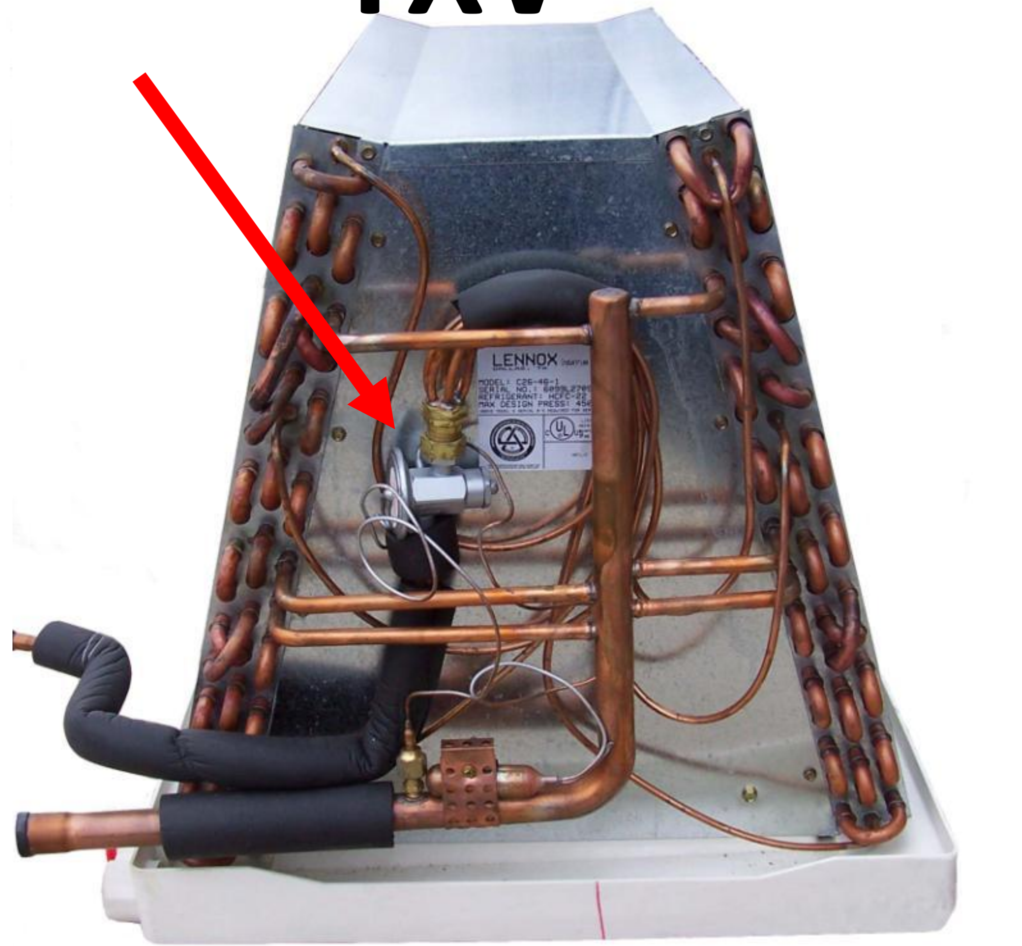
BTUh	Airflow
12,000	400 CFM
18,000	600 CFM
24,000	800 CFM
30,000	1000 CFM
36,000	1200 CFM
42,000	1400 CFM
48,000	1600 CFM
60,000	2000 CFM

ID the metering device

Fixed



TXV



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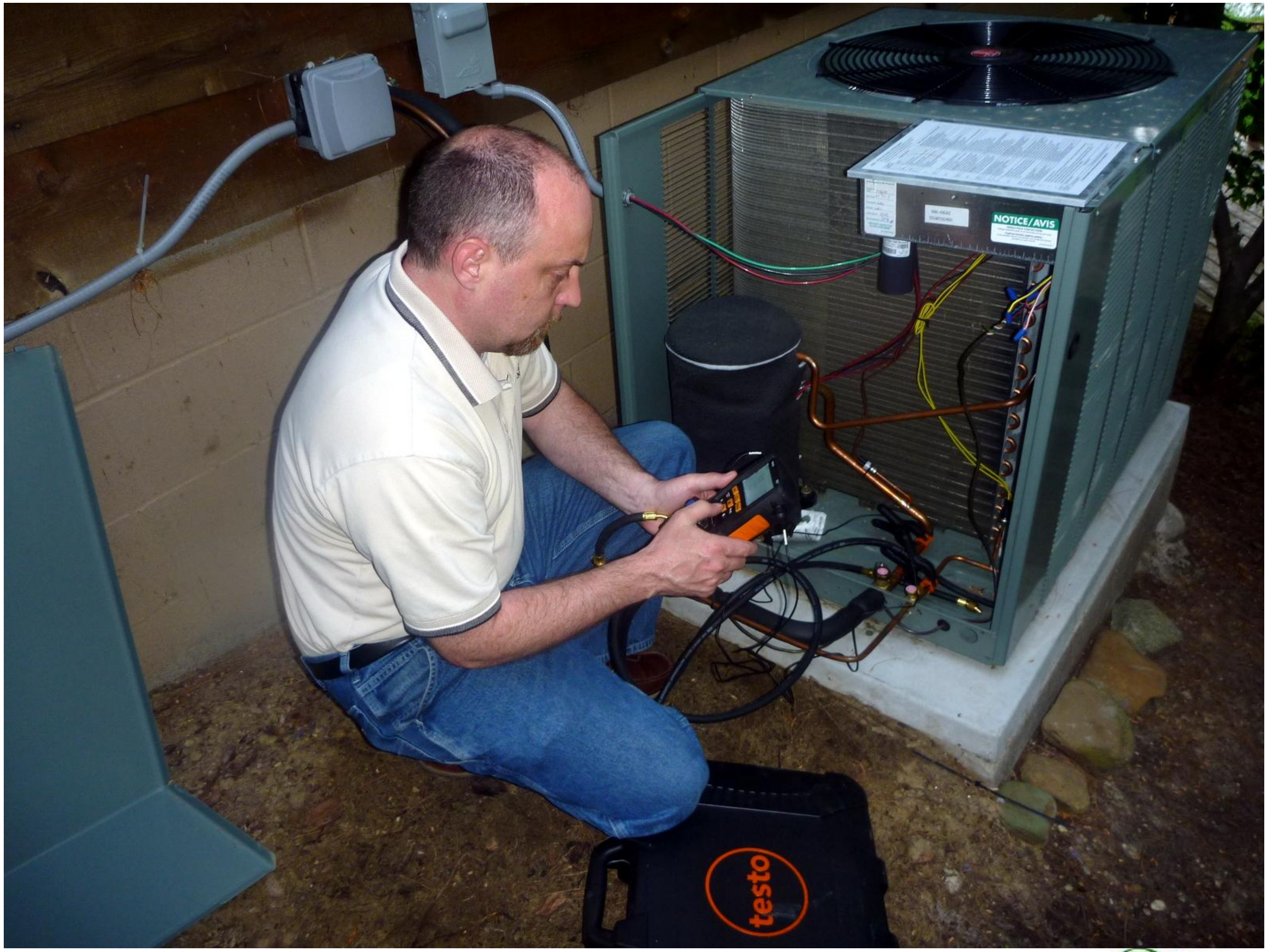
The Digital Dilemma
Do you need to switch from analog gauges?



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Without need there is nothing but fluff

- **Do technicians really need digital gauges?**
- **What's wrong with the way I have been charging?**
- **Are there really any benefits aside from a “digital” display?**
- **How many systems suffer from incorrect charge?**
- **Are they expensive to buy and maintain?**
- **Are they reliable?**
- **Are they easy to use?**

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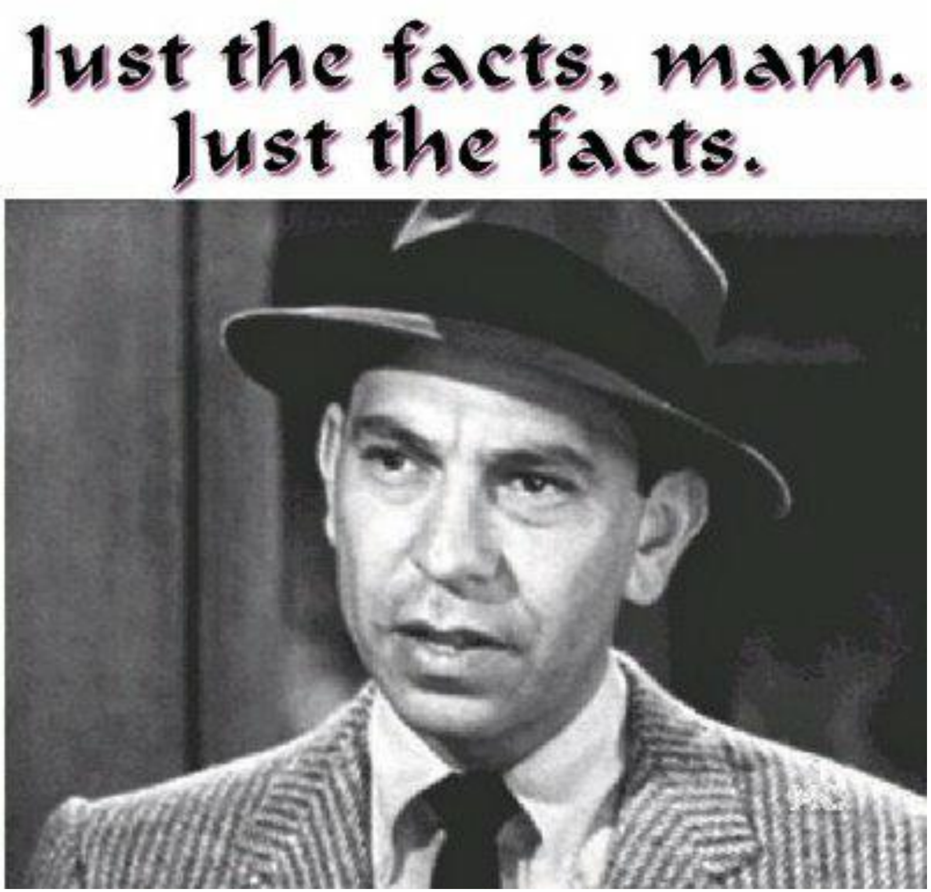
Are there really problems with Analog Instruments?



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Old School Tools

Tools of the Trade

•Gauges for each refrigerant
•Temperature pressure chart
•Thermometer
•Calculator
•Pen
•Paper

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Current refrigeration gauges

- Are using the same technology for the last century and a half!
  - Albeit, today more precisely manufactured
- With much care can produce readings that are OK
- Were in specification when they left the factory
  - Only to +/-3%, +/-2%, +/-3 %
  - But is close enough, good enough?

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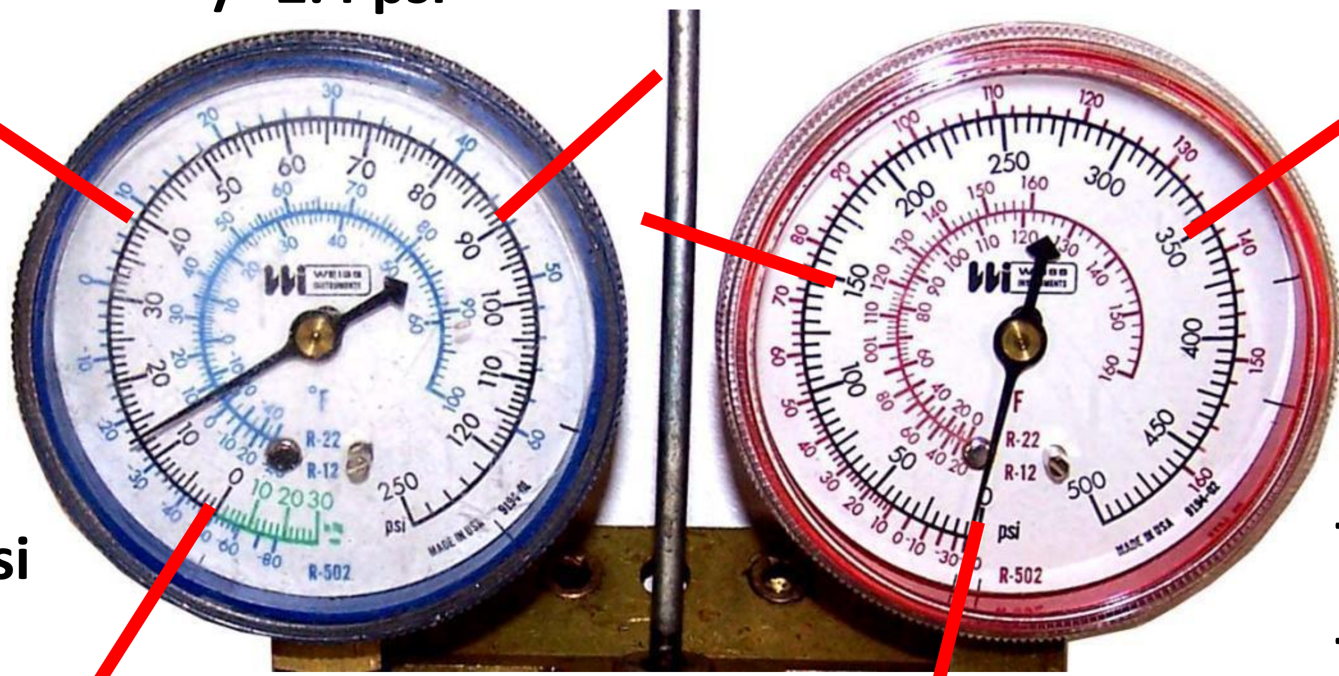
Standard 3-2-3 Gauges

+/- 2%

+/- 2.4 psi

+/-2%

+/-10 psi



+/- 3%

+/- 3.6 psi

+/-3%

+/-15 psi

+/-3%

+/-15 psi

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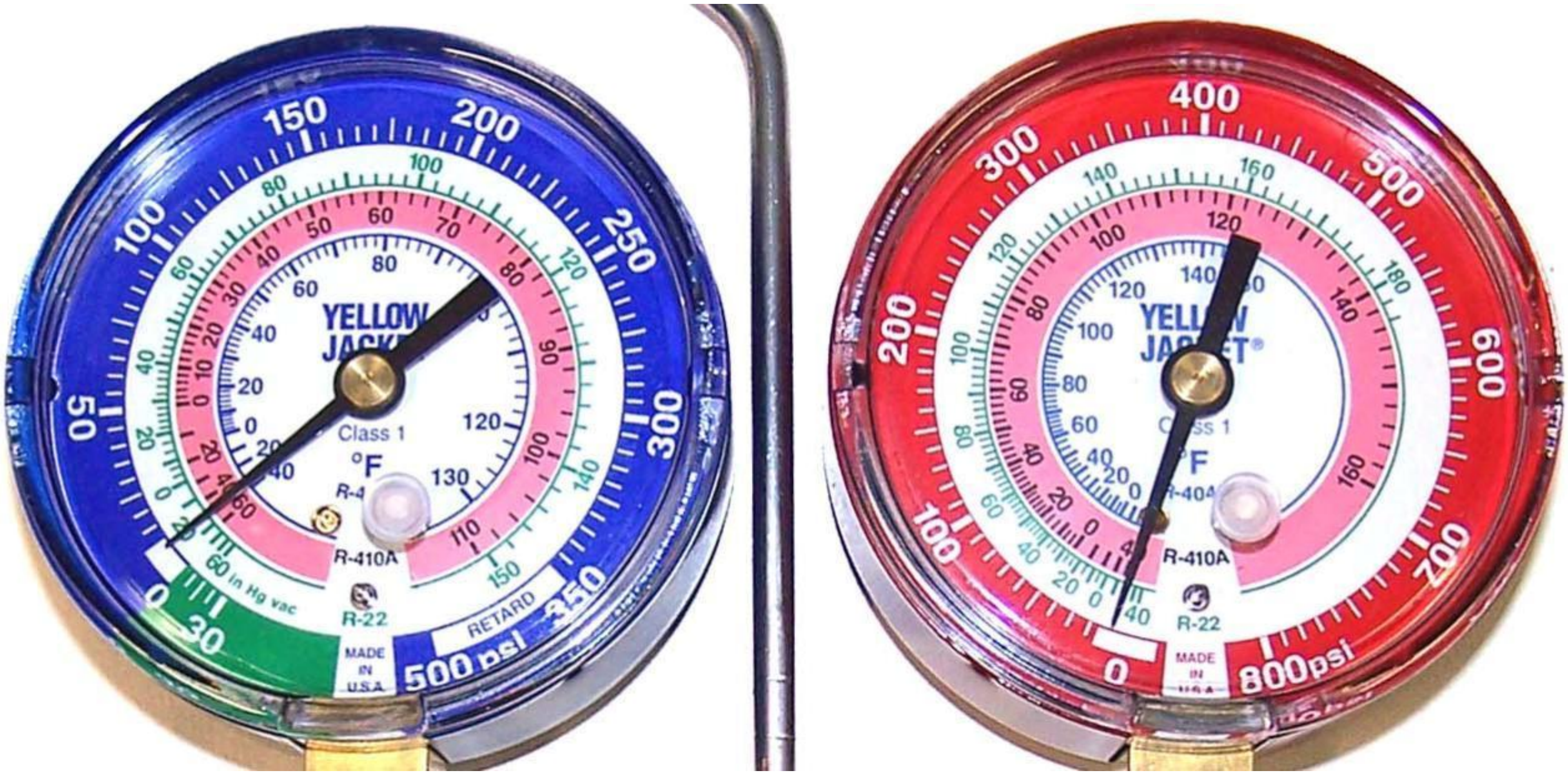
So what about 1% accuracy???



+/-3.5 psi **+/-8.0 psi**

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Vacuum-Inches of Mercury
Italic Figures

TEMPERATURE PRESSURE CHART - at sea level

Pressure-Pounds Per Square Inch Gauge
Bold Figures

TEMPERATURE		REFRIGERANT (SPORLAN CODE)			
°F	°C	R-22(V)	R-410A(Z)	R-407C(N)	R-134a(J)
-60	-51.1	*11.9*	*0.9*	*16.0*	*21.6*
-55	-48.3	*9.2*	1.8	*13.7*	*20.2*
-50	-45.6	*6.1*	4.3	*11.1*	*18.6*
-45	-42.8	*2.7*	7.0	*8.1*	*16.7*
-40	-40.0	0.6	10.1	*4.8*	*14.7*
-35	-37.2	2.6	13.5	*1.1*	*12.3*
-30	-34.4	4.9	17.2	1.5	*9.7*
-25	-31.7	7.5	21.4	3.7	*6.8*
-20	-28.9	10.2	25.9	6.2	*3.6*
-18	-27.8	11.4	27.8	7.2	*2.2*
-16	-26.7	12.6	29.7	8.4	*0.7*
-14	-25.6	13.9	31.8	9.5	0.4
-12	-24.4	15.2	33.9	10.7	1.2
-10	-23.3	16.5	36.1	11.9	2.0
-8	-22.2	17.9	38.4	13.2	2.8
-6	-21.1	19.4	40.7	14.6	3.7
-4	-20.0	20.9	43.1	15.9	4.6
-2	-18.9	22.4	45.6	17.4	5.5
0	-17.8	24.0	48.2	18.9	6.5
1	-17.2	24.8	49.5	19.6	7.0
2	-16.7	25.7	50.9	20.4	7.5
3	-16.1	26.5	52.2	21.2	8.0
4	-15.6	27.4	53.6	22.0	8.6
5	-15.0	28.3	55.0	22.8	9.1
6	-14.4	29.1	56.4	23.7	9.7
7	-13.9	30.0	57.9	24.5	10.2
8	-13.3	31.0	59.3	25.4	10.8
9	-12.8	31.9	60.8	26.2	11.4
10	-12.2	32.8	62.3	27.1	12.0
11	-11.7	33.8	63.9	28.0	12.6

TEMPERATURE		REFRIGERANT (SPORLAN CODE)			
°F	°C	R-22(V)	R-410A(Z)	R-407C(N)	R-134a(J)
12	-11.1	34.8	65.4	29.0	13.2
13	-10.6	35.8	67.0	29.9	13.8
14	-10.0	36.8	68.6	30.9	14.4
15	-9.4	37.8	70.2	31.8	15.1
16	-8.9	38.8	71.9	32.8	15.7
17	-8.3	39.9	73.5	33.8	16.4
18	-7.8	40.9	75.2	34.8	17.1
19	-7.2	42.0	77.0	35.9	17.7
20	-6.7	43.1	78.7	36.9	18.4
21	-6.1	44.2	80.5	38.0	19.2
22	-5.6	45.3	82.3	39.1	19.9
23	-5.0	46.5	84.1	40.2	20.6
24	-4.4	47.6	85.9	41.3	21.4
25	-3.9	48.8	87.8	42.4	22.1
26	-3.3	50.0	89.7	43.6	22.9
27	-2.8	51.2	91.6	44.7	23.7
28	-2.2	52.4	93.5	45.9	24.5
29	-1.7	53.7	95.5	47.1	25.3
30	-1.1	54.9	97.5	48.4	26.1
31	-0.6	56.2	99.5	49.6	26.9
32	0	57.5	101.6	50.9	27.8
33	0.6	58.8	103.6	52.1	28.6
34	1.1	60.2	105.7	53.4	29.5
35	1.7	61.5	107.9	54.8	30.4
36	2.2	62.9	110.0	56.1	31.3
37	2.8	64.3	112.2	57.5	32.2
38	3.3	65.7	114.4	58.9	33.1
39	3.9	67.1	116.7	60.3	34.1
40	4.4	68.6	118.9	61.7	35.0
41	5.0	70.0	121.2	63.1	36.0

TEMPERATURE		REFRIGERANT (SPORLAN CODE)			
°F	°C	R-22(V)	R-410A(Z)	R-407C(N)	R-134a(J)
42	5.6	71.5	123.6	64.6	37.0
43	6.1	73.0	125.9	66.1	38.0
44	6.7	74.5	128.3	67.6	39.0
45	7.2	76.1	130.7	69.1	40.0
46	7.8	77.6	133.2	70.6	14.1
47	8.3	79.2	135.6	72.2	42.2
48	8.9	80.8	138.2	73.8	43.2
49	9.4	82.4	140.7	75.4	44.3
50	10.0	84.1	143.3	77.1	45.4
55	12.8	92.6	156.6	106.0	51.2
60	15.6	101.6	170.7	116.2	57.4
65	18.3	111.3	185.7	127.0	64.0
70	21.1	121.5	201.5	138.5	71.1
75	23.9	132.2	218.2	150.6	78.6
80	26.7	143.7	235.9	163.5	86.7
85	29.4	155.7	254.6	177.0	95.2
90	32.2	168.4	274.3	191.3	104.3
95	35.0	181.9	295.0	206.4	113.9
100	37.8	196.0	316.9	222.3	124.1
105	40.6	210.8	339.9	239.0	134.9
110	43.3	226.4	364.1	256.5	146.3
115	46.1	242.8	389.6	274.9	158.4
120	48.9	260.0	416.4	294.2	171.1
125	51.7	278.1	444.5	314.5	184.5
130	54.4	297.0	474.0	335.7	198.7
135	57.2	316.7	505.0	357.8	213.5
140	60.0	337.4	537.6	380.9	229.2
145	62.8	359.1	571.7	405.1	245.6
150	65.6	381.7	607.6	430.3	262.8
155	68.3	405.4	645.2	456.6	281.0

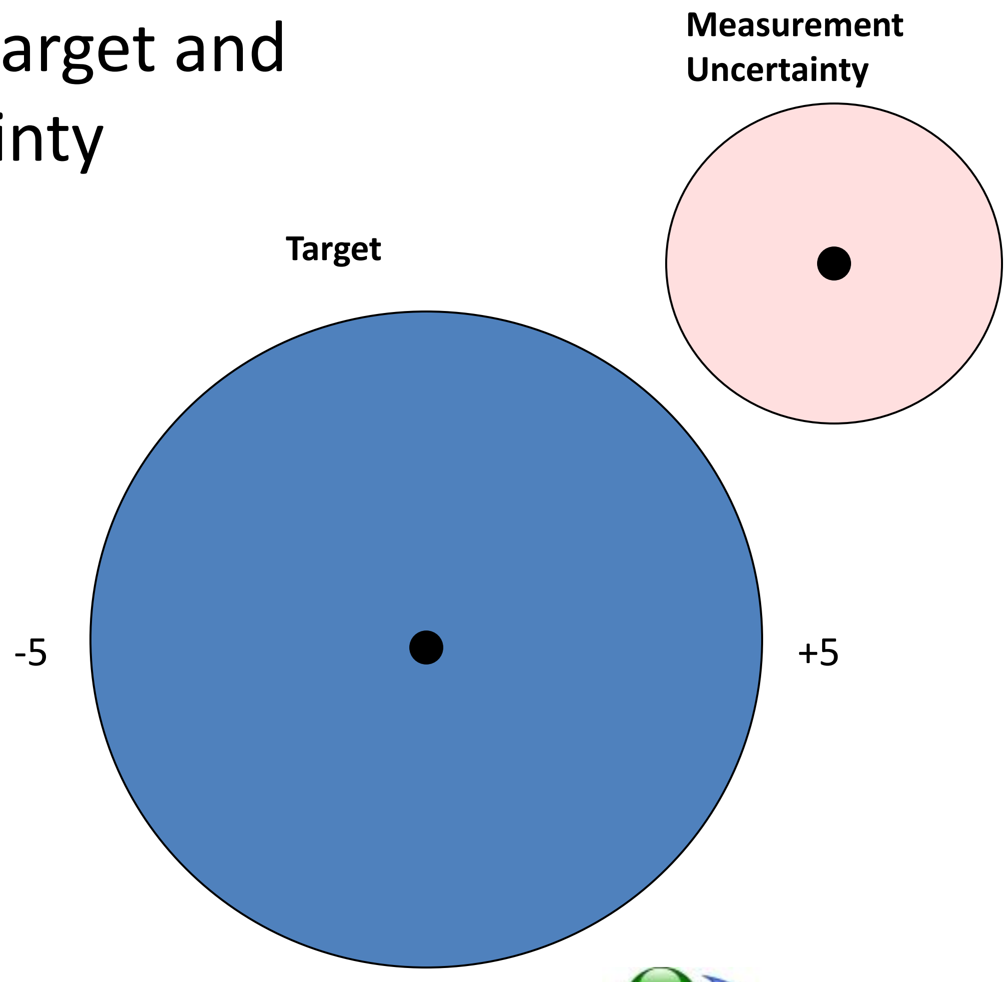
To determine ***subcooling*** for refrigerant R-407C use BUBBLE POINT values (Temperatures above 50°F — Gray Background); to determine ***superheat*** R-407C, use DEW POINT values (Temperatures 50°F and below).

Measurement Accuracy

Is close enough good enough?

Every method has the a target and measurement uncertainty

- Superheat
- Subcooling
- Wet-bulb
- Dry-bulb
- Line temperatures

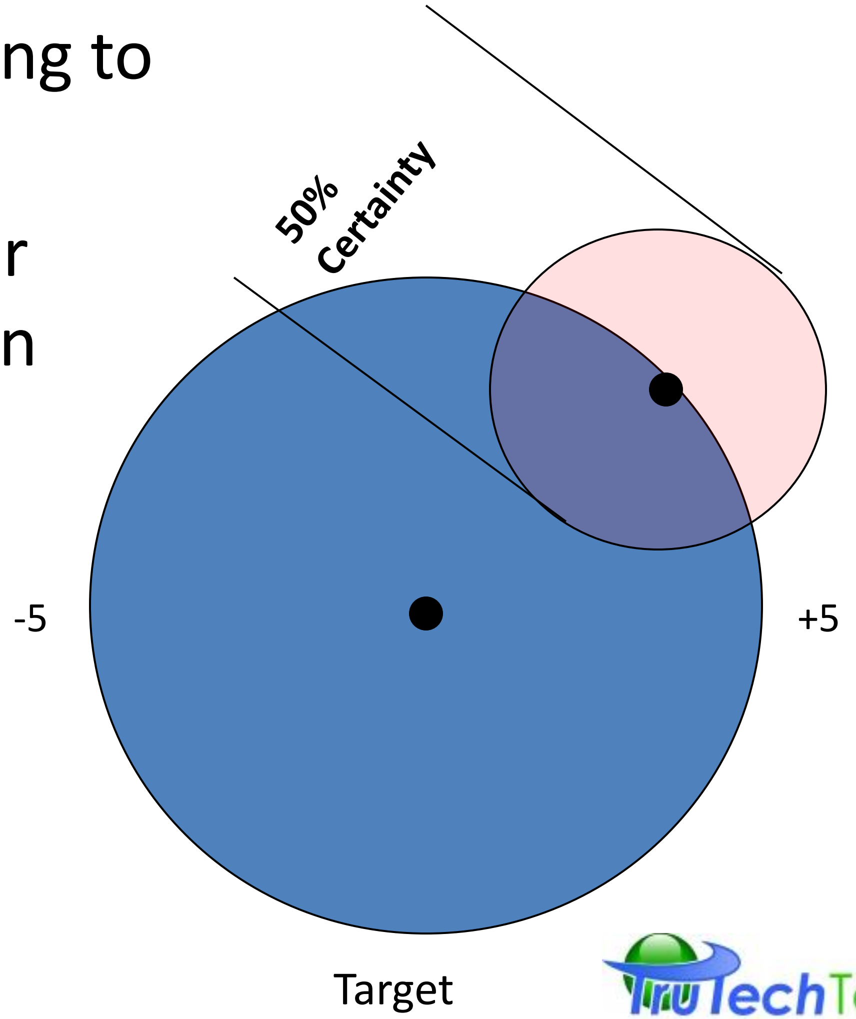


Measurement Accuracy

Is close enough good enough?

Charging to the target for most technicians means getting to the edge.

Within 5° for superheat for example can still have an uncertainty of 50%



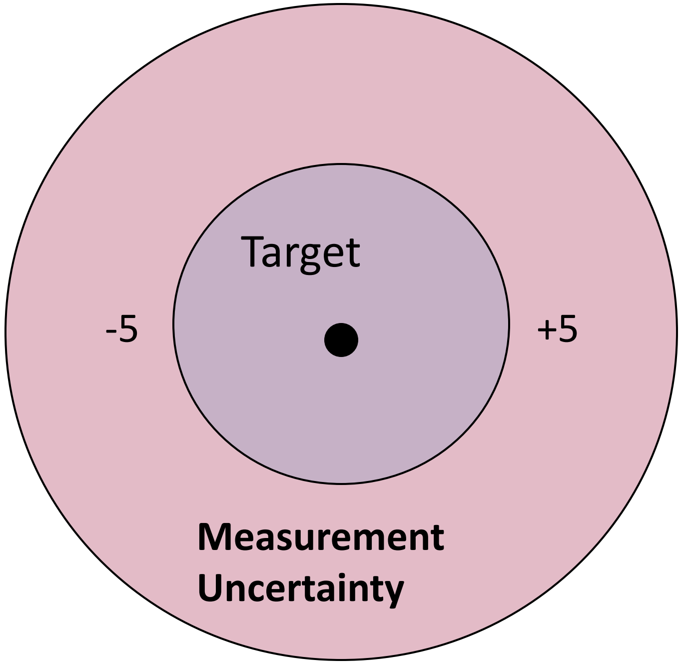
Measurement Accuracy

Is close enough good enough?

Analog technology and related inherent error make the uncertainty overshadow the target.

Causes:

- Substandard
- Out of calibration
- Lack of training
- Incorrect measuring techniques



Measurement Uncertainty

- K-type +/- 4°F
- Gauge (psi)

  +/- 2.4 to 3.5 low side

  +/- 8 to 10 high side

Both easily loose calibration and accuracy, voltage effect on thermocouples

- Thermistor +/- 1.8°F
- Transducer +/- 2.5 psi
  - Temperature compensated
  - Altitude compensated

Excellent Long term stability and accuracy

SOURCE: The International Journal of Sensing for Industry
Volume 21, No. 3 2001.

	Thermocouple	RTD (Pt100)	Thermistor
Operating Range	-200 °C to 2000 °C	-250 to 850 °C	-100 to 300 °C
Accuracy	Low 1 °C common	Very High 0.03 °C common	High 0.1°C common
Linearity*	Medium	High	Low
Thermal Response**	Fast	Slow	Medium
Cost	Low	High	Low to moderate
Noise Problems	High	Medium	Low
Long term stability	Low	High	Medium
Cost of measuring instrument	Medium	High	Low

* Linearity is not an issue if using modern digital measuring instruments, as look-up tables stored in memory provide compensation.

** Thermal response is considered for the measuring element only, not its enclosure.

Condensing Temps Analog
1-2% accuracy (+/- 8-10 PSI)

(°F)	R410a	R-22
105	339.6	210.8
106	344.4	213.8
107	349.3	216.9
108	354.2	220.0
109	**359.1**	**223.2**
110	364.1	226.4
111	369.1	229.6
112	374.2	232.8
113	379.4	236.1

- R22@ 220 psig (+/- 10 PSI @2%)
  - Low 105, high 111
    +/- 3°F saturation
- R410a @ 359 psig (+/-8 PSI @1%)
  - Low 107, high 111
    +/- 2° saturation
- Temp +/- 4°F

10°F max Uncertainty R22

8°F max Uncertainty 410a

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Condensing Temps Digital
0.5% accuracy (+/- 2.5 PSI)

(°F)	R410a	R-22
105	339.6	210.8
106	344.4	213.8
107	349.3	216.9
108	354.2	220.0
109	**359.1**	**223.2**
110	364.1	226.4
111	369.1	229.6
112	374.2	232.8
113	379.4	236.1

- R22@ 220 psig (+/- 2.5 PSI @0.5%)
  - Low 107.5, high 109

    +/- <1°F saturation temp (calc)
- R410a @ 359 (+/- 2.5 PSI @0.5%)
  - Low 108.5, high 110

    +/- <0.5°F saturation temp (calc)
- Temp +/- 1.8°F

2.3-2.8° max Uncertainty for R22 or 410a

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Charging Accuracy

Is close enough good enough?

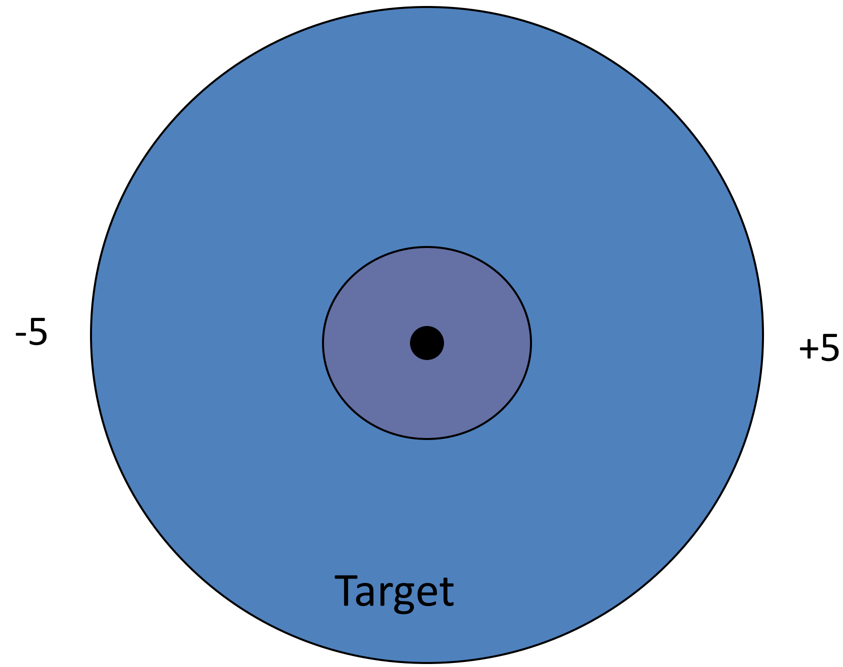
With Digital Gauges

Smaller uncertainty

Higher accuracy

Human factor is reduced or eliminated

Probability of correct charge significantly increased.



Allowed range as a function of superheat and subcooling measured uncertainty

Uncertainty in measured Superheat	Adjusted Allowed Superheat (target – measured)	Uncertainty in measured Subcooling	Adjusted Allowed Subcooling (target – measured)
± 0.0 ° F	± 5.0 ° F	± 0.0 °F	± 3.0 ° F
± 1.0 ° F	± 4.1 ° F	± 1.0 ° F	± 2.1 ° F
± 2.0 ° F	± 3.2 ° F	± 2.0 ° F	± 1.2 ° F
± 3.0 ° F	± 2.3 ° F	± 3.0 ° F	± 0.1 ° F
± 4.0 ° F	± 1.4 ° F		
± 5.0 ° F	± 0.5 ° F		

HVAC Energy Efficiency
Maintenance Study
Issued: December 29, 2010
By the Davis Energy Group and the WCEC (Western Cooling Efficiency Center)

Digital does it better!

- Allows trending & more complex functions
- Higher accuracy reduces callbacks
- Calculates without human error
- Stays in calibration
- High reliability
- Excellent repeatability

TruTechTools

Thick Film Pressure Transducers

- High chemical compatibility
- Resistant to corrosion
- High linearity and low hysteresis
- Wide temperature range
- High long term stability
- 0.5% full scale accuracy
- **+/- 2.5 psi high and low side**
- Temperature compensated

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Charging the system

- The proper mass of refrigerant that allows the system to operate at its optional state for reliability, capacity and efficiency
  - Verified by superheat and subcooling
  - Weighing in the charge does not guarantee proper operation

Remember

Think clean

Look for the obvious


1A115


6003L42813


RUUD
HIGH EFFICIENCY

Notes on Charge

- Systems come with enough refrigerant for a matched coil and typically 15’ of line set
- Length and lift can impact charging requirements
- Consult manufacturer’s instructions for line sets over 50’

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Weigh in is Best

sometimes

- Correct Charge must be known!
- Can be done all year
- Airflow must be set prior to evaluating charge
- Must be evaluated under proper conditions
  - Must have proper indoor load
- Check both the superheat and the subcooling!

Does not guarantee proper operation!

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The Fixed Orifice System

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AHRI Design Conditions

- 80° indoor air dry bulb (DB)
- 50% relative humidity (rH)
- 95° outdoor air (ODA)

A typical A/C unit is engineered to operate at optimal efficiency and rated capacity under a single set of conditions.

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

PSYCHROMETRIC CHART

Normal Temperature

I-P Units

1500 FEET

BAROMETRIC PRESSURE: 28.335 in. HG

Heat Gain/Loss Equations

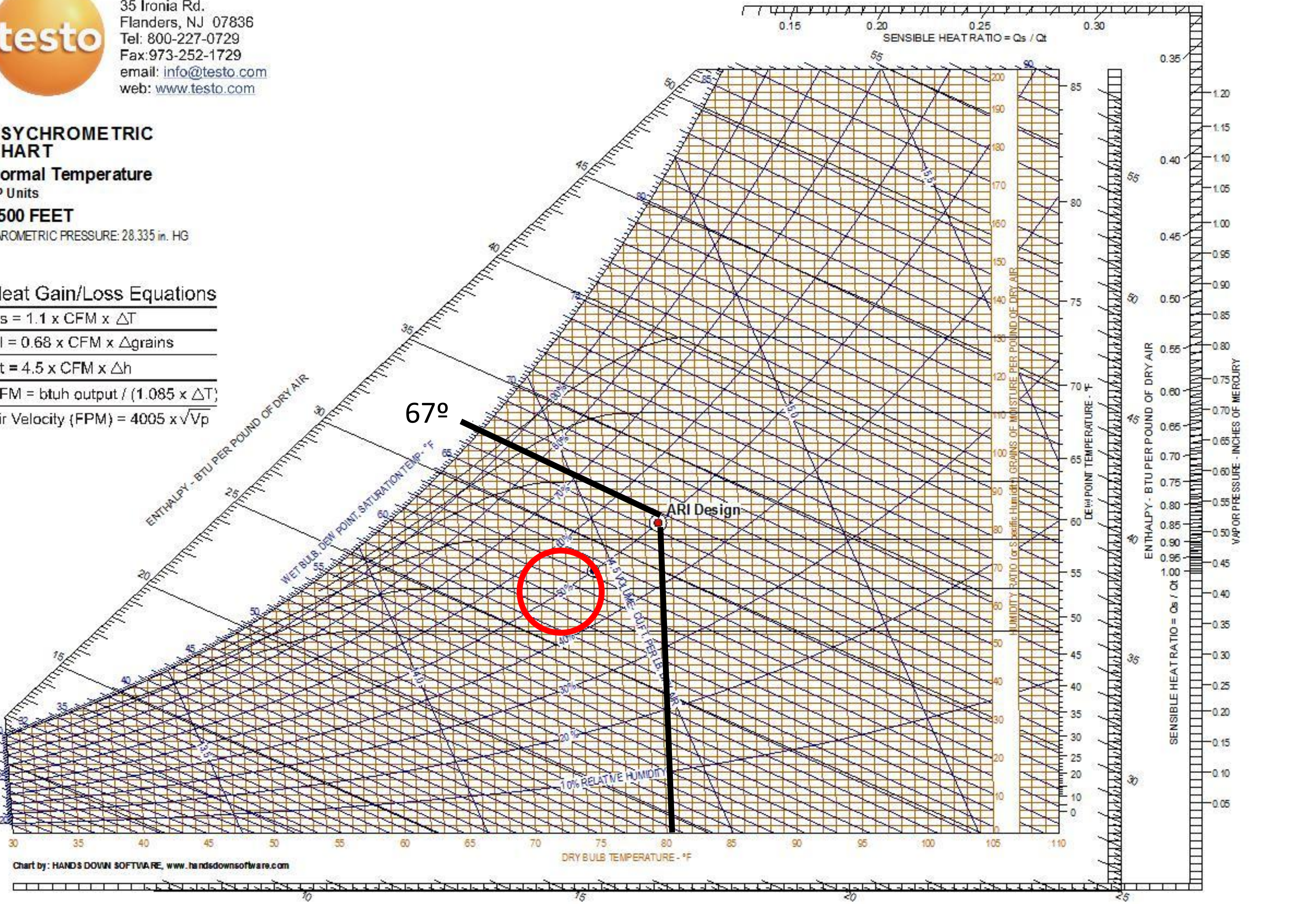
Qs = 1.1 x CFM x ΔT

Ql = 0.68 x CFM x Δgrains

Qt = 4.5 x CFM x Δh

CFM = btuh output / (1.085 x ΔT)

Air Velocity (FPM) = 4005 x √Vp



AHRI Design Conditions

67° Wet bulb (Wb)
95° outdoor air (ODA)

When close to design
12° Superheat
10° Subcooling

Table RD-2: Target Superheat (Suction Line Temperature - Evaporator Saturation Temperature) (continued)

	Return Air Wet-Bulb Temperature (°F) ($T_{return, wb}$)																										
Condenser Air Dry-Bulb Temperature (°F)	50	51	52	53	54	55	56	57	58	59	60	61	62	63	64	65	66	67	68	69	70	71	72	73	74	75	76
91	-	-	-	-	-	-	-	-	-	-	-	-	-	6.1	8.1	10.3	12.2	14.1	15.9	17.8	19.7	21.5	23.4	25.2	27.1	28.9	30.8
92	-	-	-	-	-	-	-	-	-	-	-	-	-	5.4	7.5	9.8	11.7	13.5	15.4	17.3	19.2	21.1	22.9	24.8	26.7	28.5	30.4
93	-	-	-	-	-	-	-	-	-	-	-	-	-	-	6.8	9.2	11.1	13.0	14.9	16.8	18.7	20.6	22.5	24.4	26.3	28.2	30.1
94	-	-	-	-	-	-	-	-	-	-	-	-	-	-	6.2	8.7	10.6	12.5	14.4	16.3	18.2	20.2	22.1	24.0	25.9	27.8	29.7
95	-	-	-	-	-	-	-	-	-	-	-	-	-	-	5.6	8.1	10.0	12.0	13.9	15.8	17.8	19.7	21.6	23.6	25.5	27.4	29.4
96	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	7.5	9.5	11.4	13.4	15.3	17.3	19.2	21.2	23.2	25.1	27.1	29.0
97	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	7.0	8.9	10.9	12.9	14.9	16.8	18.8	20.8	22.7	24.7	26.7	28.7
98	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	6.4	8.4	10.4	12.4	14.4	16.4	18.3	20.3	22.3	24.3	26.3	28.3
99	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	5.8	7.9	9.9	11.9	13.9	15.9	17.9	19.9	21.9	24.0	26.0	28.0
100	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	5.3	7.3	9.3	11.4	13.4	15.4	17.5	19.5	21.5	23.6	25.6	27.7
101	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	6.8	8.8	10.9	12.9	15.0	17.0	19.1	21.1	23.2	25.3	27.3
102	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	6.2	8.3	10.4	12.4	14.5	16.6	18.6	20.7	22.8	24.9	27.0
103	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	5.7	7.8	9.9	11.9	14.0	16.1	18.2	20.3	22.4	24.5	26.7
104	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	5.2	7.2	9.3	11.5	13.6	15.7	17.8	19.9	22.1	24.2	26.3
105	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	6.7	8.8	11.0	13.1	15.2	17.4	19.5	21.7	23.8	26.0
106	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	6.2	8.3	10.5	12.6	14.8	17.0	19.1	21.3	23.5	25.7
107	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	5.7	7.9	10.0	12.2	14.4	16.6	18.7	21.0	23.2	25.4
108	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	5.2	7.4	9.5	11.7	13.9	16.1	18.4	20.6	22.8	25.1
109	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	6.9	9.1	11.3	13.5	15.7	18.0	20.2	22.5	24.7
110	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	6.4	8.6	10.8	13.1	15.3	17.6	19.9	22.1	24.4

TruTechTools

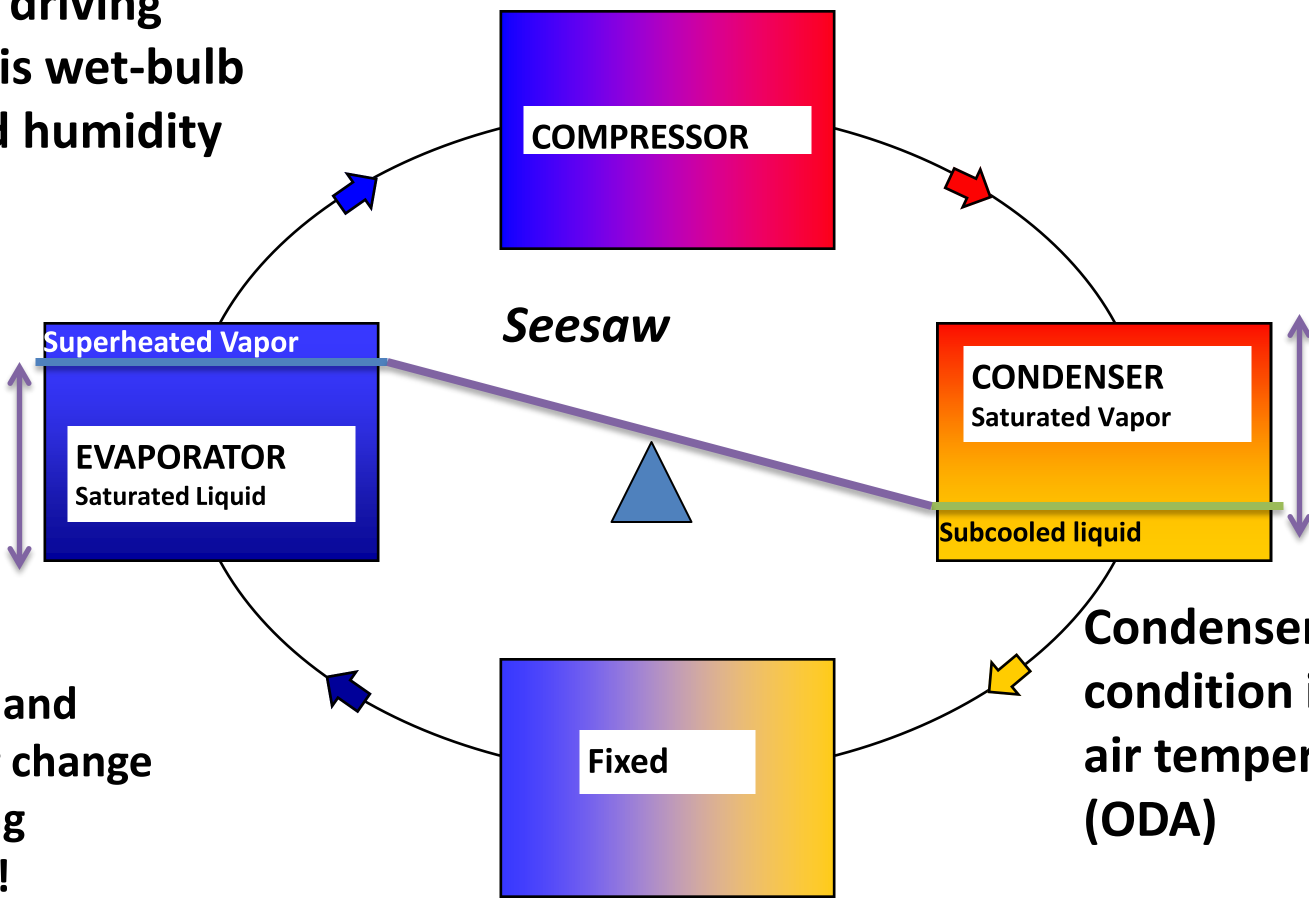
The Fixed Orifice System (Piston)

- Critically charged under all load conditions
- Charged by total superheat method
- Has a target superheat which must be calculated or derived
- Varies in capacity with load conditions
- Simple, but not as efficient at removing heat and humidity under a varying load

TruTechTools

The Fixed Orifice System

Evaporator driving conditions is wet-bulb or heat and humidity



Condenser driving condition is outdoor air temperature (ODA)

Superheat and subcooling change with driving conditions!

Charging by Total Superheat (Fixed)

Superheat

- Measure outdoor temperature (D/B)
- Measure indoor wet bulb (W/B)
- Charge by total superheat method
- Measure pressure and temperature at condenser inlet

TruTechTools

At a constant indoor Wb as outdoor air temp increases, superheat decreases

Table RD-2: Target Superheat (Suction Line Temperature - Evaporator Saturation Temperature)

Outdoor Air Driving Force

Condenser Air Dry-Bulb Temperature (°F)	Return Air Wet-Bulb Temperature (°F) ($T_{return, wb}$)																										
	50	51	52	53	54	55	56	57	58	59	60	61	62	63	64	65	66	67	68	69	70	71	72	73	74	75	76
55	8.8	10.1	11.5	12.8	14.2	15.6	17.1	18.5	20.0	21.5	23.1	24.6	26.2	27.8	29.4	31.0	32.4	33.8	35.1	36.4	37.7	39.0	40.2	41.5	42.7	43.9	45.0
56	8.6	9.9	11.2	12.6	14.0	15.4	16.8	18.2	19.7	21.2	22.7	24.2	25.7	27.3	28.9	30.5	31.8	33.2	34.6	35.9	37.2	38.5	39.7	41.0	42.2	43.4	44.6
57	8.3	9.6	11.0	12.3	13.7	15.1	16.5	17.9	19.4	20.8	22.3	23.8	25.3	26.8	28.3	29.9	31.3	32.6	34.0	35.3	36.7	38.0	39.2	40.5	41.7	43.0	44.2
58	7.9	9.3	10.6	12.0	13.4	14.8	16.2	17.6	19.0	20.4	21.9	23.3	24.8	26.3	27.8	29.3	30.7	32.1	33.5	34.8	36.1	37.5	38.7	40.0	41.3	42.5	43.7
59	7.5	8.9	10.2	11.6	13.0	14.4	15.8	17.2	18.6	20.0	21.4	22.9	24.3	25.7	27.2	28.7	30.1	31.5	32.9	34.3	35.6	36.9	38.3	39.5	40.8	42.1	43.3
60	7.0	8.4	9.8	11.2	12.6	14.0	15.4	16.8	18.2	19.6	21.0	22.4	23.8	25.2	26.6	28.1	29.6	31.0	32.4	33.7	35.1	36.4	37.8	39.1	40.4	41.6	42.9
61	6.5	7.9	9.3	10.7	12.1	13.5	14.9	16.3	17.7	19.1	20.5	21.9	23.3	24.7	26.1	27.5	29.0	30.4	31.8	33.2	34.6	35.9	37.3	38.6	39.9	41.2	42.4
62	6.0	7.4	8.8	10.2	11.7	13.1	14.5	15.9	17.3	18.7	20.1	21.4	22.8	24.2	25.5	27.0	28.4	29.9	31.3	32.7	34.1	35.4	36.8	38.1	39.4	40.7	42.0
63	5.3	6.8	8.3	9.7	11.1	12.6	14.0	15.4	16.8	18.2	19.6	20.9	22.3	23.6	25.0	26.4	27.8	29.3	30.7	32.2	33.6	34.9	36.3	37.7	39.0	40.3	41.6
64	-	6.1	7.6	9.1	10.6	12.0	13.5	14.9	16.3	17.7	19.0	20.4	21.7	23.1	24.4	25.8	27.3	28.7	30.2	31.6	33.0	34.4	35.8	37.2	38.5	39.9	41.2
65	-	5.4	7.0	8.5	10.0	11.5	12.9	14.3	15.8	17.1	18.5	19.9	21.2	22.5	23.8	25.2	26.7	28.2	29.7	31.1	32.5	33.9	35.3	36.7	38.1	39.4	40.8
66	-		6.3	7.8	9.3	10.8	12.3	13.8	15.2	16.6	18.0	19.3	20.7	22.0	23.2	24.6	26.1	27.6	29.1	30.6	32.0	33.4	34.9	36.3	37.6	39.0	40.4
67	-	-	5.5	7.1	8.7	10.2	11.7	13.2	14.6	16.0	17.4	18.8	20.1	21.4	22.7	24.1	25.6	27.1	28.6	30.1	31.5	33.0	34.4	35.8	37.2	38.6	39.9
68	-	-	-	6.3	8.0	9.5	11.1	12.6	14.0	15.5	16.8	18.2	19.5	20.8	22.1	23.5	25.0	26.5	28.0	29.5	31.0	32.5	33.9	35.3	36.8	38.1	39.5
69	-	-	-	5.5	7.2	8.8	10.4	11.9	13.4	14.8	16.3	17.6	19.0	20.3	21.5	22.9	24.4	26.0	27.5	29.0	30.5	32.0	33.4	34.9	36.3	37.7	39.1
70	-	-	-	-	6.4	8.1	9.7	11.2	12.7	14.2	15.7	17.0	18.4	19.7	20.9	22.3	23.9	25.4	27.0	28.5	30.0	31.5	33.0	34.4	35.9	37.3	38.7
71	-	-	-	-	5.6	7.3	8.9	10.5	12.1	13.6	15.0	16.4	17.8	19.1	20.3	21.7	23.3	24.9	26.4	28.0	29.5	31.0	32.5	34.0	35.4	36.9	38.3
72	-	-	-	-	-	6.4	8.1	9.8	11.4	12.9	14.4	15.8	17.2	18.5	19.7	21.2	22.8	24.3	25.9	27.4	29.0	30.5	32.0	33.5	35.0	36.5	37.9
73	-	-	-	-	-	5.6	7.3	9.0	10.7	12.2	13.7	15.2	16.6	17.9	19.2	20.6	22.2	23.8	25.4	26.9	28.5	30.0	31.5	33.1	34.6	36.0	37.5
74	-	-	-	-	-	-	6.5	8.2	9.9	11.5	13.1	14.5	15.9	17.3	18.6	20.0	21.6	23.2	24.8	26.4	28.0	29.5	31.1	32.6	34.1	35.6	37.1
75	-	-	-	-	-	-	5.6	7.4	9.2	10.8	12.4	13.9	15.3	16.7	18.0	19.4	21.1	22.7	24.3	25.9	27.5	29.1	30.6	32.2	33.7	35.2	36.7
76	-	-	-	-	-	-	-	6.6	8.4	10.1	11.7	13.2	14.7	16.1	17.4	18.9	20.5	22.1	23.8	25.4	27.0	28.6	30.1	31.7	33.3	34.8	36.3
77	-	-	-	-	-	-	-	5.7	7.5	9.3	11.0	12.5	14.0	15.4	16.8	18.3	20.0	21.6	23.2	24.9	26.5	28.1	29.7	31.3	32.8	34.4	36.0
78	-	-	-	-	-	-	-	-	6.7	8.5	10.2	11.8	13.4	14.8	16.2	17.7	19.4	21.1	22.7	24.4	26.0	27.6	29.2	30.8	32.4	34.0	35.6
79	-	-	-	-	-	-	-	-	5.9	7.7	9.5	11.1	12.7	14.2	15.6	17.1	18.8	20.5	22.2	23.8	25.5	27.1	28.8	30.4	32.0	33.6	35.2
80	-	-	-	-	-	-	-	-	-	6.9	8.7	10.4	12.0	13.5	15.0	16.6	18.3	20.0	21.7	23.3	25.0	26.7	28.3	29.9	31.6	33.2	34.8
81	-	-	-	-	-	-	-	-	-	6.0	7.9	9.7	11.3	12.9	14.3	16.0	17.7	19.4	21.1	22.8	24.5	26.2	27.9	29.5	31.2	32.8	34.4
82	-	-	-	-	-	-	-	-	-	5.2	7.1	8.9	10.6	12.2	13.7	15.4	17.2	18.9	20.6	22.3	24.0	25.7	27.4	29.1	30.7	32.4	34.0
83	-	-	-	-	-	-	-	-	-	-	6.3	8.2	9.9	11.6	13.1	14.9	16.6	18.4	20.1	21.8	23.5	25.2	26.9	28.6	30.3	32.0	33.7

At a constant ODA temperature as Wb increases superheat increases

Evaporator Driving Force

Table RD-2: Target Superheat (Suction Line Temperature - Evaporator Saturation Temperature)

Return Air Wet-Bulb Temperature (°F) ($T_{return, wb}$)

Condenser Air Dry-Bulb Temperature (°F)	50	51	52	53	54	55	56	57	58	59	60	61	62	63	64	65	66	67	68	69	70	71	72	73	74	75	76
55	8.8	10.1	11.5	12.8	14.2	15.6	17.1	18.5	20.0	21.5	23.1	24.6	26.2	27.8	29.4	31.0	32.4	33.8	35.1	36.4	37.7	39.0	40.2	41.5	42.7	43.9	45.0
56	8.6	9.9	11.2	12.6	14.0	15.4	16.8	18.2	19.7	21.2	22.7	24.2	25.7	27.3	28.9	30.5	31.8	33.2	34.6	35.9	37.2	38.5	39.7	41.0	42.2	43.4	44.6
57	8.3	9.6	11.0	12.3	13.7	15.1	16.5	17.9	19.4	20.8	22.3	23.8	25.3	26.8	28.3	29.9	31.3	32.6	34.0	35.3	36.7	38.0	39.2	40.5	41.7	43.0	44.2
58	7.9	9.3	10.6	12.0	13.4	14.8	16.2	17.6	19.0	20.4	21.9	23.3	24.8	26.3	27.8	29.3	30.7	32.1	33.5	34.8	36.1	37.5	38.7	40.0	41.3	42.5	43.7
59	7.5	8.9	10.2	11.6	13.0	14.4	15.8	17.2	18.6	20.0	21.4	22.9	24.3	25.7	27.2	28.7	30.1	31.5	32.9	34.3	35.6	36.9	38.3	39.5	40.8	42.1	43.3
60	7.0	8.4	9.8	11.2	12.6	14.0	15.4	16.8	18.2	19.6	21.0	22.4	23.8	25.2	26.6	28.1	29.6	31.0	32.4	33.7	35.1	36.4	37.8	39.1	40.4	41.6	42.9
61	6.5	7.9	9.3	10.7	12.1	13.5	14.9	16.3	17.7	19.1	20.5	21.9	23.3	24.7	26.1	27.5	29.0	30.4	31.8	33.2	34.6	35.9	37.3	38.6	39.9	41.2	42.4
62	6.0	7.4	8.8	10.2	11.7	13.1	14.5	15.9	17.3	18.7	20.1	21.4	22.8	24.2	25.5	27.0	28.4	29.9	31.3	32.7	34.1	35.4	36.8	38.1	39.4	40.7	42.0
63	5.3	6.8	8.3	9.7	11.1	12.6	14.0	15.4	16.8	18.2	19.6	20.9	22.3	23.6	25.0	26.4	27.8	29.3	30.7	32.2	33.6	34.9	36.3	37.7	39.0	40.3	41.6
64	-	6.1	7.6	9.1	10.6	12.0	13.5	14.9	16.3	17.7	19.0	20.4	21.7	23.1	24.4	25.8	27.3	28.7	30.2	31.6	33.0	34.4	35.8	37.2	38.5	39.9	41.2
65	-	5.4	7.0	8.5	10.0	11.5	12.9	14.3	15.8	17.1	18.5	19.9	21.2	22.5	23.8	25.2	26.7	28.2	29.7	31.1	32.5	33.9	35.3	36.7	38.1	39.4	40.8
66	-		6.3	7.8	9.3	10.8	12.3	13.8	15.2	16.6	18.0	19.3	20.7	22.0	23.2	24.6	26.1	27.6	29.1	30.6	32.0	33.4	34.9	36.3	37.6	39.0	40.4
67	-	-	5.5	7.1	8.7	10.2	11.7	13.2	14.6	16.0	17.4	18.8	20.1	21.4	22.7	24.1	25.6	27.1	28.6	30.1	31.5	33.0	34.4	35.8	37.2	38.6	39.9
68	-	-	-	6.3	8.0	9.5	11.1	12.6	14.0	15.5	16.8	18.2	19.5	20.8	22.1	23.5	25.0	26.5	28.0	29.5	31.0	32.5	33.9	35.3	36.8	38.1	39.5
69	-	-	-	5.5	7.2	8.8	10.4	11.9	13.4	14.8	16.3	17.6	19.0	20.3	21.5	22.9	24.4	26.0	27.5	29.0	30.5	32.0	33.4	34.9	36.3	37.7	39.1
70	-	-	-	-	6.4	8.1	9.7	11.2	12.7	14.2	15.7	17.0	18.4	19.7	20.9	22.3	23.9	25.4	27.0	28.5	30.0	31.5	33.0	34.4	35.9	37.3	38.7
71	-	-	-	-	5.6	7.3	8.9	10.5	12.1	13.6	15.0	16.4	17.8	19.1	20.3	21.7	23.3	24.9	26.4	28.0	29.5	31.0	32.5	34.0	35.4	36.9	38.3
72	-	-	-	-	-	6.4	8.1	9.8	11.4	12.9	14.4	15.8	17.2	18.5	19.7	21.2	22.8	24.3	25.9	27.4	29.0	30.5	32.0	33.5	35.0	36.5	37.9
73	-	-	-	-	-	5.6	7.3	9.0	10.7	12.2	13.7	15.2	16.6	17.9	19.2	20.6	22.2	23.8	25.4	26.9	28.5	30.0	31.5	33.1	34.6	36.0	37.5
74	-	-	-	-	-	-	6.5	8.2	9.9	11.5	13.1	14.5	15.9	17.3	18.6	20.0	21.6	23.2	24.8	26.4	28.0	29.5	31.1	32.6	34.1	35.6	37.1
75	-	-	-	-	-	-	5.6	7.4	9.2	10.8	12.4	13.9	15.3	16.7	18.0	19.4	21.1	22.7	24.3	25.9	27.5	29.1	30.6	32.2	33.7	35.2	36.7
76	-	-	-	-	-	-	-	6.6	8.4	10.1	11.7	13.2	14.7	16.1	17.4	18.9	20.5	22.1	23.8	25.4	27.0	28.6	30.1	31.7	33.3	34.8	36.3
77	-	-	-	-	-	-	-	5.7	7.5	9.3	11.0	12.5	14.0	15.4	16.8	18.3	20.0	21.6	23.2	24.9	26.5	28.1	29.7	31.3	32.8	34.4	36.0
78	-	-	-	-	-	-	-	-	6.7	8.5	10.2	11.8	13.4	14.8	16.2	17.7	19.4	21.1	22.7	24.4	26.0	27.6	29.2	30.8	32.4	34.0	35.6
79	-	-	-	-	-	-	-	-	5.9	7.7	9.5	11.1	12.7	14.2	15.6	17.1	18.8	20.5	22.2	23.8	25.5	27.1	28.8	30.4	32.0	33.6	35.2
80	-	-	-	-	-	-	-	-	-	6.9	8.7	10.4	12.0	13.5	15.0	16.6	18.3	20.0	21.7	23.3	25.0	26.7	28.3	29.9	31.6	33.2	34.8
81	-	-	-	-	-	-	-	-	-	6.0	7.9	9.7	11.3	12.9	14.3	16.0	17.7	19.4	21.1	22.8	24.5	26.2	27.9	29.5	31.2	32.8	34.4
82	-	-	-	-	-	-	-	-	-	5.2	7.1	8.9	10.6	12.2	13.7	15.4	17.2	18.9	20.6	22.3	24.0	25.7	27.4	29.1	30.7	32.4	34.0
83	-	-	-	-	-	-	-	-	-	-	6.3	8.2	9.9	11.6	13.1	14.9	16.6	18.4	20.1	21.8	23.5	25.2	26.9	28.6	30.3	32.0	33.7

When is the Charge Correct?

- When the actual superheat and the target superheat agree
- There will be some subcooling
  - How much?
  - Who knows? - as little as 3 as much as 30

Remember a fixed orifice system is only evaluated for charge by the total superheat of the system.

The TXV System

TruTechTools

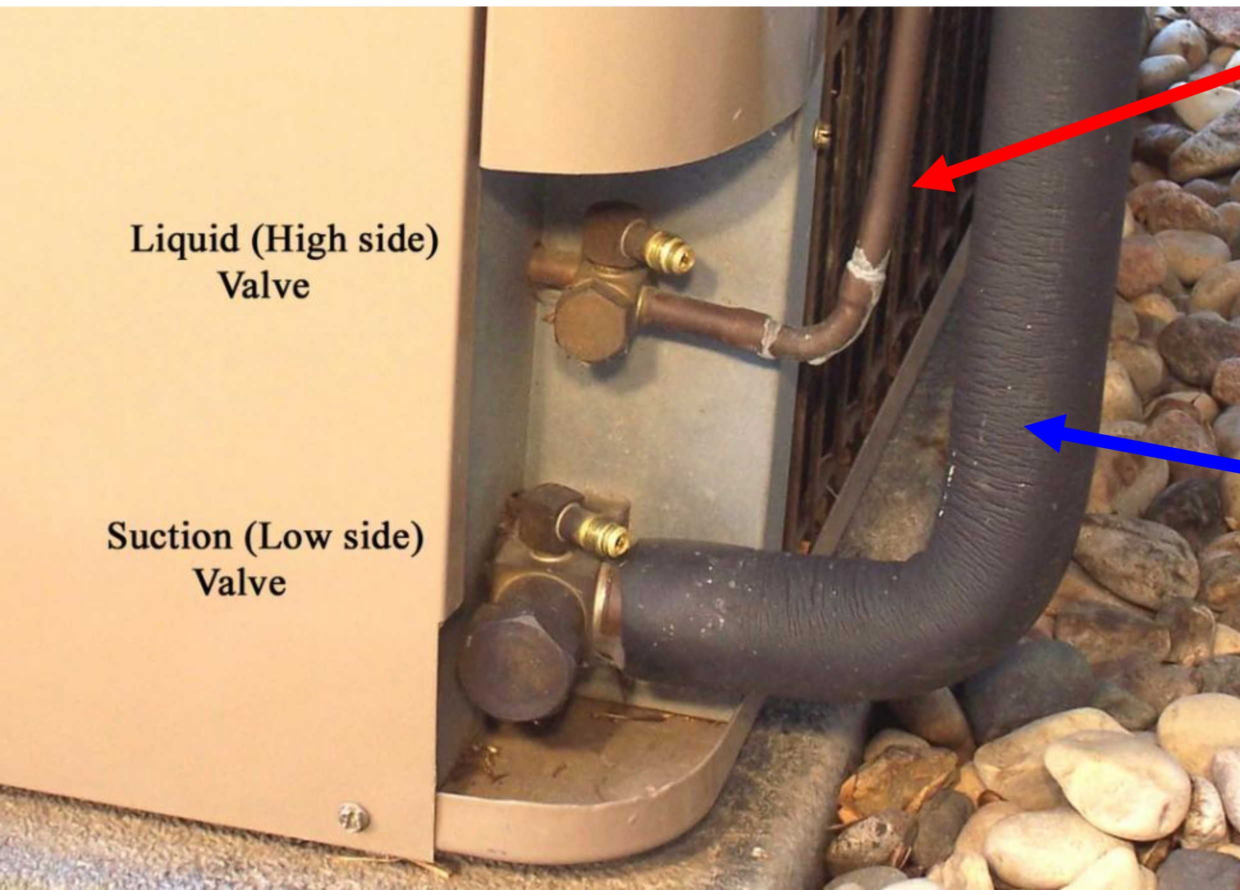
Thermal **E**xpansion **V**alve

- Critically charged at full load
- Charged verified by condenser subcooling
- Maintains a constant superheat (8-12º typical)
- Maintains capacity under a wide range of load conditions
- Better rH removal under a wide range of loads
- Capable of maintaining a constant suction pressure independent of ODA temp.
- If installed properly, as reliable as a fixed orifice

TruTechTools

Probe Positioning

Superheat and subcooling are measured at access ports



TXV

Measure subcooling

Fixed

Measure total superheat

TruTechTools

TXV Systems

1. Find required subcooling from equipment tag
2. Charge directly by subcooling to required level
3. Verify P/T and evaporator superheat

Subcooling Notes

The metering device needs to see 4 to 6° of subcooling immediately before its inlet to minimize flash gas.

Flash Gas:

- Lowers system efficiency
- Lowers capacity (decrease in mass flow)
- Can damage the metering device
- Temperature drop in the liquid line can indicate problems
- Install a sight glass right before the metering device if desired

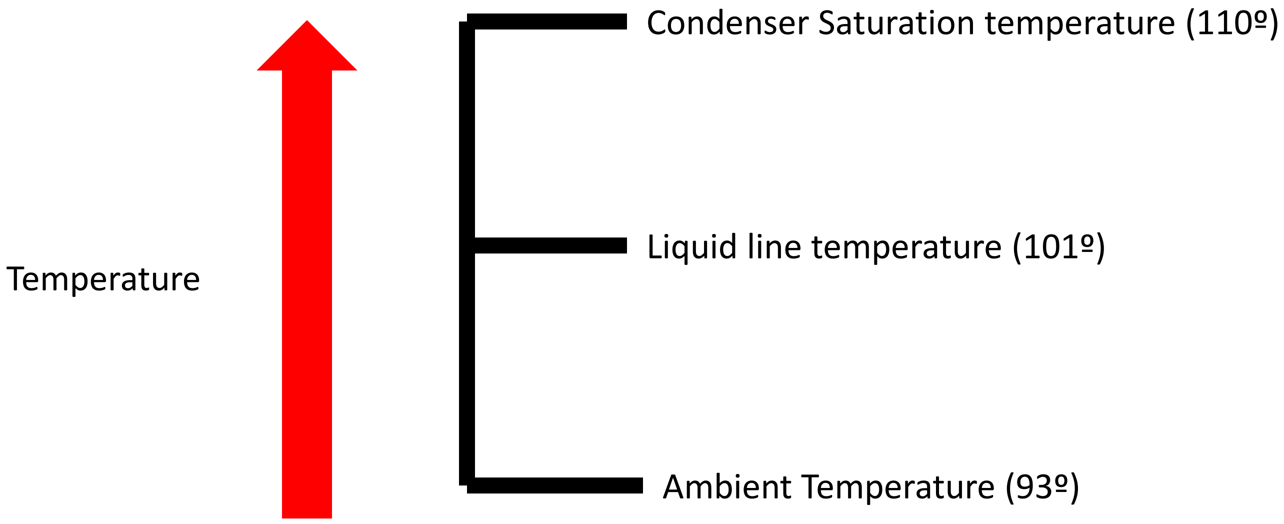
TruTechTools

Subcooling and Approach Relationship

Approach = liquid line temp – ambient (8º)

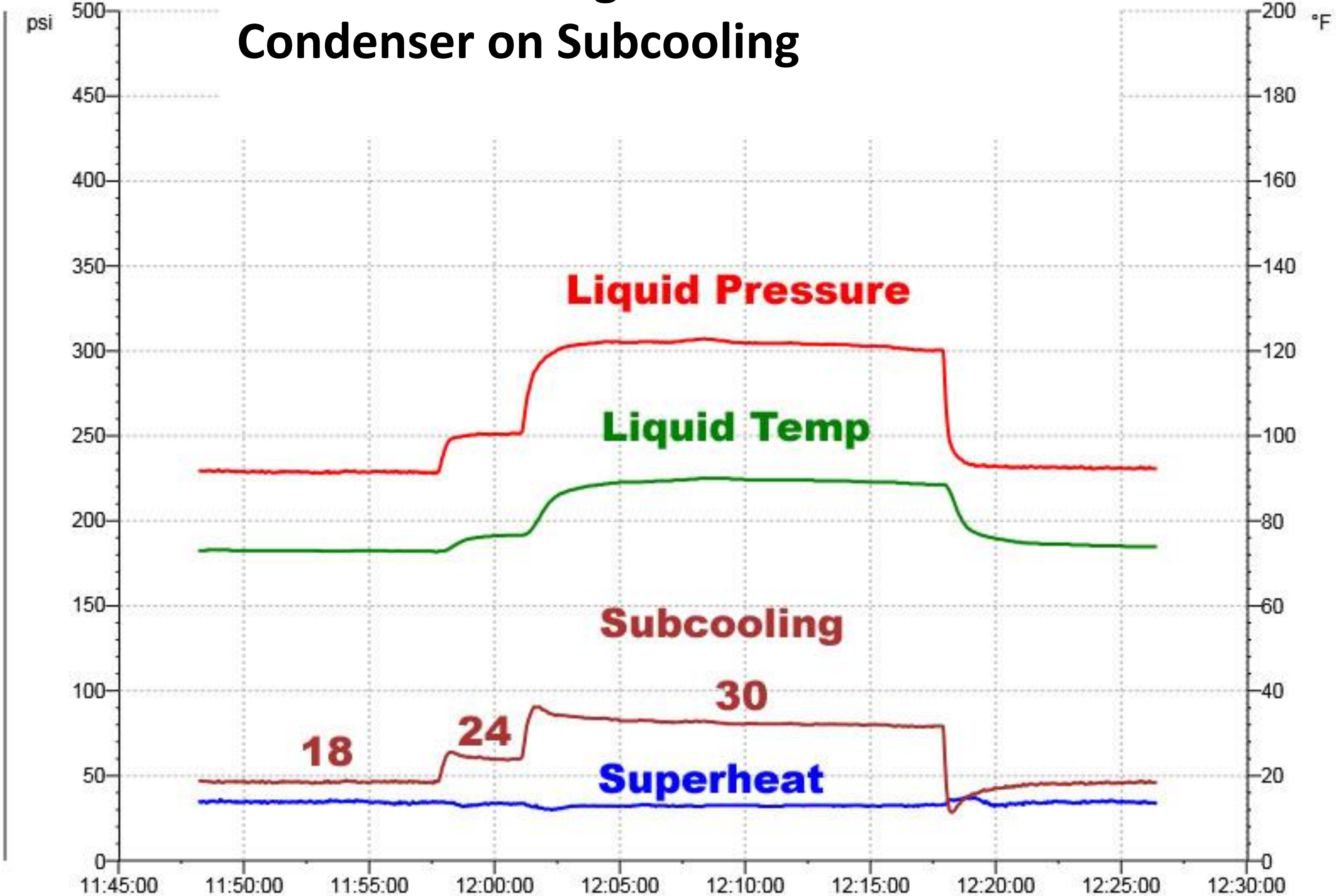
Subcooling = condenser saturation temp – liquid line temp (9º)

Condensing temp over ambient (split) = (17º)



TruTechTools

Effect of blocking Air-Flow Across Condenser on Subcooling

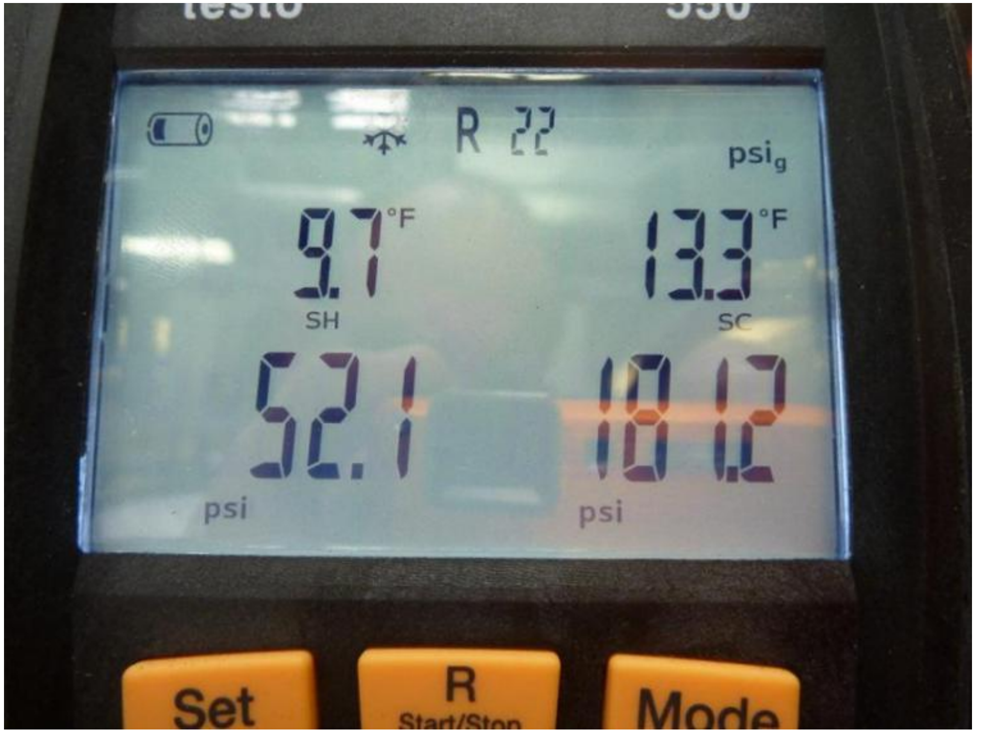


Real-Time Superheat & Subcooling

- Dual temperature inputs
- Direct display of superheat and subcooling
- Calculated for 33 refrigerants including R22 and 410a
- See what is happening not what happened
- See minimum (min) maximum (max) and mean (Mean) readings during charging

Verify Both Sides!

- Temperatures
- Pressures
- Coil temperatures
- Superheat
- Subcooling



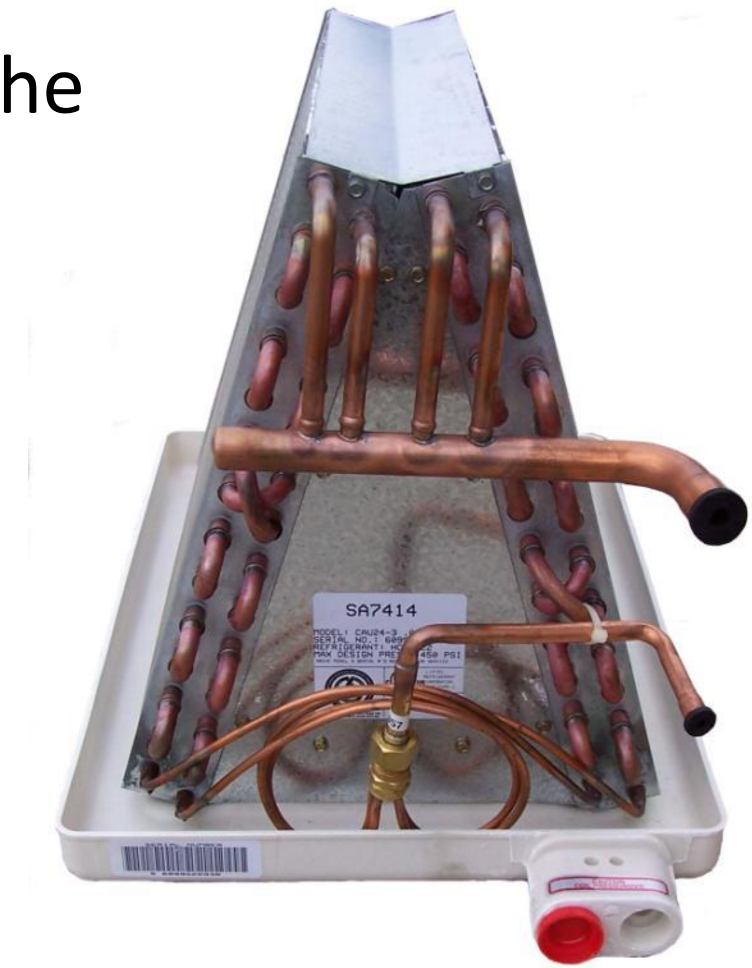
One side can lie about performance!

TruTechTools

Verify Temperature Split

Split assures that there that the airflow and the refrigerant charged are proportional.

- Verifies proper operation
- Proper rH removal
- Optimal performance



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Evaporator Temperature Drop 20°???

Evaporator temperature drop varies with the R/A humidity

FORGET ABOUT IT!!!!

It can be 16-24 degrees with ease!!

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Split at ARI Design Conditions

Table RD-3: Target Temperature Split (Return Dry-Bulb – Supply Dry-Bulb)

Return Air Dry–Bulb (°F) ($T_{return, db}$)	Return Air Wet-Bulb (°F) ($T_{return, wb}$)																										
	50	51	52	53	54	55	56	57	58	59	60	61	62	63	64	65	66	67	68	69	70	71	72	73	74	75	76
70	20.9	20.7	20.6	20.4	20.1	19.9	19.5	19.1	18.7	18.2	17.7	17.2	16.5	15.9	15.2	14.4	13.7	12.8	11.9	11.0	10.0	9.0	7.9	6.8	5.7	4.5	3.2
71	21.4	21.3	21.1	20.9	20.7	20.4	20.1	19.7	19.3	18.8	18.3	17.7	17.1	16.4	15.7	15.0	14.2	13.4	12.5	11.5	10.6	9.5	8.5	7.4	6.2	5.0	3.8
72	21.9	21.8	21.7	21.5	21.2	20.9	20.6	20.2	19.8	19.3	18.8	18.2	17.6	17.0	16.3	15.5	14.7	13.9	13.0	12.1	11.1	10.1	9.0	7.9	6.8	5.6	4.3
73	22.5	22.4	22.2	22.0	21.8	21.5	21.2	20.8	20.3	19.9	19.4	18.8	18.2	17.5	16.8	16.1	15.3	14.4	13.6	12.6	11.7	10.6	9.6	8.5	7.3	6.1	4.8
74	23.0	22.9	22.8	22.6	22.3	22.0	21.7	21.3	20.9	20.4	19.9	19.3	18.7	18.1	17.4	16.6	15.8	15.0	14.1	13.2	12.2	11.2	10.1	9.0	7.8	6.6	5.4
75	23.6	23.5	23.3	23.1	22.9	22.6	22.2	21.9	21.4	21.0	20.4	19.9	19.3	18.6	17.9	17.2	16.4	15.5	14.7	13.7	12.7	11.7	10.7	9.5	8.4	7.2	5.9
76	24.1	24.0	23.9	23.7	23.4	23.1	22.8	22.4	22.0	21.5	21.0	20.4	19.8	19.2	18.5	17.7	16.9	16.1	15.2	14.3	13.3	12.3	11.2	10.1	8.9	7.7	6.5
77	-	24.6	24.4	24.2	24.0	23.7	23.3	22.9	22.5	22.0	21.5	21.0	20.4	19.7	19.0	18.3	17.5	16.6	15.7	14.8	13.8	12.8	11.7	10.6	9.5	8.3	7.0
78	-	-	-	24.7	24.5	24.2	23.9	23.5	23.1	22.6	22.1	21.5	20.9	20.2	19.5	18.8	18.0	17.2	16.3	15.4	14.4	13.4	12.3	11.2	10.0	8.8	7.6
79	-	-	-	-	-	24.8	24.4	24.0	23.6	23.1	22.6	22.1	21.4	20.8	20.1	19.3	18.5	17.7	16.8	15.9	14.9	13.9	12.8	11.7	10.6	9.4	8.1
80	-	-	-	-	-	-	25.0	24.6	24.2	23.7	23.2	22.6	22.0	21.3	20.6	19.9	19.1	18.3	17.4	16.4	15.5	14.4	13.4	12.3	11.1	9.9	8.7
81	-	-	-	-	-	-	-	25.1	24.7	24.2	23.7	23.1	22.5	21.9	21.2	20.4	19.6	18.8	17.9	17.0	16.0	15.0	13.9	12.8	11.7	10.4	9.2
82	-	-	-	-	-	-	-	-	25.2	24.8	24.2	23.7	23.1	22.4	21.7	21.0	20.2	19.3	18.5	17.5	16.6	15.5	14.5	13.4	12.2	11.0	9.7
83	-	-	-	-	-	-	-	-	-	25.3	24.8	24.2	23.6	23.0	22.3	21.5	20.7	19.9	19.0	18.1	17.1	16.1	15.0	13.9	12.7	11.5	10.3
84	-	-	-	-	-	-	-	-	-	25.9	25.3	24.8	24.2	23.5	22.8	22.1	21.3	20.4	19.5	18.6	17.6	16.6	15.6	14.4	13.3	12.1	10.8

Split at Typical Operating Conditions

Table RD-3: Target Temperature Split (Return Dry-Bulb – Supply Dry-Bulb)

Return Air Dry–Bulb (°F) ($T_{return, db}$)	Return Air Wet-Bulb (°F) ($T_{return, wb}$)																										
	50	51	52	53	54	55	56	57	58	59	60	61	62	63	64	65	66	67	68	69	70	71	72	73	74	75	76
70	20.9	20.7	20.6	20.4	20.1	19.9	19.5	19.1	18.7	18.2	17.7	17.2	16.5	15.9	15.2	14.4	13.7	12.8	11.9	11.0	10.0						
71	21.4	21.3	21.1	20.9	20.7	20.4	20.1	19.7	19.3	18.8	18.3	17.7	17.1	16.4	15.7	15.0	14.2	13.4	12.5	11.5	10.6	9.5					
72	21.9	21.8	21.7	21.5	21.2	20.9	20.6	20.2	19.8	19.3	18.8	18.2	17.6	17.0	16.3	15.5	14.7	13.9	13.0	12.1	11.1	10.1	9.0				
73	22.5	22.4	22.2	22.0	21.8	21.5	21.2	20.8	20.3	19.9	19.4	18.8	18.2	17.5	16.8	16.1	15.3	14.4	13.6	12.6	11.7	10.6	9.6	8.5			
74	23.0	22.9	22.8	22.6	22.3	22.0	21.7	21.3	20.9	20.4	19.9	19.3	18.7	18.1	17.4	16.6	15.8	15.0	14.1	13.2	12.2	11.2	10.1	9.0	7.8		
75	23.6	23.5	23.3	23.1	22.9	22.6	22.2	21.9	21.4	21.0	20.4	19.9	19.3	18.6	17.9	17.2	16.4	15.5	14.7	13.7	12.7	11.7	10.7	9.5	8.4	7.2	
76	24.1	24.0	23.9	23.7	23.4	23.1	22.8	22.4	22.0	21.5	21.0	20.4	19.8	19.2	18.5	17.7	16.9	16.1	15.2	14.3	13.3	12.3	11.2	10.1	8.9	7.7	6.5
77	-	24.6	24.4	24.2	24.0	23.7	23.3	22.9	22.5	22.0	21.5	21.0	20.4	19.7	19.0	18.3	17.5	16.6	15.7	14.8	13.8	12.8	11.7	10.6	9.5	8.3	7.0
78	-	-	-	24.7	24.5	24.2	23.9	23.5	23.1	22.6	22.1	21.5	20.9	20.2	19.5	18.8	18.0	17.2	16.3	15.4	14.4	13.4	12.3	11.2	10.0	8.8	7.6
79	-	-	-	-	-	24.8	24.4	24.0	23.6	23.1	22.6	22.1	21.4	20.8	20.1	19.3	18.5	17.7	16.8	15.9	14.9	13.9	12.8	11.7	10.6	9.4	8.1
80	-	-	-	-	-	-	25.0	24.6	24.2	23.7	23.2	22.6	22.0	21.3	20.6	19.9	19.1	18.3	17.4	16.4	15.5	14.4	13.4	12.3	11.1	9.9	8.7
81	-	-	-	-	-	-	-	25.1	24.7	24.2	23.7	23.1	22.5	21.9	21.2	20.4	19.6	18.8	17.9	17.0	16.0	15.0	13.9	12.8	11.7	10.4	9.2
82	-	-	-	-	-	-	-	-	25.2	24.8	24.2	23.7	23.1	22.4	21.7	21.0	20.2	19.3	18.5	17.5	16.6	15.5	14.5	13.4	12.2	11.0	9.7
83	-	-	-	-	-	-	-	-	-	25.3	24.8	24.2	23.6	23.0	22.3	21.5	20.7	19.9	19.0	18.1	17.1	16.1	15.0	13.9	12.7	11.5	10.3
84	-	-	-	-	-	-	-	-	-	25.9	25.3	24.8	24.2	23.5	22.8	22.1	21.3	20.4	19.5	18.6	17.6	16.6	15.6	14.4	13.3	12.1	10.8

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TruTech Recommended Tools

- Testo 5XX series manifold or Digi-Cool AK900
- Testo 605-H2 Psychrometer (for Wet bulb)
- Testo 416 or Fieldpiece STA-2 (for airflow)
- Testo 318-V Video scope for inspections
- Testo 510 for static pressure
- TTT Static pressure test kit
- TTT Troubleshooting guides

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