ENERGY DESIGN
conference & expo

Improving Residential HVAC Performance and Energy Efficiency

Jake McAlpine

T·E·C
THE ENERGY CONSERVATORY

Bruce Stahlberg

AFFORDABLE ENERGY SOLUTIONS.COM

Feb 21-22, 2022

Introductions

Jake McAlpine

- Technical Support & Training Manager, The Energy Conservatory
- 12 years of experience in the MN Weatherization Assistance Program (WAP) as both an energy auditor and program manager
- Bachelor of Science degree in Residential Building Science & Technology from the University of Minnesota.

Bruce Stahlberg

- Owner of Affordable Energy Solutions, Inc (AES).
- Over 35 years experience, has performed over 8,000 energy audits on various building types.
- Focused on HVAC Quality Install Testing protocol including static pressure, air flow testing and Manual J calculations.

Agenda

- Mechanical HVAC system
  - Impact energy efficiency and comfort
- Manual J Sizing Calculations – Importance
- Total External Static Pressure (TESP)
  - What it is and how to measure
- How HVAC air flow impacts efficiency
  - How to (accurately) measure flow rates
- Improving efficiency in the field
  - Examples of optimizing HVAC efficiency in a home
- Q&A

Mechanical HVAC System

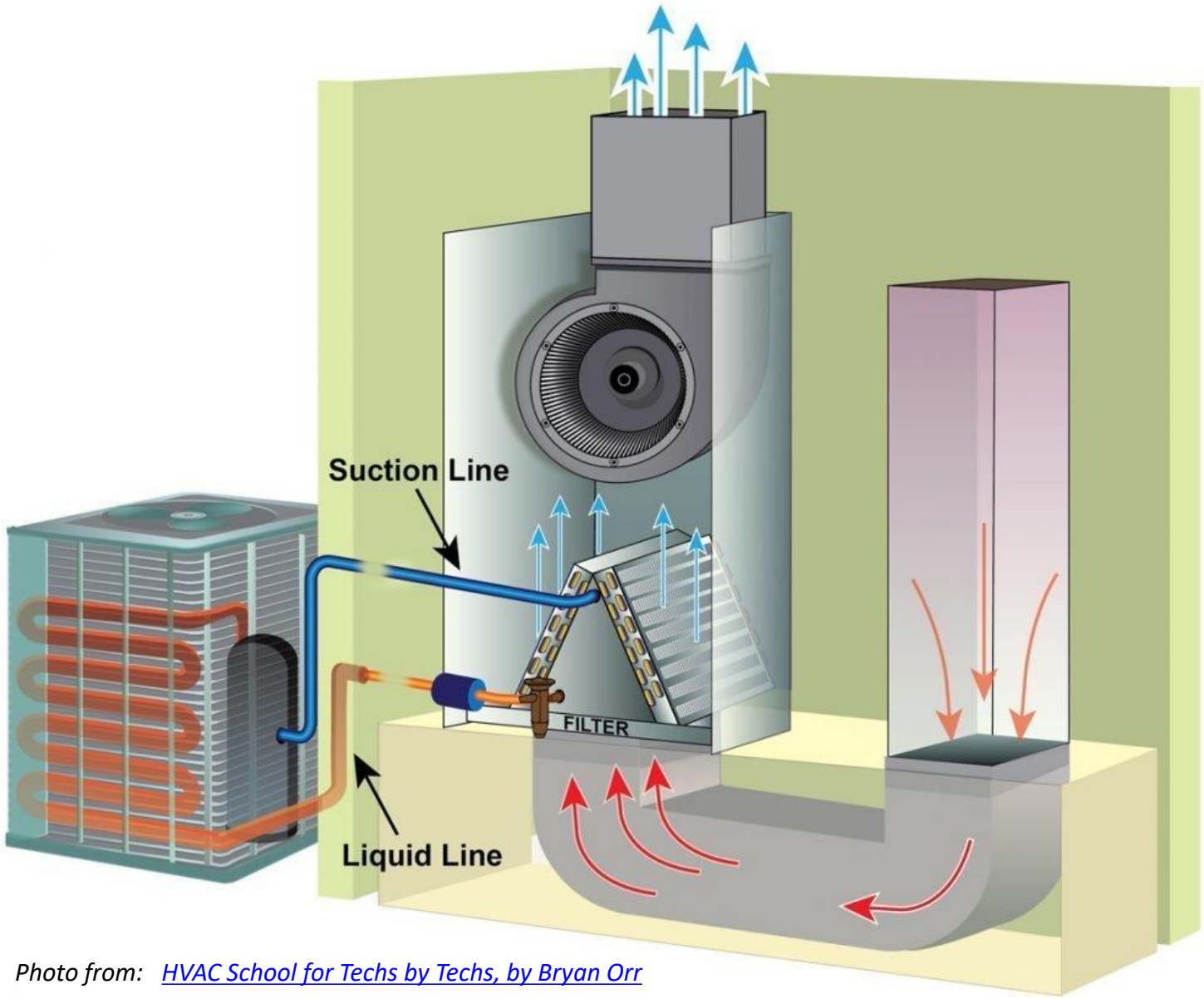


Photo from: *HVAC School for Techs by Techs, by Bryan Orr*

If both refrigerant and blower fan flow are not set in the right range, the system will not be running efficiently, and it is likely the homeowner will experience comfort issues

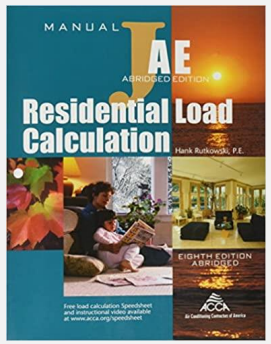
ANSI-310 Process Released in July 2020

ANSI = AMERICAN NATIONAL STANDARDS INSTITUTE

ANSI-310 Process for Grading New Installs

1. Design Review
   - Tolerances Not Met
   - Tolerances Met
2. Total Duct Leakage
   - Grade III
   - Grade I or II
   - ANSI / RESNET / ICC 380
3. Blower Fan Airflow
   - Grade III
   - Grade I or II
   - Flow Grid
   - Pressure Matching
   - Flow Hood
   - Static Press. Table
4. Blower Fan Watt Draw
   - Grade III
   - Grade I or II
   - Plug-In Watt Meter
   - Clamp-On Watt Meter
   - House Utility Meter
5. Refrigerant Charge
   - Grade III
   - Grade I
   - Non-Invasive Temp.
   - Weigh-In Verification

1



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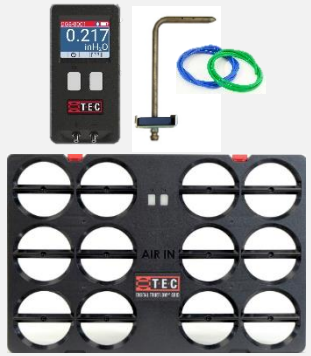

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HVAC SCHOOL
FOR TECHS BY TECHS

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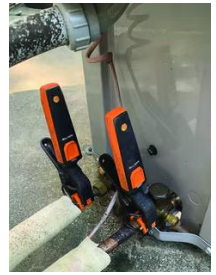
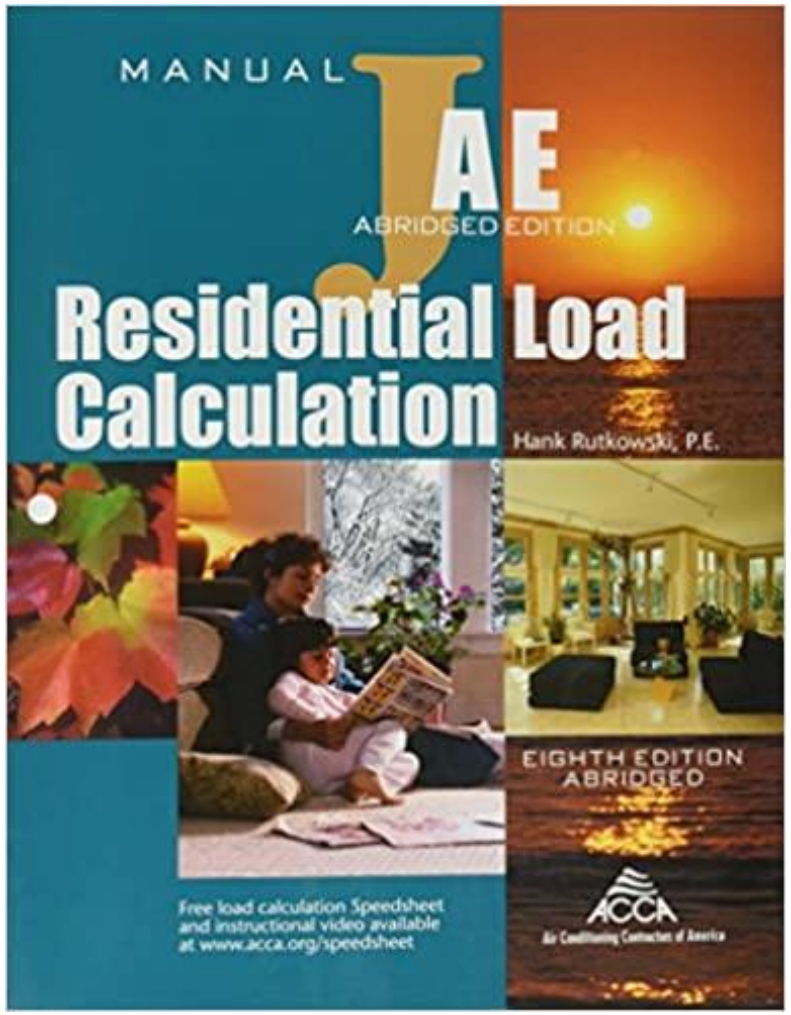


HVAC SCHOOL
FOR TECHS BY TECHS

Step 1 – Design Review – Manual J



- Manual J Load Calculations
  - Load calc impacts air flow needed
  - Oversizing very common
  - Creates pressure (and other) issues
  - Important to be accurate and reasonable

What is the BTU heat loss of this home?

- 1995 construction
- 2” x 6” walls
- 1,080 sq. ft.
- Weatherized home
- Middle unit, heated on both sides

Depends on who you ask...

- Weatherization energy modeling = 20 KBTUs
- CoolCalc.com energy modeling = 32 KBTUs
- Contractor proposed - 2017 = 36 KBTUs
- Manual J calculation = 52 KBTUs (several errors)

- New Furnace installed - 2021 = 35 KBTUs (1^{st} stage)
  = 53 KBTUs (2^{nd} stage)

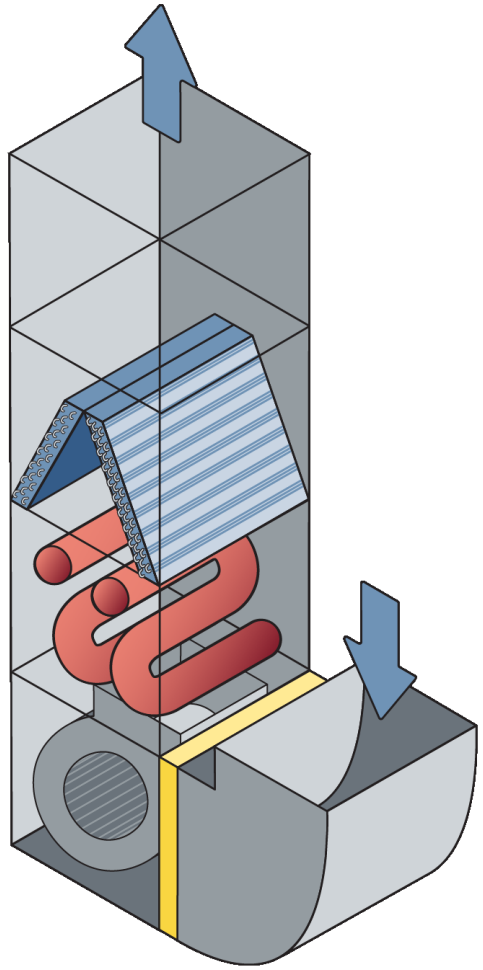
Rated TESP = 0.5”
Measured TESP = **.68”**
Measured TESP = **.96”**

How does an Upgrade to High Efficiency impact Static Pressure and Desired Flow?

System Efficiency (Type)	Input BTUs	Output BTUs	Desired Flow CFM	Static Pressure Inches of water column
Existing natural draft	80,000	64,000	640	.60
Two Scenarios for New Installation				
High Efficiency Condensing 96%	60,000	56,000	840	.79
High Efficiency Condensing 96%	45,000	43,200	648	.61

Estimated Flow Rates per Type of System

- Flow requirements
  - Natural Draft = 100 CFM per 10,000 BTUs
  - Induced Draft = 130 CFM per 10,000 BTUs
  - Condensing = 150 CFM per 10,000 BTUs



Manual J – www.CoolCalc.com

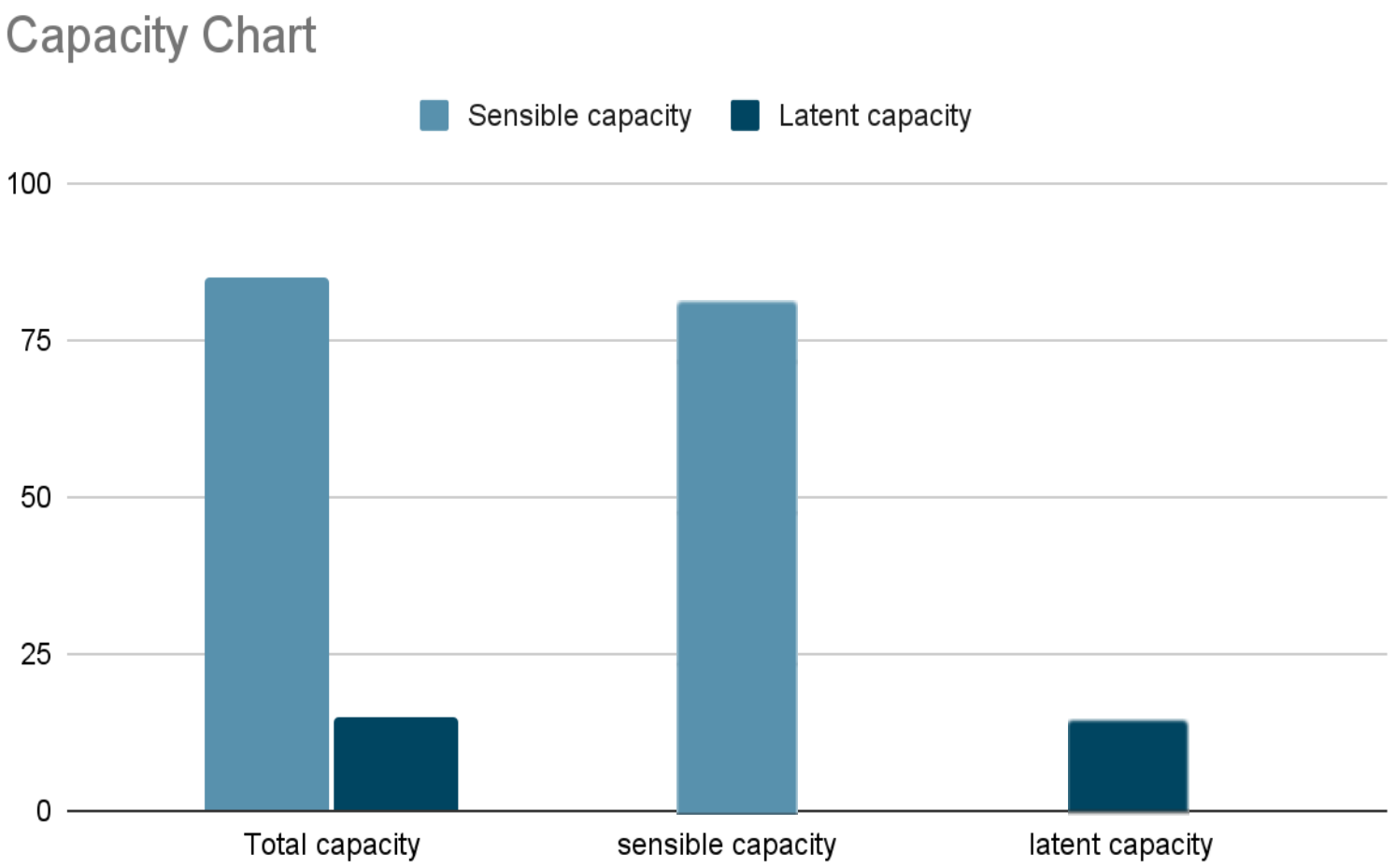
- Use or Compare with CoolCalc.com
  - ACCA approved
  - Cool Calc Manual J – YouTube
  - Need some building info:
    - Location
    - Age
    - Bonus Room?
    - Skylights?
    - HVAC ductwork

System Performance to Meet Efficiency & Comfort Goals

Comfort

Efficiency

Getting Air Flow Right Matters for SHR



85/15 SPLIT

Total Capacity:

Total energy expressed in BTU's that the air conditioner has available for the control of sensible and latent.

Sensible Capacity:

BTU's that are used to change the temperature of a room.

Latent Capacity:

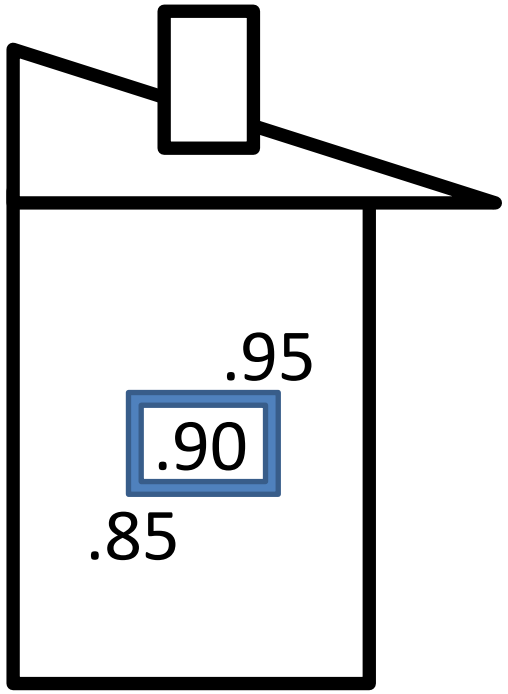
BTU's that are used to remove water from the air.

Sensible Heat Ratio (SHR):

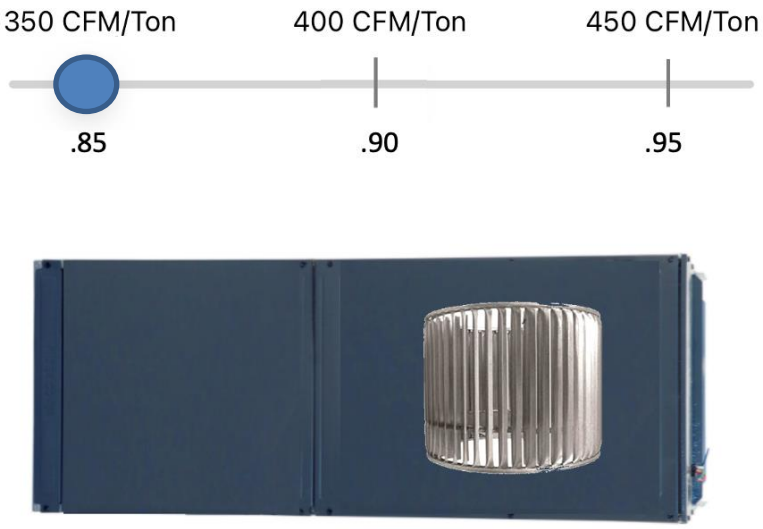
Is the fraction between sensible and latent capacity of the total capacity

First! Always Deliver The Homeowner Comfort

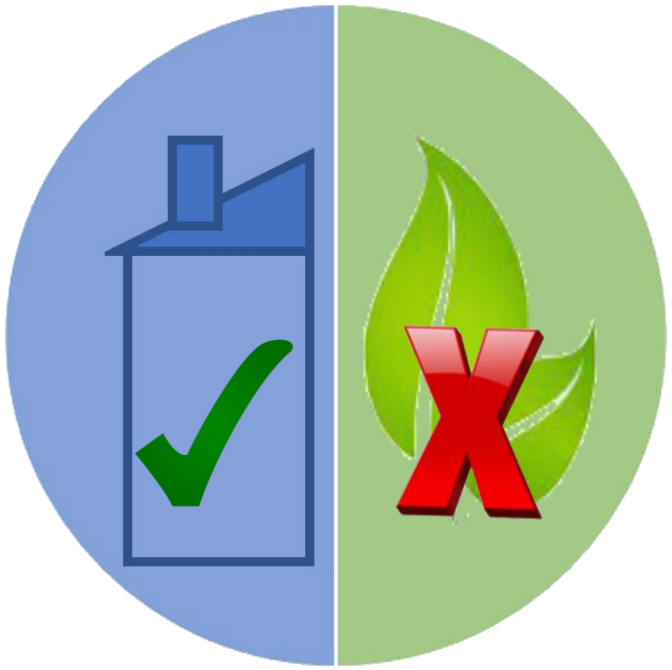
Finding House SHR + Setting AC SHR = Comfort



*Driven by the Man J load

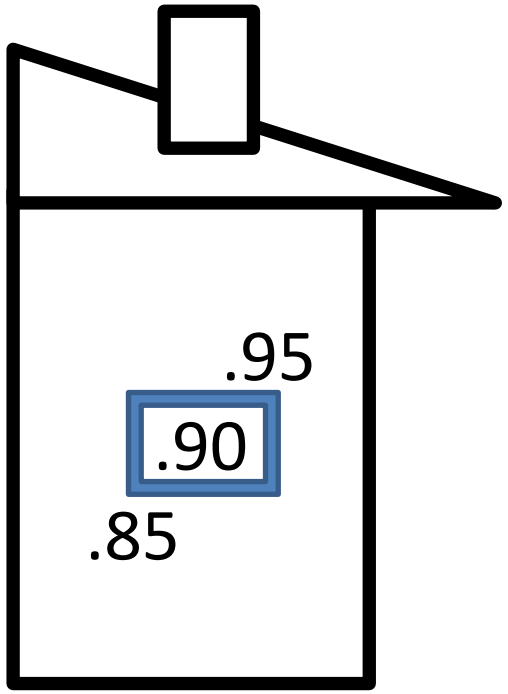


*Too little indoor airflow



First! Always Deliver The Homeowner Comfort

Finding House SHR + Setting AC SHR = Comfort



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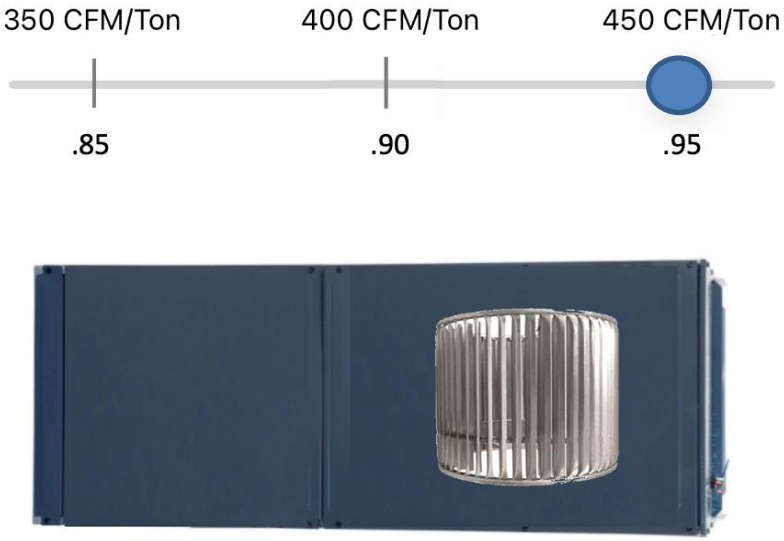
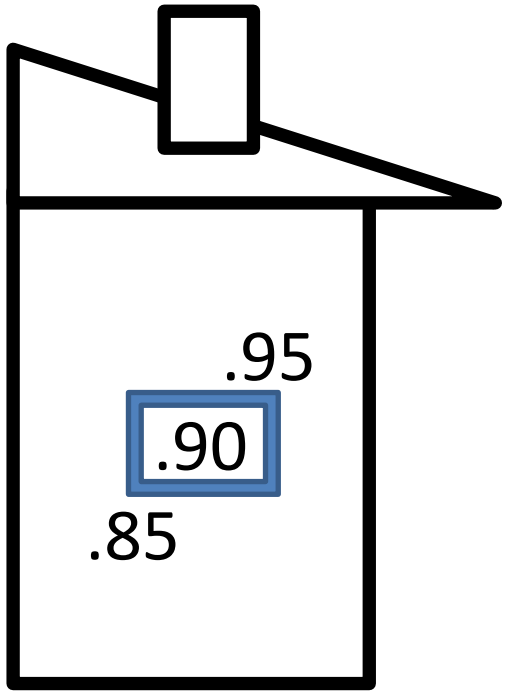
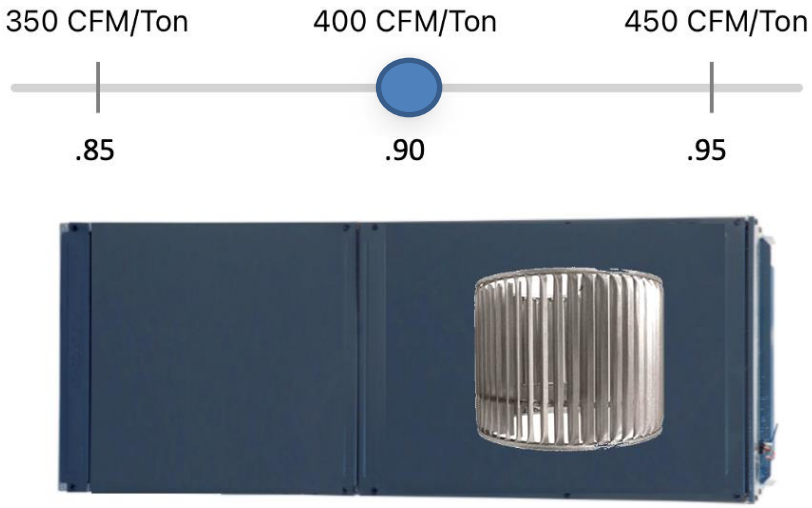


*Too much indoor airflow

First! Always Deliver The Homeowner Comfort

Finding House SHR + Setting AC SHR = Comfort





*Driven by the Man J load

*Driven by indoor airflow

But what does peak load mean for my AC?

Water Removal capacity

At 465 CFM/ton

.81 SHR = 6120 BTU/h = 6.1 pints/hr

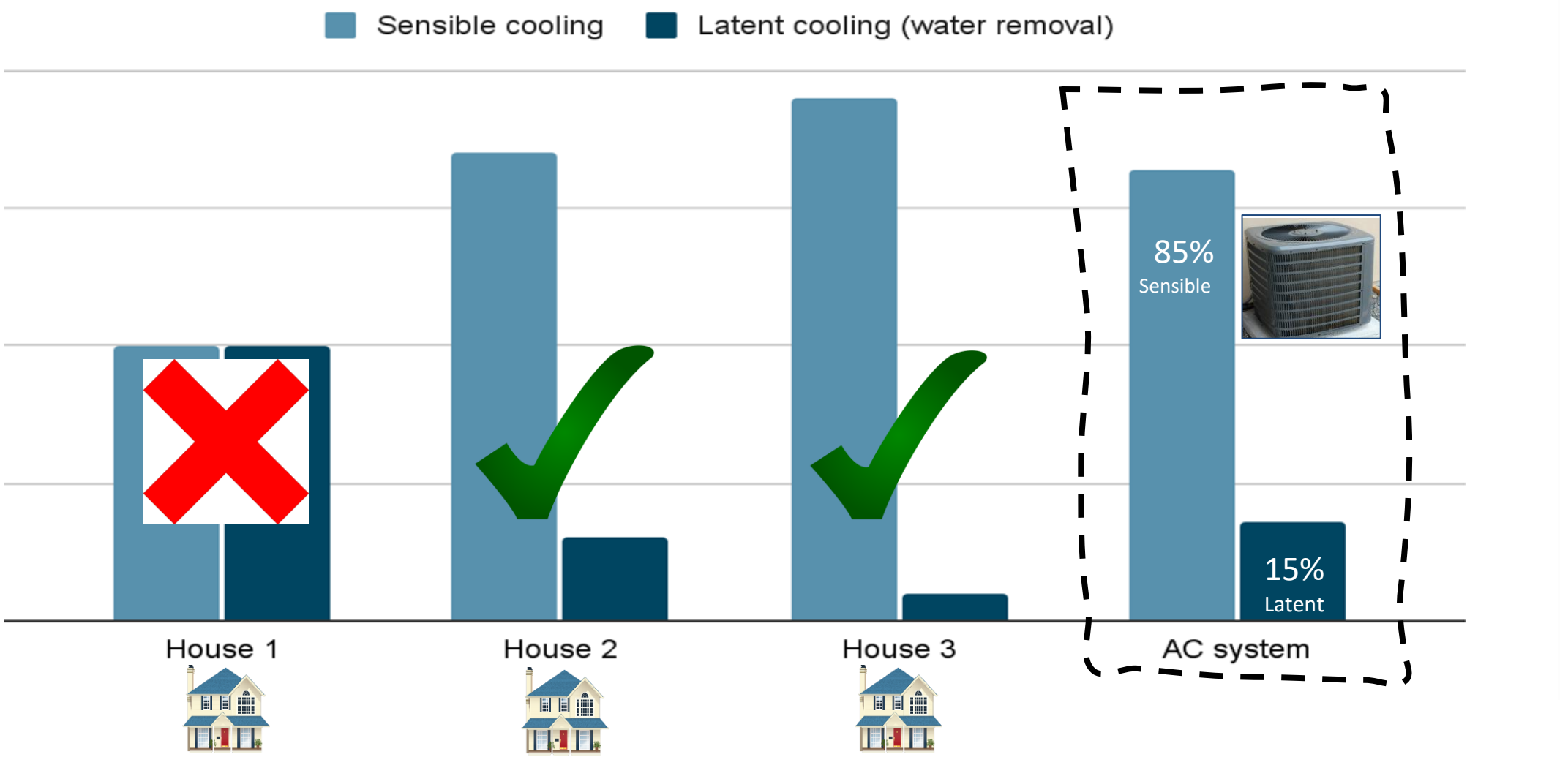
At 360 CFM/ton

.71 SHR = 9570 BTU/h = 9.5 pints/hr

This is where true comfort control comes from!

Learning Check:

Which Houses will be Comfortable with the AC on the right?



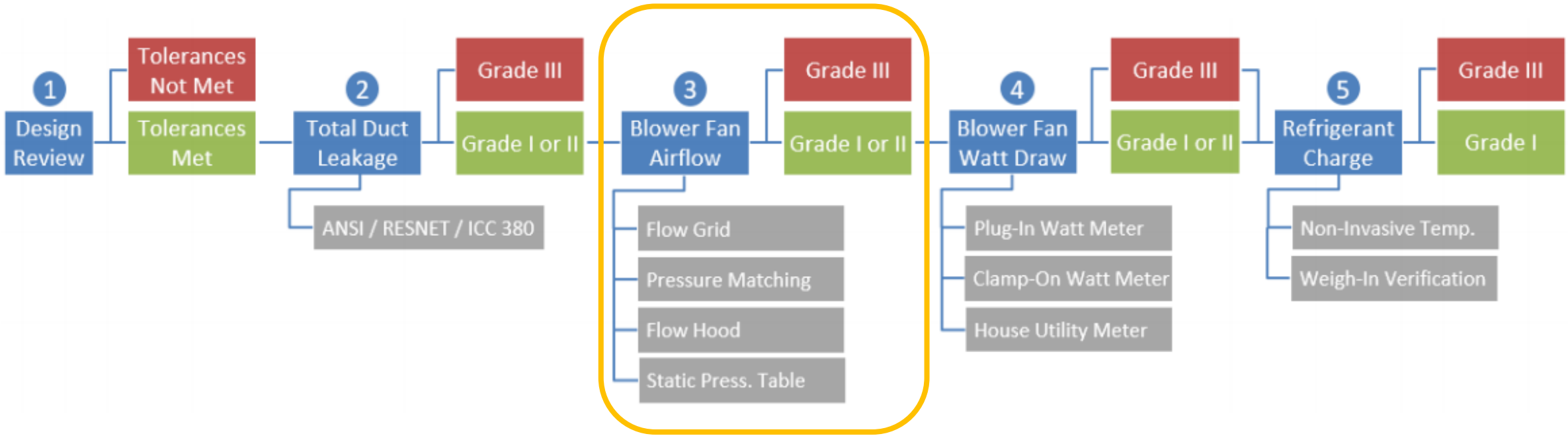
Remember you must meet 100% of the latent load.

So how do we measure air flow?

Comfort

Efficiency

ANSI-310 – Air Flow Measurement



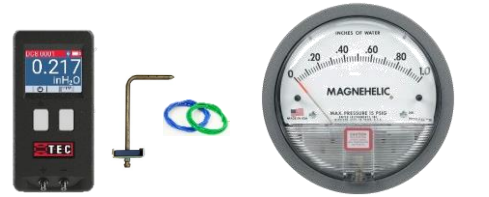
Other common methods used in commercial are not recognized by ANSI for use in Residential measurements

5, 6, 7	Duct Traverse with Hot Wire, Mini-Vane or Pitot	★☆☆☆☆	★★☆☆☆	★☆☆☆☆	$$	15 to 30
8, 9	Temp Rise / Split	★☆☆☆☆	★☆☆☆☆	★☆☆☆☆	$	5 to 20
10	Indoor Coil static press. Drop	★☆☆☆☆	★☆☆☆☆	★★☆☆☆	$	4 to 8

Comparing Four Methods of Residential Air Flow Measurement

Recognized by ANSI/ACCA/RESNET Standard 310

Method	Overall Value	Residential Accuracy	Confidence/ Consistency	Equip. Cost	Time (min)	Comments
TrueFlow® Grid	★★★★★	★★★★★	★★★★★	$$	5 to 10	Designed for residential system air flow measurement. Digital TrueFlow App Bluetooth connects, simplifies process and analysis of system. Per 310: Accepted by standard, no restrictions
TESP & Fan Table	★★★☆☆	★★☆☆☆	★★★★☆	$	5 to 10	Cost-effective method, provides good measurement on new clean systems with proper OEM chart. Is not accurate if system is dirty. Per 310: Accuracy of ± 1% of the reading or ± 0.25 Pa (0.001 inH2O) required, whichever is greater.
Pressure Matching w/ Duct Blaster®	★★☆☆☆	★★★★★	★★★★☆	$$$$	8 to 15	New equipment is very expensive. Takes time to connect duct tester to cabinet. Duct Leakage causes mismeasurement. Per 310: Can connect to Filter Grilles and Cabinet for Duct Leakage Grade 1, Cabinet only for Grade II.
Flow Hood	★★☆☆☆	★★★★☆	★★★☆☆	$$$$	4 to 8	New equipment is very expensive. May require powered flow hood for multiple returns, passive flow hood for single return. Adding multiple returns adds time. Duct Leakage causes mismeasurement. Per 310: Only allowed on Grade I Duct Leakage results.



★☆☆☆☆	*Worst Performance (15% or more)*
★★★★★	*Best Performance (5% or better)*
$	*Lowest Cost ($100 to $300)*
$$$$	*Highest Cost ($3000+)*

Understanding TESP

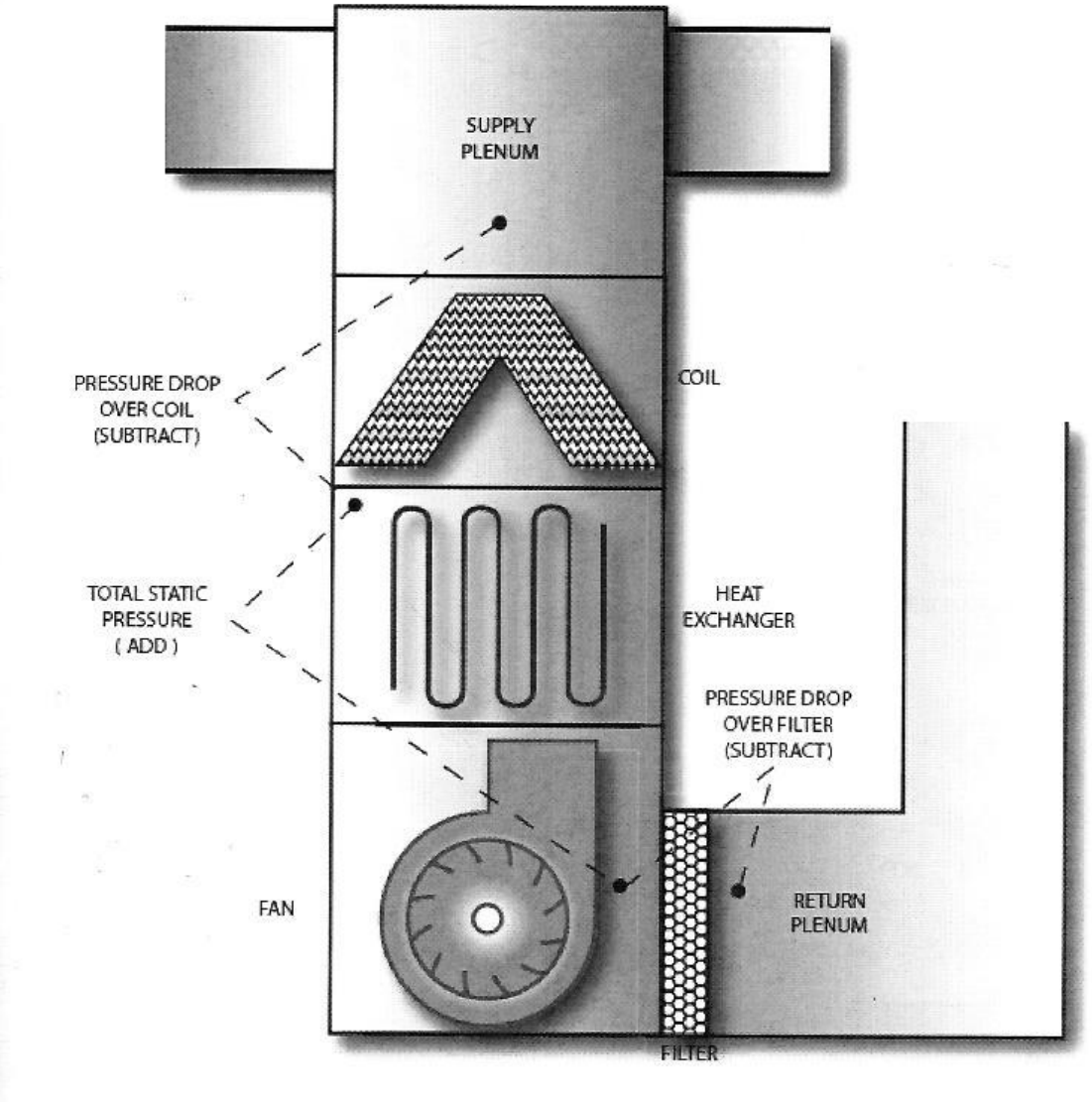
- Video 4’ 33”
  - Energy Conservatory training video on TESP

Total External Static Pressure: Tools Needed

- Step drill bit
- Pitot Tube w/magnet
- Manometer
- Plugs or aluminum tape

Testing Total External Static Pressure: The Basics

- We drill *"TEST PORTS"*
  - We do not drill "*holes*"
- Use a step drill bit
  - Not a regular bit
- TESP readings help us:
  - ✓ Troubleshooting distribution
  - ✓ Measure air flow
  - ✓ Compare with manufacturer rate



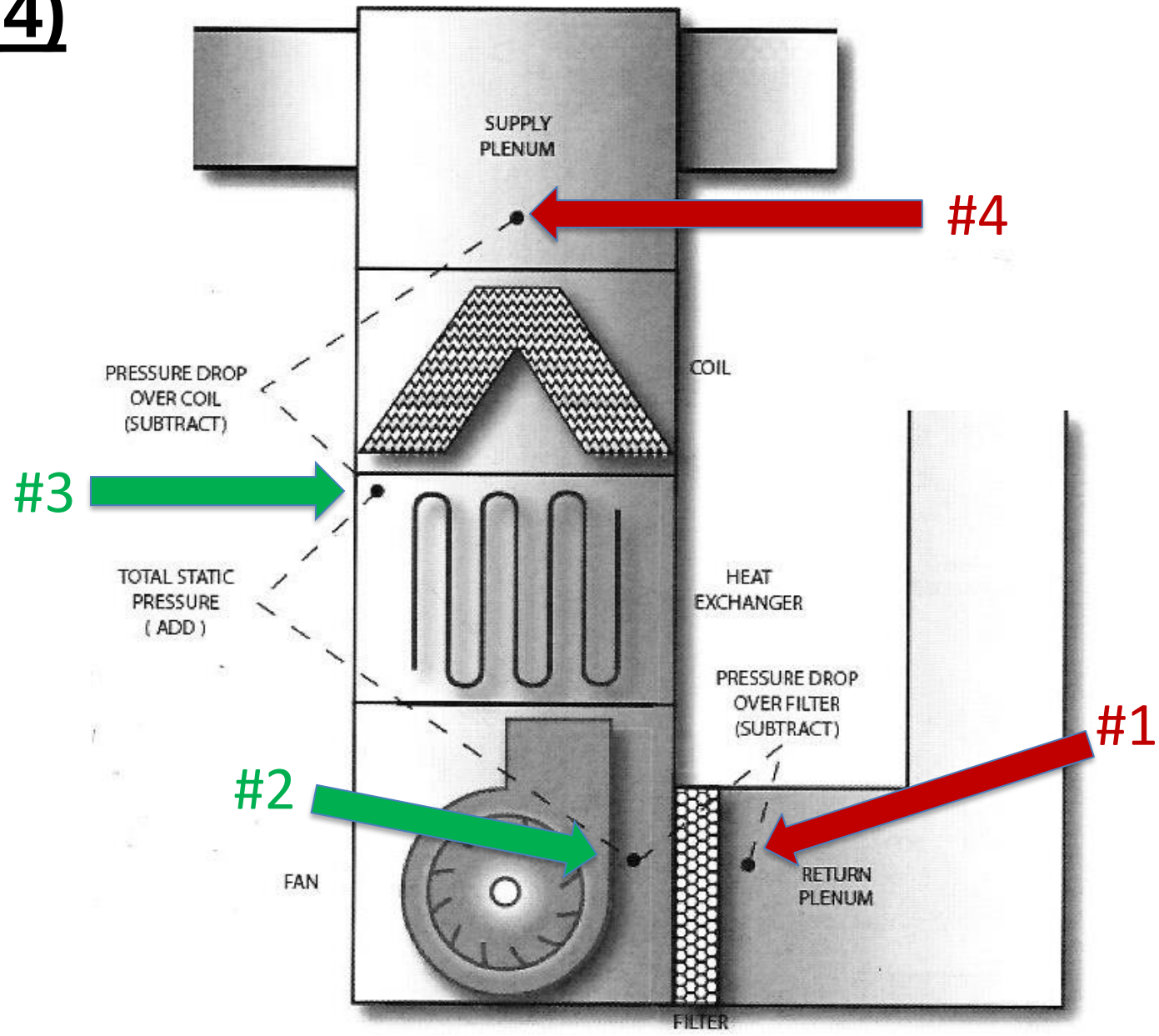
TESP Test Ports Location (4)

1. Before Filter

2. After Filter
   & before blower

3. After heat exchanger
   & before the AC coil

4. After AC coil



How to Test: Location of Test Ports

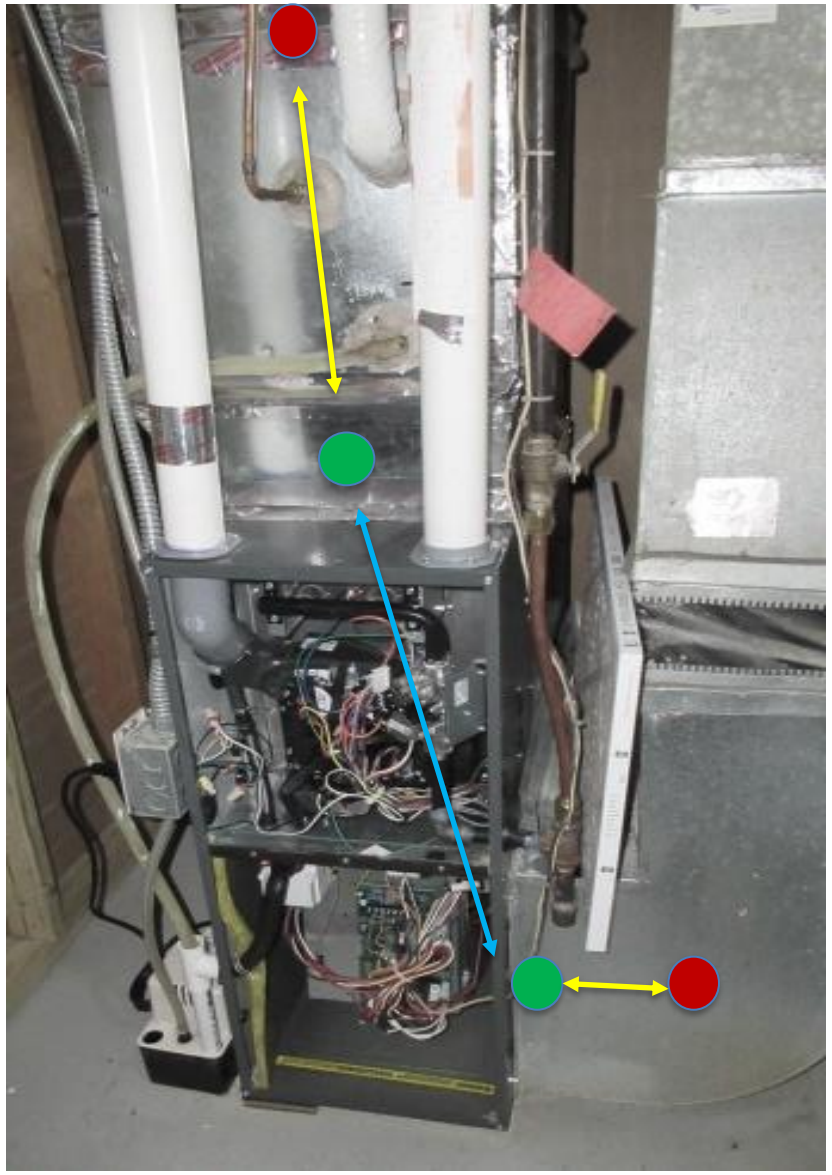
- Red to Green =

  Pressure Drop so you subtract readings

- Green to Green =

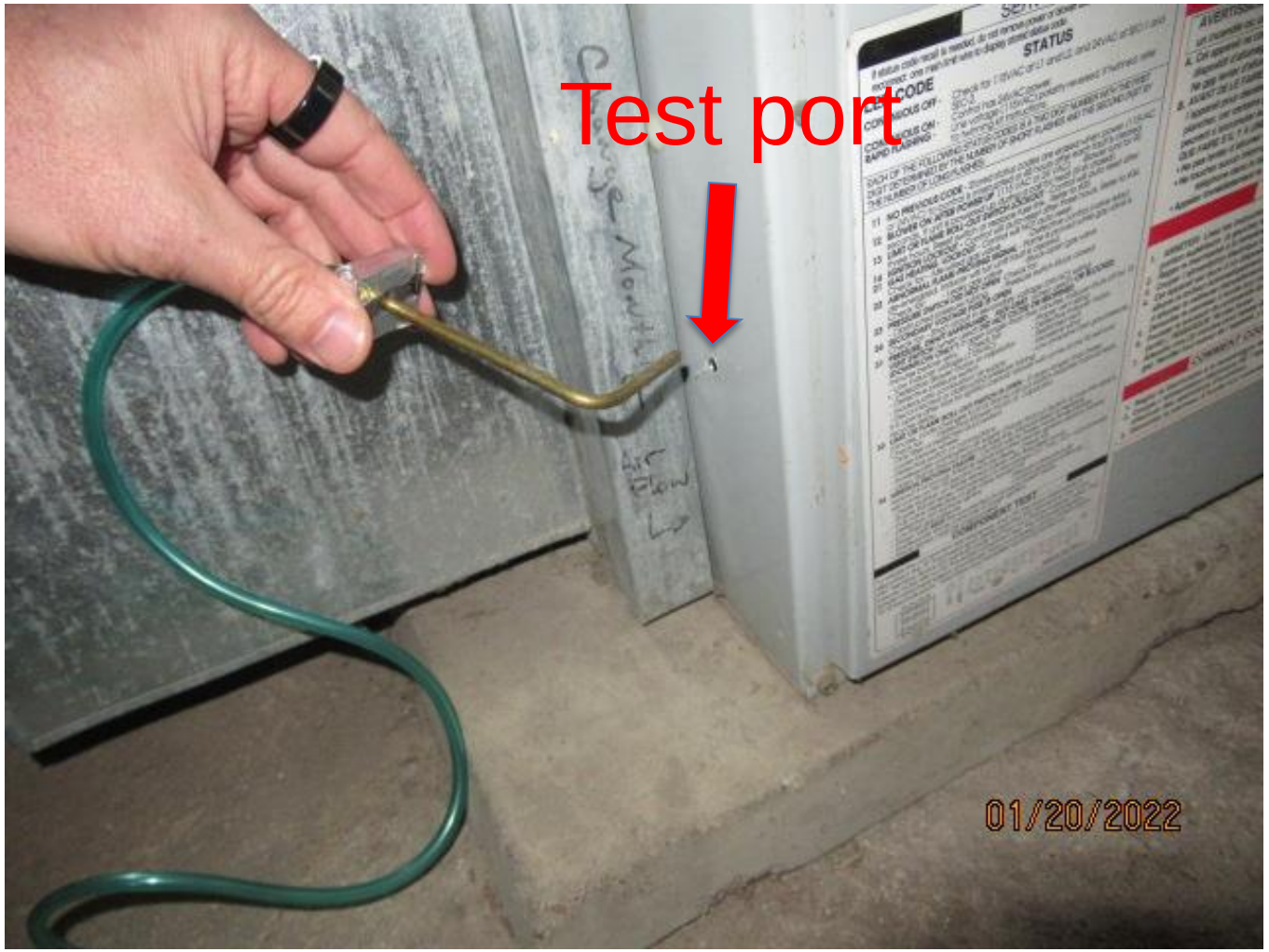
  TESP so you add readings together

- Ignore + and - signs



What if Filter Rack is directly against Furnace Cabinet?

- Drill into side of the cabinet
- Pitot Tube towards ductwork

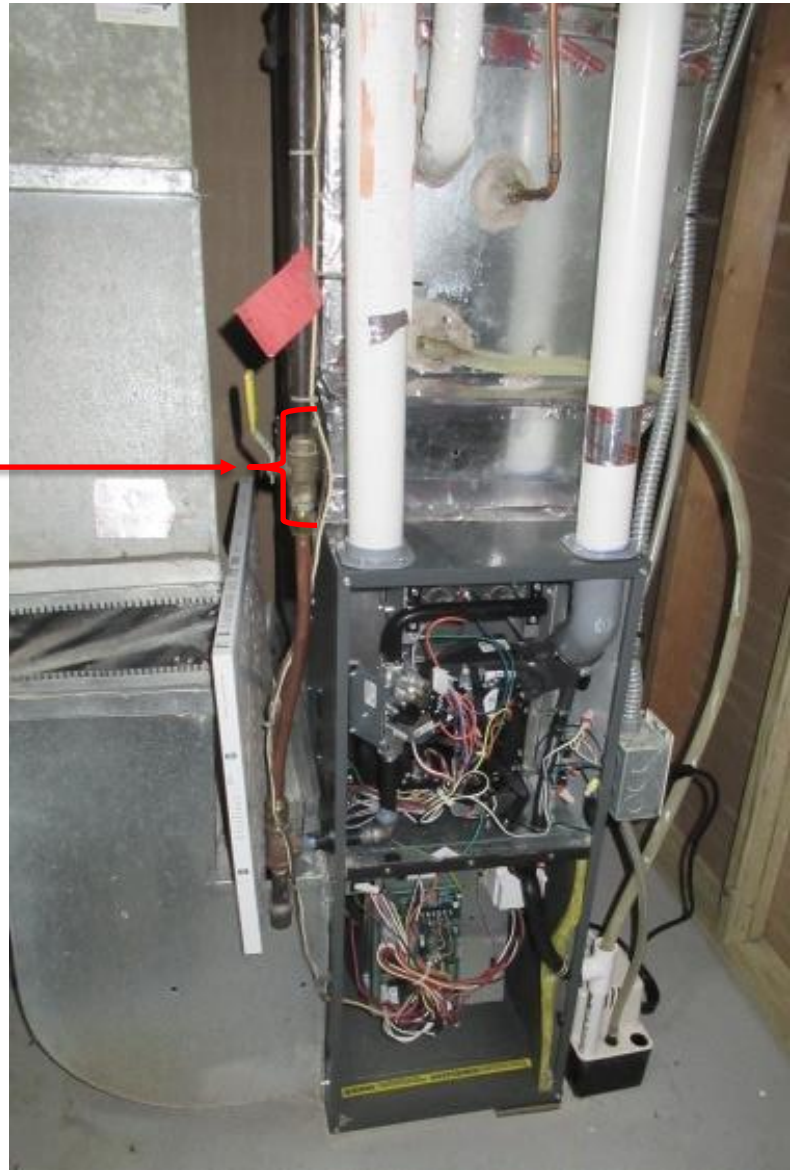


What if AC Coil is installed directly on top of Furnace Cabinet?

- Drill into cabinet
- About 1” below top for supply side reading
- Above is AC drain pan
- Pitot Tube points into air flow

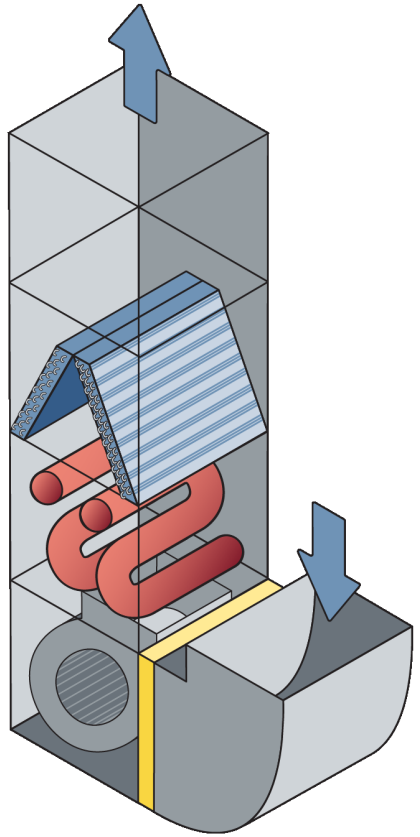
New Installations provide free space

- New furnaces are often shorter which creates a “free space” for supply side reading



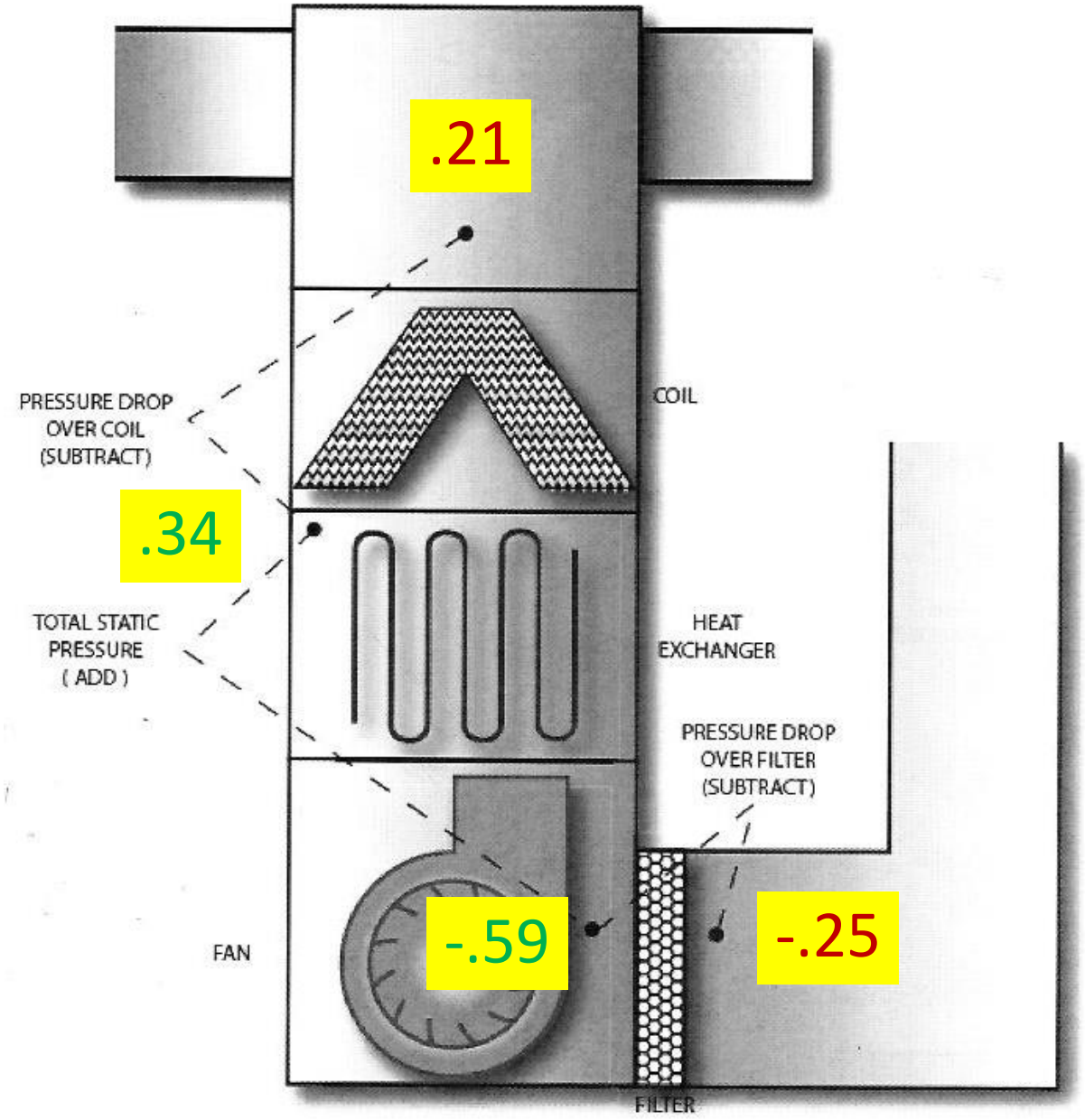
HINTS FOR TESP CONVERSATIONS

- Use whole numbers, not “inches of water column”
- .50 inches of water column = 50
- Compare to blood pressure
- High numbers are bad, restrictive
- Drill test ports, not “holes”



Static Pressure Example #1

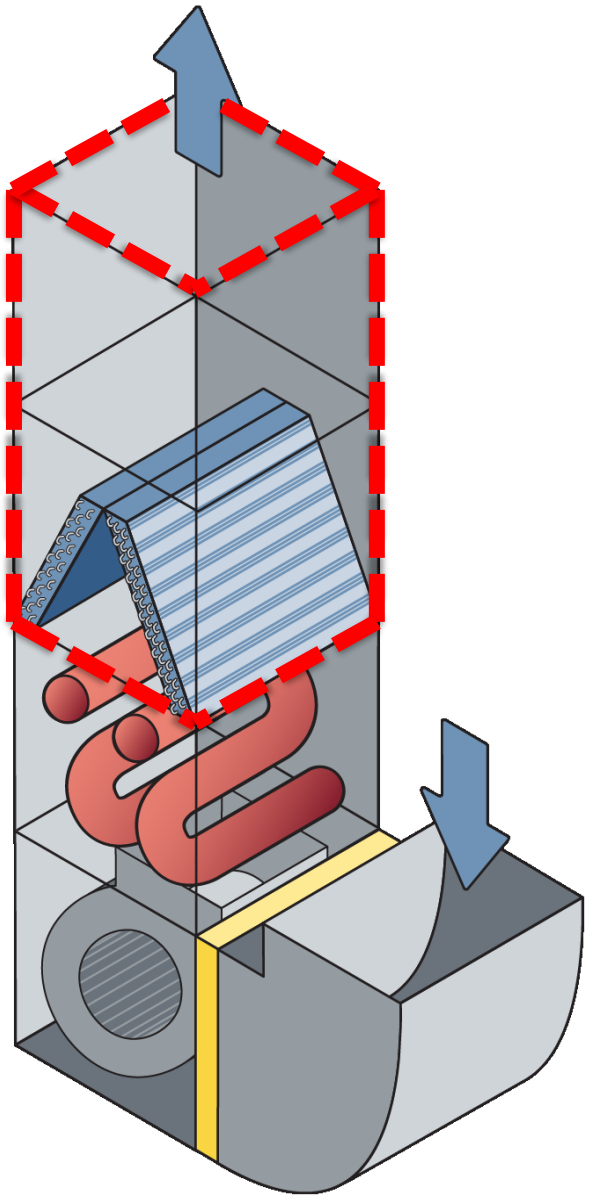
I. Pressure drop across filter
   I. -Red to Green = subtract
   II. 59-25=34
   III. “Budget” = 10
II. Pressure drop across ac coil
   I. -Red to Green = subtract
   II. 34-21=13
   III. “Budget” = 20
III. TESP
   I. Green to Green = add
   II. 59+34=93
   III. Manufacturer's Specs = 50

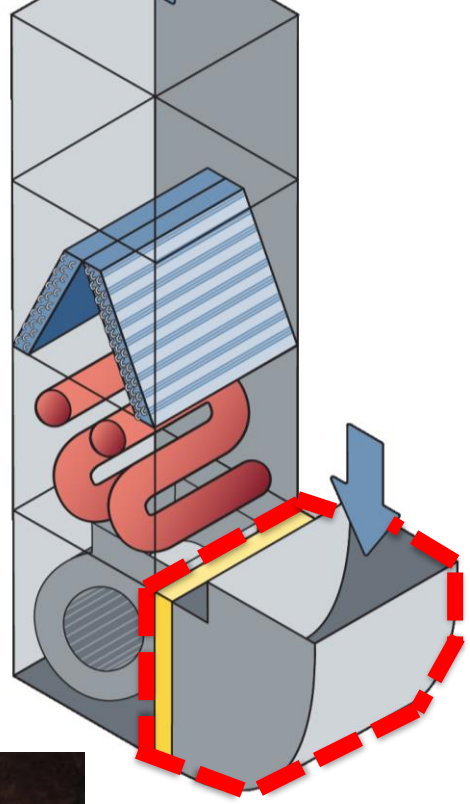


Static Pressure Example #1

TESP Rated = .50”	Before Filter	After Filter	Before AC	After AC
Static Pressure	.25” w.c.	.59” w.c.	.34” w.c.	.21” w.c.
Pressure Drop Filter & AC	59 – 25 = 34		34 – 21 = 13	
Pressure Drop recommended	20% of TESP = 10		40% of TESP = 20	
TESP Total		59 + 34 = 93		
Manufacturer TESP recommended		50		

Common Causes of High Static on the Supply Side





Common Causes of High Static on the Return Side

Which Filter is Right?

Varying units of filtration

TESP and OEM Chart

TESP	Rating	Comments
Overall Value	★★★☆☆	Cost-effective method, provides good measurement on new clean systems with proper OEM chart. Is not accurate if system is dirty.
ACCA 310	Yes	Recognized by ANSI/ACCA/RESNET
Residential Accuracy	★★☆☆☆	Good accuracy if using a Magnehelic on new systems with right OEM table. Per 310: Accuracy of ± 1% of the reading or ± 0.25 Pa (0.001 inH2O) required for manometer, whichever is greater.
Consistency	★★★☆☆	Inconsistent readings if condition of equipment is not clean (matching the OEM table).
Equip. Cost	$$	Cost-effective, can start very low (<$100, to about $600)
Time (Min)	5 to 10	Process is straightforward. NCI is a good resource for this method.

Meets Standard 310

Does not meet Standard 310

TESP and OEM

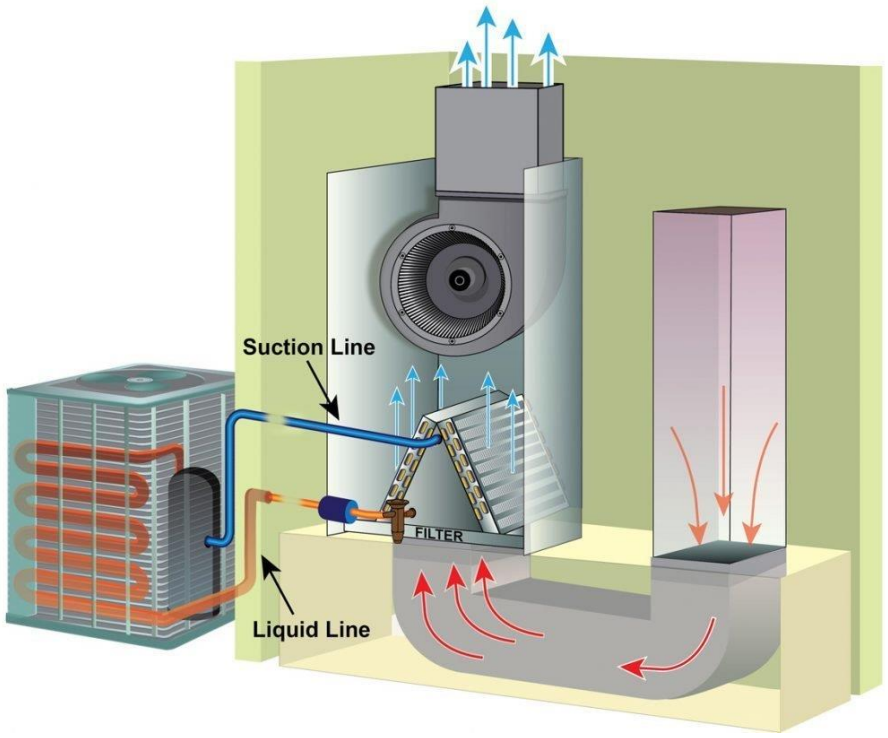
- Advantages: Low cost, Quick and easy (if table available), good for troubleshooting

- Disadvantages: Accuracy can be dramatically impacted by conditions (dirty blowers, coils, filters, etc.,)

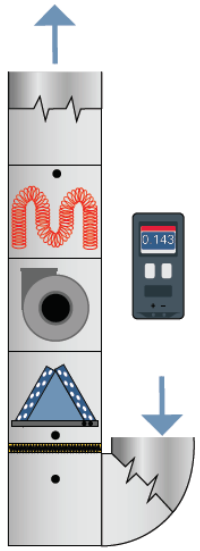
Understanding Digital True Flow

- Video 5’ 11”
- Energy Conservatory training video on Digital True Flow

True Flow example report



Summary calculations



Flow	316 CFM/ton
TESP	0.821 inH_2O
Filter Drop	0.193 inH_2O
Supply Plenum	0.064 inH_2O
Return Plenum	0.564 inH_2O

Warning Information - Suggested Actions

Flow is OK; High Return Pressure.	* Air Flow is OK, but the restriction in the return ducts may still cause high energy consumption or decreased motor life, especially for equipment with a constant air flow ECM motor * Return ducts are under-sized. Consider adding or enlarging return ducts. * Return ducts are blocked. Inspect for blockage.

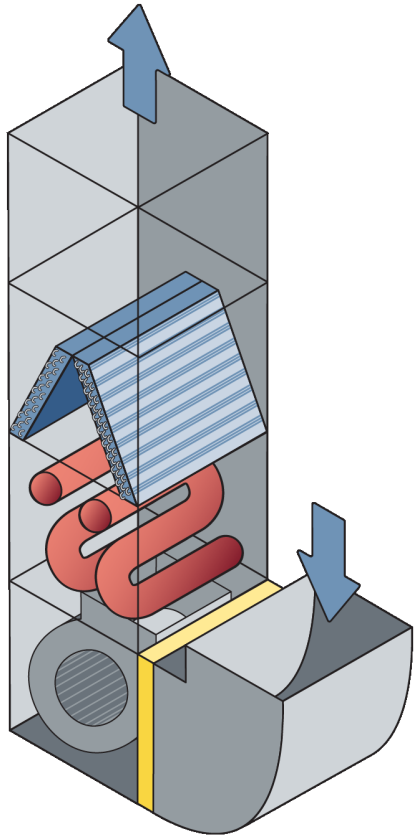
Photo from: *HVAC School for Techs by Techs, "Impacts of decreasing evaporator air flow", by Bryan Orr*

Static Pressure Example #2

- St Paul MN
- Energy retrofit with air sealing and new insulation

Detailed Steps	In Scope	Diagnosis Results for St. Paul, MN Home
HVAC Air Flow, TESP, Filtration	✓	Identified high airflow, TESP and filter pressure drop
Adjust HVAC System	1	Improve energy efficiency by lowering airflow, reducing filter drop. Consider filter slot adjustment to increase filtration.

Actions to be Taken	Airflow		TESP		Comments
	Test In (cfm/ton)	Test Out (cfm/ton)	Test In (inH2O)	Test Out (inH2O)	
Adjust HVAC System	**480**	**413**	**0.921**	**0.717**	Better latent capacity, reduce TESP Filter drop 0.281 to 0.228 inH2O

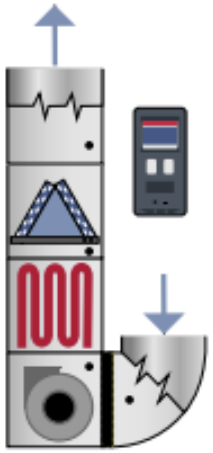


Static Pressure Example #2

As found cooling set to high

Summary calculations

Flow	480 CFM/ton
TESP	0.921 inH_2O
Filter Drop	0.281 inH_2O
Evap. Coil Drop	0.159 inH_2O
Supply Plenum	0.138 inH_2O
Return Plenum	0.342 inH_2O



Summary of Warnings

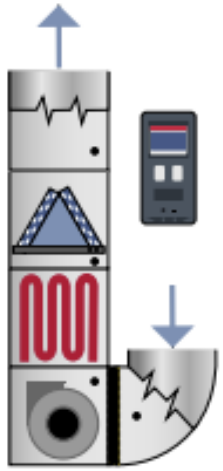
Flow is OK, very high filter drop

Flow is OK; High Return Pressure.

After Adjustment – cooling set to low

Summary calculations

Flow	413 CFM/ton
TESP	0.717 inH_2O
Filter Drop	0.228 inH_2O
Evap. Coil Drop	0.122 inH_2O
Supply Plenum	0.110 inH_2O
Return Plenum	0.257 inH_2O



Summary of Warnings

Flow is OK, high filter drop

Questions?

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T·E·C
THE ENERGY CONSERVATORY

Bruce Stahlberg

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Thank You!