Best Practices for HVAC and Heat Pump Performance for Residential Structures

Steve Easley,
www.steveeasley.com

Steve Easley

Steve Easley is an internationally recognized construction consultant specializing in solving building science related problems and educating building industry professionals and their trade partners. His work focuses on increasing quality of construction, sustainability, performance, and reducing costly mistakes that lead to construction defects and call backs.

- Steve's mission is helping industry professionals build & remodel structures that are durable, energy efficient, healthy and comfortable to live and work in.

For articles and publications visit www.steveeasley.com

Google Steve Easley videos

Course Description

- Heat pump technologies have evolved greatly in efficiency and popularity in recent years.
- In this class you will learn how heat pumps work to heat and cool homes. This class will detail proper design and installation as well as the common mistakes that lead to poor performance, call backs and high bills. This class will explain how heat pump efficiency is measured and how to select heat pumps for performance and comfort. Steve Easley uses pictures from real world successes and failures so you will learn how to get the most out heat pump technologies.
- Will Illustrate common installation mistakes.

Objectives

- Understand how heat pumps work
- Learn how heat pumps compare to traditional fossil fuel equipment for space heating including their strengths and weaknesses
- Compare air source, ground source and water source heat pumps.
- Understand how set customer expectations in terms of comfort and operating costs
- Know the operational requirements to achieve expected efficiencies.
- Learn the common design and installation mistakes made that can forfeit efficiency and energy savings

Disclaimer

The topics discussed and the content of this presentation are for **informational purposes only** and are not intended to be construed as exhaustive presentations of specific information or advice on any specific topic. Building designs, construction practices, building codes, and climate conditions vary widely throughout North America, and the rest of the world. Construction practices must be adapted accordingly. Viewers are strongly advised to seek counsel with local expertise and follow all local codes requirements regarding any project.

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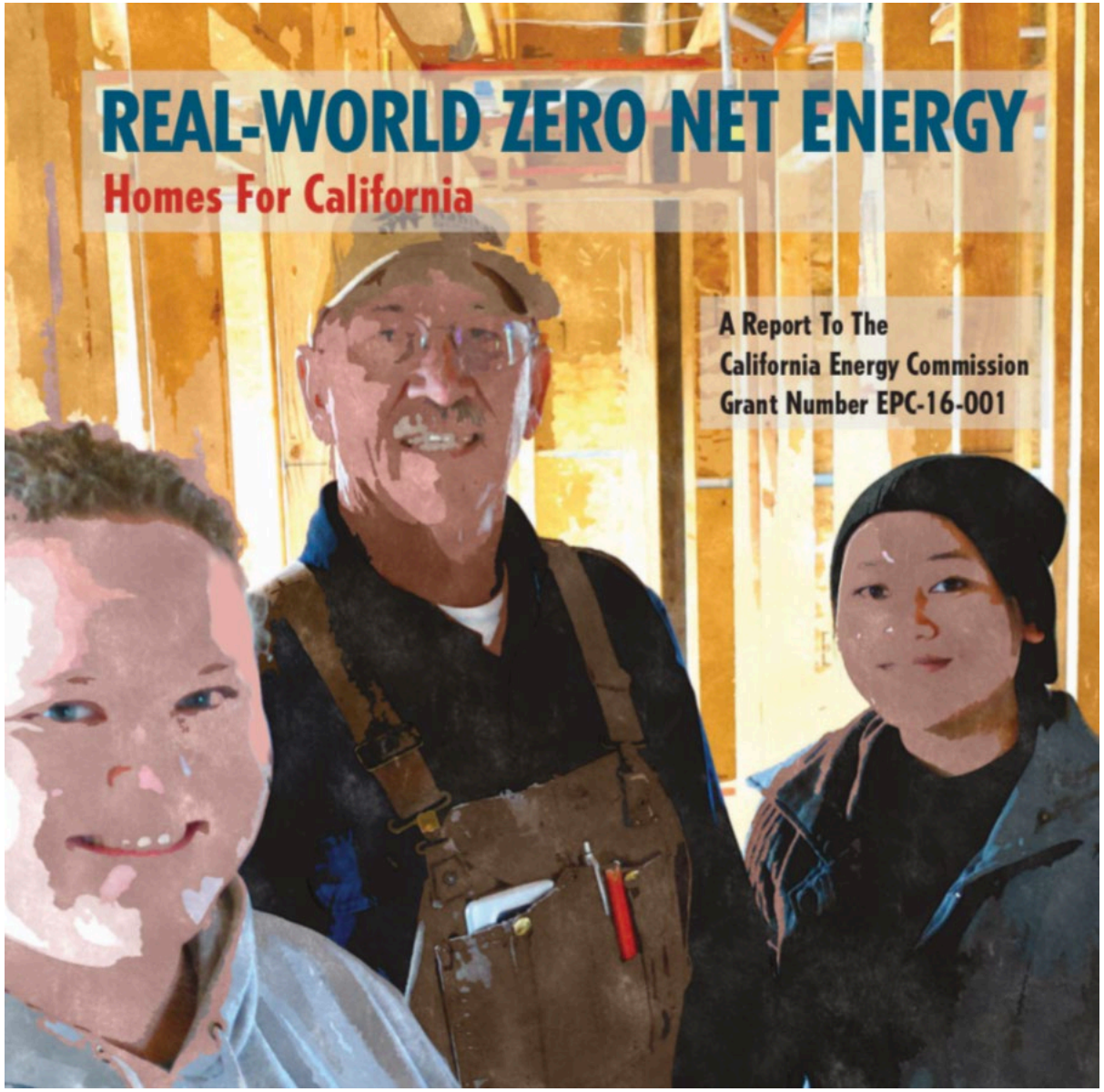
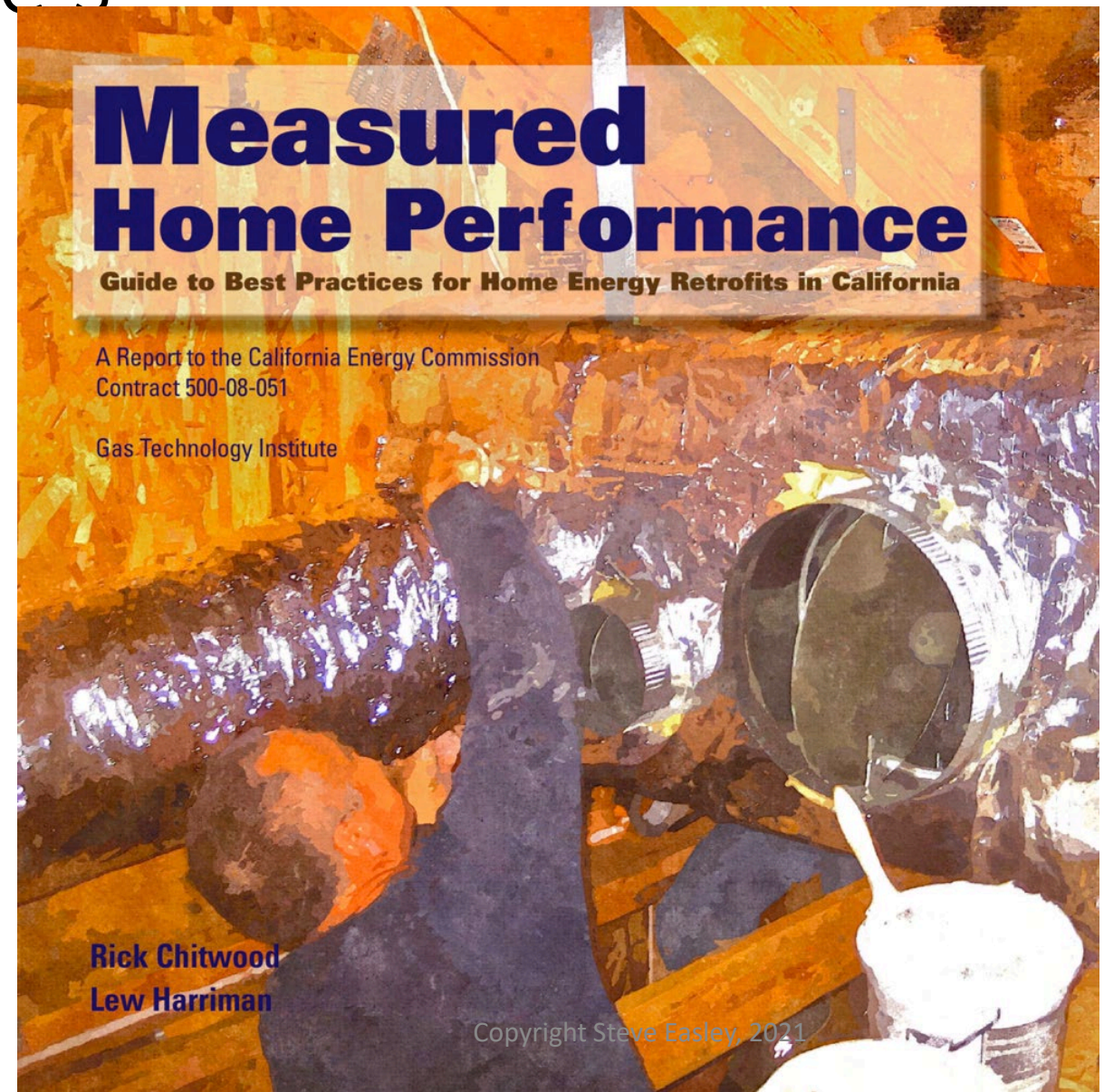
Resource's


REAL-WORLD ZERO NET ENERGY
Homes For California
A Report To The
California Energy Commission
Grant Number EPC-16-001

Resource's



ARTICLES & PUBLICATIONS

Steve has authored numerous articles featured in various periodicals, some of which include:

Builder Magazine

- Fine Home Building
- Custom Builder
- Popular Science
- Professional Builder
- Journal of Light Construction
- Coastal Contractor
- Smart Home Owner
- Lumberman's Journal

STEVE'S ARTICLES & BOOKS

GREEN BUILDER®
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https://www.greenbuildermedia.com/revision-house-scottsdale

THE FOREVER HOUSE
Remodeling for Sanctuary

Green Builder Media has joined forces with internationally renowned building science expert Steve Easley and his wife, Indoor Air Quality expert Susan Raterman, to retrofit a 3,050 square foot house in Scottsdale, Arizona. The goal of the project is to showcase to consumers and building professionals alike how to optimize performance, sustainability, wellness, aesthetics, intelligence, and durability in a remodeling project using the most advanced products, systems and technologies available on the market today.

See Project Videos

Uniquely positioned on a lake in McCormick Ranch, the ReVISION House Scottsdale will showcase cost-effective strategies for achieving net zero in a remodeling project using renewable energy, efficient mechanical systems, and advanced smart home technologies.

The project will also highlight trending lifestyle issues, such as health and wellness and aging in place designs and technologies.

Subscribe to updates on this project

Email*

MEET THE INFLUENCERS

Steve Easley, Msc, is an internationally recognized construction consultant specializing in solving building science related problems and educating building industry professionals and their trade partners. His work focuses on increasing quality of construction, sustainability, performance, and reducing costly mistakes that lead to construction defects and call backs.

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Project Updates

The Forever House: Remodeling for Sanctuary
by Matt Power, Editor-In-Chief posted at 12/9/20 12:05 PM

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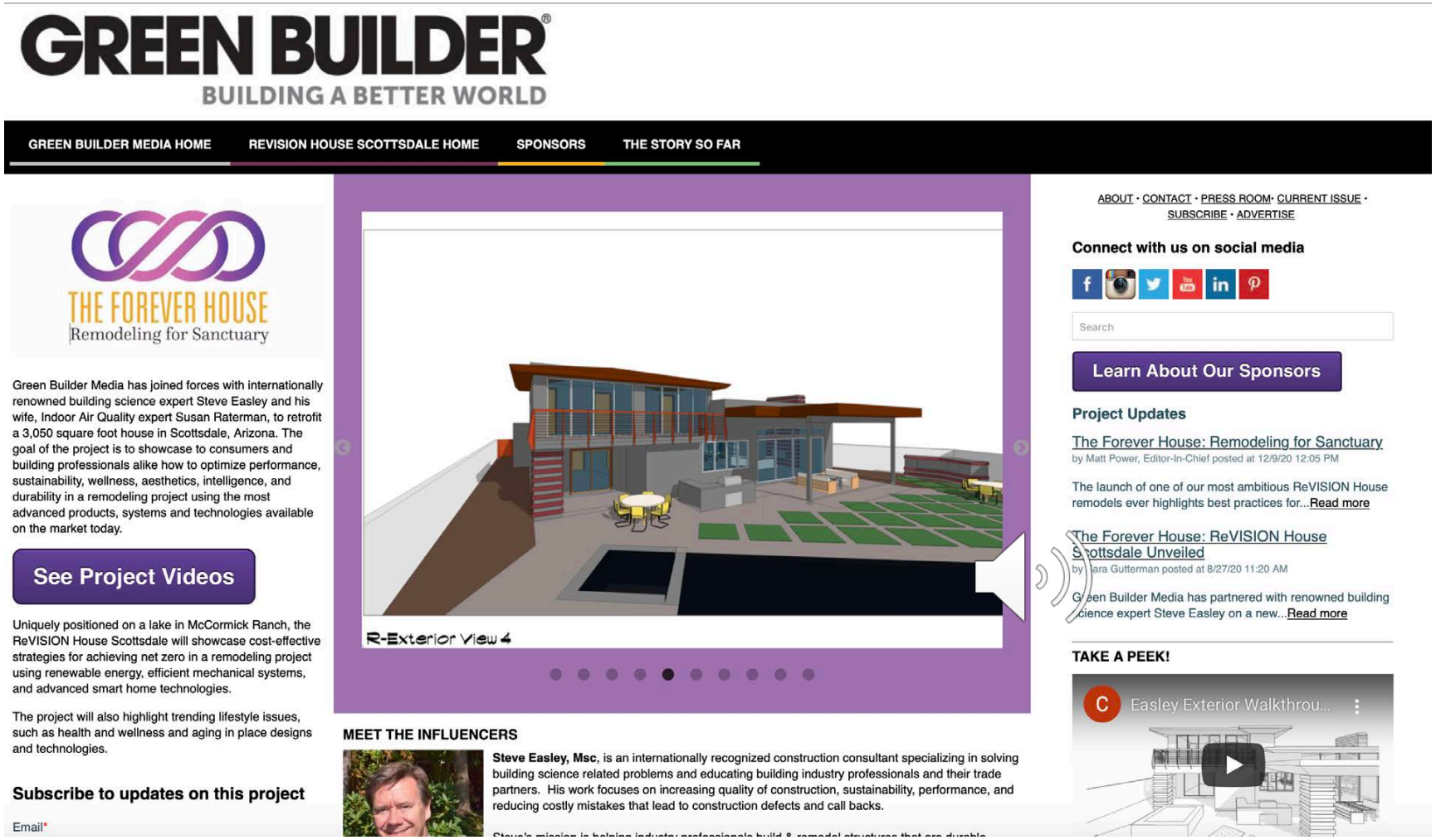
The Forever House: ReVISION House Scottsdale Unveiled
by Sara Gutterman posted at 8/27/20 11:20 AM

Green Builder Media has partnered with renowned building science expert Steve Easley on a new...Read more

TAKE A PEEK!



https://www.greenbuildermedia.com/revision-house-scottsdale

www.buildingamerica.gov

U.S. DEPARTMENT OF ENERGY | Energy Efficiency & Renewable Energy

BUILDING TECHNOLOGIES PROGRAM

VOLUME 14.

BUILDING AMERICA BEST PRACTICES SERIES

Energy Renovations

HVAC

A Guide for Contractors to Share with Homeowners

PREPARED BY

Pacific Northwest National Laboratory
& Oak Ridge National Laboratory

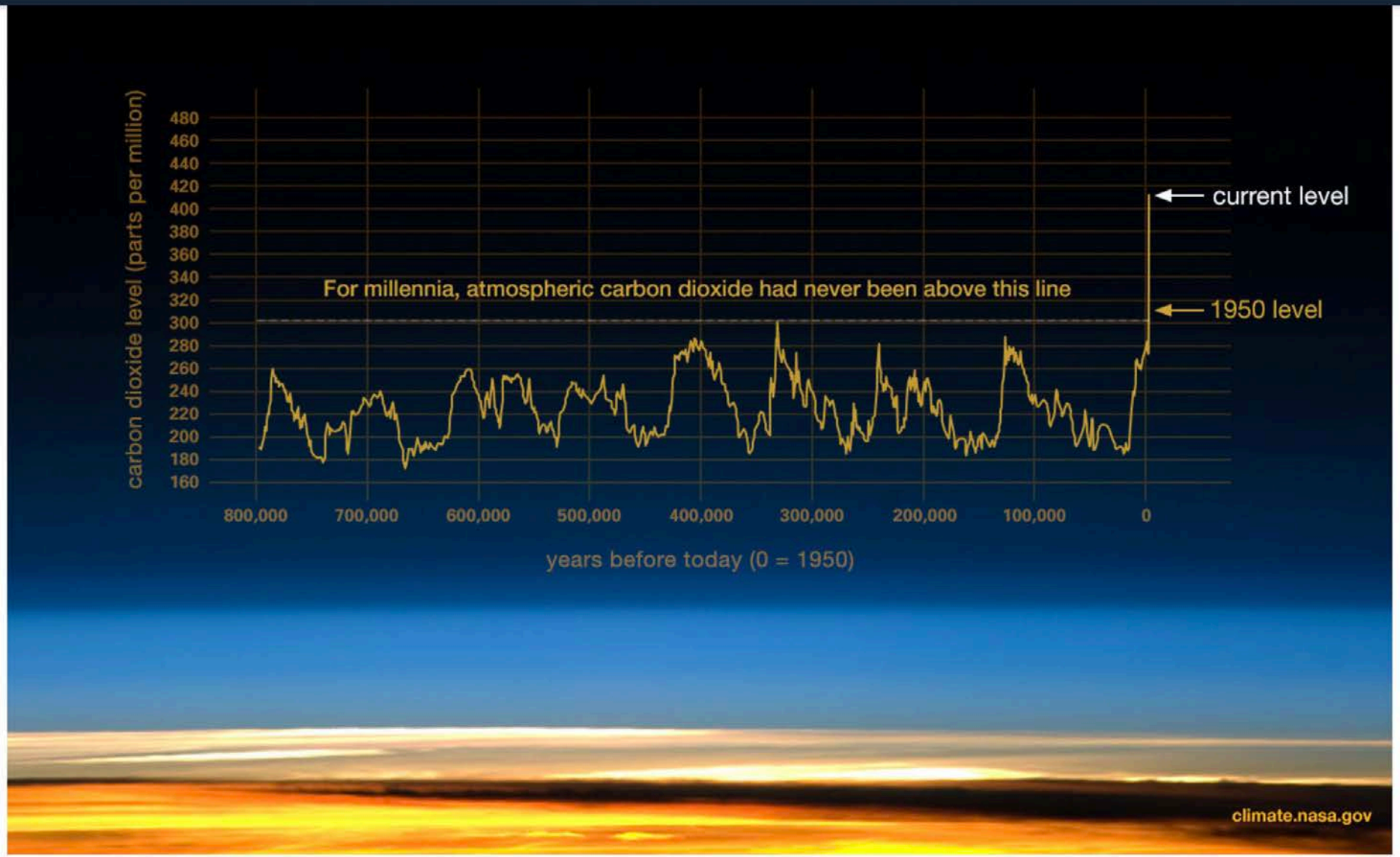
August 2011

Building AMERICA
U.S. Department of Energy

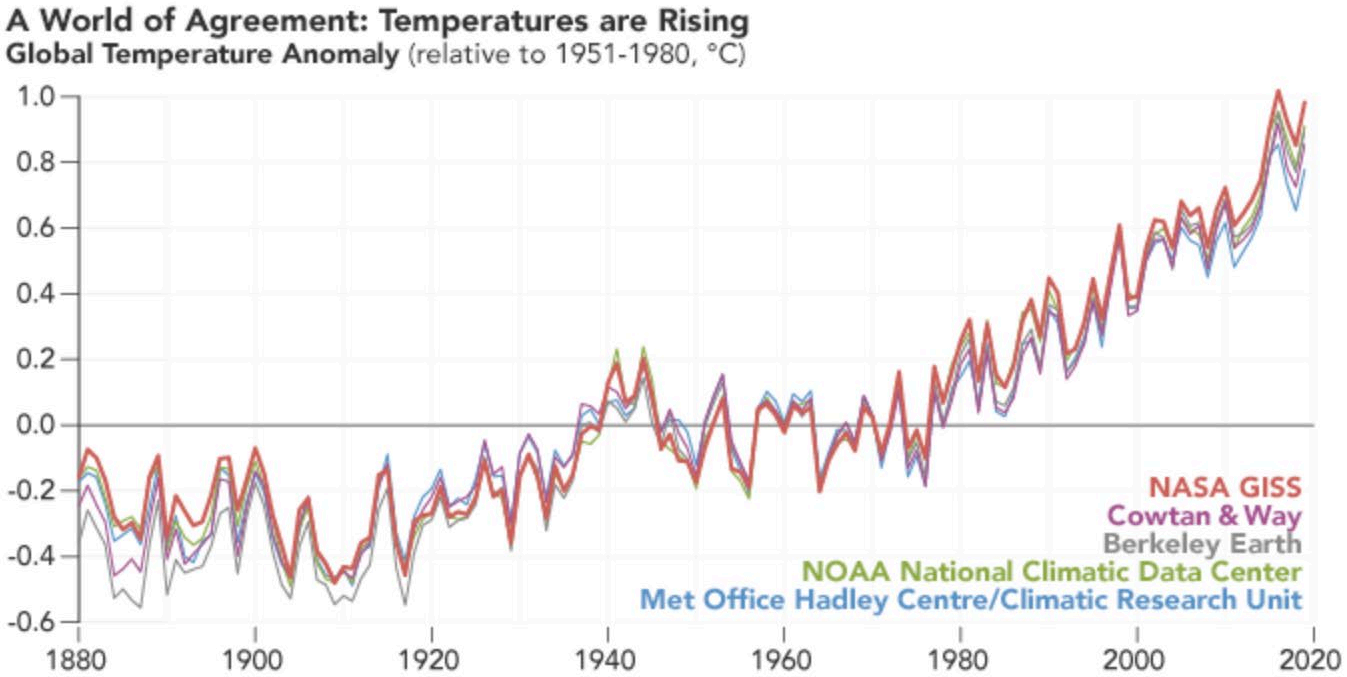
August 2011 • PNNL-20421

Why Heat Pumps for HVAC & DHW?

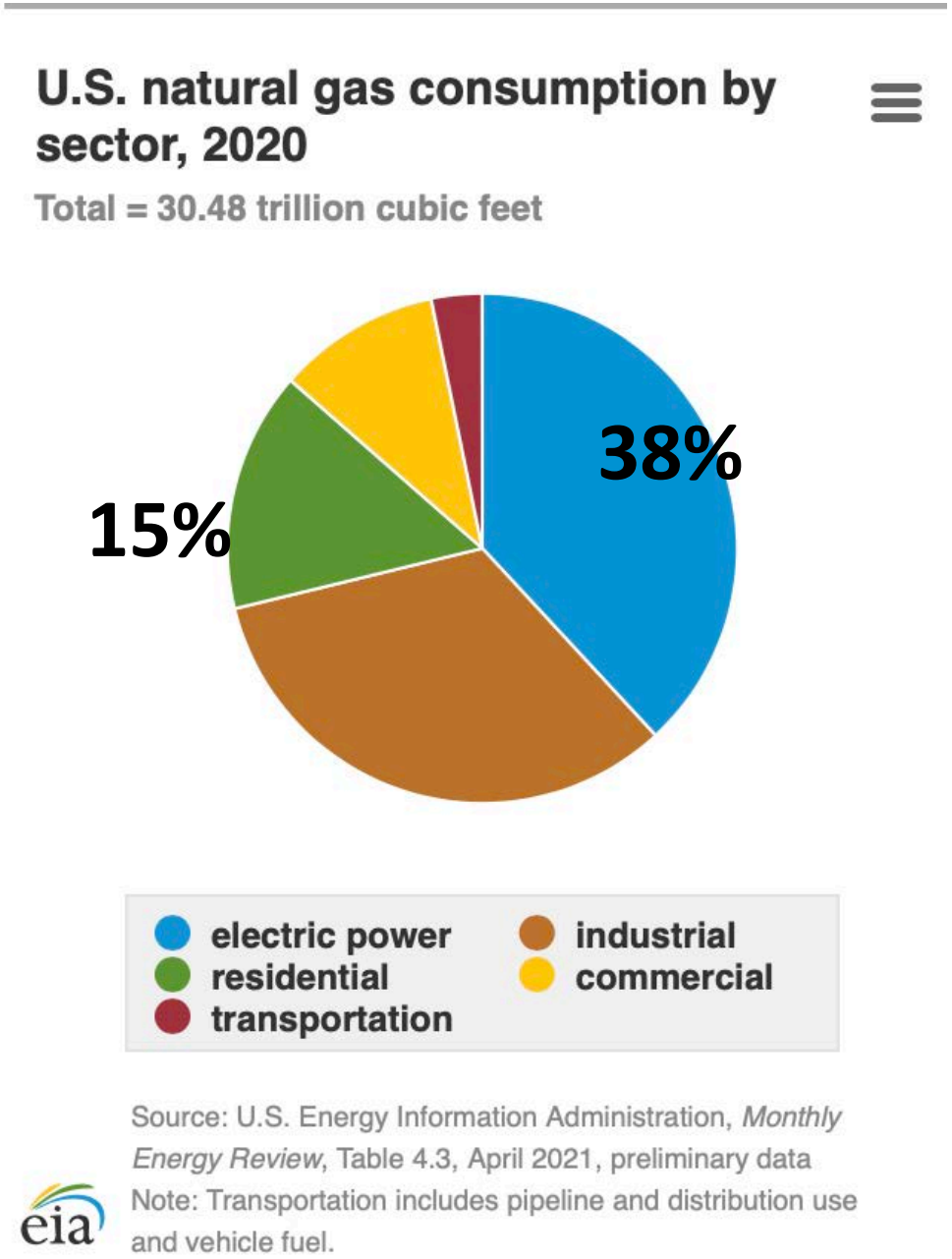
- 2-3X the efficiency
- Lower operating costs
- Better suited for low load homes
- Compact size for easy zoning
- No venting issues
- Less environmental impact than electric resistant systems
- Fossil fuel free heating and cooling



This graph, based on the comparison of atmospheric samples contained in ice cores and more recent direct measurements, provides evidence that atmospheric CO_2 has increased since the Industrial Revolution. (Credit: Luthi, D., et al.. 2008; Etheridge, D.M., et al. 2010; Vostok ice core data/J.R. Petit et al.; NOAA Mauna Loa CO_2 record.) Find out more about ice cores (external site).



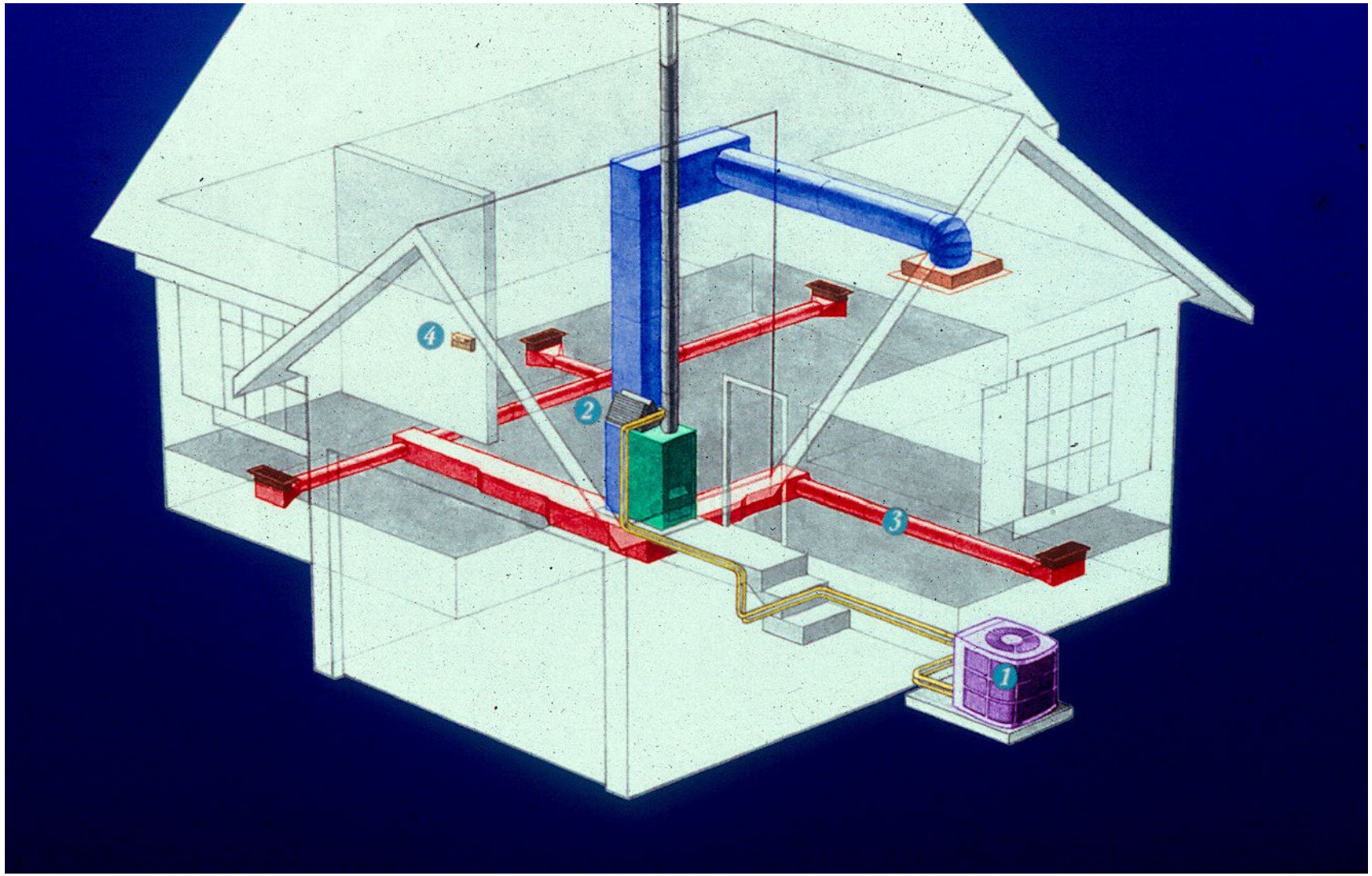
In 2020, the United States consumed an average of about 18.12 million barrels of petroleum per day and 30.5 Trillion CF/yr of Natural Gas Source E.I.A.gov

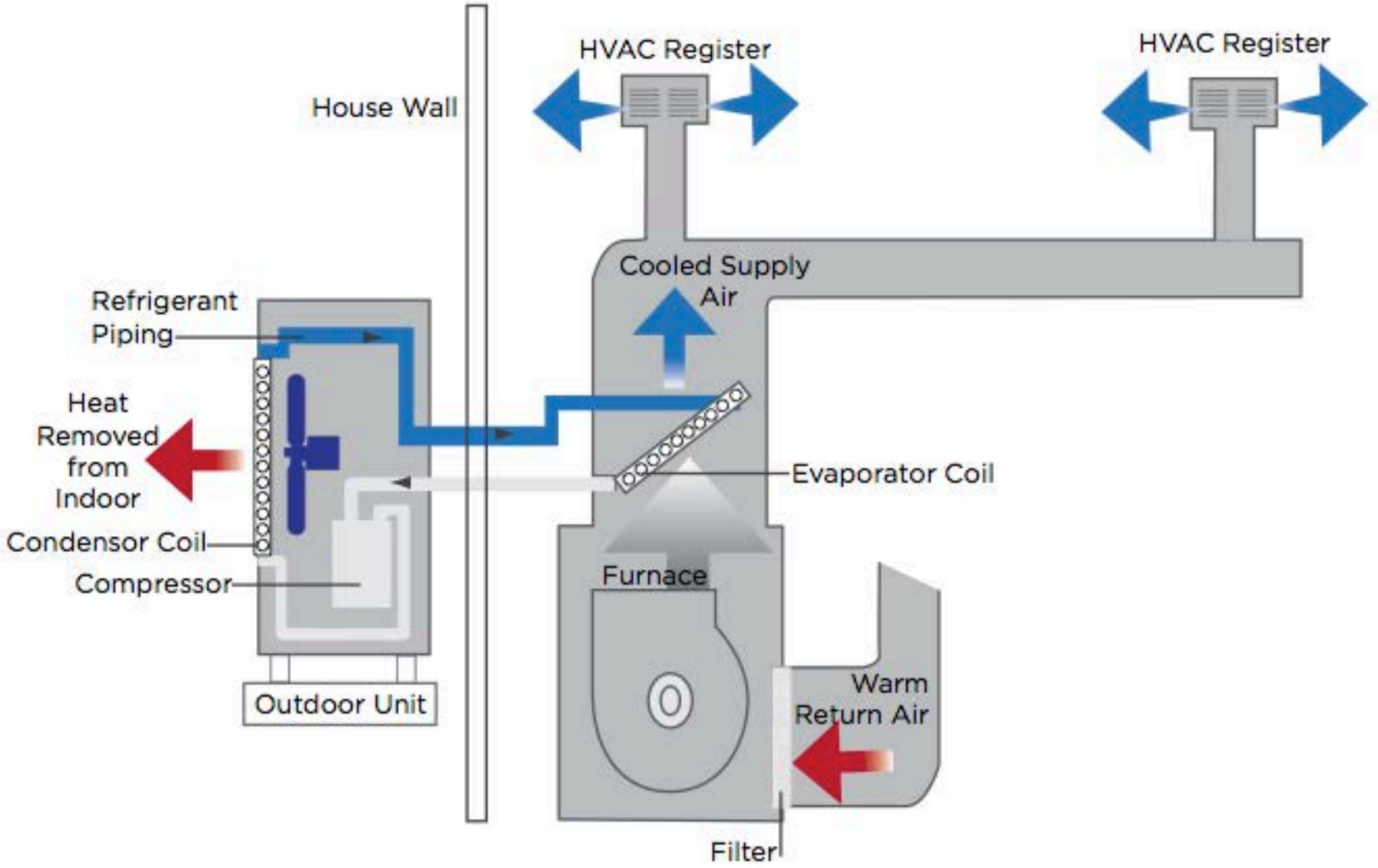


For Electrification To Be Successful

- Set realistic customer expectations, heat pumps operate differently.
- In retrofits the building enclosure needs to be of focus.
- The distribution system is KEY to performance and comfort.
- Installers NEED education!
- Customers need to be educated on how to operate them for efficiency and comfort.

Terminology



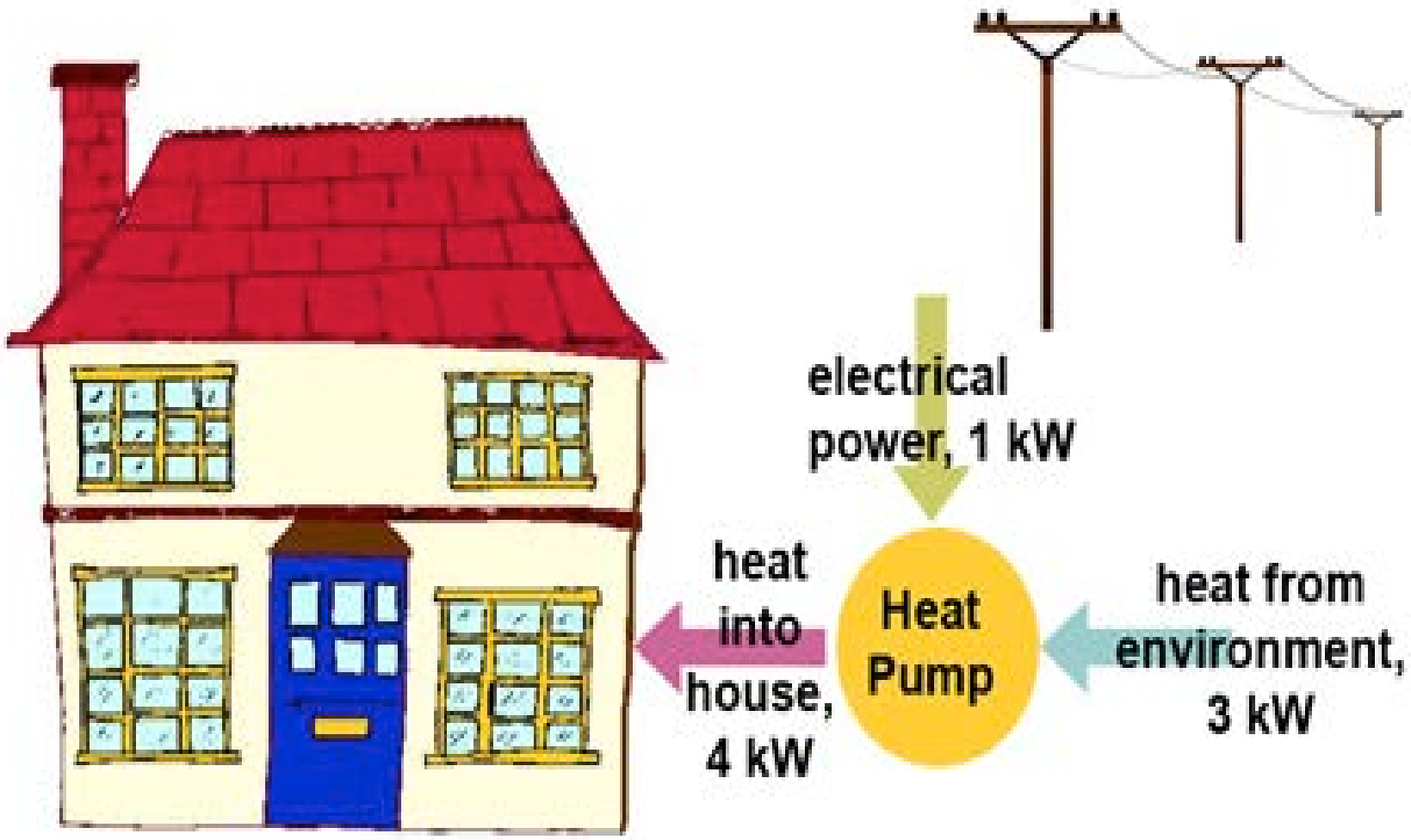


Central air conditioning equipment shares the air handler cabinet and duct distribution system with the furnace.

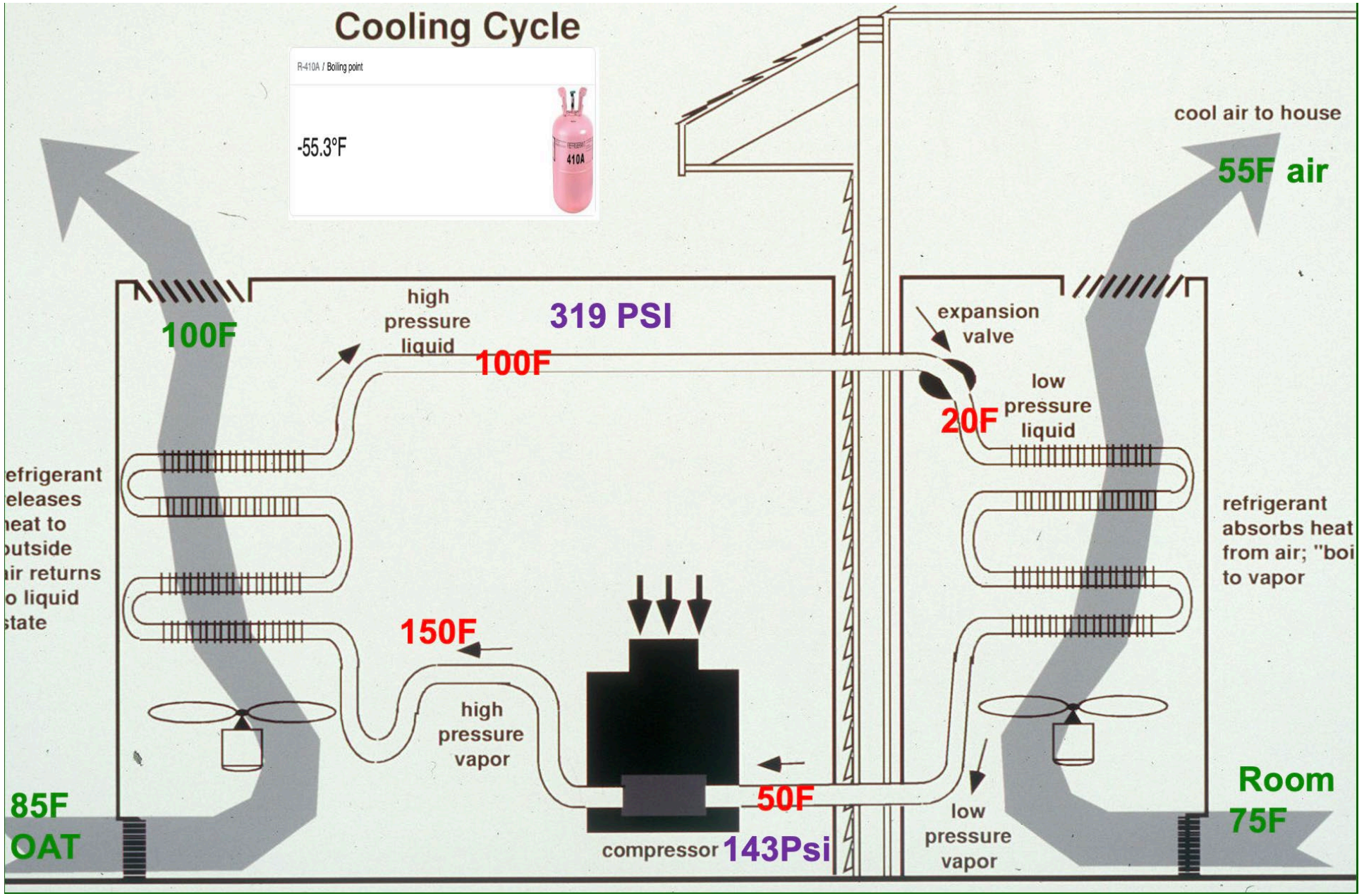
There are 1.6 Billion A/C Units Globally

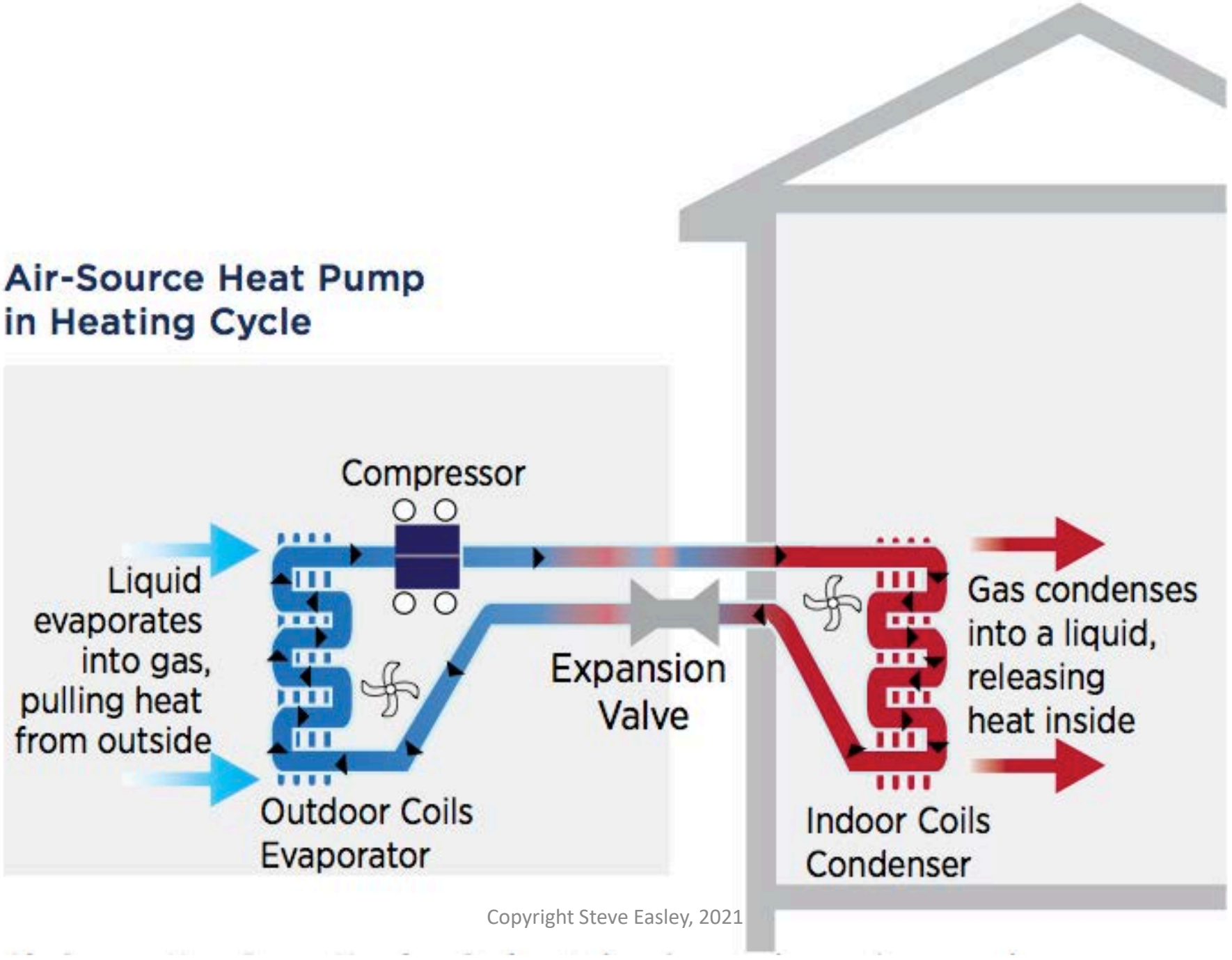
Types of Heat Pumps

- Air to air
- Ground source
- Water source
- Domestic hot water heating
- Clothes dryers




91%
isopropyl
alcohol
70°F
148°F
ALARM
DOT





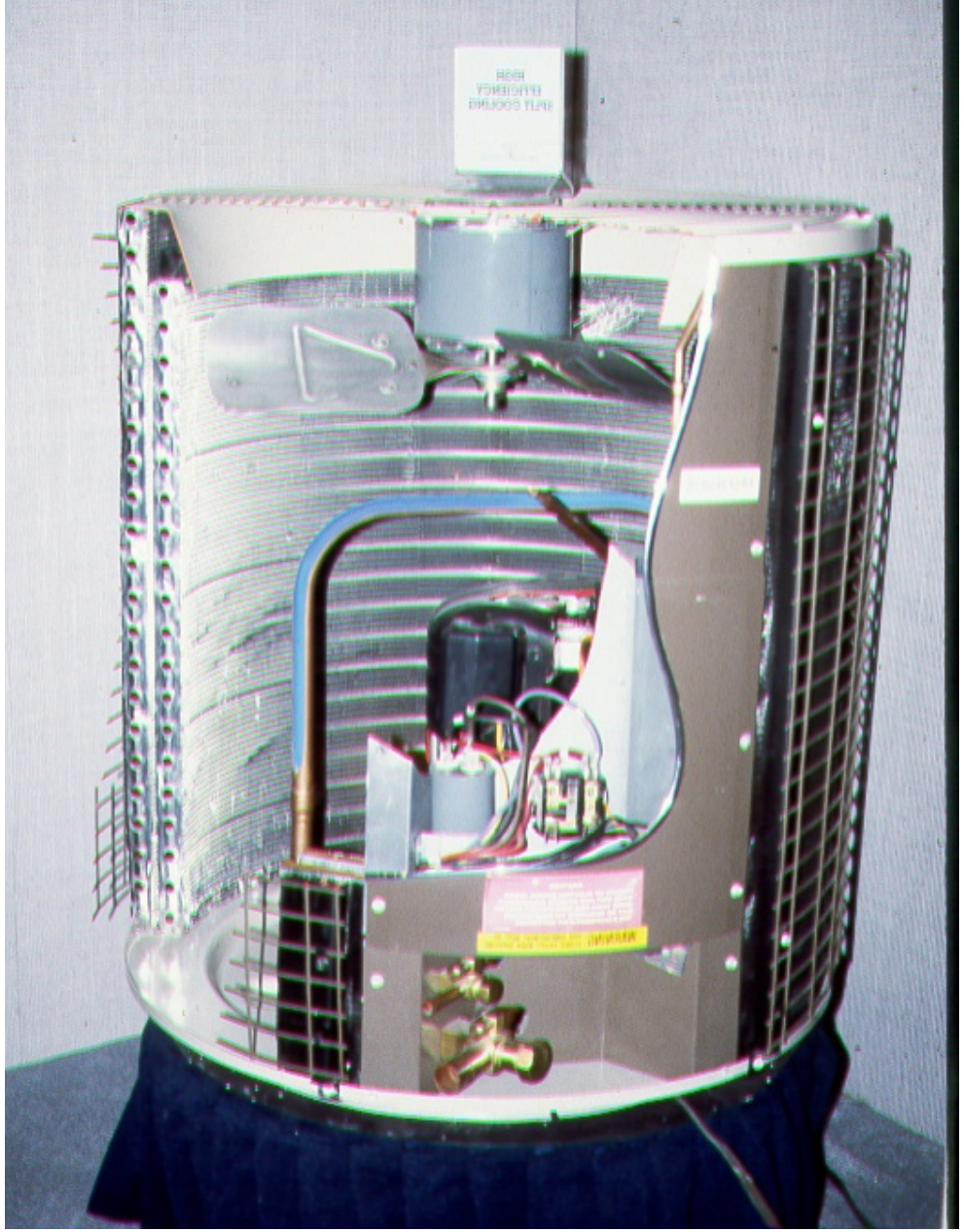
Variable Speed

2 Speed

Single Speed

Piston, Rotary, Screw and

Scroll Mechanics

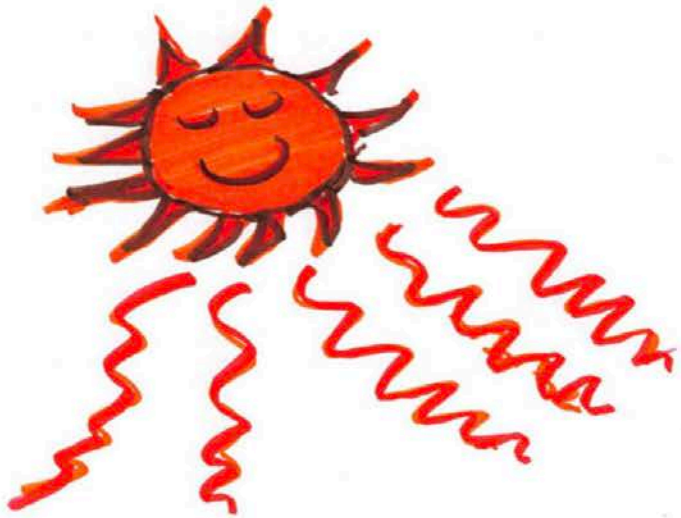


Types of compressors

HVAC Efficiency Metrics

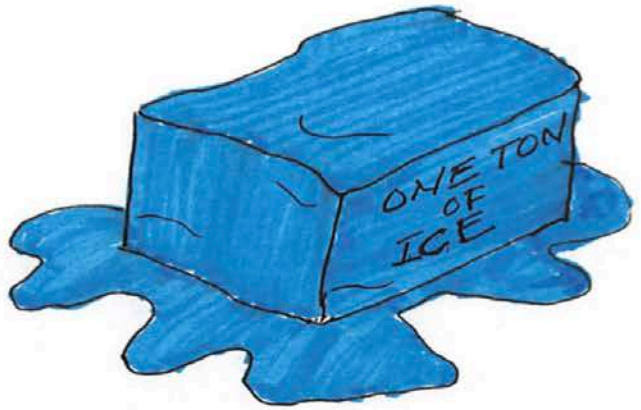
- AFUE
- SEER
- EER
- COP
- HSPF

A 2017 report from the Consumer Federation of America showed that these standards have saved consumers over $1 trillion dollars.



Cooling Capacity is measured in Tons. One ton = 12,000 BTU/hour

12,000 BTU/hour is the amount heat it takes to melt **one ton of ice** in 24 hours



One Ton of cooling

SEER, Seasonal & Energy Efficiency Ratio

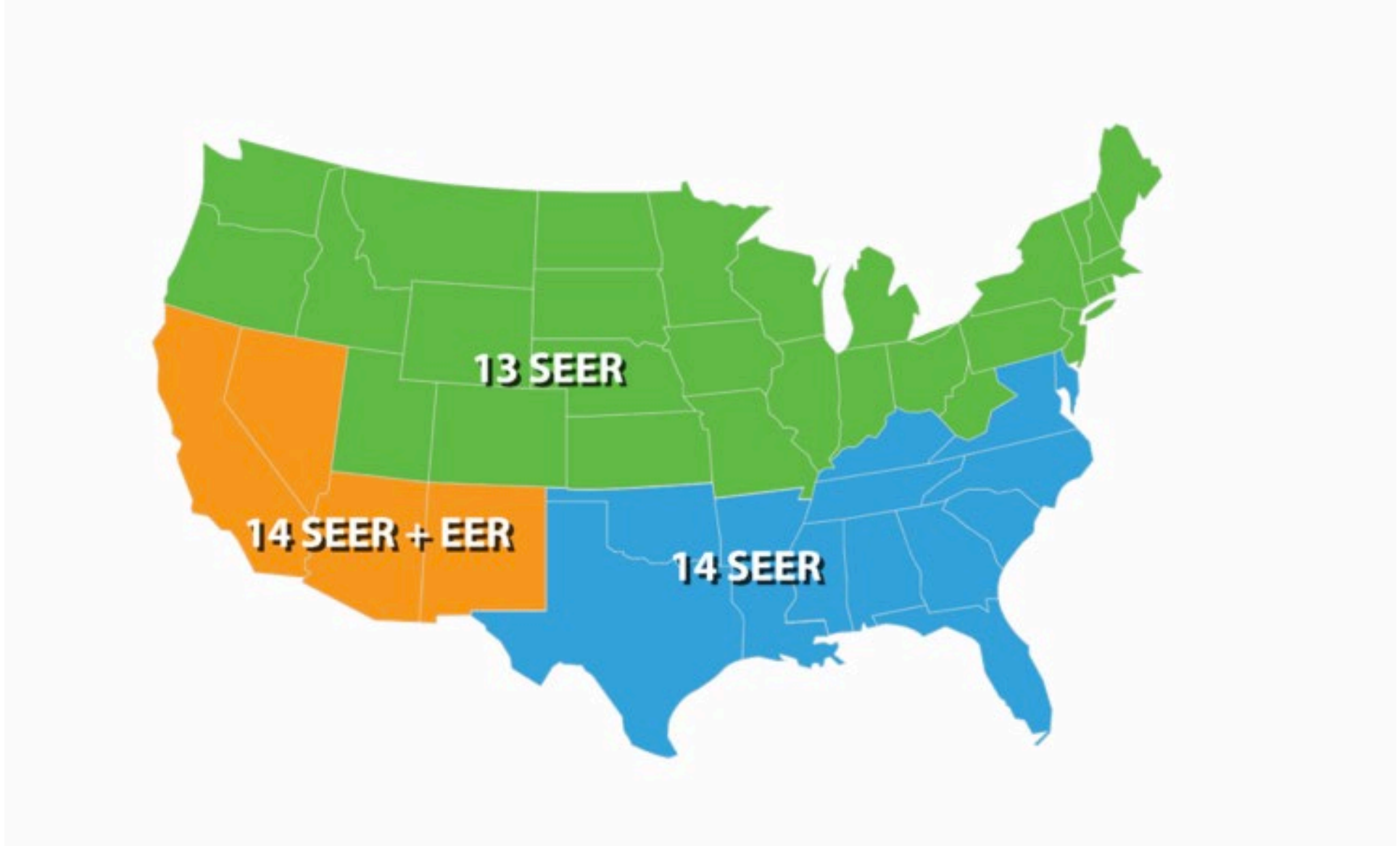
- EER = BTUH/input wattage

- SEER is the EER for a typical cooling season.

EER

$$EER = \frac{NetCapacity(Btuh)}{PowerInput(kW)}$$

48,000 BTUH/ 4800 watts = 10



Heating Seasonal Performance Factor

$$\text{HSPF} = \frac{\text{total heating during season, Btu output}}{\text{total electrical power input, watt-hours}}$$

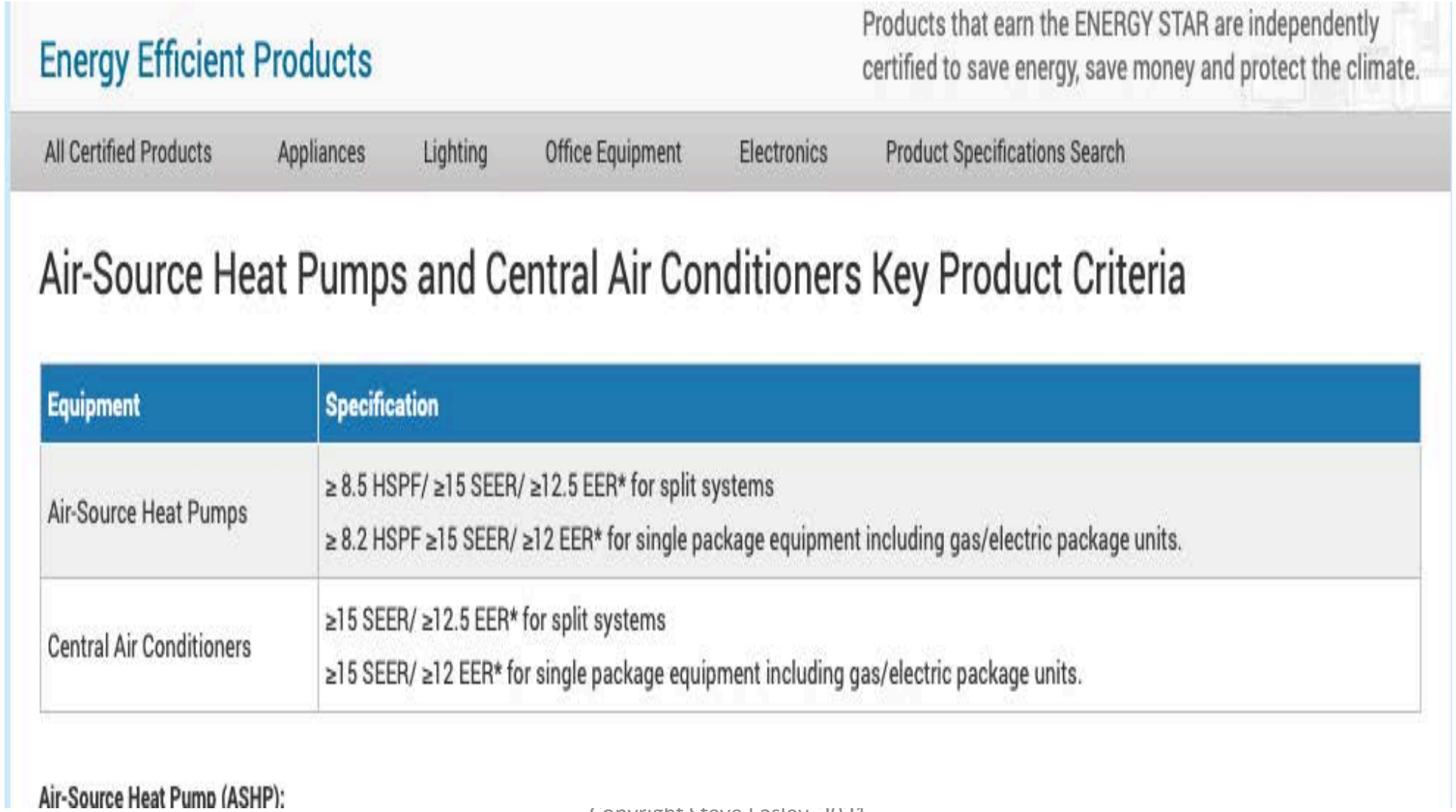
Minimum HSPF= 8.2-8.5 for Split Systems, as of Jan. 2015

HSPF rating of 8.2 will output 8.2 BTUs for every k

Example: a heat pump with an HSPF of 8.2 outputs 2.4 times (or 240 percent) the amount of BTUs than the energy it consumes, because 8.2 divided by 3.414 is 2.4

A heat pump with an HSPF rating of 9 is 23 percent more energy efficient than one with an HSPF rating of 8.2

Energy Star



Energy Efficient Products

Products that earn the ENERGY STAR are independently certified to save energy, save money and protect the climate.

All Certified Products | Appliances | Lighting | Office Equipment | Electronics | Product Specifications Search

Air-Source Heat Pumps and Central Air Conditioners Key Product Criteria

Equipment	Specification
Air-Source Heat Pumps	≥ 8.5 HSPF/ ≥15 SEER/ ≥12.5 EER* for split systems ≥ 8.2 HSPF ≥15 SEER/ ≥12 EER* for single package equipment including gas/electric package units.
Central Air Conditioners	≥15 SEER/ ≥12.5 EER* for split systems ≥15 SEER/ ≥12 EER* for single package equipment including gas/electric package units.

Air-Source Heat Pump (ASHP):

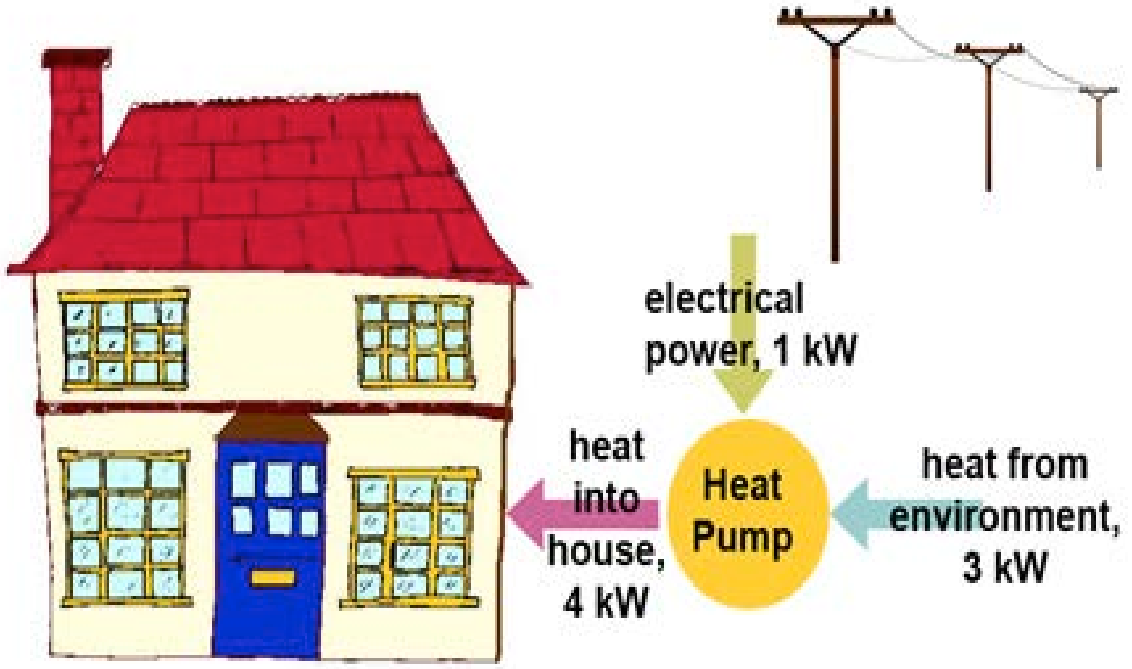
Coefficient of Performance

$$\text{COP} = \frac{\text{useful energy output, Btu/h}}{\text{energy input, watts} \times 3.413 \text{ Btu/h/watt}}$$

COP

- A COP of 3 means 1 KWH of electricity yields 3 KHW of heat
- Out door air already contains heat

0 degree air contains 82% of the heat of air at 100 degrees F

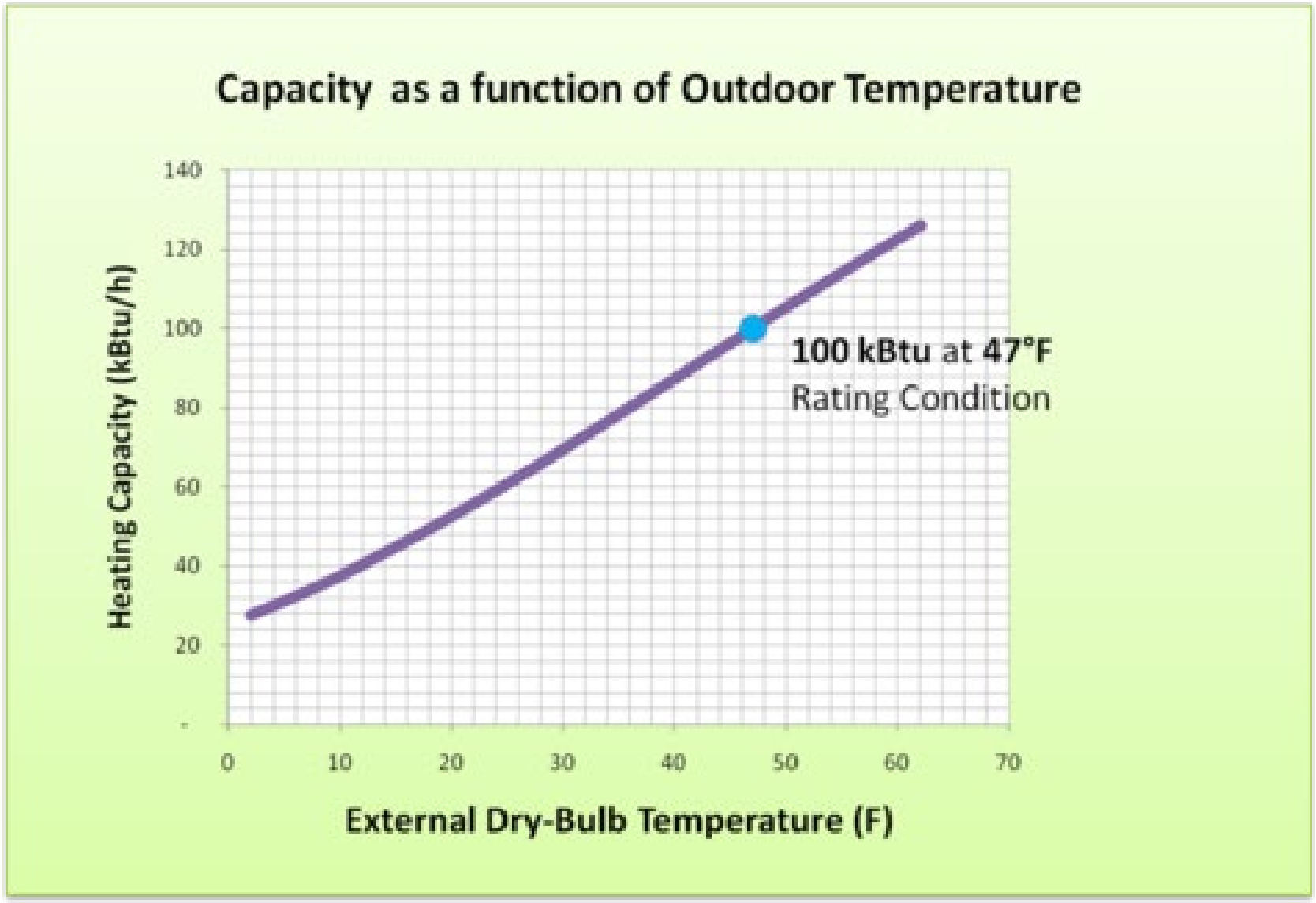


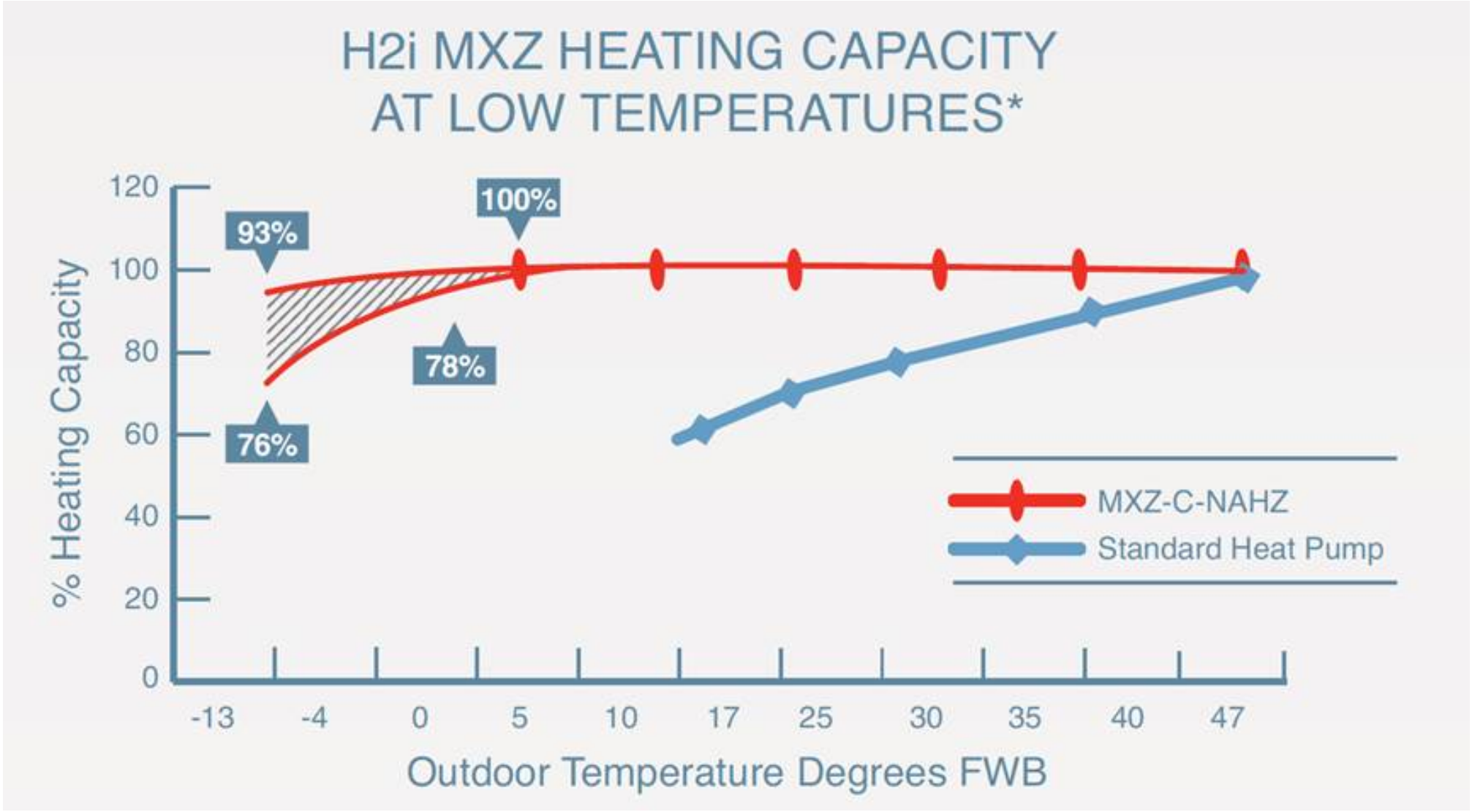
COP & EER Conversations

- **COP = EER/3.413**
- **EER = COP X 3.413**

Heat Pumps & Efficiency

- Efficiency is related to (OAT) Outdoor air Temperature
- Capacity can related to (OAT) Outdoor air Temperature
- The colder the air the longer the unit has to run to extract the needed heat from the colder air
- The colder the air the lower the COP





Courtesy Mitsubishi

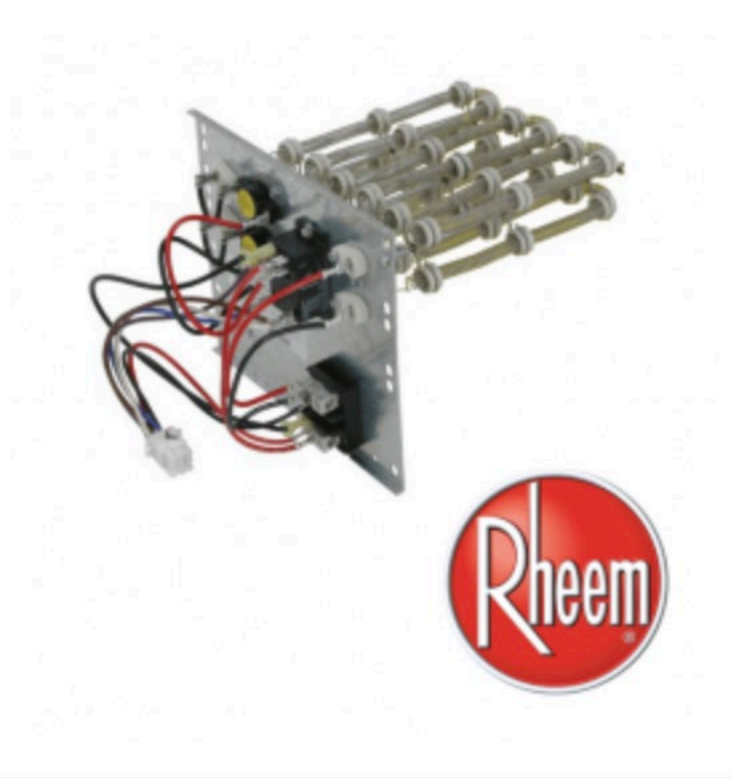
Heat Pumps & Comfort Concepts

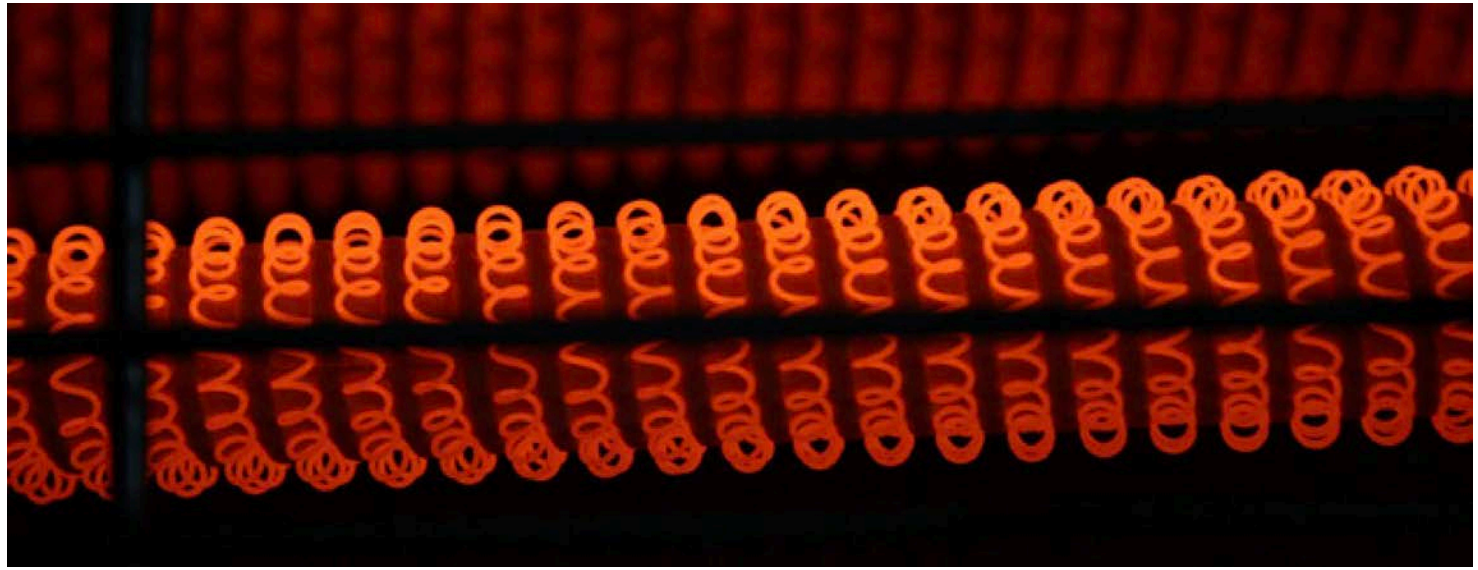
- Discharge temps lower (Function of OAT)
- Longer recovery time
- Enclosure air leakage rates have greater impacts
- Duct leakage & duct insulation has greater impact
- Get the enclosure right

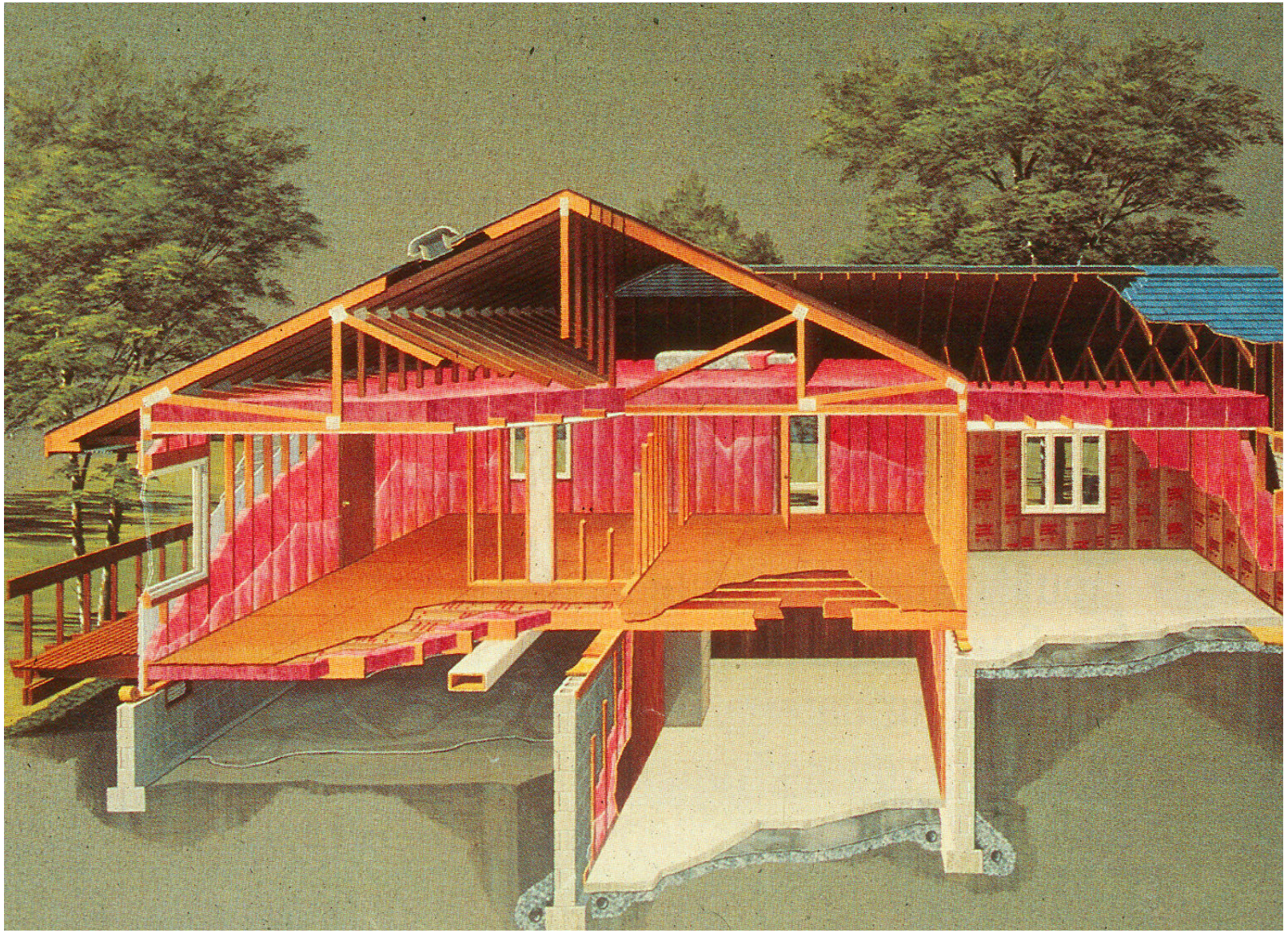
Understanding Customer Complaints… Setting Customer Expectations is Key to Reducing Call backs

- Takes too long to heat up my house
- Register discharge temperatures are Lower
- My bills are higher than they thought

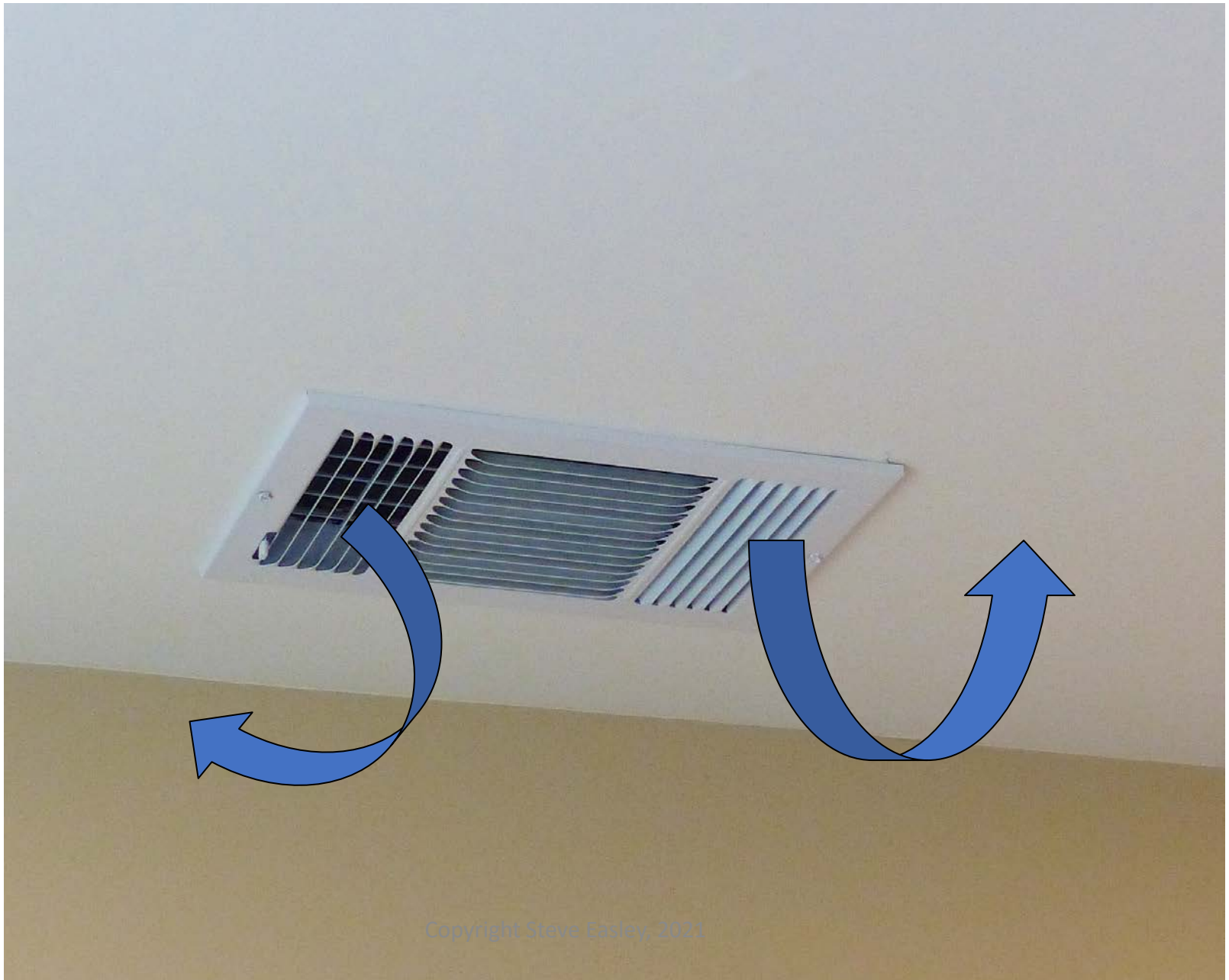
Heat Pumps Often Have Electric Back Up Strips





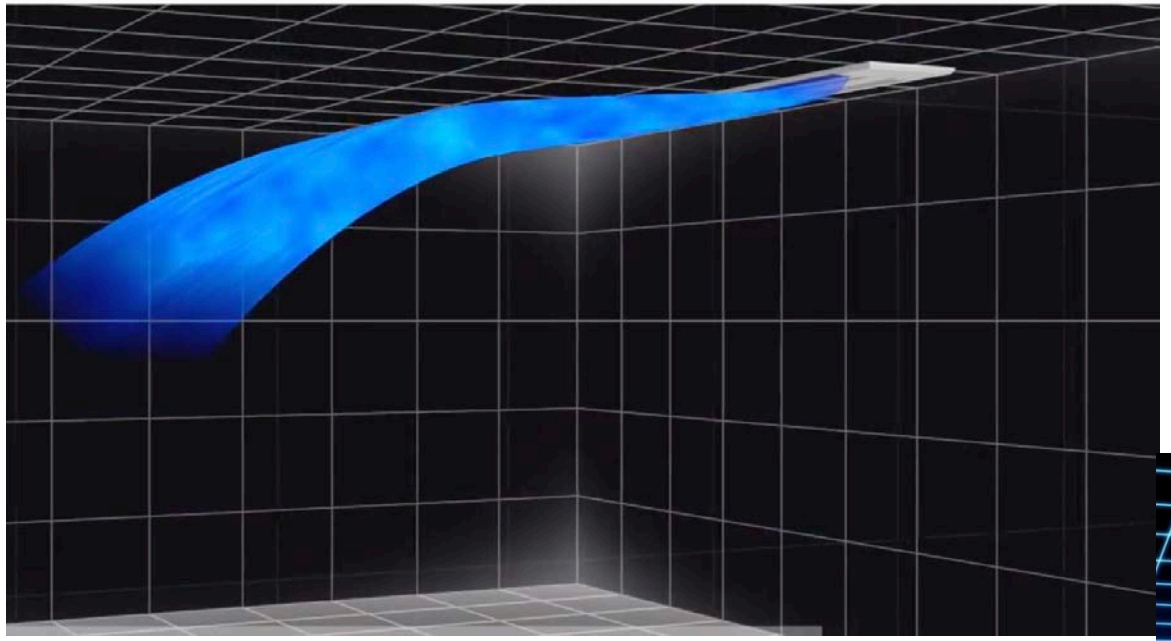


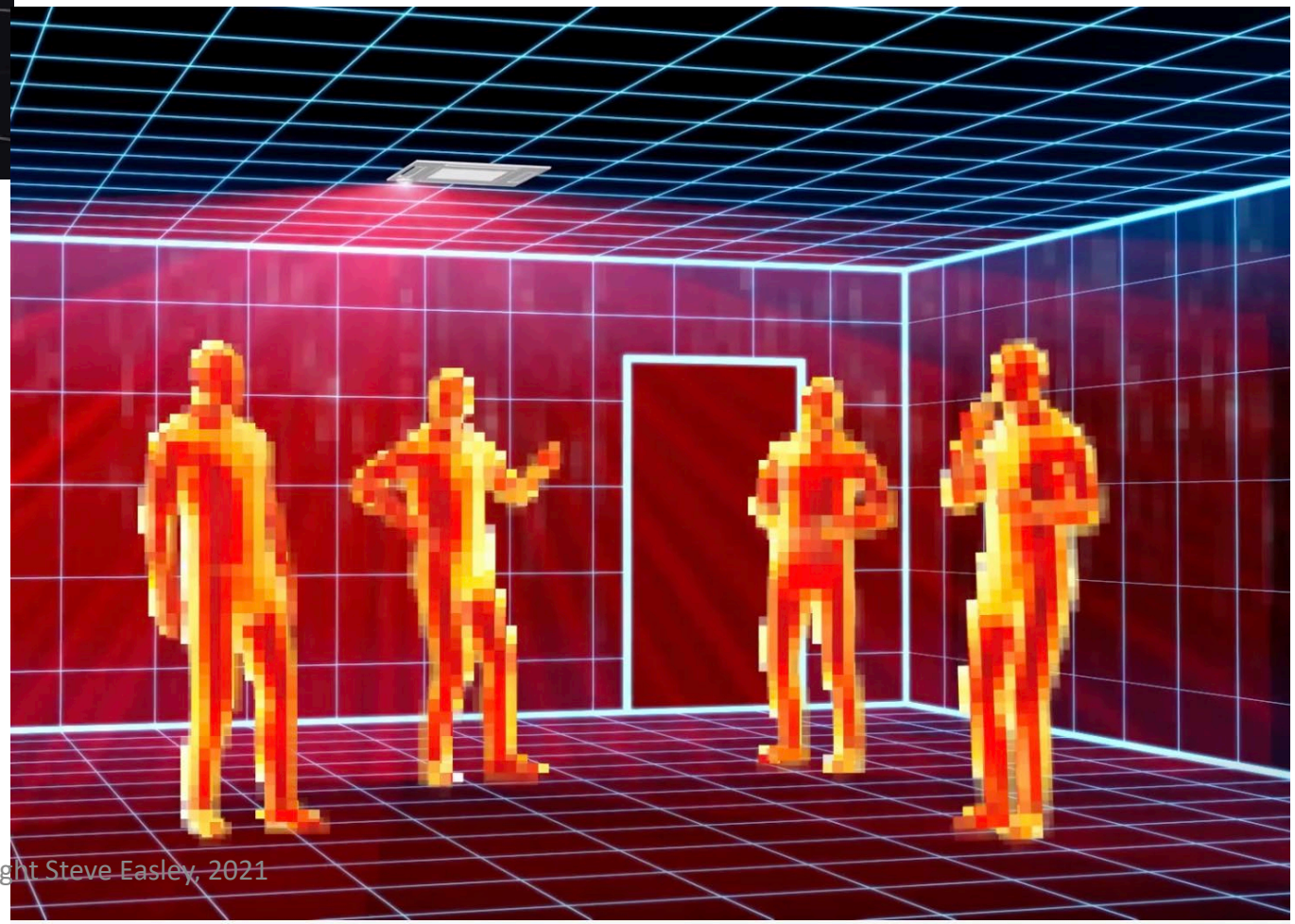
Air flow & comfort



Courtesy: Mitsubishi Electric Trane HVAC US LLC

Courtesy: Mitsubishi Electric Trane HVAC US LLC





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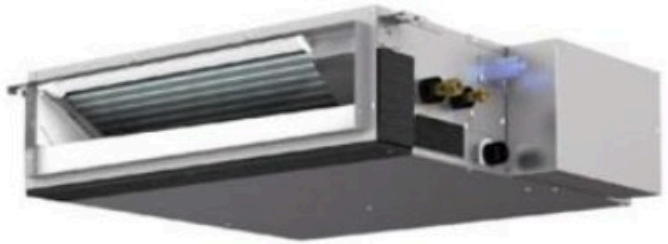
Heat pump space heating



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Geothermal Systems

- Water source
- Ground source

HOME PRODUCTS GEOTHERMAL

GEOTHERMAL

Harness the power of the earth in your home. No matter your region, EnviroWise™ geothermal systems tap into this renewable, sustainable fuel source to efficiently heat and cool your home, even your water.

EnviroWise™ Geothermal Systems

What's right for my home?

T2GX/T1GX

Geothermal water systems efficiently heat and cool your home by circulating fluid underground and transferring heat to another fluid loop built into your home. Paired with the reliability of Trane, it's more than smart. It's EnviroWise™.

- Up to 29.40 EER
- Variable-speed air flow
- Single- or two-stage compressor

T2GX/T1GX

- Up to 29.40 EER
- Variable-speed air flow
- Single- or two-stage compressor

T2GY

- Up to 23.70 EER
- Hot water generation
- Two-stage heating & cooling

NOT SURE WHERE TO START?

What's right for my home > | *Contact a Trane Comfort Specialist >*

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U.S. DEPARTMENT OF ENERGY | Energy Efficiency & Renewable Energy

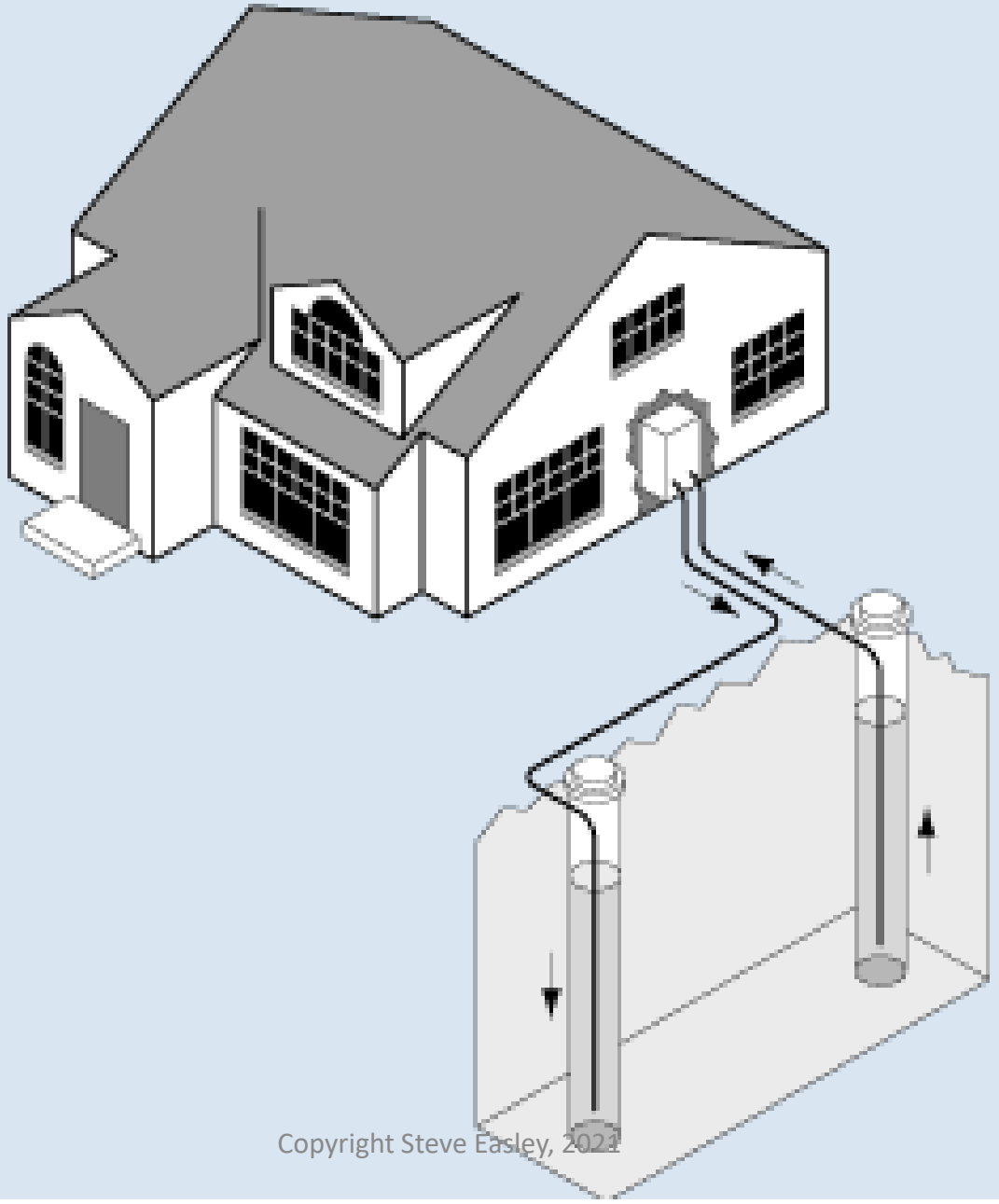
An In-Depth Look at Ground Source Heat Pumps and Other Electric Loads in Two GreenMax Homes

Srikanth Puttagunta and Carl Shapiro
Consortium for Advanced Residential Buildings

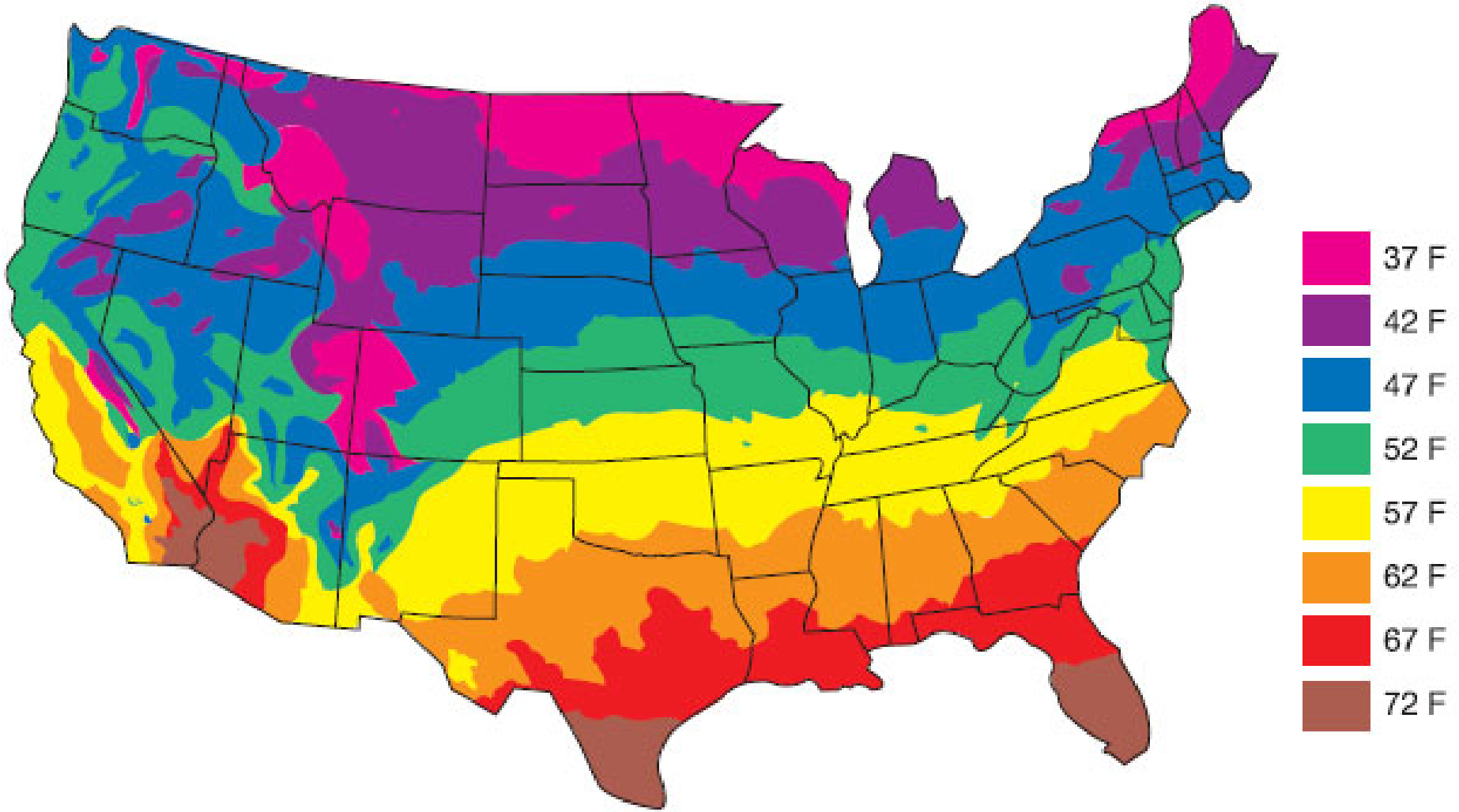
April 2012

Building AMERICA
U.S. Department of Energy

Open Loop Systems



Average Ground Water Temperature Across The USA



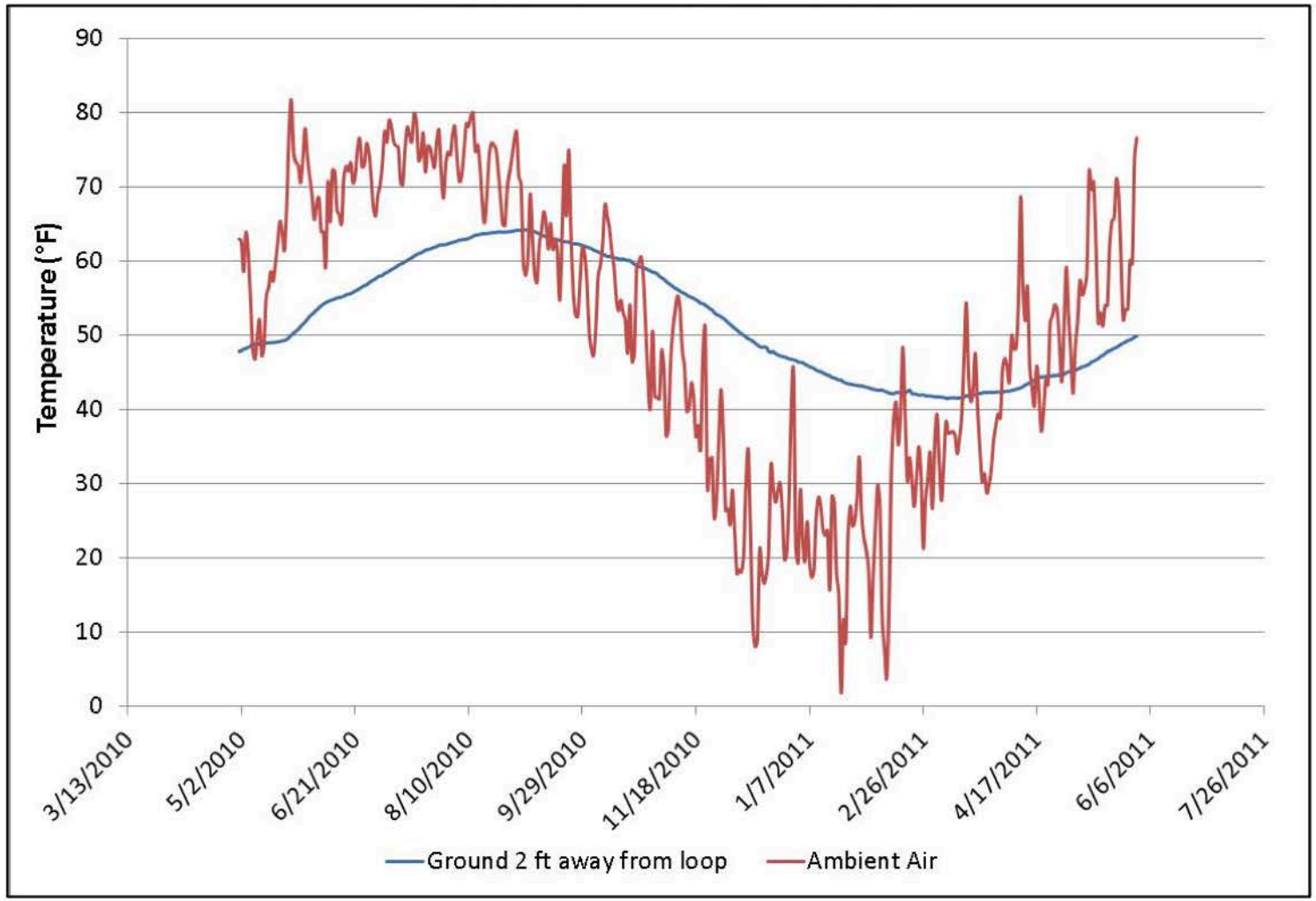
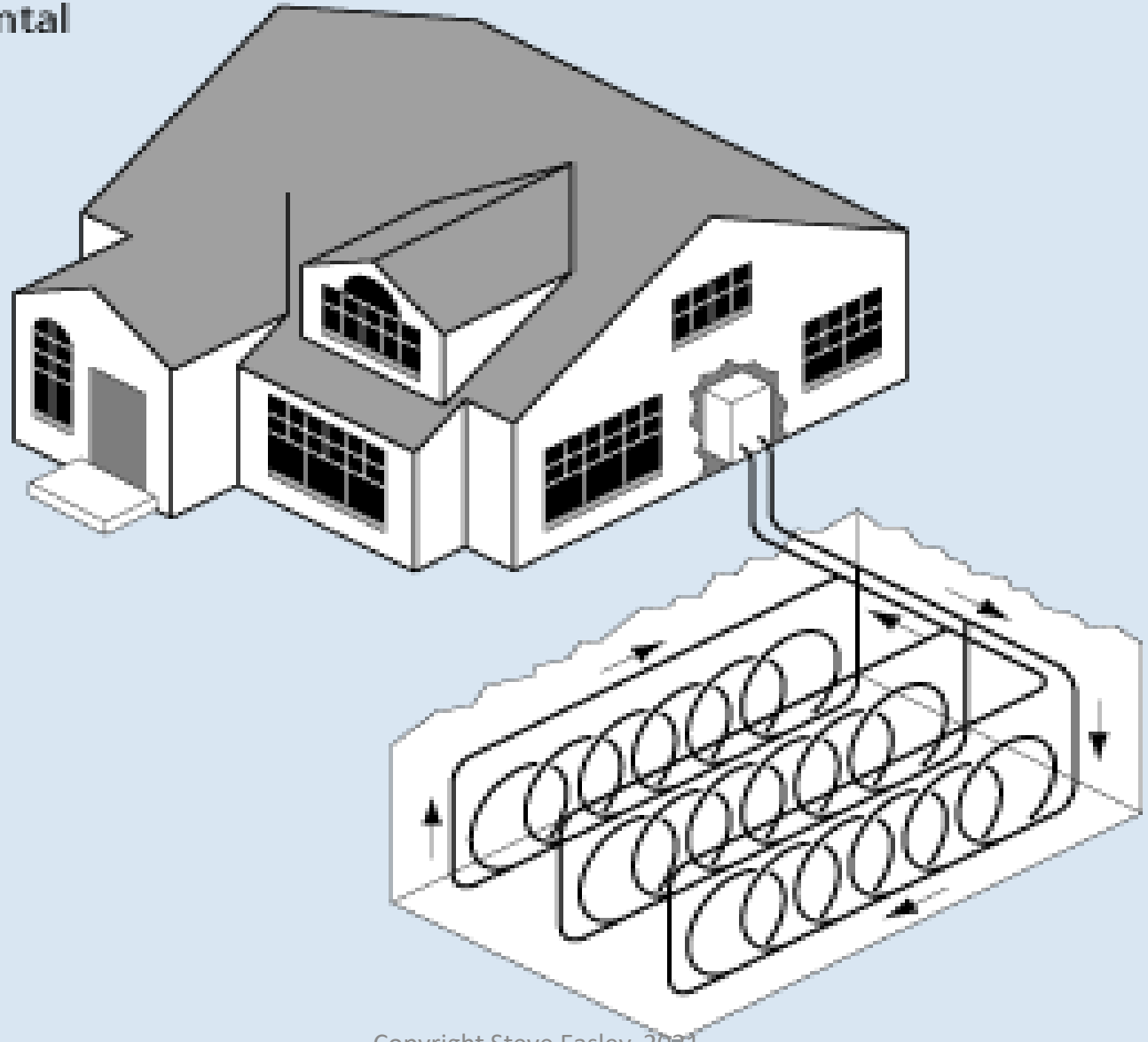


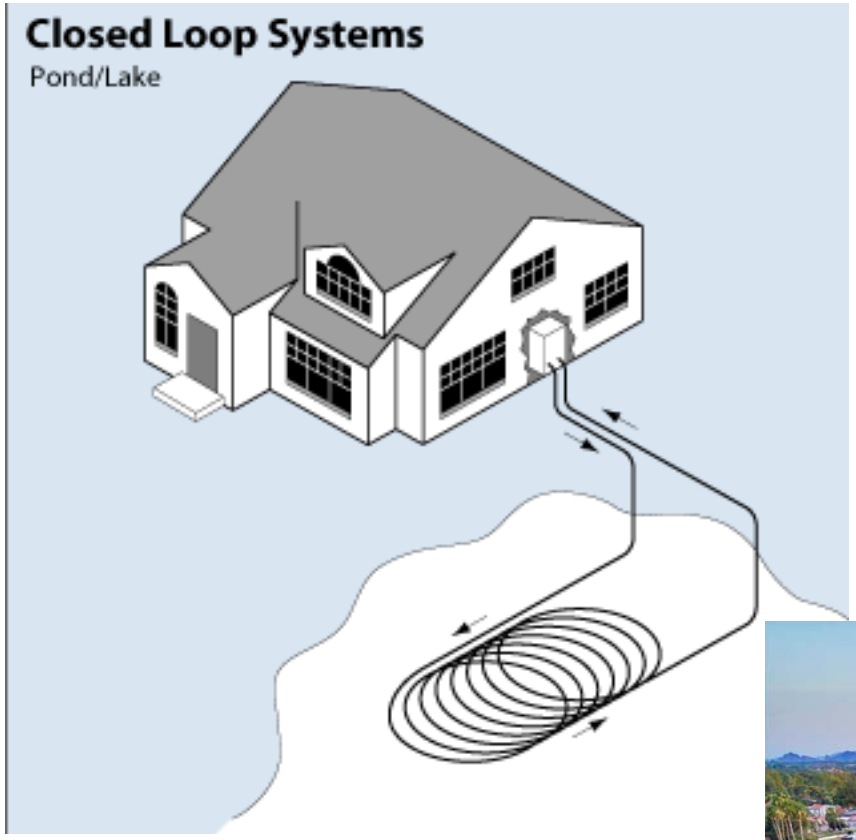
Figure 14. Mean daily ground temperature of the Stoughton home ground source field loop

Closed Loop Systems

Horizontal

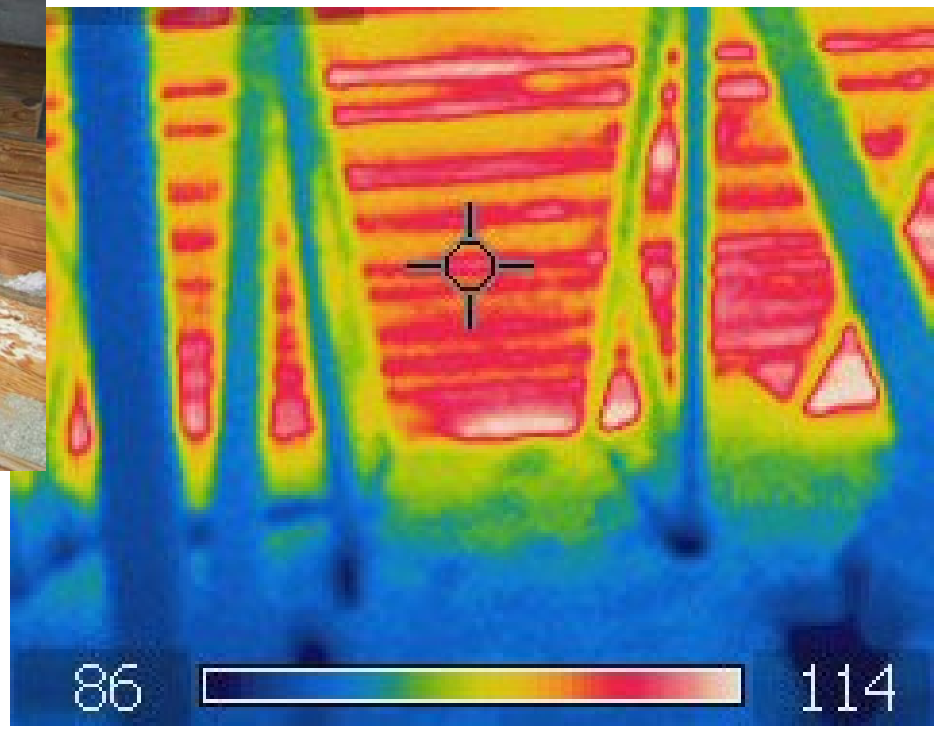


Vertical Helix


Closed Loop Systems
Pond/Lake

Reducing Call Backs & Heat Pump Pump Efficiency

Attics, Leaky are and Ducts are Leaky Poorly Insulated



Duct Summer Heat Gain

- Duct conduction can be calculated with the formula

  Q=(A* T-DIF)/R

Ducts surface area typically = 40% of floor area

Q = Heat Gain

Ex. 1 Duct Summer Heat Gain

- If a 2,000 square foot house has an attic temperature of 140^{o}F what is the duct conduction when the system is running and the duct insulation is R-2.1?

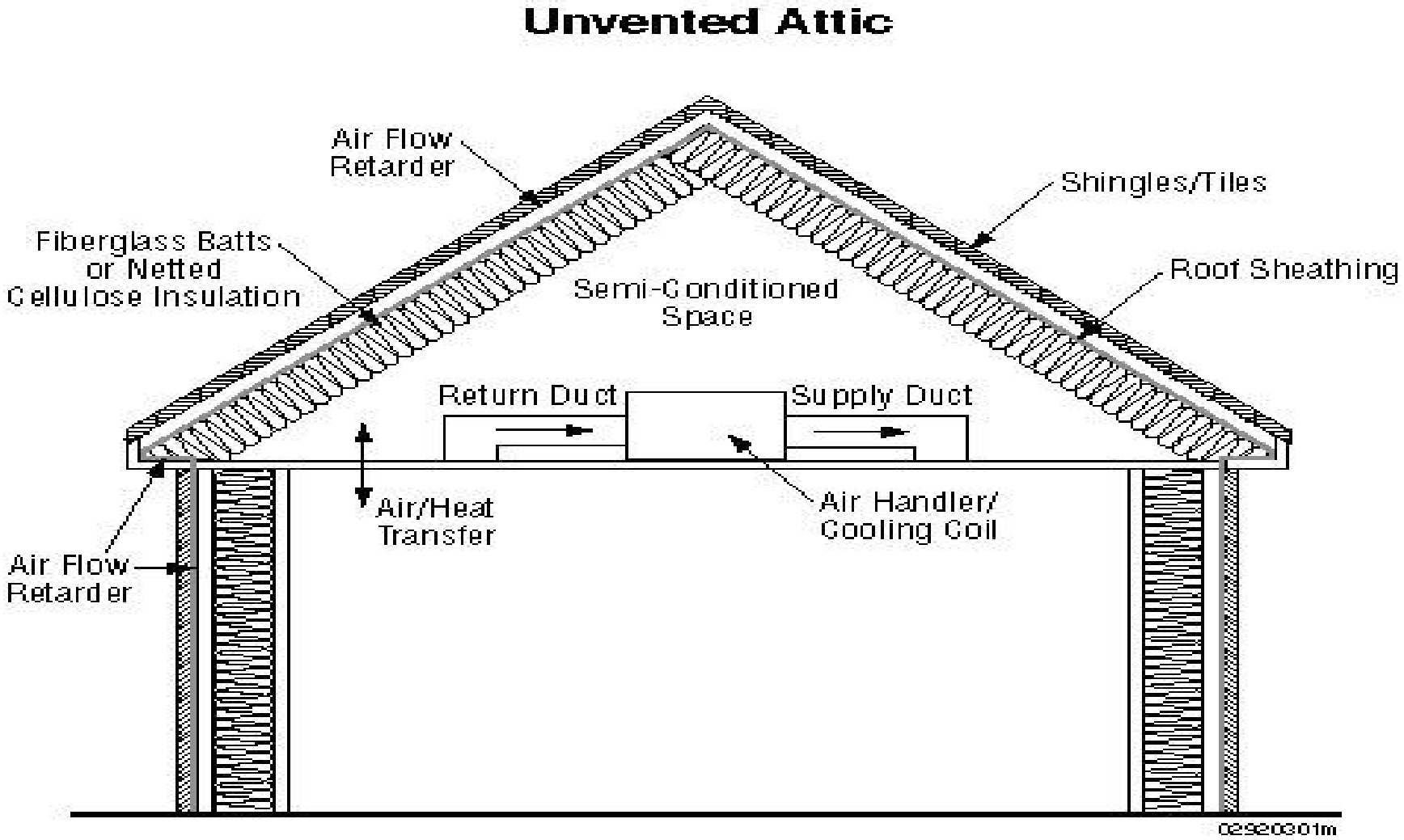
1. Q = (A* DT)/R
2. Q = ((2,000 sq.ft. * 0.4) * (140^{o}F – 60^{o}F)) / R2.1
3. Q = 800 * 80^{o}F / R2.1
4. Q = 30,500 BtuH (2.5 Tons)

Ex. 2 Duct Summer Heat Gain

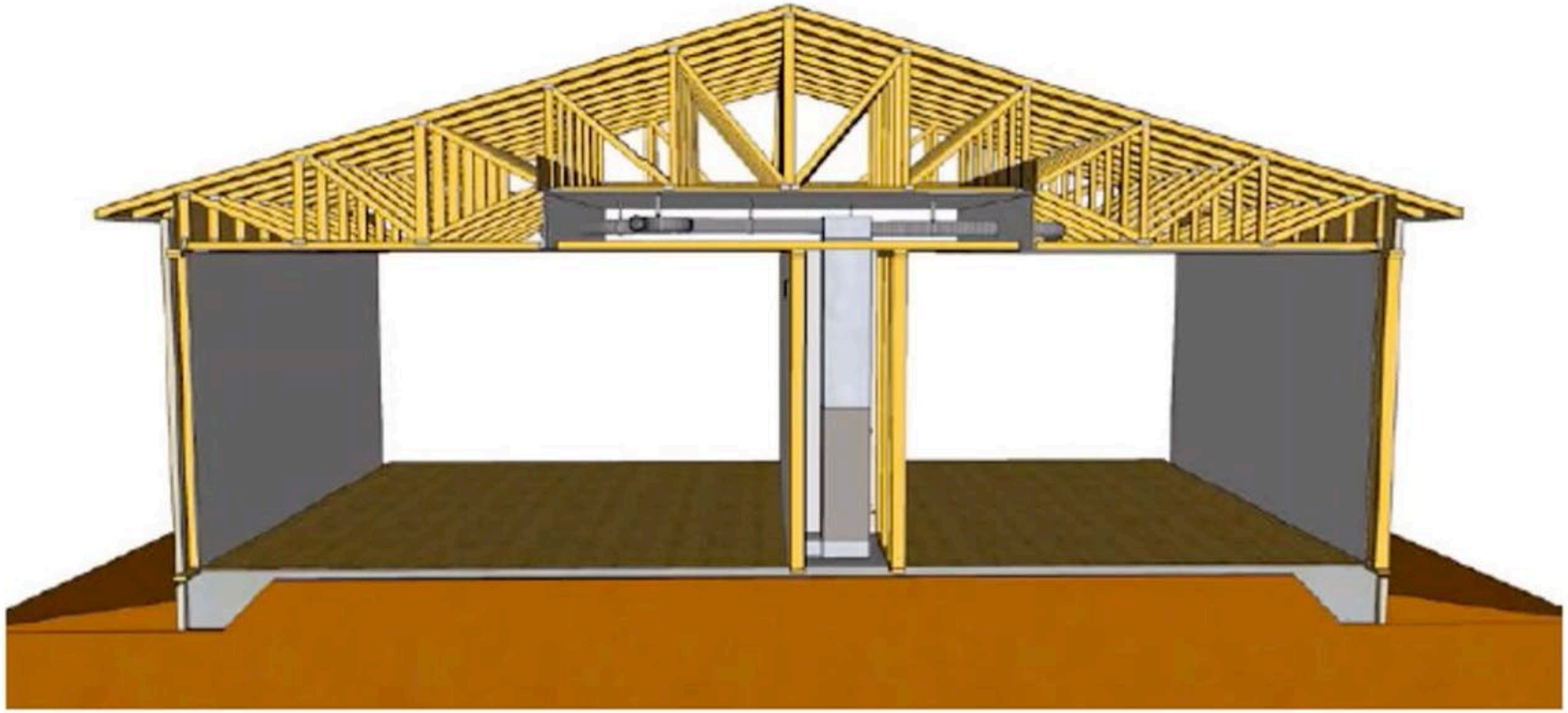
- If a 2,000 square foot house has an attic temperature of 140^{o}F what is the duct conduction when the system is running and the duct insulation is R-8?

1. Q = (A* DT)/R
2. Q = ((2,000 Sq.ft. * 0.4) * (140^{o}F – 60^{o}F)) / R 8
3. Q = 800 * 80^{o}F / R8
4. Q = 8000 BtuH (.67 Tons)

Unvented – “Conditioned Attics”



HPA-C (Ducts in conditioned space)



Note to File:

- **Installation has a bigger impact on performance and efficiency of heat pumps than conventional systems!**
- **WHY???**

- **Because Heat pumps have a longer recovery times than fossil fuel equipment!**


A.O.SMITH

The Impact of Defects

Condition	EER Impact	
	Non-TXV	TXV
15% duct leakage[1]	-18.10%	
23% low airflow	-4.70%	
50% condenser coil blockage	-5.80%	
50% evaporator coil blockage[2]	-4.60%	-4.20%
20% overcharge	-3.50%	-7.90%
20% undercharge	-29.40%	-13.80%
0.3% non-condensable	-18.20%	-12.20%
Liquid line restriction	-29.70%	-36.10%
Ducts, evap, 50' line in attic[3]	-10.50%	
Attic equipment, 25% low airflow, 10% undercharge, 30% duct leakage, 50% coil blockage	-53.50%	

[1]2% duct leakage baseline, 118°F attic

[2]Equipment in conditioned space

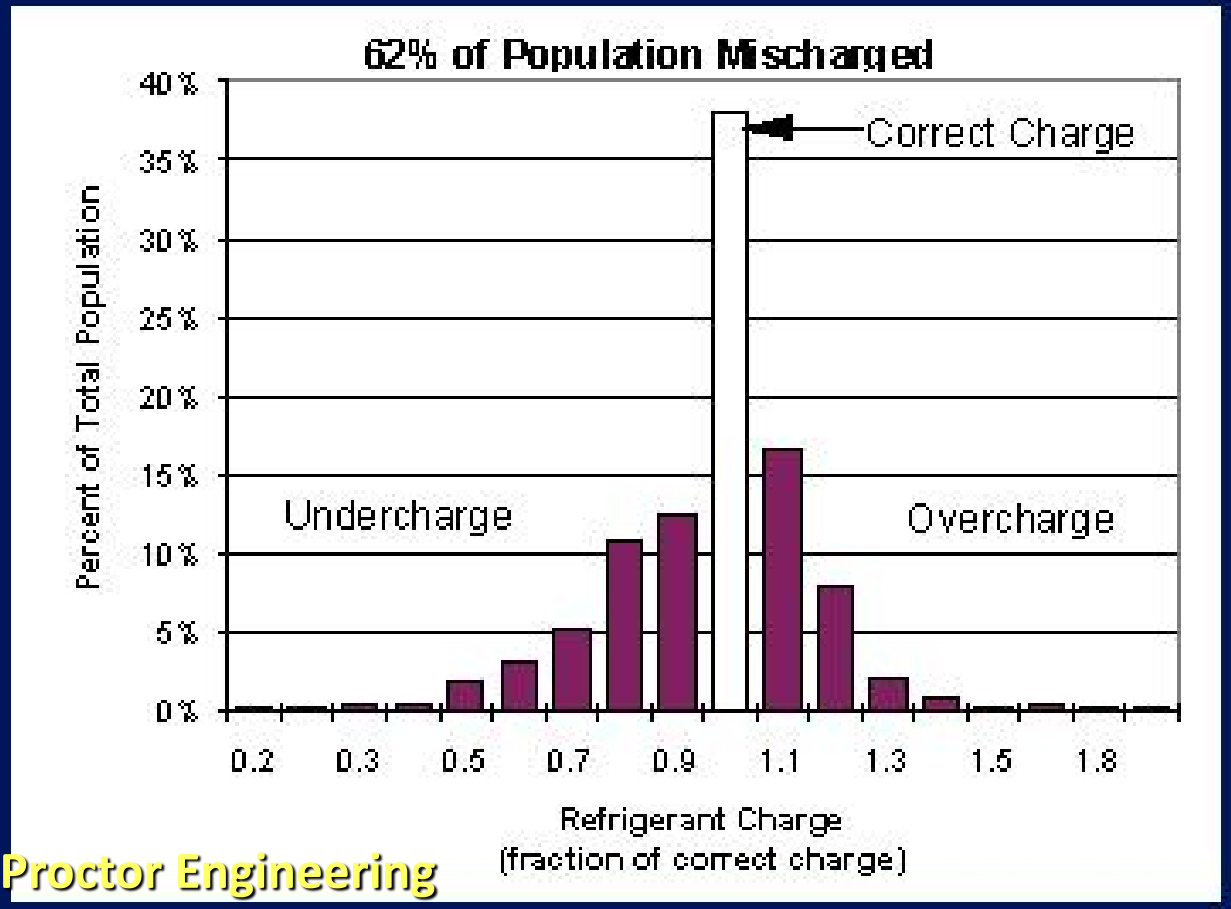
[3]118°F attic, compared to ducts & equipment in conditioned space

Reference: R. Mowris, Jones, E., Eshom, R. 2012. "Laboratory Measurements of HVAC Installation and Maintenance Faults" ASHRAE Transactions, Vol. 188, Pt. 2

Unit Installation

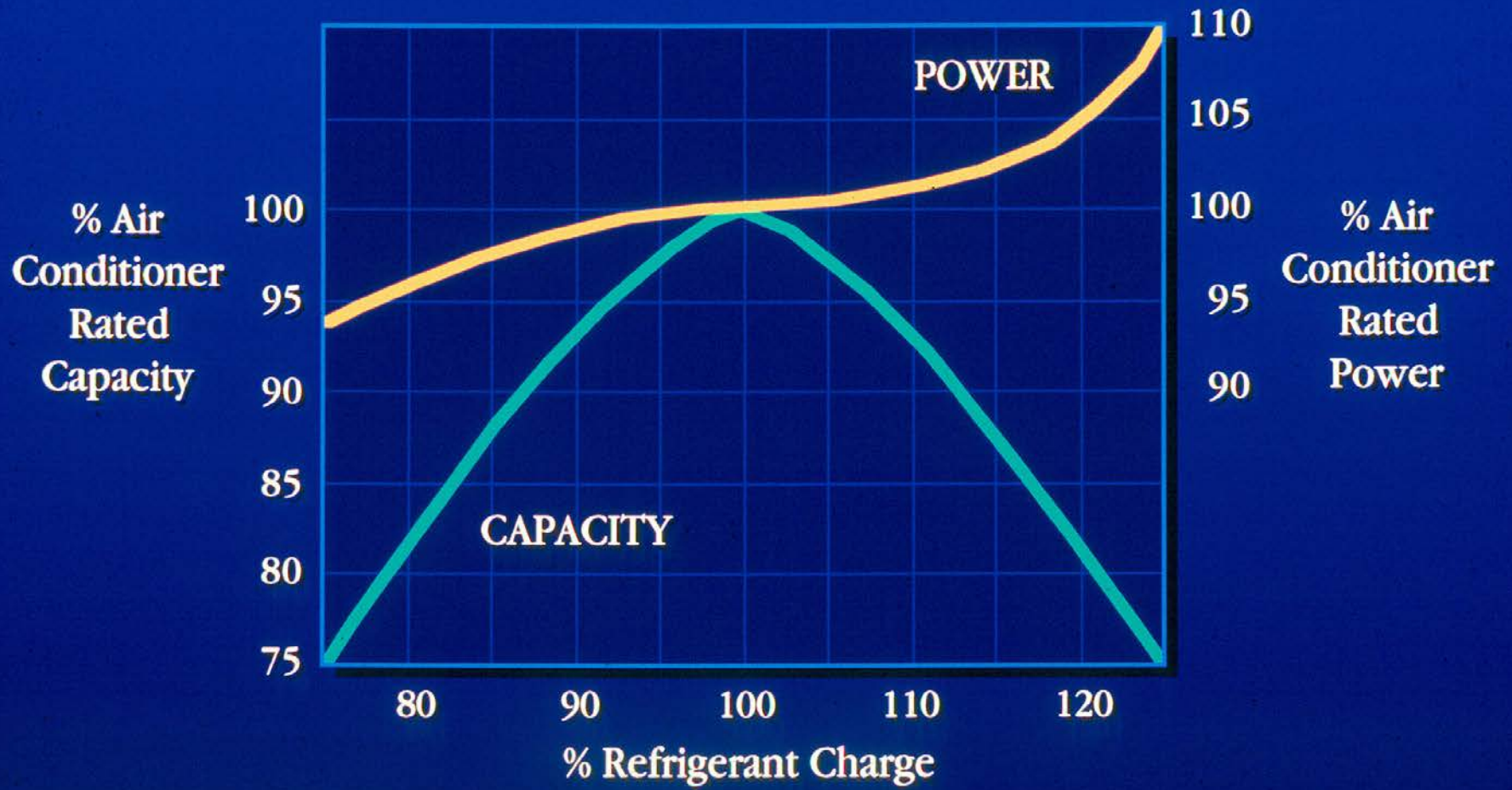
- Unit must properly charged.

Charge Incorrect 62% of Time



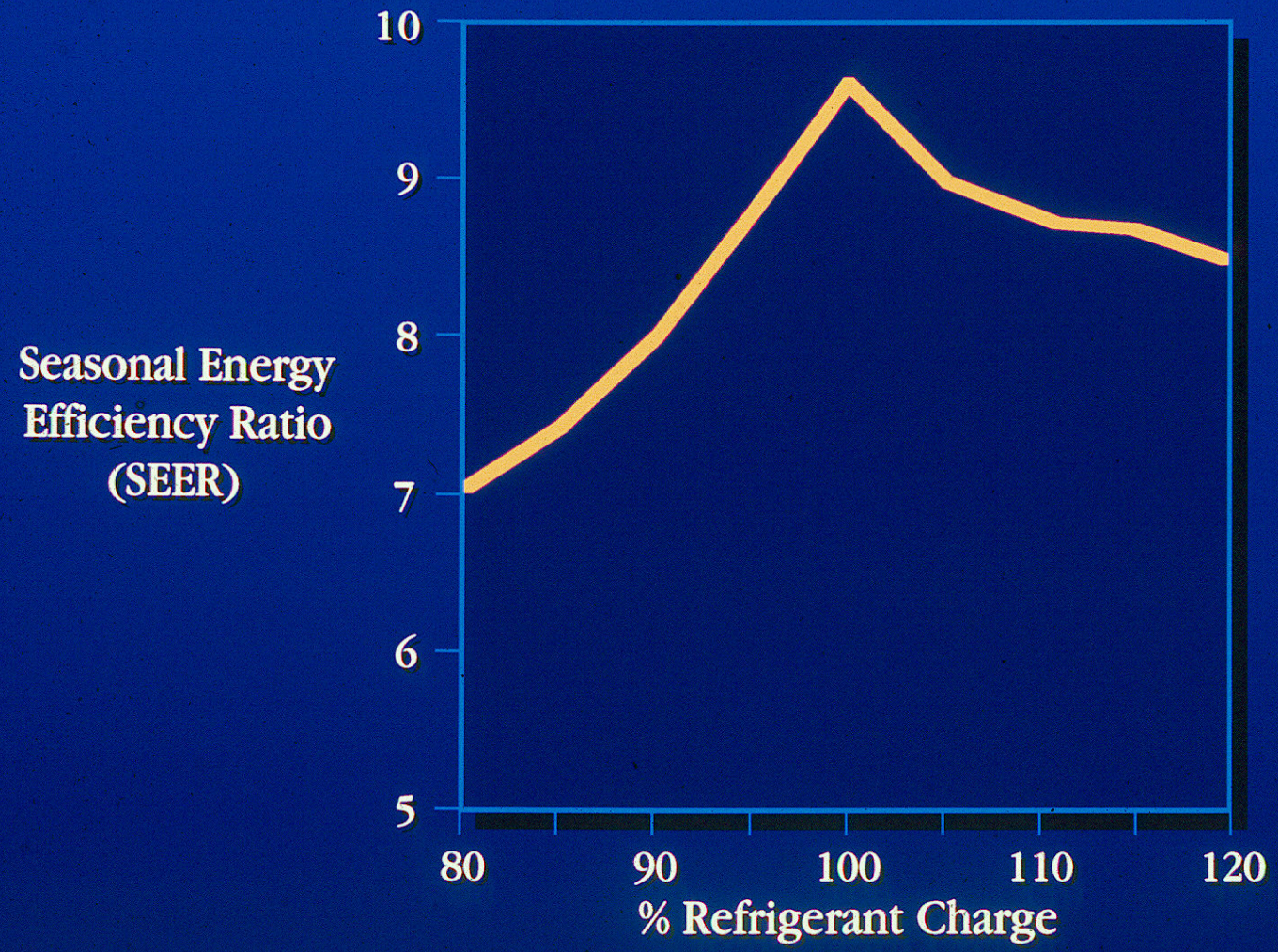
Source: Proctor Engineering

Effects of Refrigerant Charge on Capacity and Power Input (simulated)



Source: Home Energy Magazine, May/June 1992

Effects of Charge on SEER



Source: Home Energy Magazine, May/June 1992

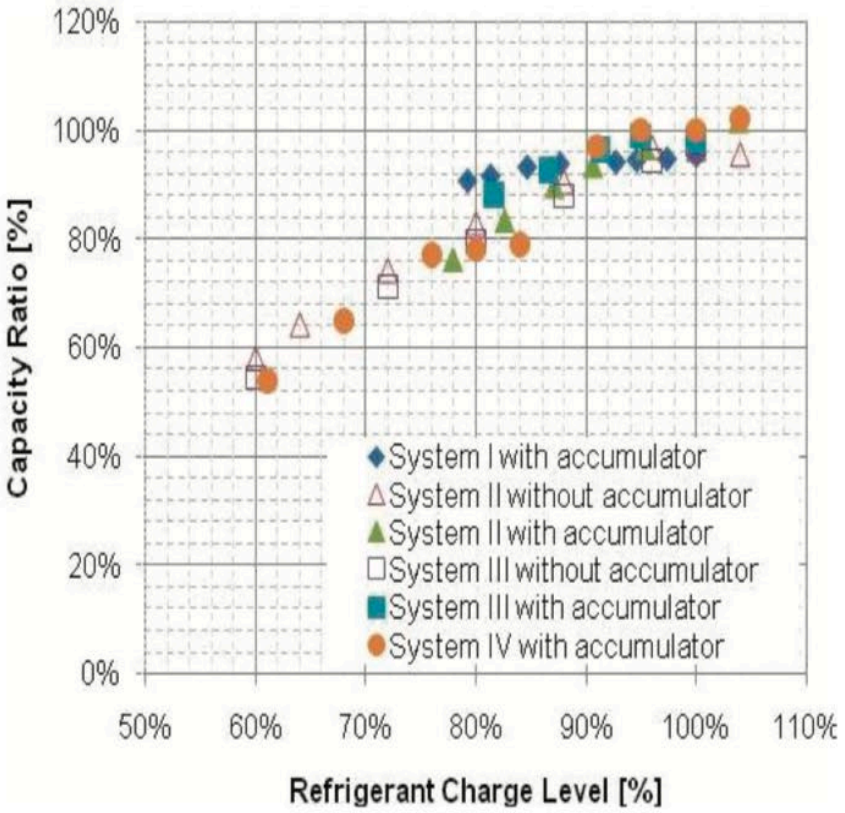


Fig. 1 Impact of charge on capacity for existing test data

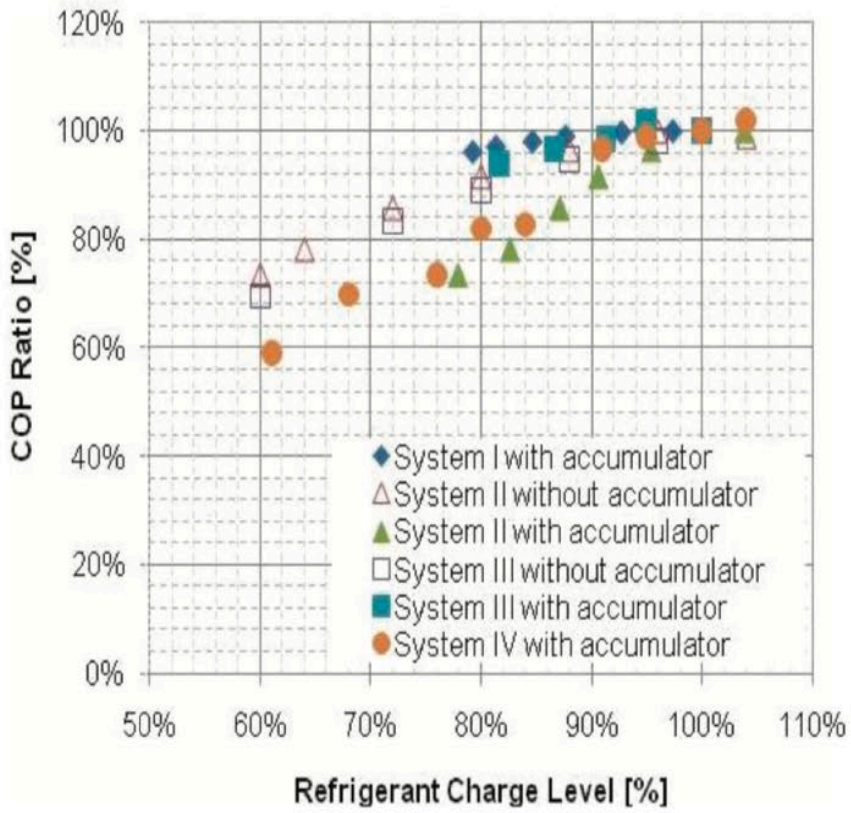


Fig. 2 Impact of charge on COP for existing test data

Impacts of Refrigerant Charge on Air Conditioner and Heat Pump Performance

Woohyun Kim
Purdue University
James E. Braun
Purdue University

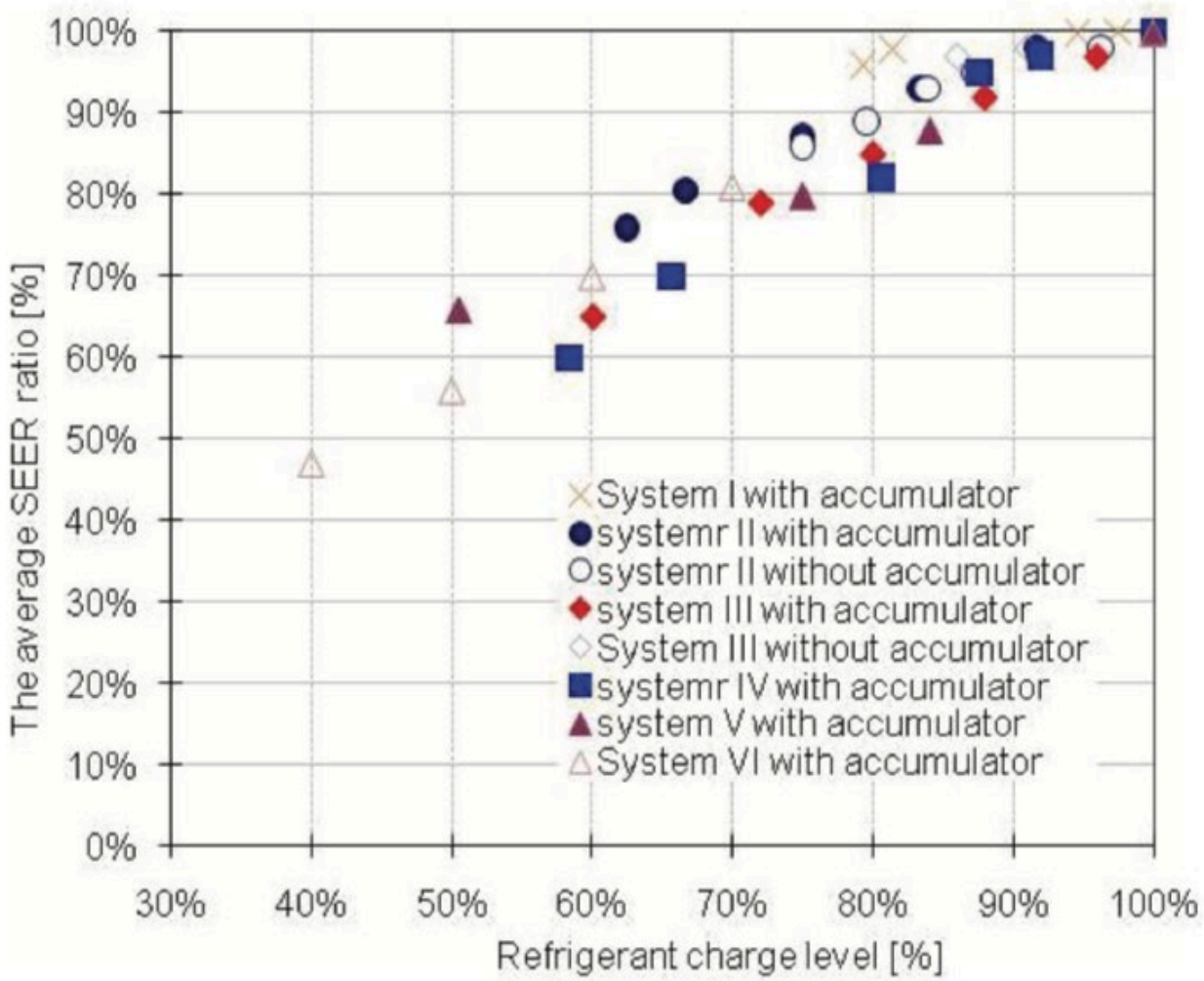


Fig. 12 The average SEER ratio for all testing data based on the refrigerant charge

Impacts of Refrigerant Charge on Air Conditioner and Heat Pump Performance

Woohyun Kim
Purdue University
James E. Braun
Purdue University

What is this ??

System Sizing

- Comfort
- Energy Efficiency
- Performance

Correct System Sizing is Critical

- Based on actual loads, not rule of thumb estimates
- Over sizing can create
  - Insufficient dehumidification due to short cycling
  - Shortened equipment life
  - Increased energy costs up to 20%
  - Equip. costs can be much higher

System Sizing

- Sized no more than 10% greater than ACCA manual “J” current version
- Use indoor design temp of no less than 75° F
- Indoor and outdoor coils should be matched
- Ducts should be sized per manual “D” calculations
- Bedrooms to have return air ducts and grills designed per manual “D” specifications

Duct Installation

- **Duct installation has a huge impact on the building envelope.**
- **Duct leaks can create pressure differentials that cause air infiltration and exfiltration**
- **The average homes has 300 to 400 cfm of duct leaks**
- **Duct leakage wastes energy**

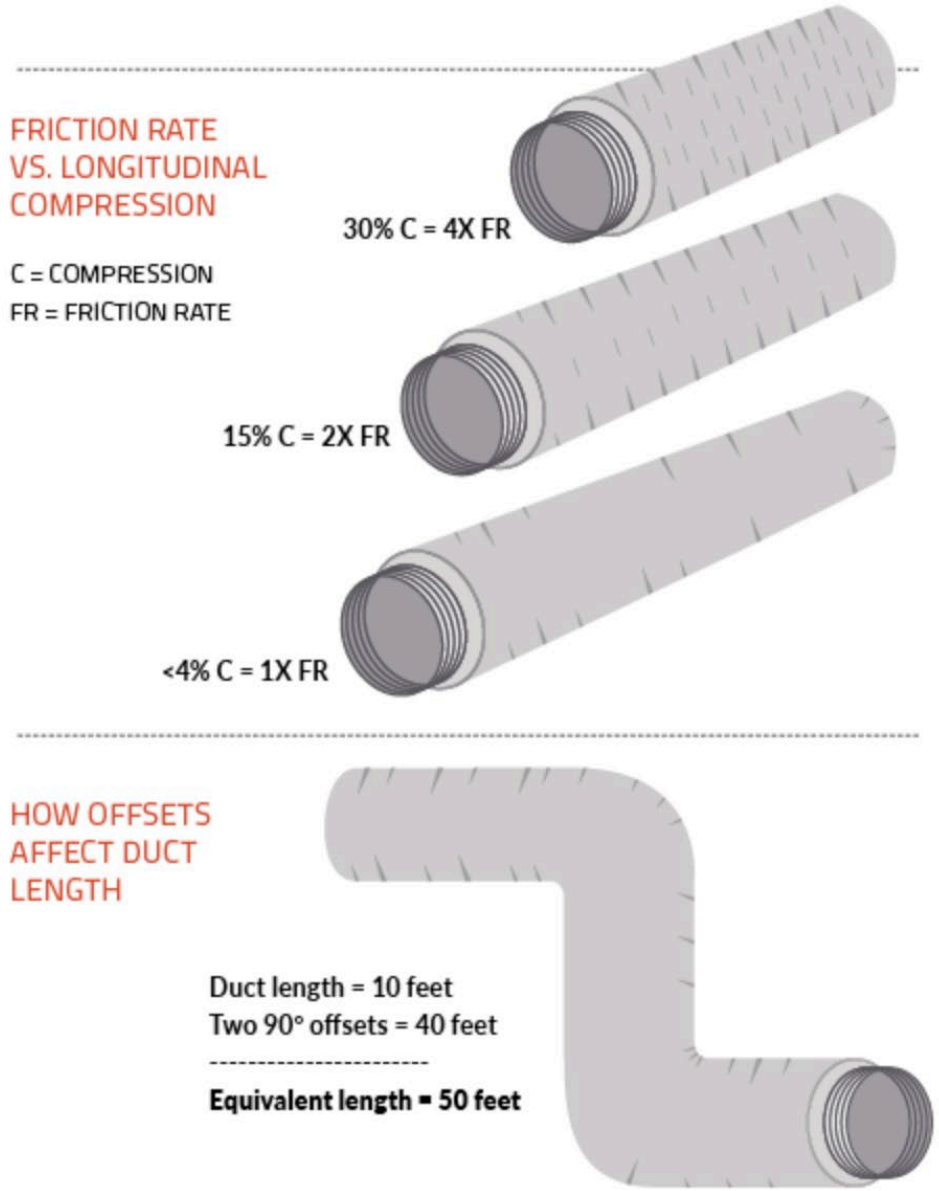
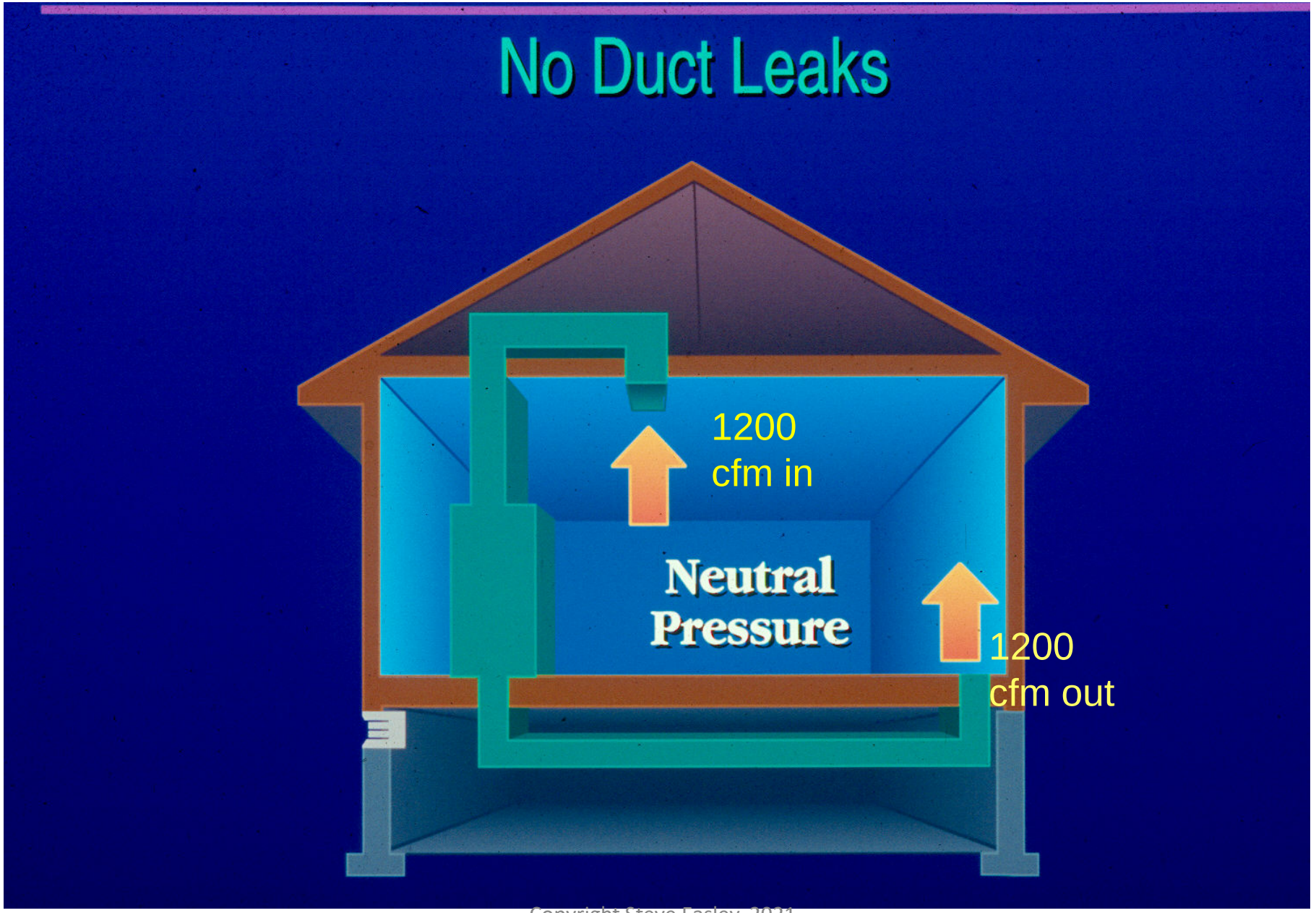
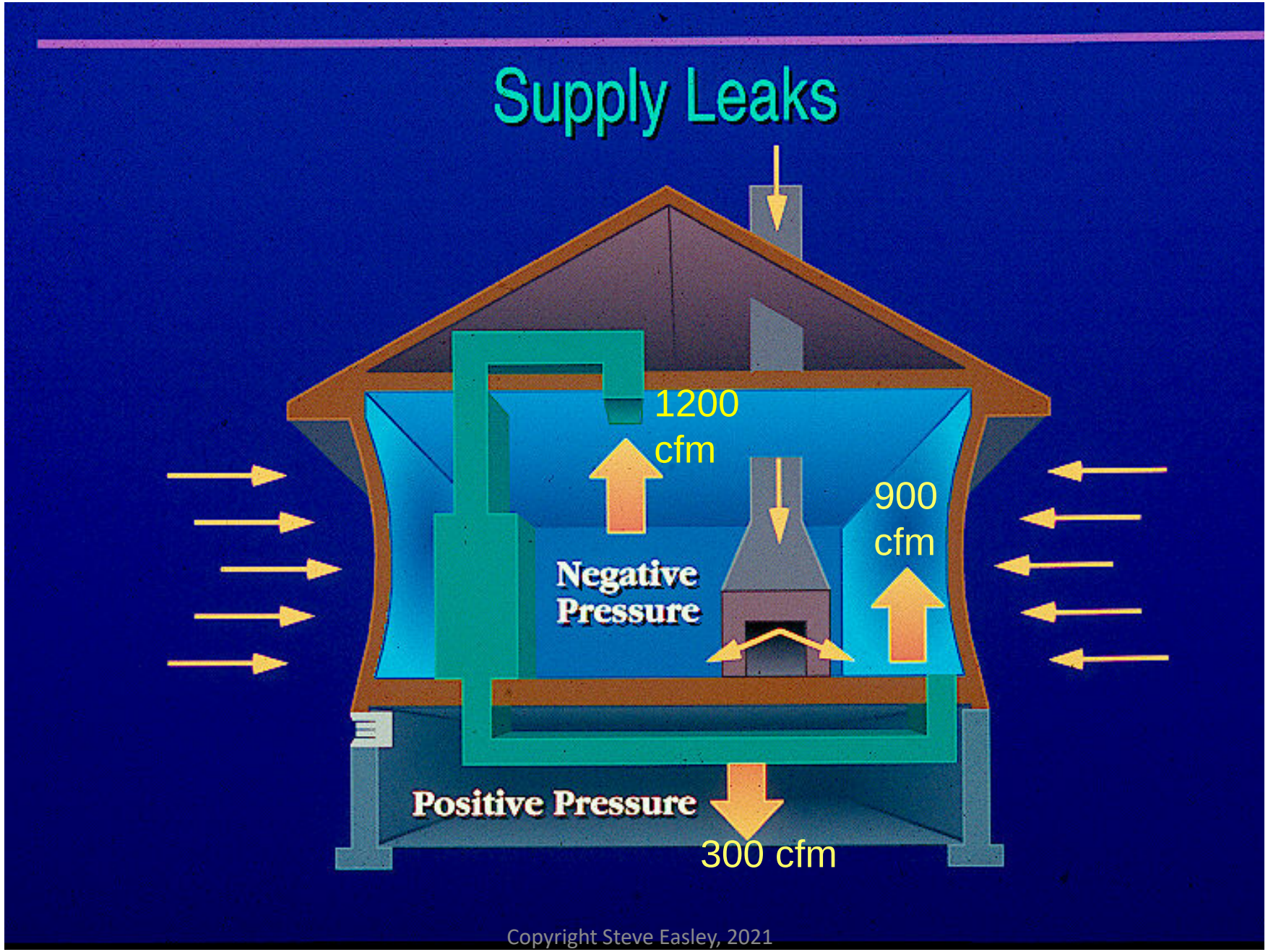
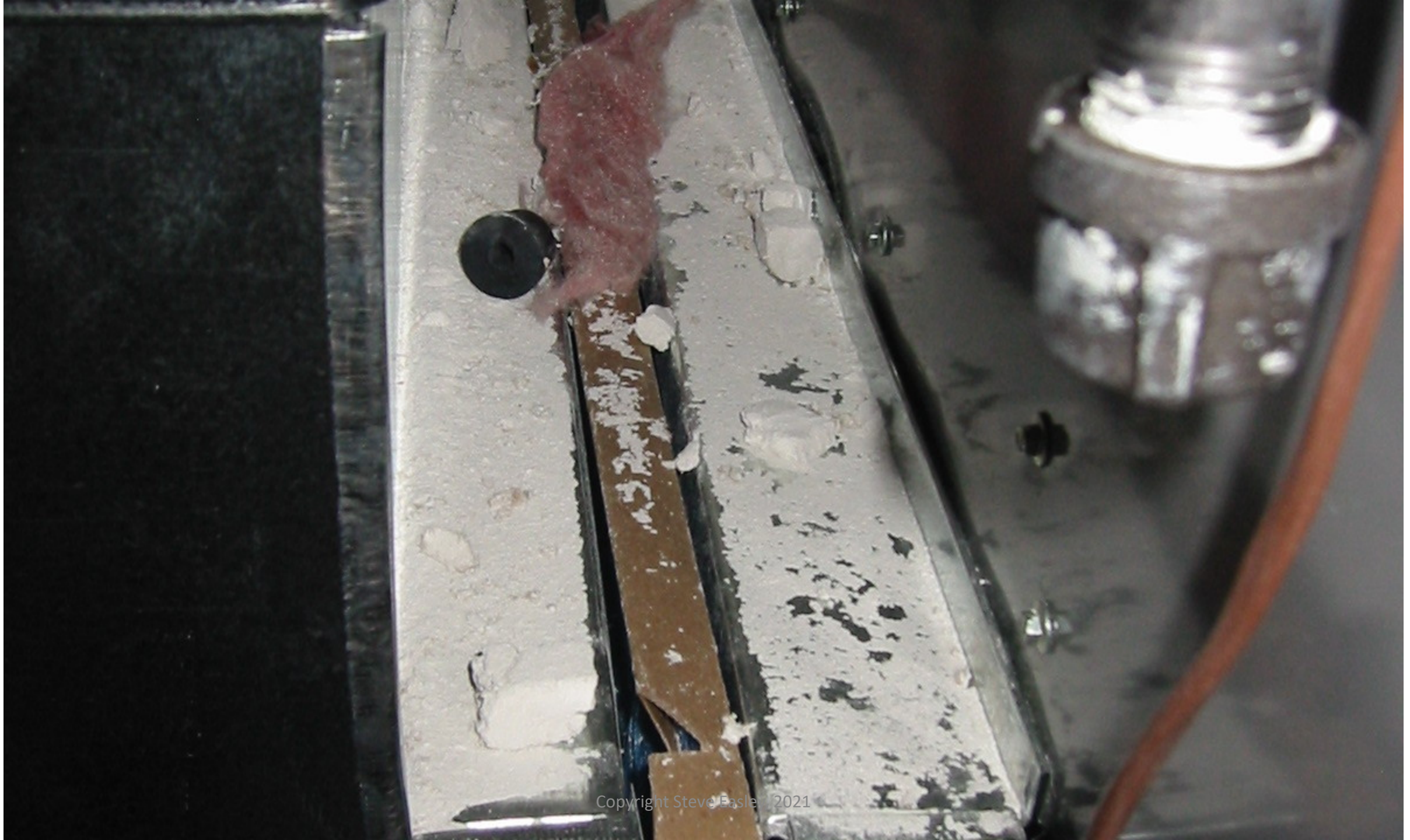


Illustration: Air Diffusion Council, “Flexible Duct Performance & Installation Standards,” 5th Edition



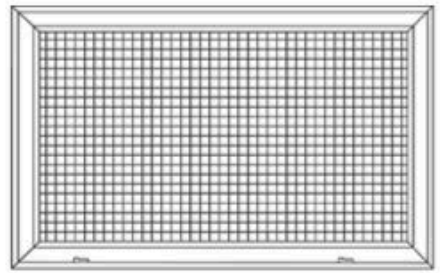




Commercial Submittal Sheet

600FG Series

Aluminum Lattice 1" Filter Grille

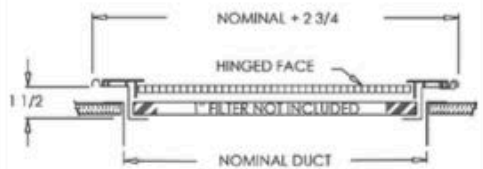


Model: 600FG

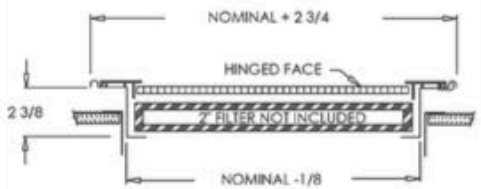
Description: Aluminum Lattice 1" Filter Grille

Standard Features:

- Extruded aluminum frame with signature line marks set in a filter frame
- 1/2 x 1/2 x 1/2 aluminum lattice face
- Hinged removable face with hinges parallel to longest side
- Hand operated lever for easy filter access
- 4-way reversible door on square sizes
- 2-way reversible door on rectangular sizes
- Concealed mounting holes
- Holds up to a 1" filter (not included)
- Filter retention tabs
- Soft White



600 FG



600 FG2

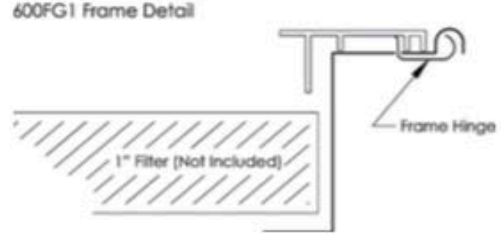
Options:

- ☐ 2" Filter capacity (600FG2)
- ☐ 1/2" x 1/2" x 1" Lattice
- ☐ 1" x 1" x 1" Lattice
- ☐ Available in T-Bar application (600TFG)
- ☐ Alternative hinge and latch options available (please fill out Filter Grille Order Supplement form)

Finishes:

Standard Colors	Designer Colors		Other
☐ Soft White	☐ Almond	☐ Coffee Tan	☐ Satin Anodized
☐ Driftwood Tan	☐ Black Velvet	☐ Navajo White	
	☐ Bronze	☐ Vanilla	
	☐ Camaro Silver		

600FG1 Frame Detail



Product Notes:

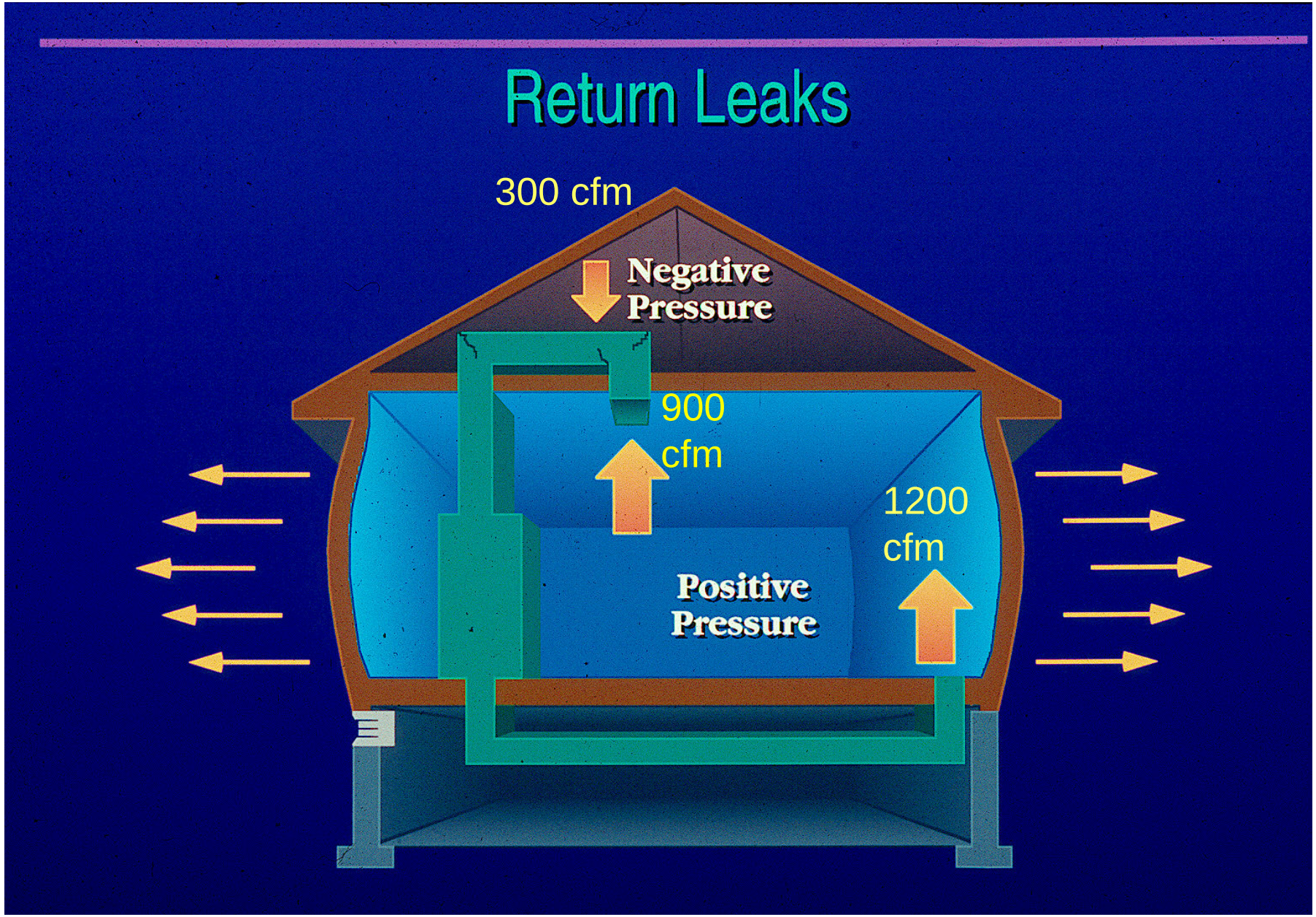
Filter grilles are manufactured 3/16" undersized nominal duct outside dimension for ease of installation. Air filter should be ¼" to ½" undersized. Verify with air filter manufacturer for air specifications.

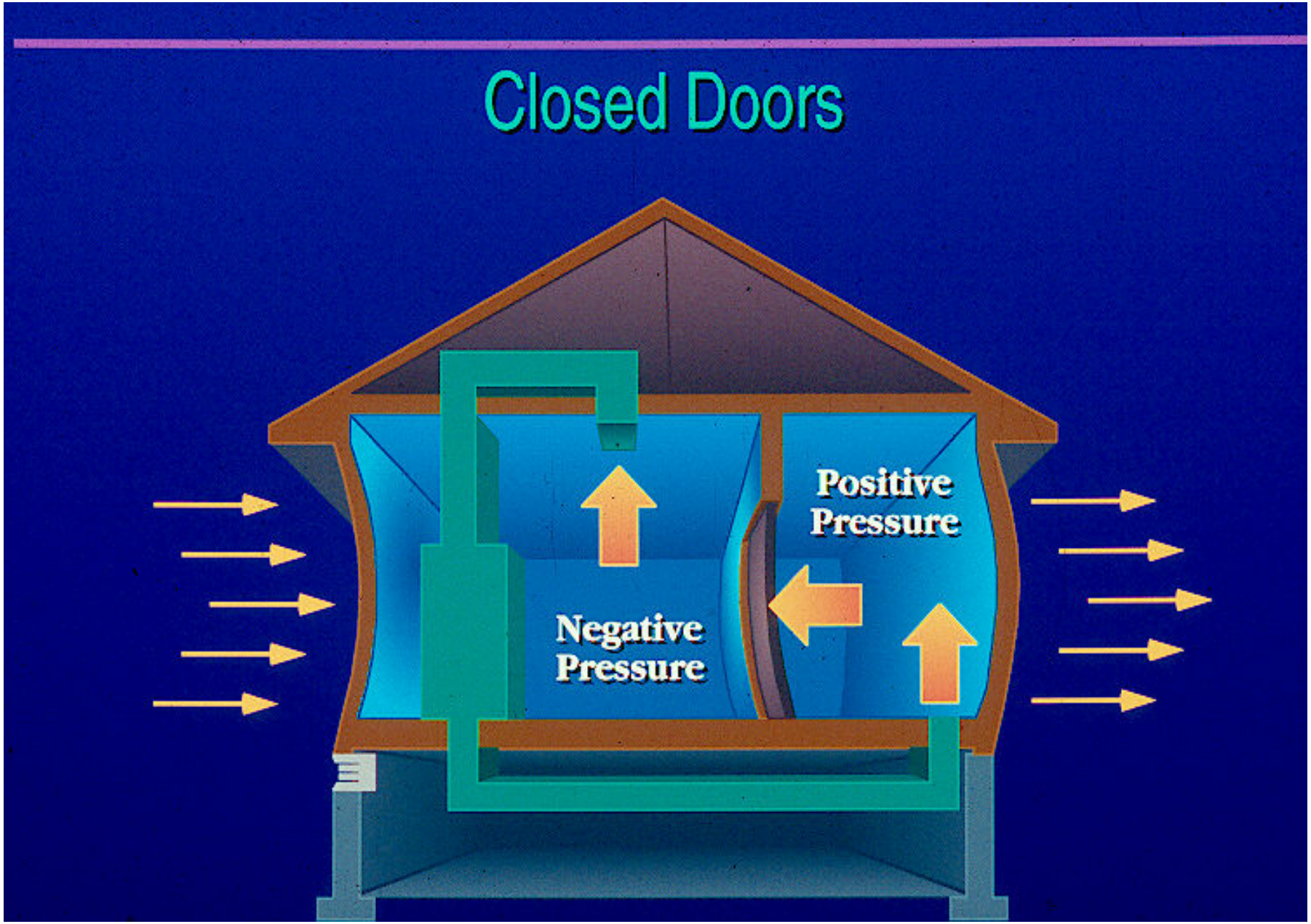
Shoemaker filter grilles allow for installation of larger thickness filters which can reduce pressure drop on the overall system, improving air flow through the heat exchanger and allowing more time between filter changes.

Minimum. Efficiency Reporting. Value.

TABLE 3: MERV PARAMETERS

Standard 52.2 Minimum Efficiency Reporting Value (MERV)	Composite Average Particle Size Efficiency, % in Size Range, µm			
	Range 1 (0.3-1.0)	Range 2 (1.0-3.0)	Range 3 (3.0-10.0)	Average Arrestance, %
1	n/a	n/a	$E_3 < 20$	$A_{avg} < 65$
2	n/a	n/a	$E_3 < 20$	$65 \le A_{avg} < 70$
3	n/a	n/a	$E_3 < 20$	$70 \le A_{avg} < 75$
4	n/a	n/a	$E_3 < 20$	$75 \le A_{avg}$
5	n/a	n/a	$20 \le E_3 < 35$	n/a
6	n/a	n/a	$35 \le E_3 < 50$	n/a
7	n/a	n/a	$50 \le E_3 < 70$	n/a
8	n/a	$20 \le E_2$	$70 \le E_3$	n/a
9	n/a	$35 \le E_2$	$75 \le E_3$	n/a
10	n/a	$50 \le E_2 < 65$	$80 \le E_3$	n/a
11	$20 \le E_1$	$65 \le E_2 < 80$	$85 \le E_3$	n/a
12	$35 \le E_1$	$80 \le E_2$	$90 \le E_3$	n/a
13	$50 \le E_1$	$85 \le E_2$	$90 \le E_3$	n/a
14	$75 \le E_1 < 85$	$90 \le E_2$	$95 \le E_3$	n/a
15	$85 \le E_1 < 95$	$90 \le E_2$	$95 \le E_3$	n/a
16	$95 \le E_1$	$95 \le E_2$	$95 \le E_3$	n/a





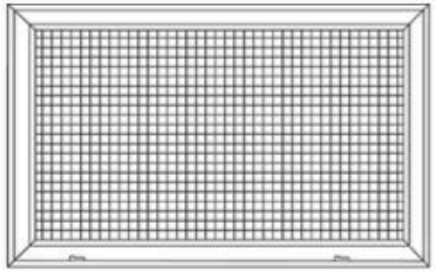
Return-Air Pathways

Minimum Door Cut Height for Return Air							
Cfm Under Door	Door Width (Inches)						
	24	**30**	**36**	**42**	**28**	**54**	**60**
	Clearance to Floor or Top of Carpet (inches)						
100	2.0	1.6	1.3	1.1	1.0	0.9	0.8
200	4.0	3.2	2.7	2.3	2.0	1.8	1.6
300	6.0	4.8	4.0	3.4	3.0	2.7	2.4
400	8.0	6.4	5.3	4.6	4.0	3.6	3.2

Commercial Submittal Sheet

600FG Series

Aluminum Lattice 1" Filter Grille

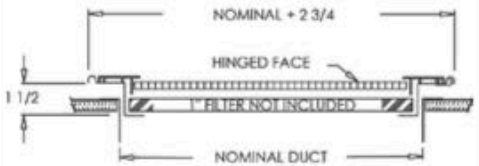


Model: 600FG

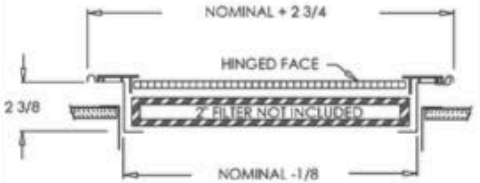
Description: Aluminum Lattice 1" Filter Grille

Standard Features:

- Extruded aluminum frame with signature line marks set in a filter frame
- 1/2 x 1/2 x 1/2 aluminum lattice face
- Hinged removable face with hinges parallel to longest side
- Hand operated lever for easy filter access
- 4-way reversible door on square sizes
- 2-way reversible door on rectangular sizes
- Concealed mounting holes
- Holds up to a 1" filter (not included)
- Filter retention tabs
- Soft White



600 FG



600 FG2

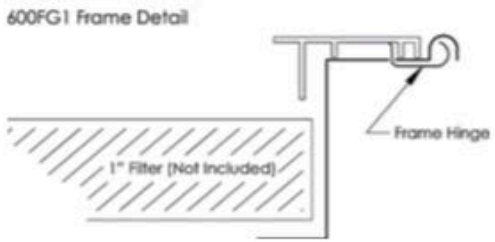
Options:

- ☐ 2" Filter capacity (600FG2)
- ☐ 1/2" x 1/2" x 1" Lattice
- ☐ 1" x 1" x 1" Lattice
- ☐ Available in T-Bar application (600TFG)
- ☐ Alternative hinge and latch options available (please fill out Filter Grille Order Supplement form)

Finishes:

Standard Colors	Designer Colors		Other
☐ Soft White	☐ Almond	☐ Coffee Tan	☐ Satin Anodized
☐ Driftwood Tan	☐ Black Velvet	☐ Navajo White	
	☐ Bronze	☐ Vanilla	
	☐ Camaro Silver		

600FG1 Frame Detail



Product Notes:

Filter grilles are manufactured 3/16" undersized nominal duct outside dimension for ease of installation. Air filter should be ¼" to ½" undersized. Verify with air filter manufacturer for air specifications.

Shoemaker filter grilles allow for installation of larger thickness filters which can reduce pressure drop on the overall system, improving air flow through the heat exchanger and allowing more time between filter changes.

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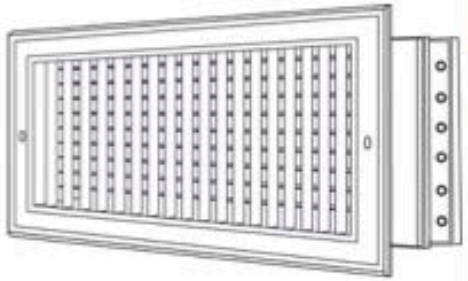
2	n/a	n/a	$E_3 < 20$	$65 \le A_{avg} < 70$
3	n/a	n/a	$E_3 < 20$	$70 \le A_{avg} < 75$
4	n/a	n/a	$E_3 < 20$	$75 \le A_{avg}$
5	n/a	n/a	$20 \le E_3 < 35$	n/a
6	n/a	n/a	$35 \le E_3 < 50$	n/a
7	n/a	n/a	$50 \le E_3 < 70$	n/a
8	n/a	$20 \le E_2$	$70 \le E_3$	n/a
9	n/a	$35 \le E_2$	$75 \le E_3$	n/a
10	n/a	$50 \le E_2 < 65$	$80 \le E_3$	n/a
11	$20 \le E_1$	$65 \le E_2 < 80$	$85 \le E_3$	n/a
12	$35 \le E_1$	$80 \le E_2$	$90 \le E_3$	n/a
13	$50 \le E_1$	$85 \le E_2$	$90 \le E_3$	n/a
14	$75 \le E_1 < 85$	$90 \le E_2$	$95 \le E_3$	n/a
15	$85 \le E_1 < 95$	$90 \le E_2$	$95 \le E_3$	n/a
16	$95 \le E_1$	$95 \le E_2$	$95 \le E_3$	n/a

Commercial Submittal Sheet

SHOEMAKER MANUFACTURING

904 Series

Aluminum Airfoil Blade Double Deflection Diffuser

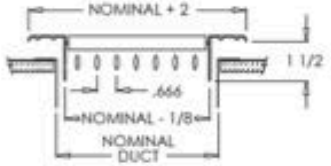


Model: 904

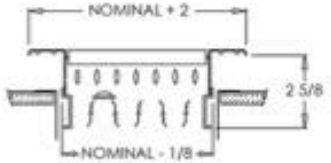
Description: Adjustable Aluminum Airfoil Blade Double Deflection Diffuser with Vertical Front Blades

Standard Features:

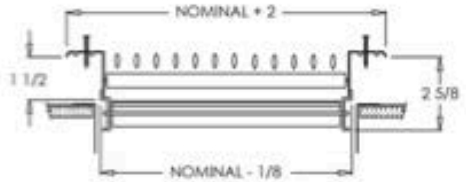
- Extruded aluminum surface mount frame with signature line marks
- Double deflection diffuser allows 4-way air flow
- Front adjustable airfoil blades are parallel to shortest dimension
- Back adjustable airfoil blades are parallel to longest dimension
- Nylon bushings for easy adjustment and quiet setting of airfoil blades
- Countersunk mounting holes for flush appearance with color matching Phillips posi-drive screws
- Soft White



904



904 O



904 O

Options:

- ☐ Recessed screwdriver operated Opposed Blade Damper (904-0)
- ☐ Square to round ADC compliant 2" No Labor Collar with roll formed retention bead (904-NLC), available in square sizes only
- ☐ Heavy duty construction (904-HD)
- ☐ Insect Screen (904-IS)
- ☐ Fractional I.D. and O.D. sizes available

Tamper Proof Screws

- ☐ "F" Torx Center Pin

Finishes:

Standard Colors	Designer Colors		Other
☐ Soft White	☐ Almond	☐ Coffee Tan	☐ Satin Anodized
☐ Driftwood Tan	☐ Black Velvet	☐ Navajo White	
	☐ Bronze	☐ Vanilla	
	☐ Camaro Silver		

e Easley, 2021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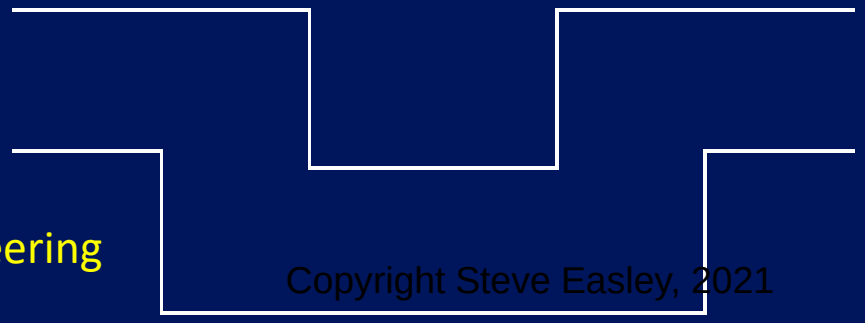
How Long is the Duct System? (from air molecules' views)

- A 200 ft. straight pipe is 200 feet long

- This 4 ft. section of pipe is how long?

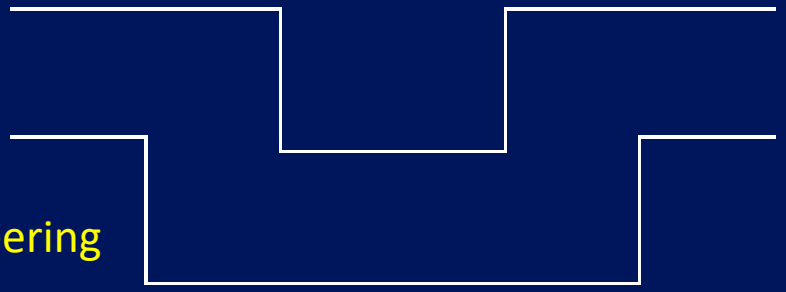


Proctor Engineering

How Long is the Duct System? (from air molecules' views)

- A 200 ft. straight pipe is 200 feet long

- This 4 ft. section of pipe is how long?



Proctor Engineering

330 Feet!

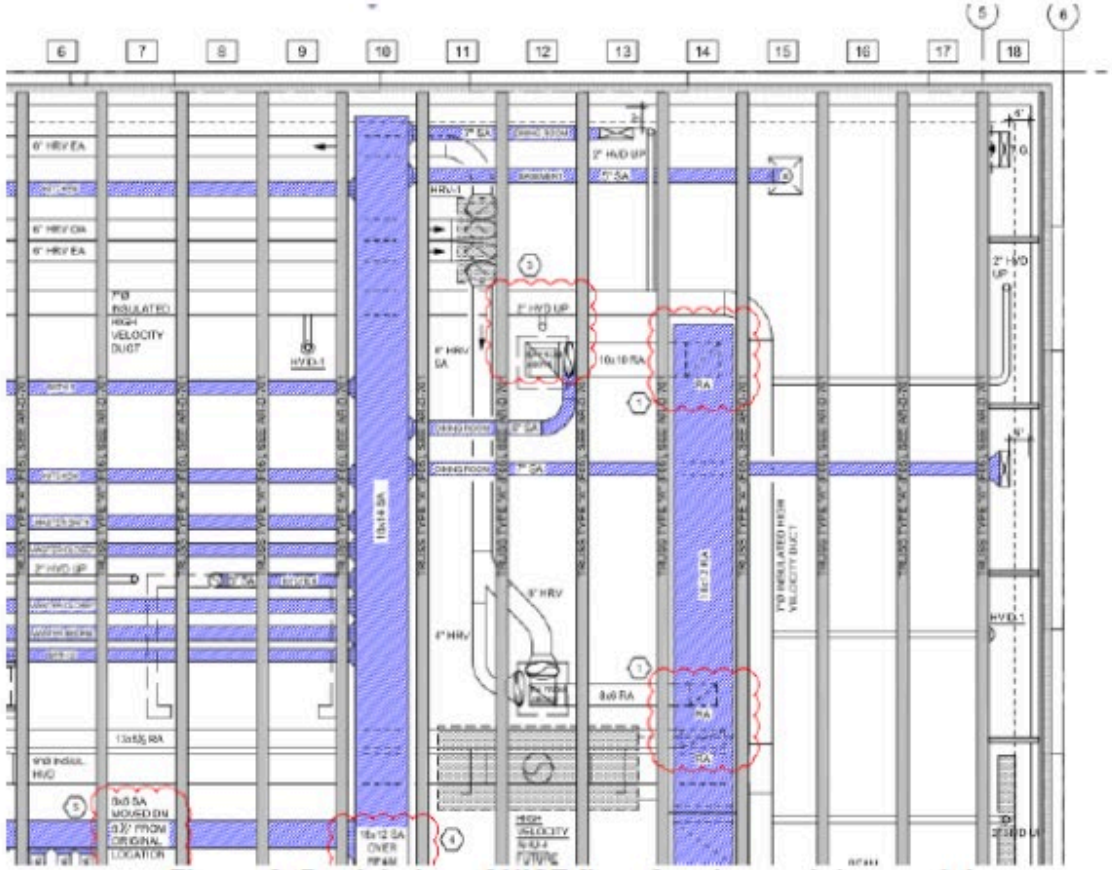
Furnace Flue

Return air Duct chase

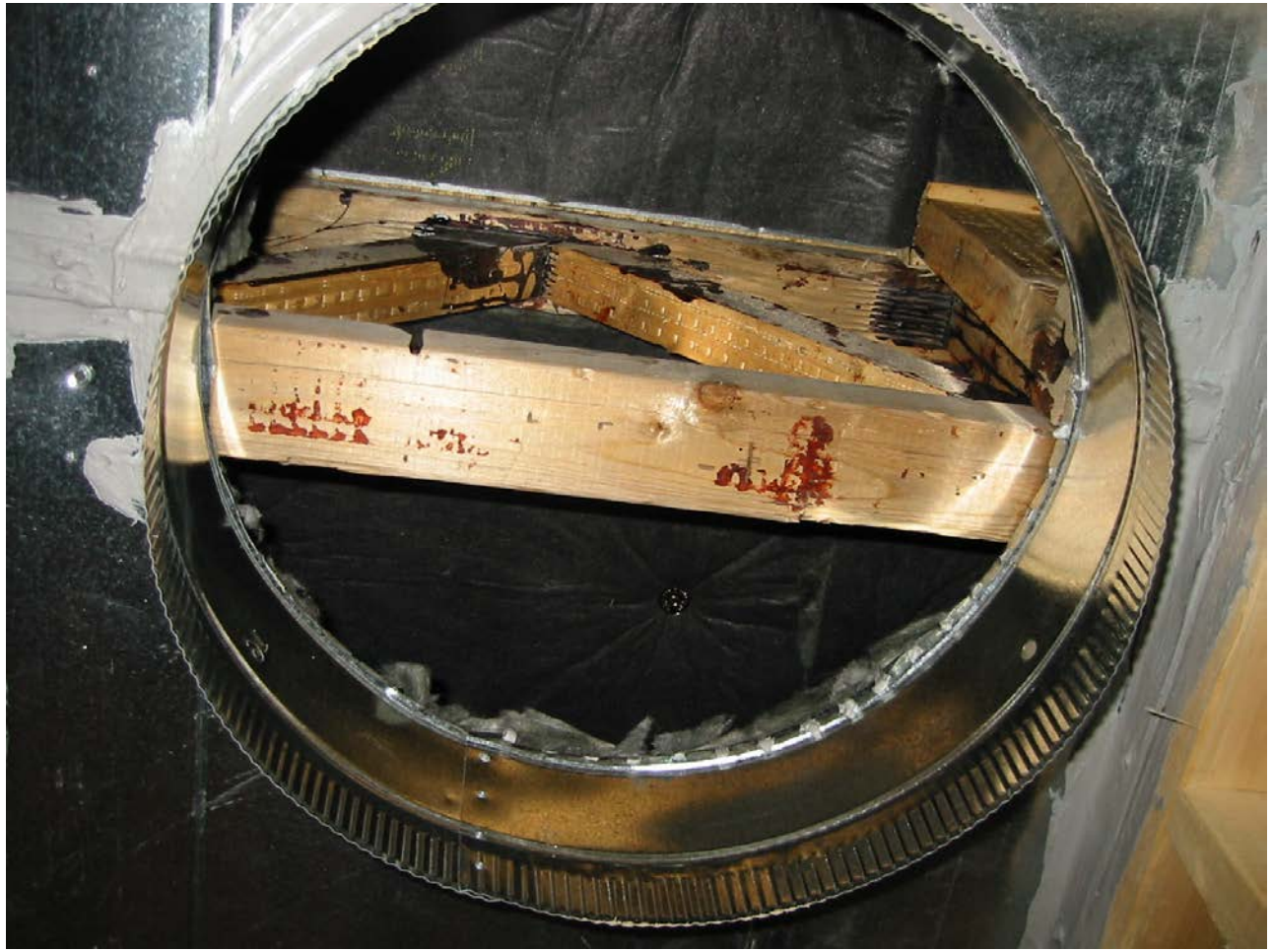
Return Air duct

QMS Strategies for ZERH

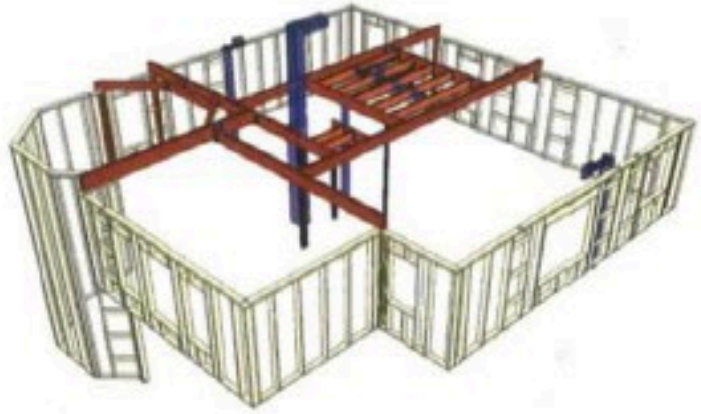
Example coordination drawing for framing and ducts



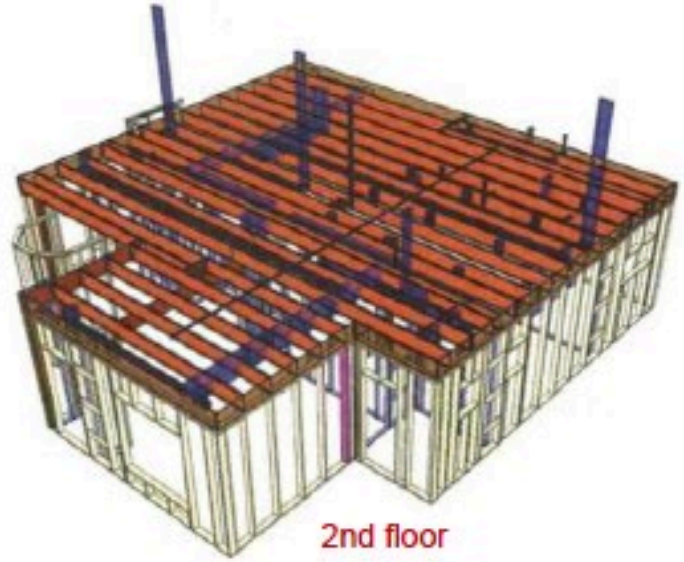
Home Innovation
RESEARCH LABS



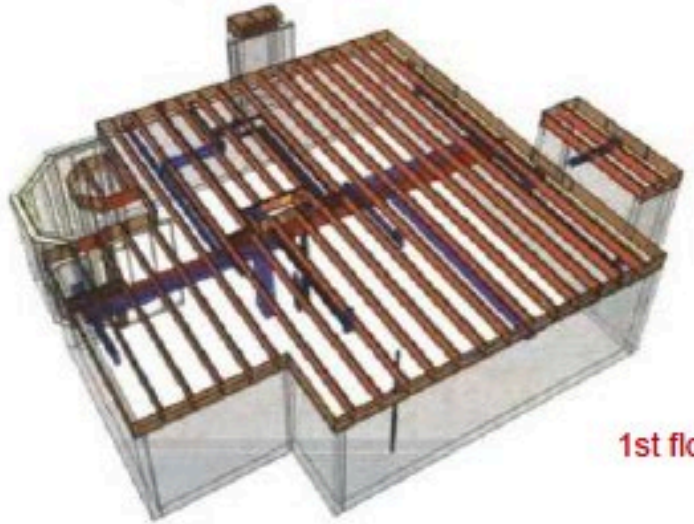
Duct layout in 3-D plan to assure accurate and consistent installation



3rd floor



2nd floor

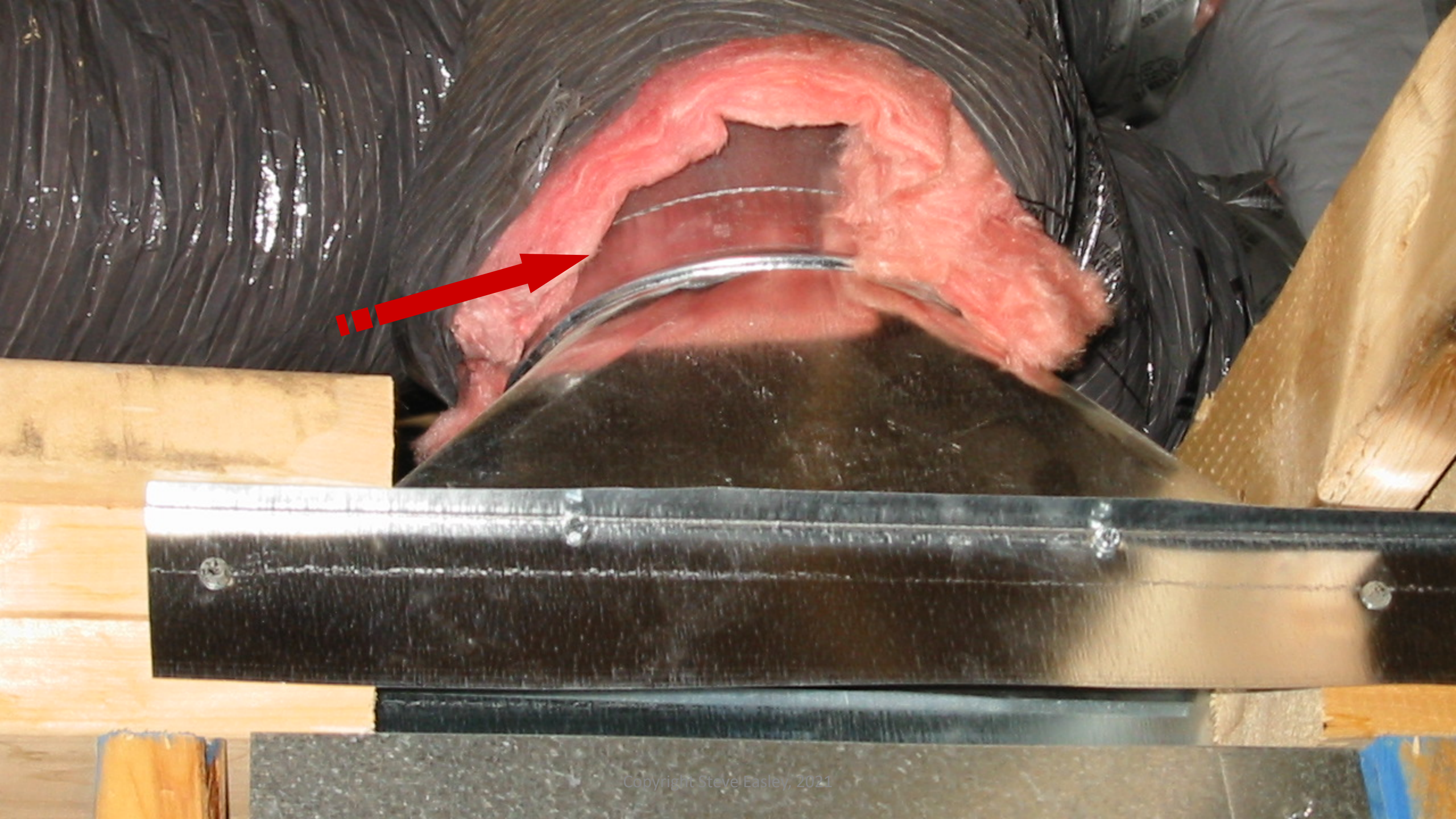


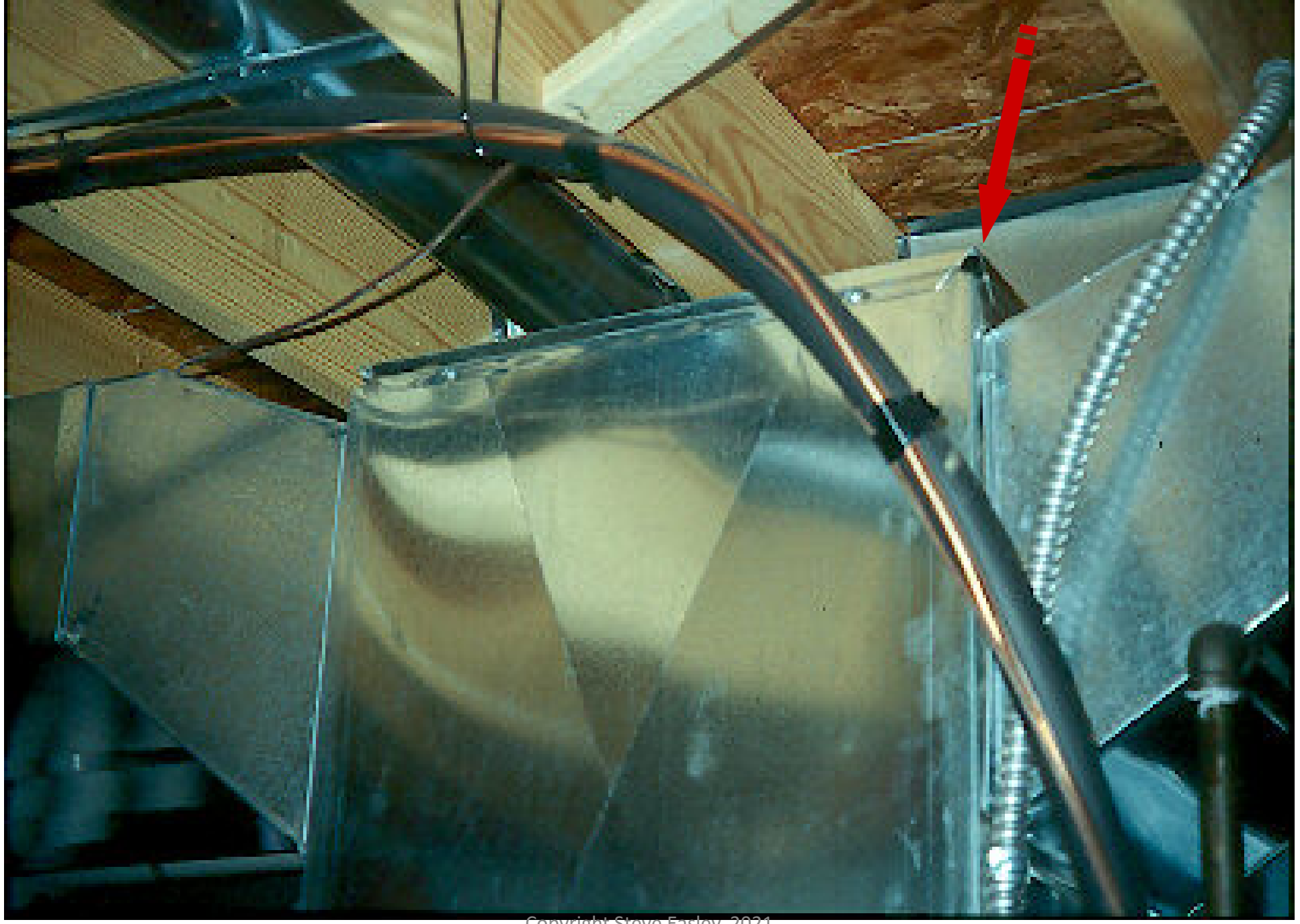
1st floor

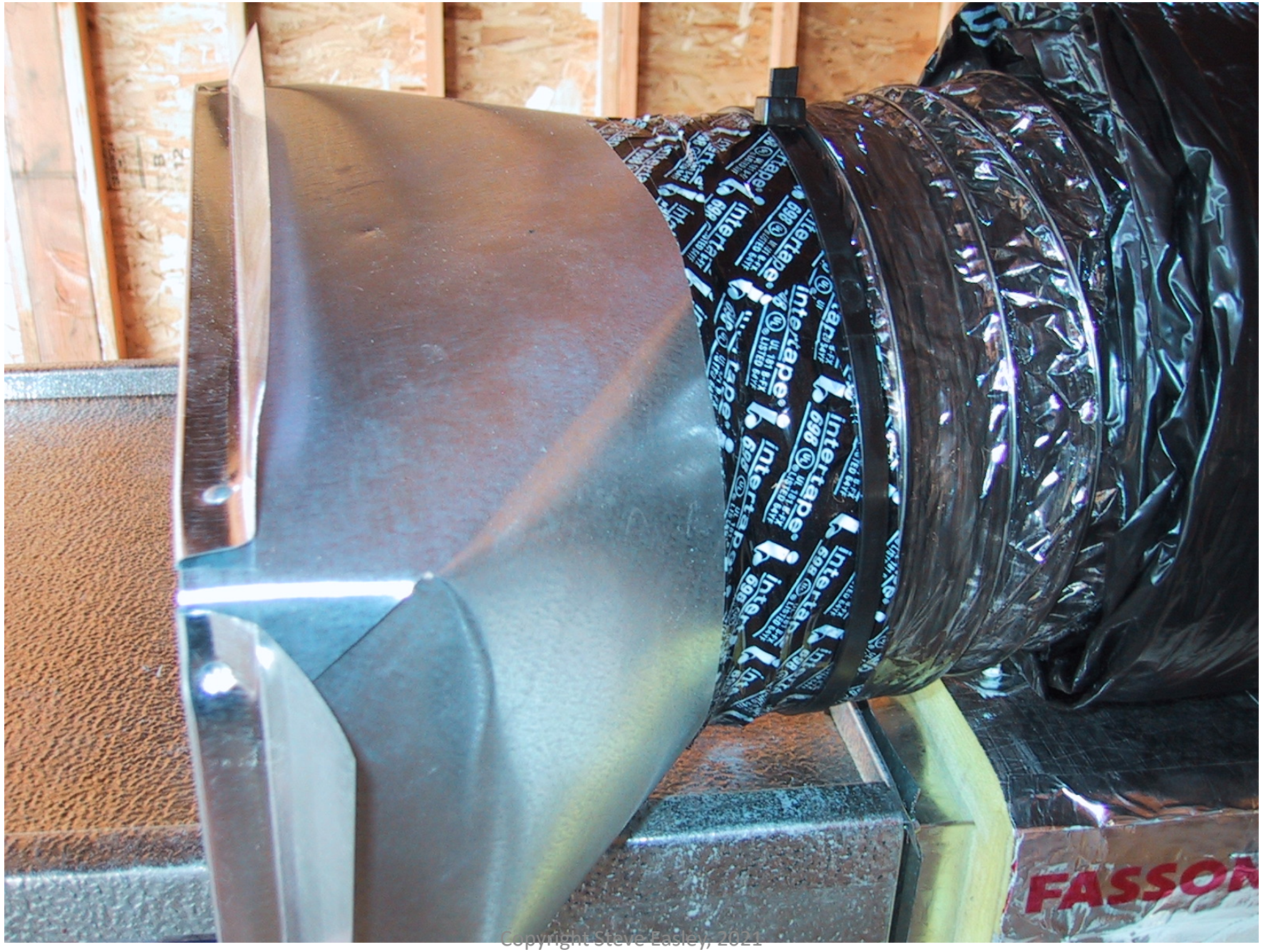

ALNOR

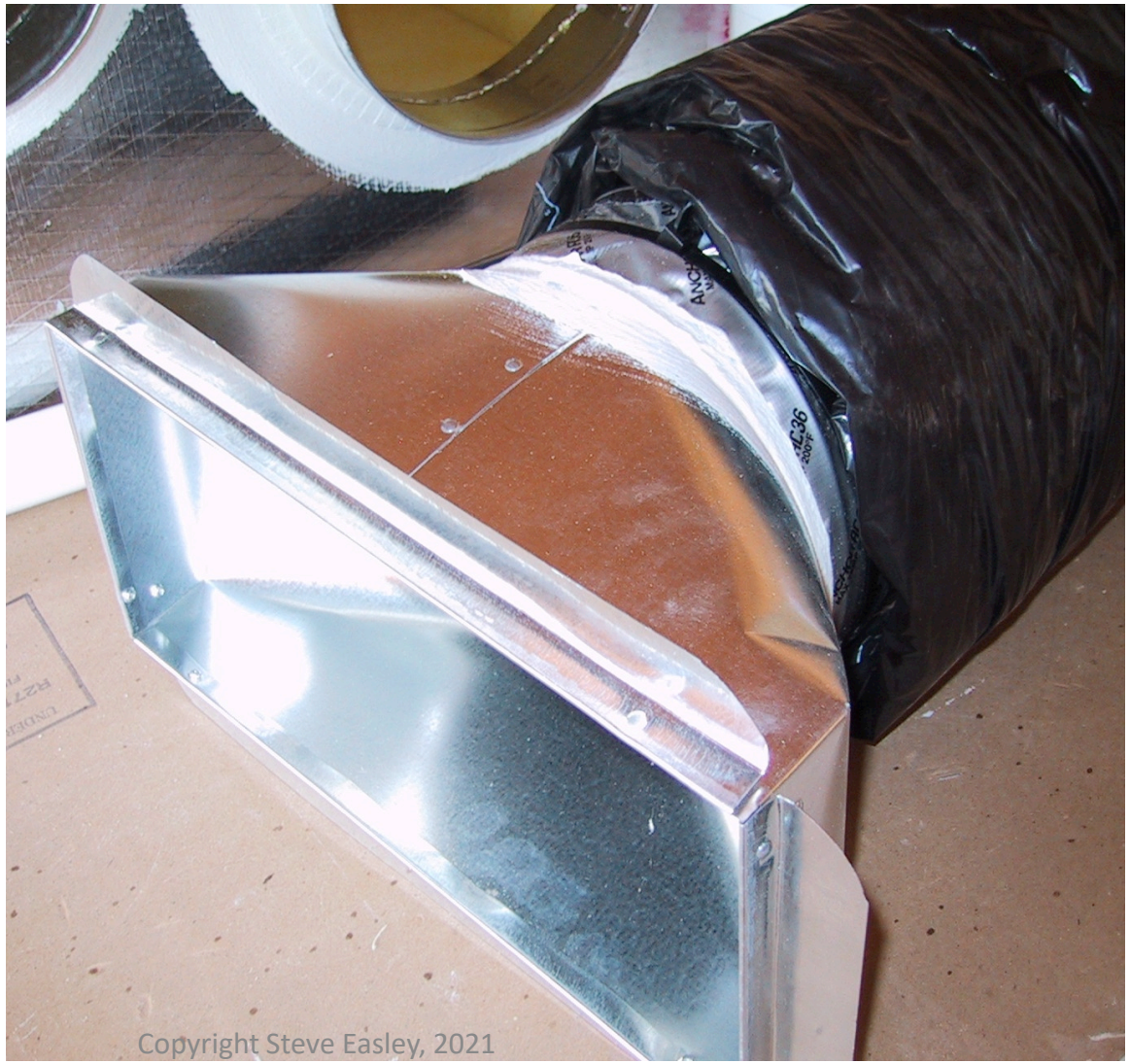
Duct Installation

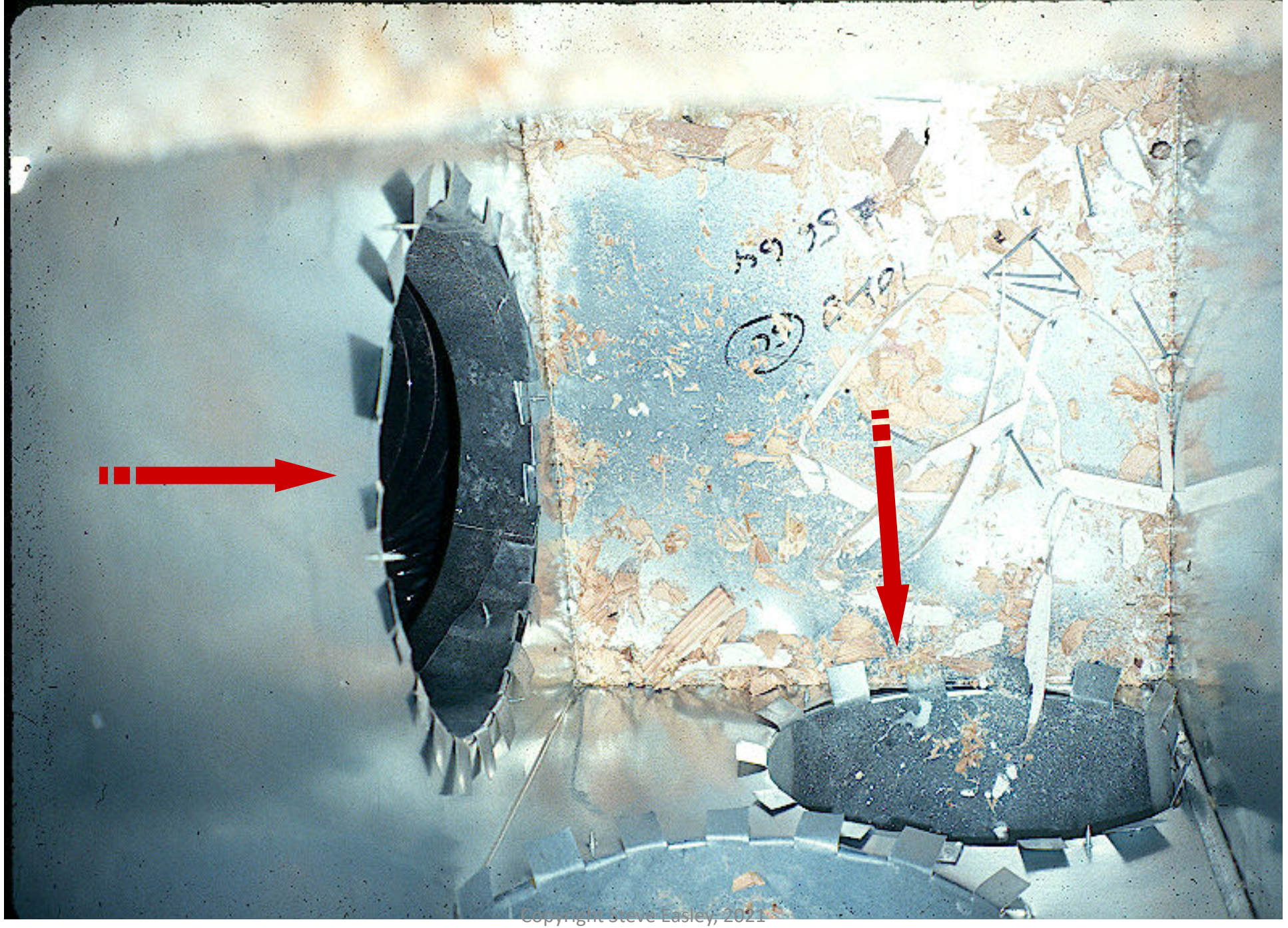
- Duct runs straight with no kinks or crushed areas.
- Ducts to have no more than 90˚ angle turns.
- Ducts sealed with mastic sealant.
- Flex duct connections to boots fastened with duct ties
- Duct leakage to meet T-24 standards











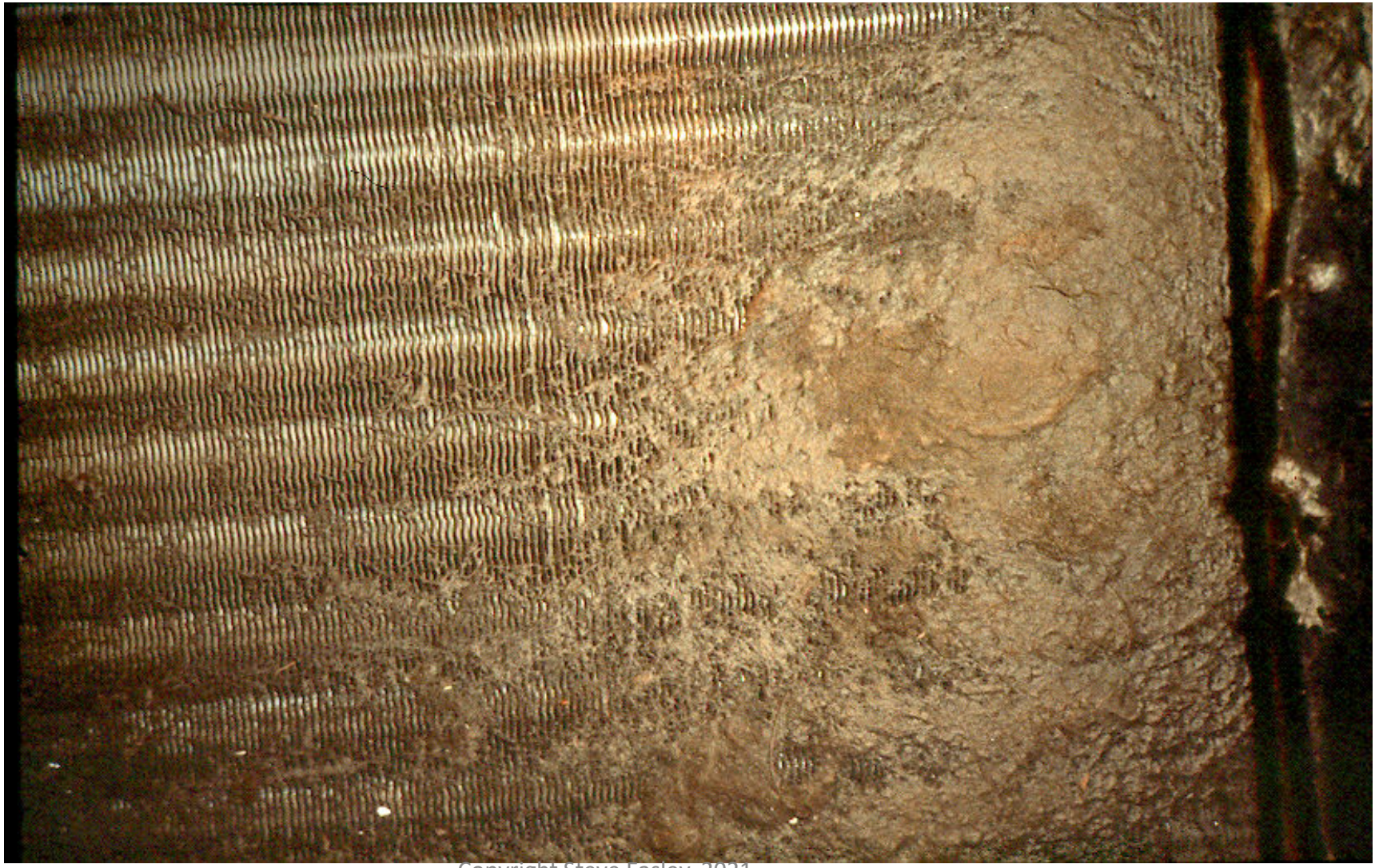
- Cavity returns leak

- Cavity returns are tough to seal

Unit Installation

- Accessible, easy to change filters.
- Removable access panel to clean dirty side of indoor coil.
- Airflow across indoor coil should be between 5 and 15% above manufacturers specifications.
- Outdoor unit placed in a cool shady location.
- Outdoor unit to have unrestricted airflow.
- Plenum to be sealed with mastic sealants and gaskets at connections.

Clogged Evaporator Coil



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The project will also highlight trending lifestyle issues, such as health and wellness and aging in place designs and technologies.

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Steve Easley, Msc, is an internationally recognized construction consultant specializing in solving building science related problems and educating building industry professionals and their trade partners. His work focuses on increasing quality of construction, sustainability, performance, and reducing costly mistakes that lead to construction defects and call backs.

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