We will be starting soon!

Thanks for joining us

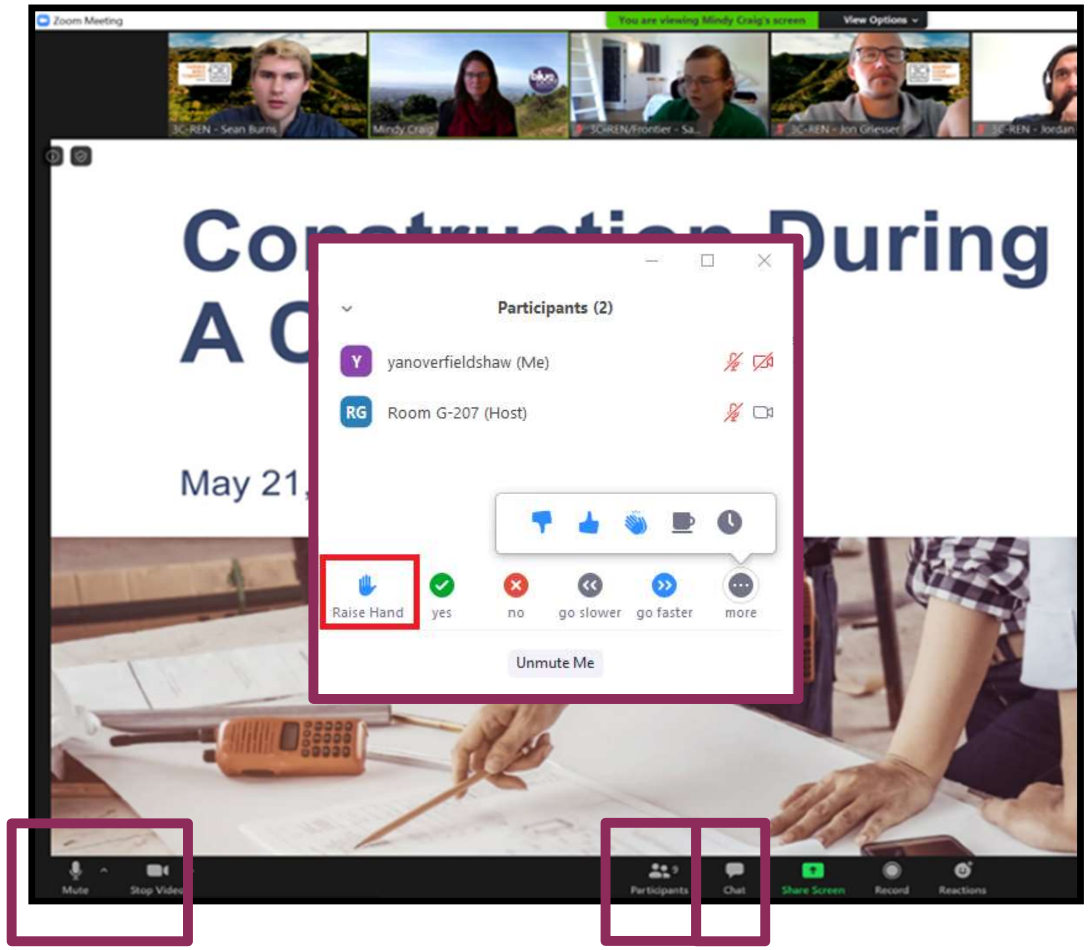
Heat Pump Fundamentals: Space Conditioning and Water Heating

Dan Perunko, Balance Point Home Performace

September 13, 2022

Zoom Orientation

- Please be sure your full name is displayed
- Please mute upon joining
- Use "Chat“ box to share questions or comments
- Under "Participant" select "Raise Hand" to share a question or comment verbally
- The session may be recorded and posted to 3C-REN's on-demand page. Feel free to ask questions via the chat and keep video off if you want to remain anonymous in the recording.



3C-REN: Tri-County Regional Energy Network

- Three counties working together to improve energy efficiency in the region
- Services for –
  - **Building Professionals:** industry events, training, and energy code compliance support
  - **Households:** free and discounted home upgrades
- Funded by ratepayer dollars that 3C-REN returns to the region

3C-REN
Staff Online

3C-REN ENERGY CODE CONNECT

3C-REN HOME ENERGY SAVINGS

3C-REN BUILDING PERFORMANCE TRAINING

3C-REN

ENERGY CODE CONNECT

- Serves all building professionals
- Three services –
  - **Energy Code Coach**
  - **Training and Support**
  - **Regional Forums**
- Makes the Energy Code easy to follow

Energy Code Coach:
3c-ren.org/codes
805.220.9991

Event Registration:
3c-ren.org/events

3C REN HOME ENERGY SAVINGS

Multifamily (5+ units)

- No cost technical assistance
- Rebates up to $750/apartment plus additional rebates for specialty measures like heat pumps

Single Family (up to 4 units)

- Sign up to participate!
- Get paid for the metered energy savings of your customers

3C-REN.org/home

BUILDING PERFORMANCE TRAINING

- Serves current and prospective building professionals
- Expert instruction:
  - **Technical skills**
  - **Soft skills**
- Helps workers to thrive in an evolving industry

Event Registration:
3c-ren.org/events

Introducing 3C-REN's new High-Performance Fundamentals (HPF) Program

Context

- “High performance” refers to buildings that are designed, built, and commissioned to achieve above-code, optimized performance.
- Specialized companies offering high-performance design and construction services in many parts of the State experience high demand, ongoing backlogs, and difficulty finding qualified new hires.

Goals

- Prepare aspiring building practitioners to for competitive job opportunities.
- For those in the industry, provide a refresher or supplement prior building science knowledge

Content

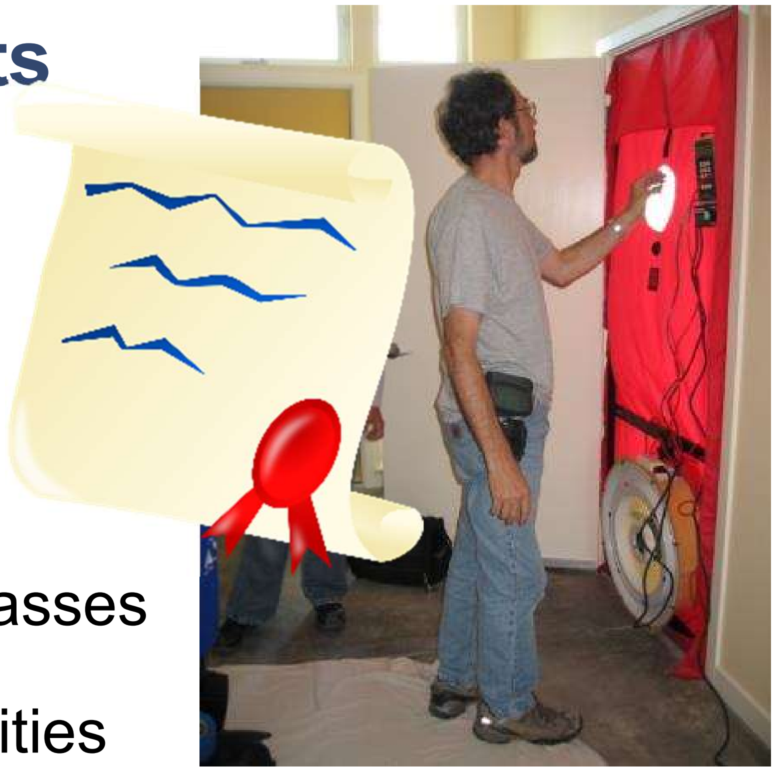
- Developed in consultation with dozens of national experts in high-performance building businesses
- Based on the foundational knowledge they are looking for in new hires
- Rooted in the fundamentals of building science and the design, construction, and business practices that distinguish high-performance practitioners from their conventionally-trained competitors

Classes

1. High-Performance Buildings and Careers: ~~June 21~~
2. The Role of Building Science in High-Performance Buildings: ~~May 17 & 19~~
3. Enclosure Best Practices: Air Sealing, Insulation, Testing & Metrics: ~~July 12~~
4. Heat Pump Fundamentals: Space Conditioning and Water Heating: September 13
5. Water Heating Distribution Best Practices: ***Coming in October***
6. How To Assess a Home for Electrification: ***Coming in November***

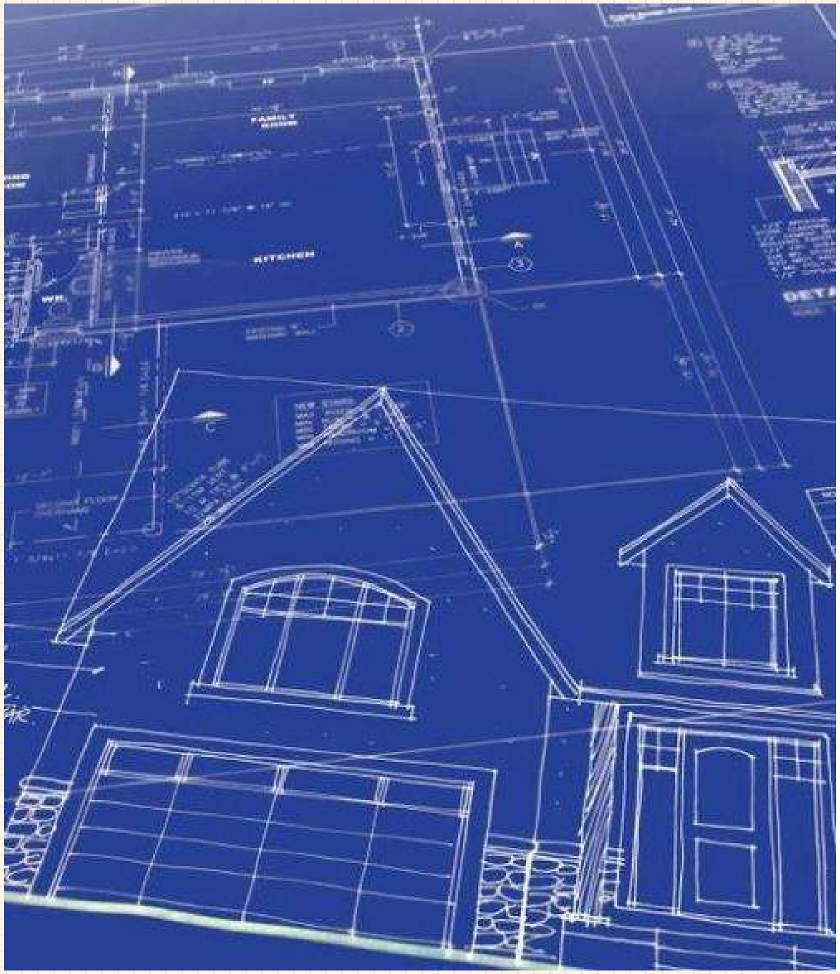
3C REN

Other HPF Program Elements



3C-REN's plans for further program development include:

- Formal certificate of completion
- Field-based, hands-on classes to complement initial series of lecture classes
- Mentorship and/or peer learning activities to support participants' learning process



Heat Pump Fundamentals: Space Conditioning and Water Heating

DAN PERUNKO

DAN@BALANCEPOINTHP.COM

Developed in partnership with 3C-REN




Dan’s Background

1. **Working contractor and installer**
2. **My first exposure to HVAC systems was through a ‘high performance’ buildings class.**
3. **Learned how to build high performance HVAC by testing and modifying our installations until they met performance targets.**
4. **Everything that matters with regard to operating performance can be tested during the installation process.**
5. **High performance is my daily practice – in both very hot and very cold and snowy climates – Sierra mountains and foothills.**

www.balancepointhp.com

balance point
home performance

530-477-0695
Dan@balancepointhp.com
Construction, Consulting, Training

Dan’s Background

Dan's Background

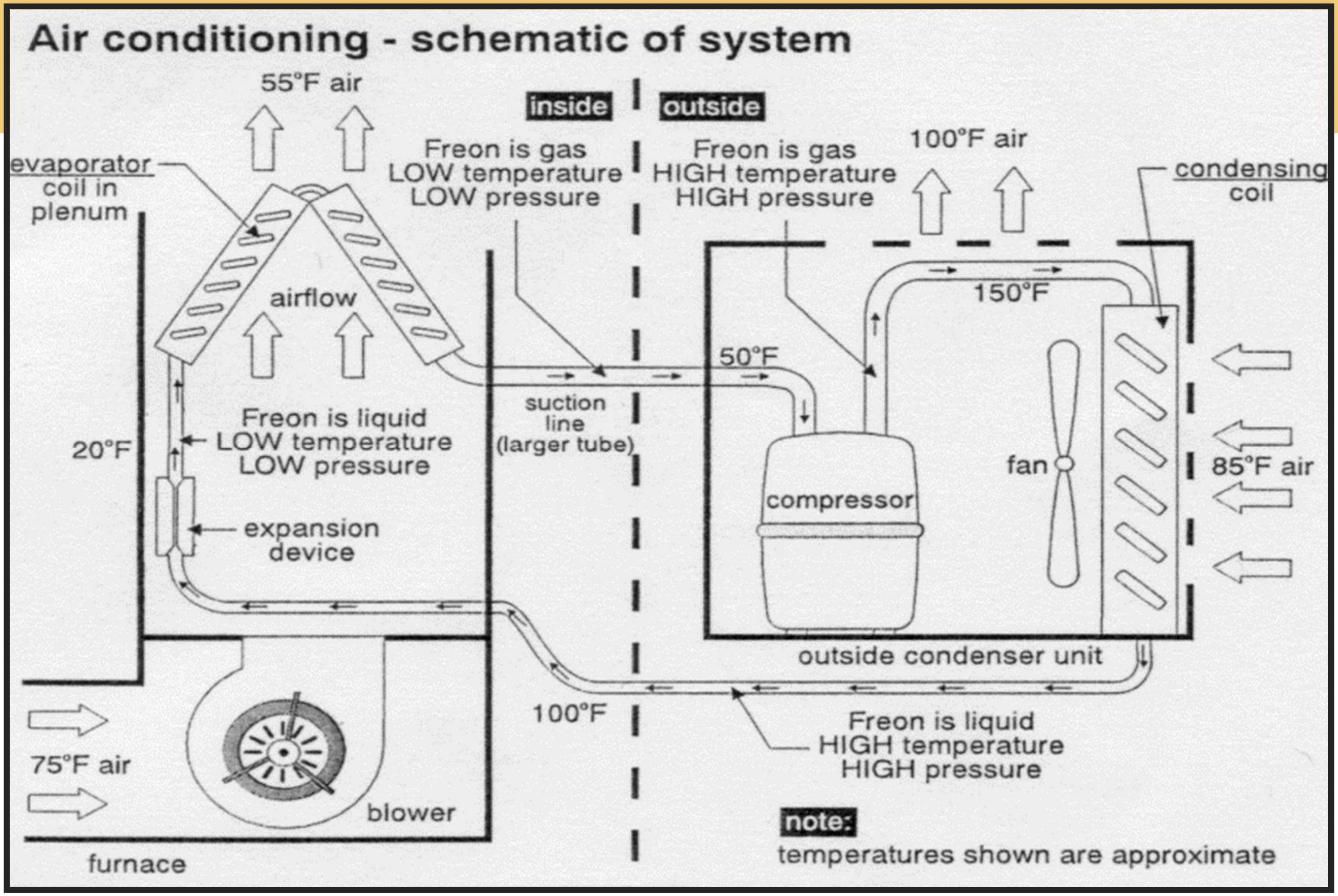
Agenda

1. What is a heat pump?
2. What are heat pumps used For?
3. Heat pump benefits
4. Refrigerants and the environment
5. Heat pump design and installation
6. Heat pump water heaters
7. Q&A (15 minutes)

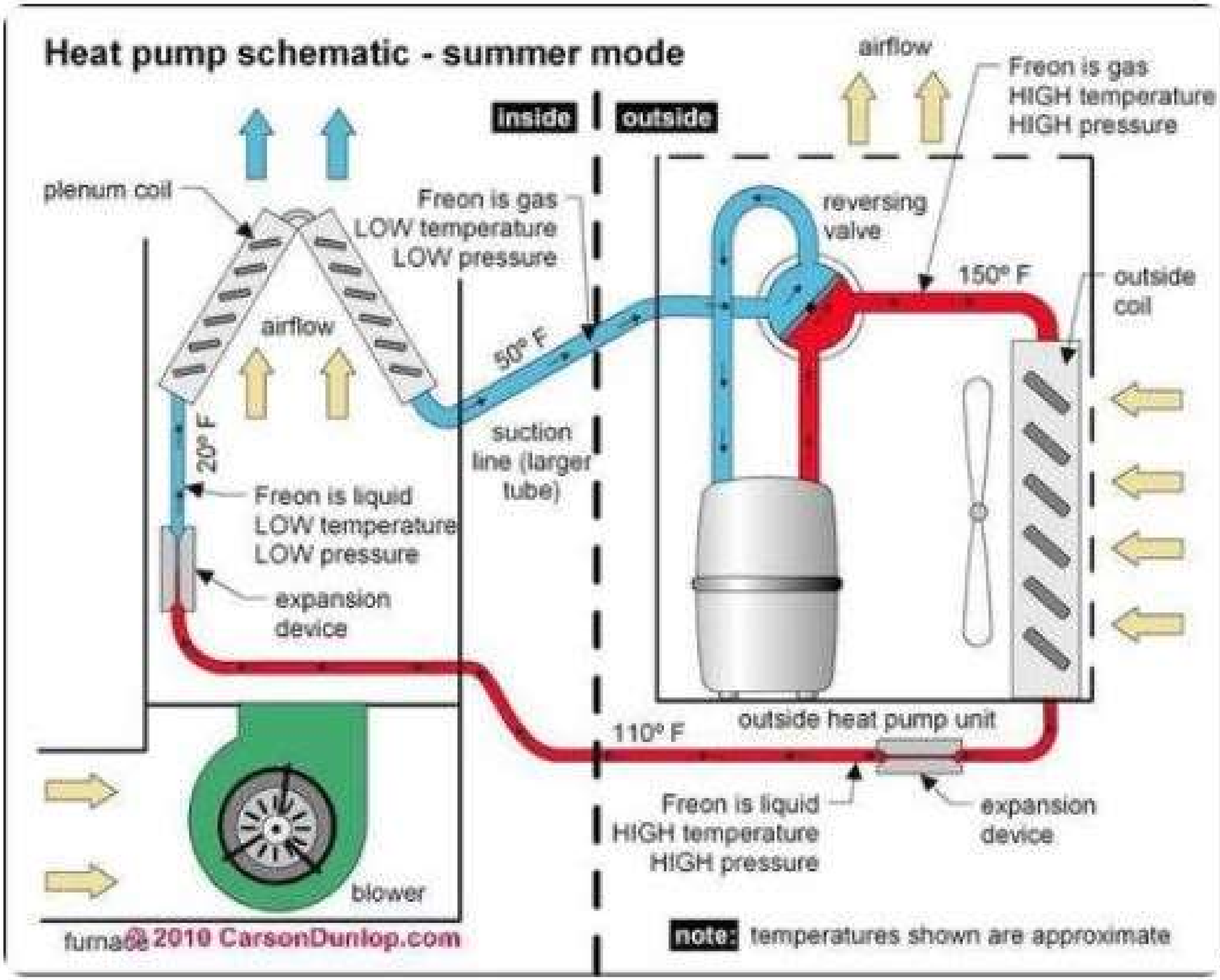
1. What is A Heat Pump

EXPLANATION AND EXAMPLES

Heat pumps are based on a minor change to technology we have relied on for decades



www.balancepointhp.com 530-477-0695


Heat pump schematic - summer mode
inside
outside
airflow
Freon is gas
HIGH temperature
HIGH pressure
plenum coil
Freon is gas
LOW temperature
LOW pressure
reversing
valve
150° F
outside
coil
airflow
50° F
suction
line (larger
tube)
20° F
Freon is liquid
LOW temperature
LOW pressure
expansion
device
outside heat pump unit
110° F
Freon is liquid
HIGH temperature
HIGH pressure
expansion
device
blower
furnace 2010 CarsonDunlop.com
note: temperatures shown are approximate

2. How Heat Pumps Are Used

CONCEPT CONFIRMATION

Uses

Space Conditioning – Heating and Cooling

- Single speed – legacy
- Multi speed and variable speed - communicating
- Ductless mini split
- Ducted mini split

Water Heating

- Split System
- Unitary System

Single Speed Split - Legacy

SEER 15-16

Multi Speed or Variable Speed Split System - Communicating

SEER 18 - 24

Ductless Mini Splits

Single Head
SEER 19-30.5

Multi Head
SEER 18-22

Ductless Mini Splits

Multi Head Ductless Mini Splits

Ceiling Cassette - Ductless

Mind the Building Enclosure

Ducted Mini Split

Water Heating with Heat Pumps

The Same Basic Technology

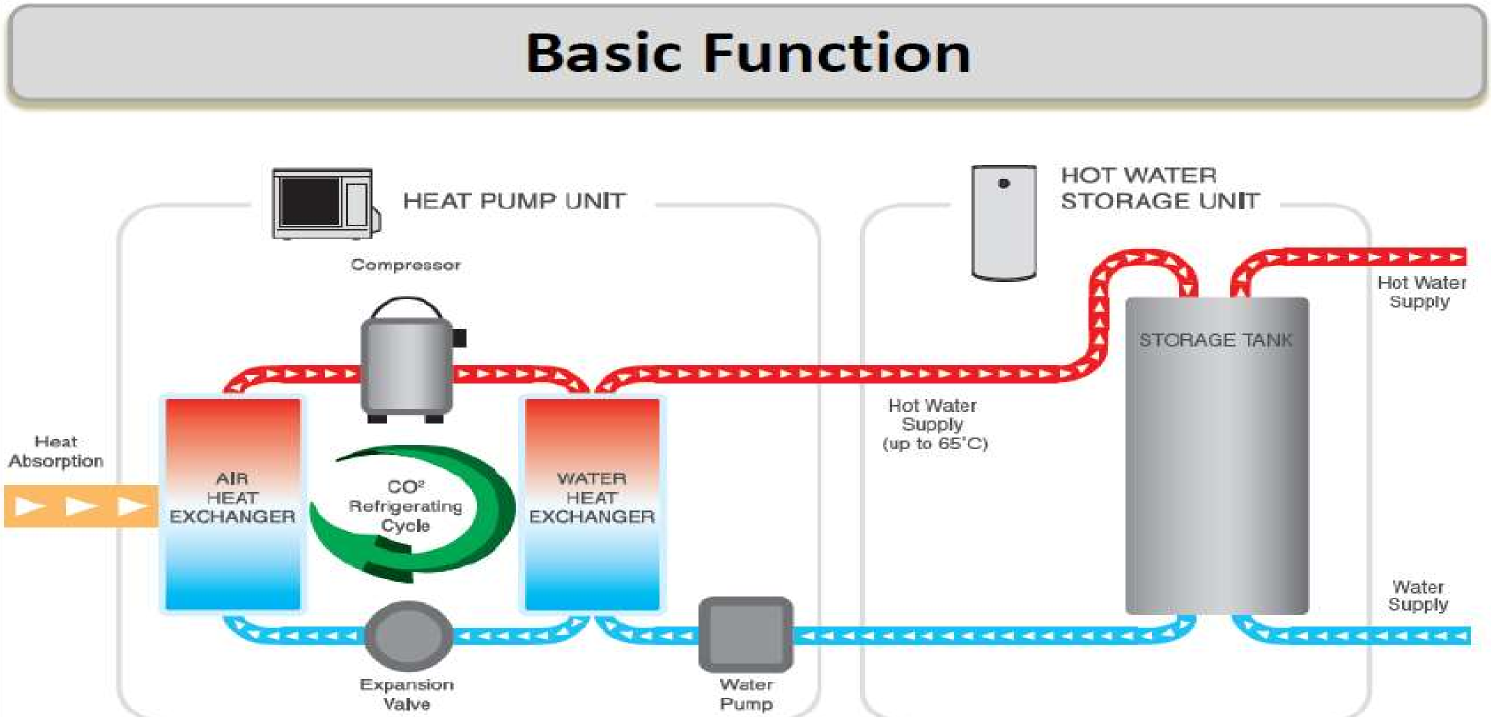


Illustration from Sanden Brochure

Heat Pump Water Heaters

Unitary

Split System

Heat Pump Water Heaters

RHEEM


Water
Residential Electric
Professional *Prestige* ProTerra
Plugin Heat Pump Water Heaters

The new degree of comfort.®

Professional *Prestige*® ProTerra™ Plugin Heat Pump is the most efficient water heater available

Efficiency
- Up to 3.0 UEF reduces operating cost
- ENERGY STAR® rated

Performance
- Ambient operating range: 45-140° F is widest in class designed to meet Northern Climate Spec (Tier 2)

Easy Installation
- Easy access side connections
- Factory installed plugin power cord, direct plugin.
- Easily replaces a standard gas water heater

Integration
- LED Screen with built-in water sensor alert with audible alarm[1]

EcoNet®

- Integrated EcoNet® WiFi-connected[2] technology and free mobile app gives users control over water heater, allowing for customizable temperature, vacation settings, energy savings and system monitoring at home or away. Visit Rheem.com/hybridsolutions

Operation Modes
- Heat Pump
- Vacation/Away: 2-28 days (or placed on hold indefinitely)

Plus...
- Premium grade anode rod with resistor extends the life of the tank
- 3/4" NPT water inlet and outlet; 3/4" condensate drain connections
- Easy access, top mounted washable air filters
- 2" Non-CFC foam insulation
- Enhanced flow brass drain valve
- Temperature and pressure relief valve installed
- Design certified to NSF/ANSI 372 (Lead Content)

Warranty
- 10-Year limited tank and parts warranty

See Residential Warranty Certificate for complete information

Units meet or exceed ANSI requirements and have been tested according to D.O.E. procedures. Units meet or exceed the energy efficiency requirements of NAECA, ASHRAE standard 90, ICC Code and all state energy efficiency performance criteria.

Professional *Prestige* ProTerra Plugin Heat Pump
40 and 50 Capacities
120 Volt / 1 PH
Electric

LEED Points = 3

GE also is releasing a 120 V model

Requires 20A 120V circuit

12,000 Btuh

3. Heat Pump Benefits

HIGHEST EFFICIENCY AVAILABLE!

Why Heat Pumps Offer Advantages

- **Allow buildings to move to "Zero Carbon"**
- **Allow building owners to be in line with California Climate Goals – Shut-down the gas distribution System.**
- **Gas Appliances will become obsolete at the time the gas infrastructure goes offline.**
- **Current operating cost can be lower for heat pumps than gas appliances.**

The Math – Cost to Deliver One Million Btu of Heat

Natural gas furnace as typically found (80% furnace, attic ducts):

10 Therms (MMBtu) * $2.33/Therm / (80% * 50%) = $58.25

New natural gas furnace and new duct system (95%, new ducts):

10 Therms (MMBtu) * $2.33/Therm / (95% * 85%) = $28.85

The Math – Cost to Deliver One Million Btu of Heat

New electric ducted mini-split heat pump (HSPF-12.2):

293 KWH (MMBtu) * $0.2824/KWH / (360% * 85%) = $27.04

New electric ducted mini-split heat pump (HSPF-12.2, ducts inside):

293 KWH (MMBtu) * $0.2824/KWH / (360% * 100%) = $22.98

The Math – Cost to Deliver One Million Btu of Heat

New ducted heat pump ducts as typically found (80% furnace, attic ducts):

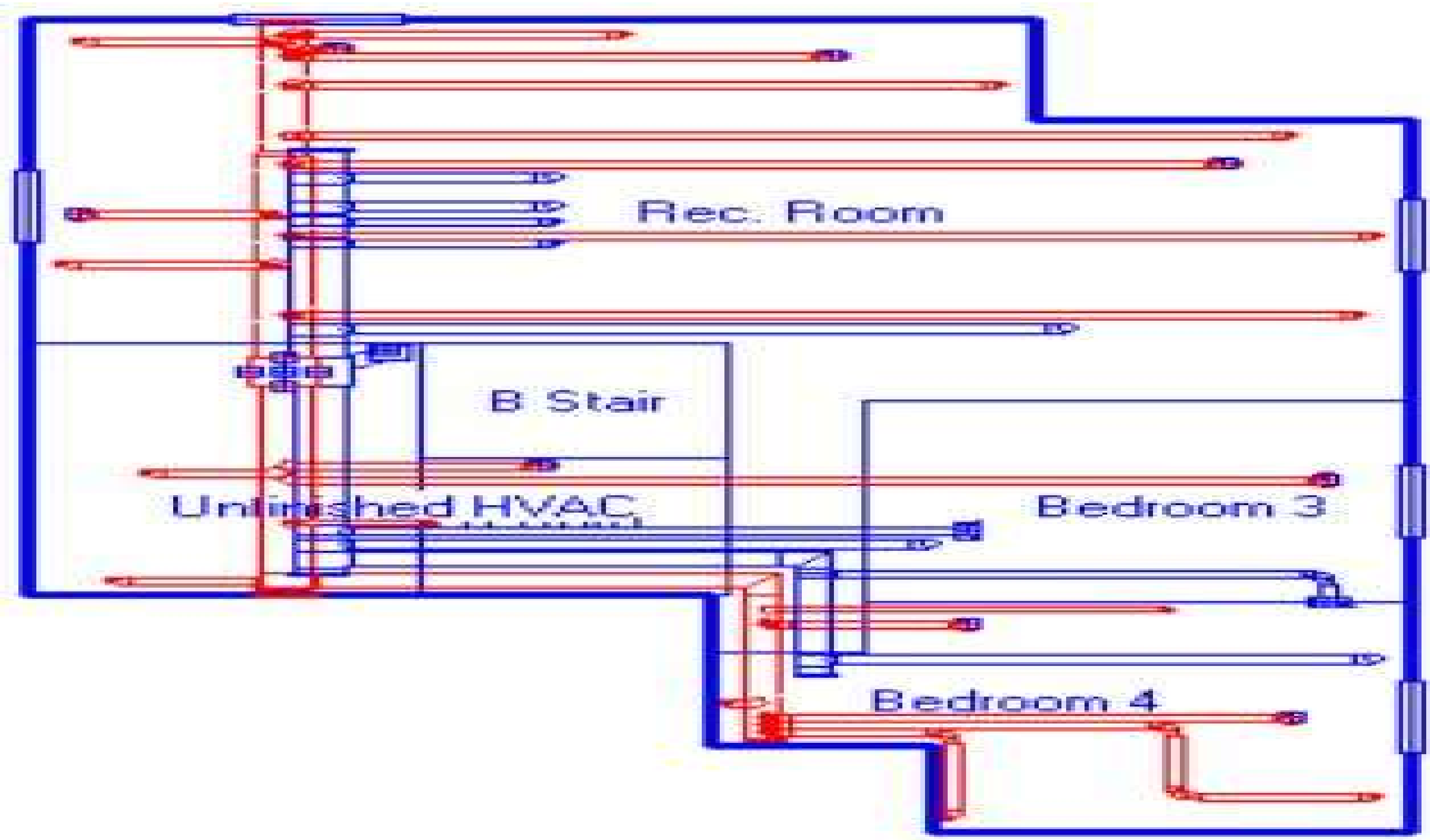
293 KWH (MMBtu) * $0.2824/KWH / (360% * 50%) = $45.96

“Box swaps” with heat pumps are a really bad idea

The largest operating cost savings appear when heat pumps are combined with onsite gerneration.

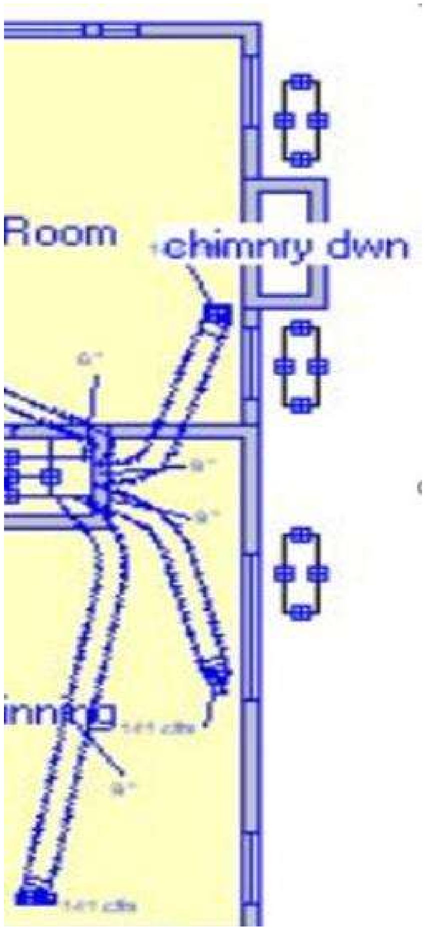
Why Heat Pumps Offer Advantages

We Get to STOP Doing This!!!!



Why Heat Pumps Offer Advantages

Why Heat Pumps offer Advantages

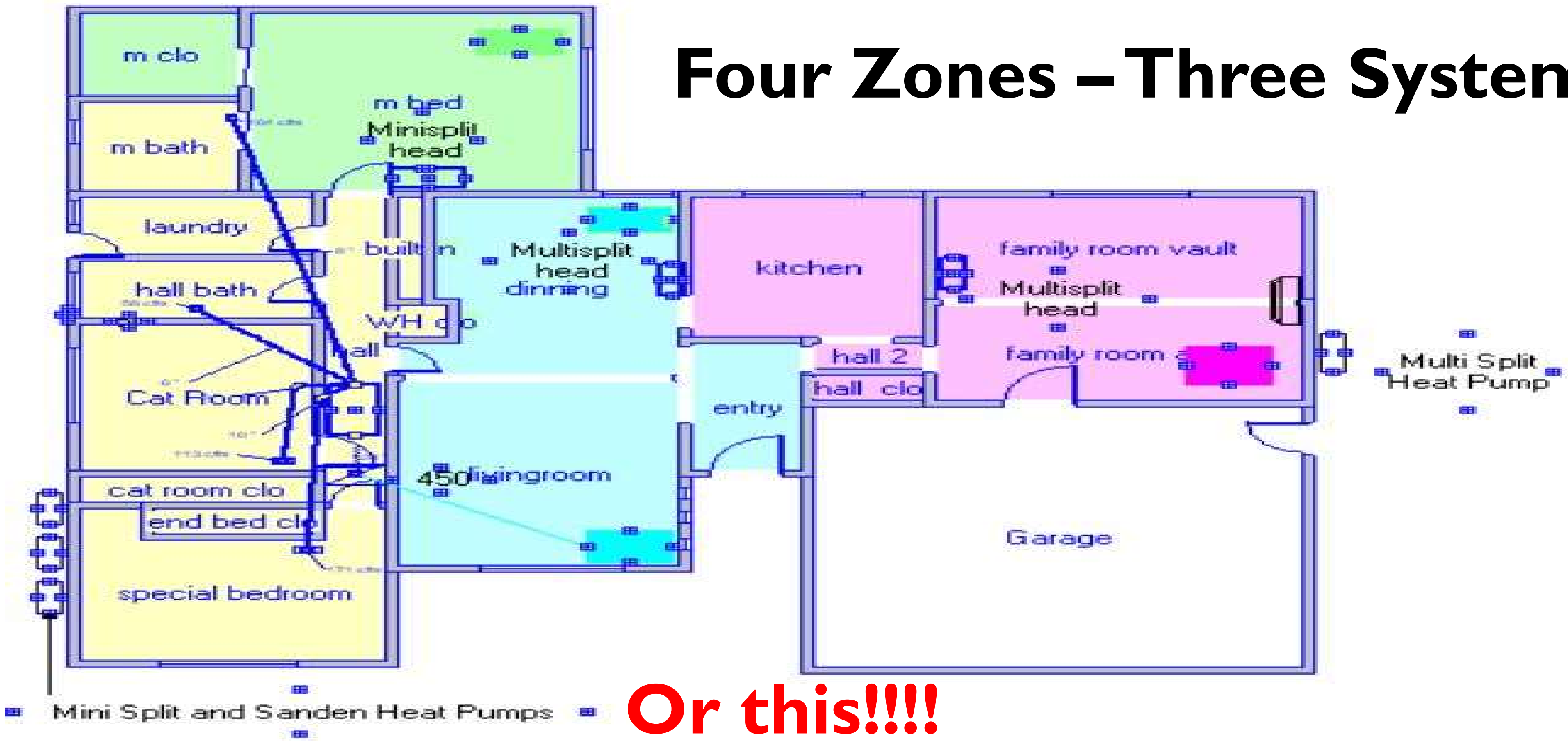


Instead we can do this!!!!

Three Zones!

Three Systems!

Four Zones – Three Systems



Or this!!!!

Why Heat Pumps Offer Advantages

If for no other reason, mini splits are great because we can fit them in our building's structure.

Why Heat Pumps Offer Advantages

Why Heat Pumps Offer Advantages

The Installed efficiency of ductless systems is higher than anything else available.

We can choose single head installs for the highest efficiency

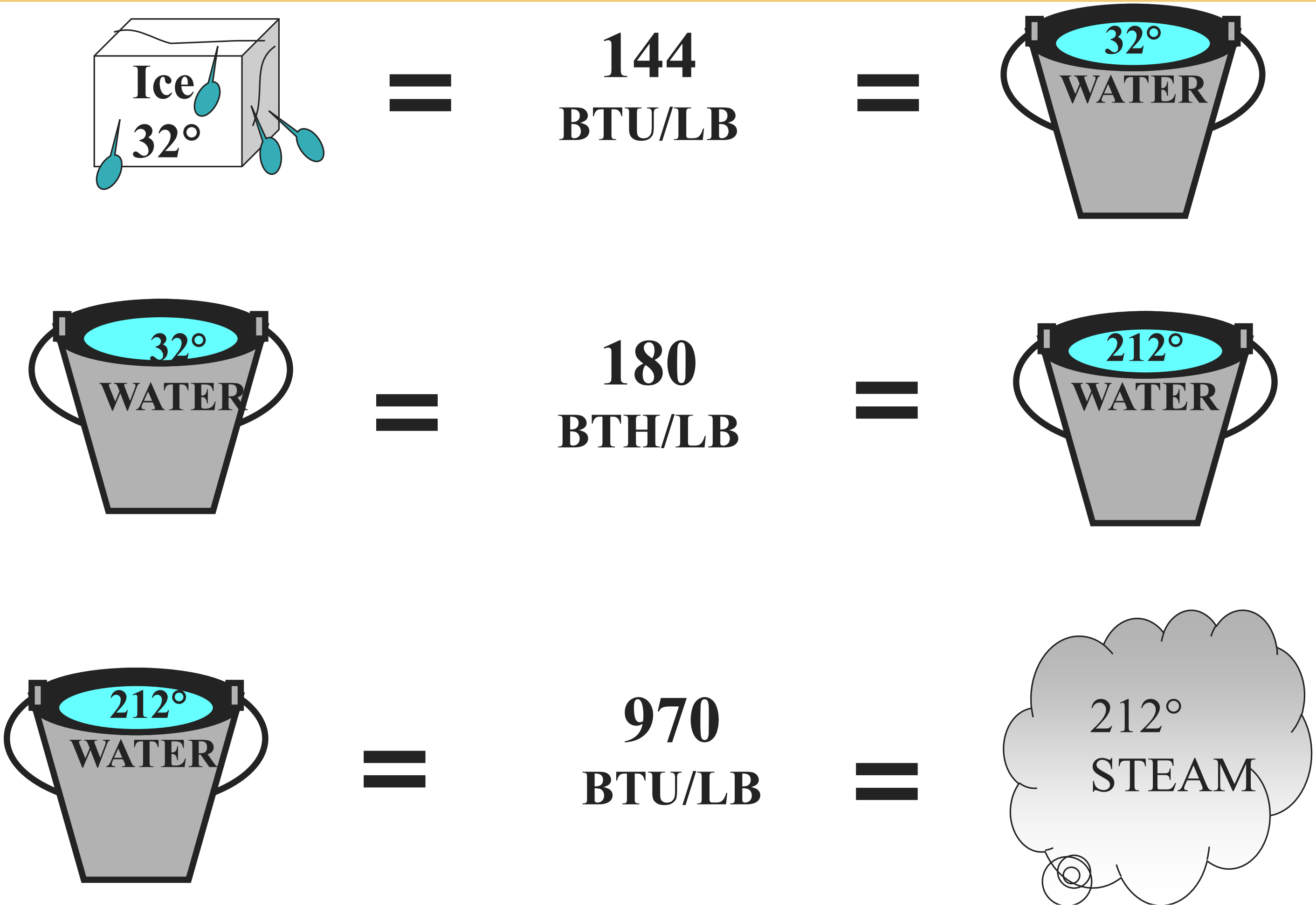
We can choose multi head installs to lower upfront costs

We can choose VRF systems which allow a much larger buildings to be served by one unit and lots of indoor heads.

4. Refrigerants

THE CLIMATE AND YOUR PROFITABILITY

Heat Pumps use “phase change” to move large quantities of heat



Refrigerants, Climate Change, and Profitability

- **Leaking systems are very common**
- **Leaking refrigerants have a huge global warming impact**
- **Leaking systems during the warranty period are very expensive for contractors**
- **Proper installation techniques are needed to limit leaks**
- **Normal service and maintenance activities can dramatically undermine our carbon reduction efforts**

To succeed in lowering carbon emissions, we need new service procedures & new refrigerants – NOW!

Profitability

Repairing a refrigerant leak is a 4 to 8 hour service call if done well.

A system that leaks in the warranty period can easily cost a contractor (per technician):

- **Direct labor cost $320 to $640, plus materials**
- **Lost revenue $600 to $1200**

(Assumes labor cost of $80 per hour and billing rate of $150 per hour)

How do Heat Pumps Interact with Global Climate Change?

- Refrigerants have large global Warming Potential
- Leak Potential – Manufacture, Install, Lifetime Service, Recovery, Reprocessing
- Refrigerant mishandling has heavy penalties and virtually no enforcement.
- "De minimis" release is legal

100 Year Global Warming Potential

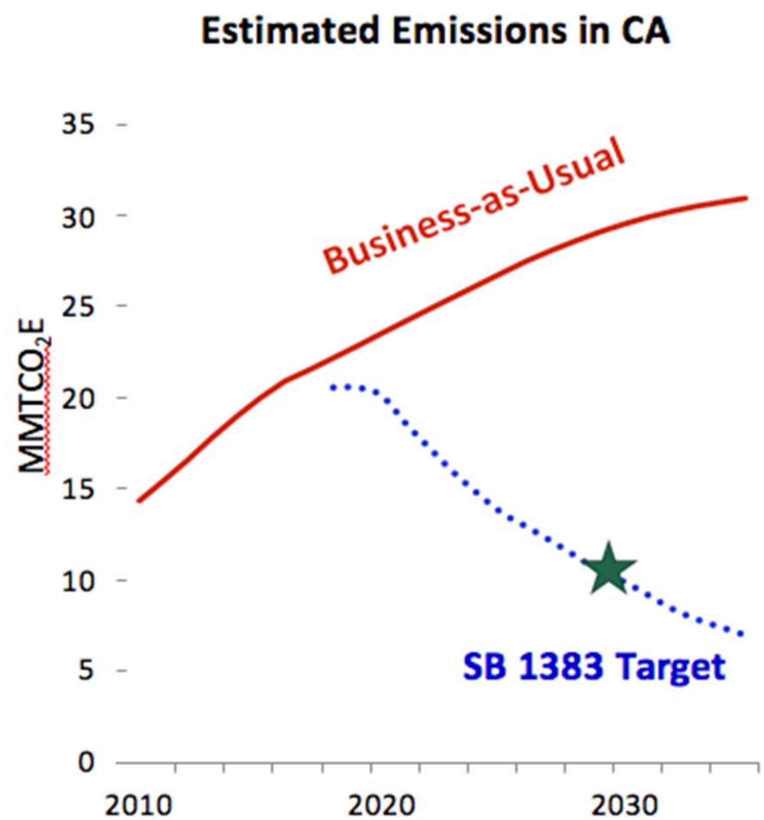
Gas	GWP_{100}
CO_2	1
Methane CH_4	25
N_2O	298
R-12 (CFC) ozone depletion	10,900
R-22 (HCFC) less ozone depletion	1810
R-410A (HFC)	**2090**
Propane R-290	3
Ammonia	0

In California HFCs are the Fastest Growing Source of Greenhouse Gases

- Currently 4% of California GHG Emissions
- Emissions projected to double over 20 years

- SB 1383 reduction goal: 40% below 2013 levels by 2030

CARB



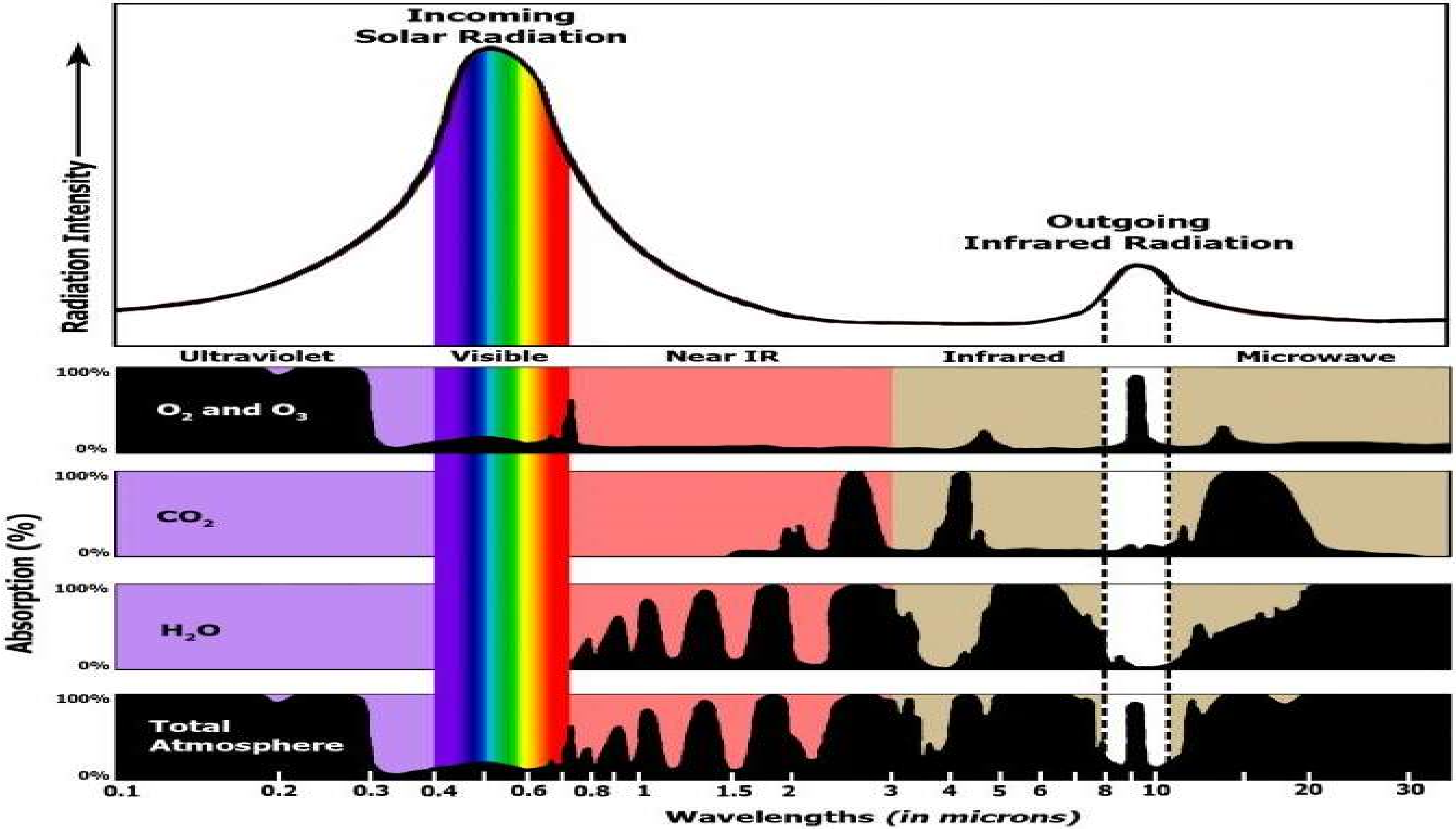
What is Wrong with HFCs (and the earlier refrigerants)?

High global warming potential (GWP)

They are closing the only window of Outgoing Radiation

Just 1 pound of R-410A
= Over a Ton of CO_2
(GWP_{100} of 2090)

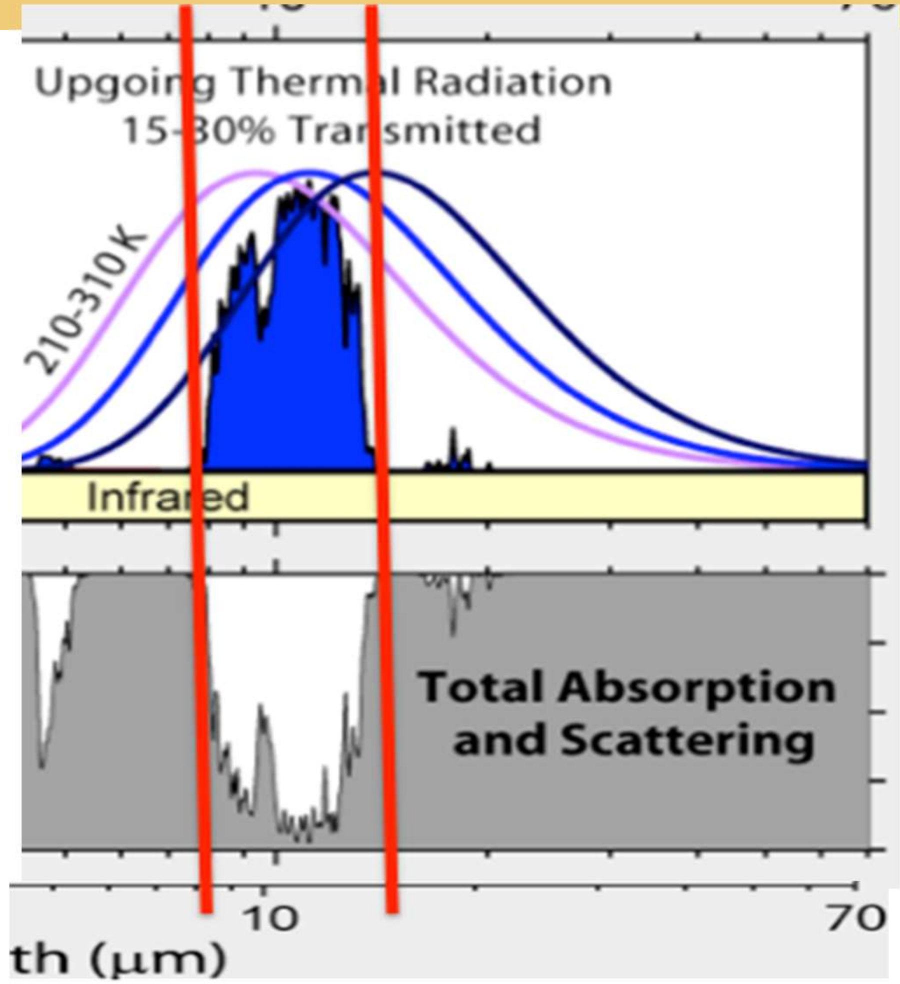
CARB


Incoming
Solar Radiation
Radiation Intensity
Outgoing
Infrared Radiation
Ultraviolet
Visible
Near IR
Infrared
Microwave
100%
0%
O2 and O3
CO2
H2O
Total
Atmosphere
Absorption (%)
0.1
0.2
0.3
0.4
0.6
0.8
1
1.5
2
3
4
5
6
8
10
20
30
Wavelengths (in microns)

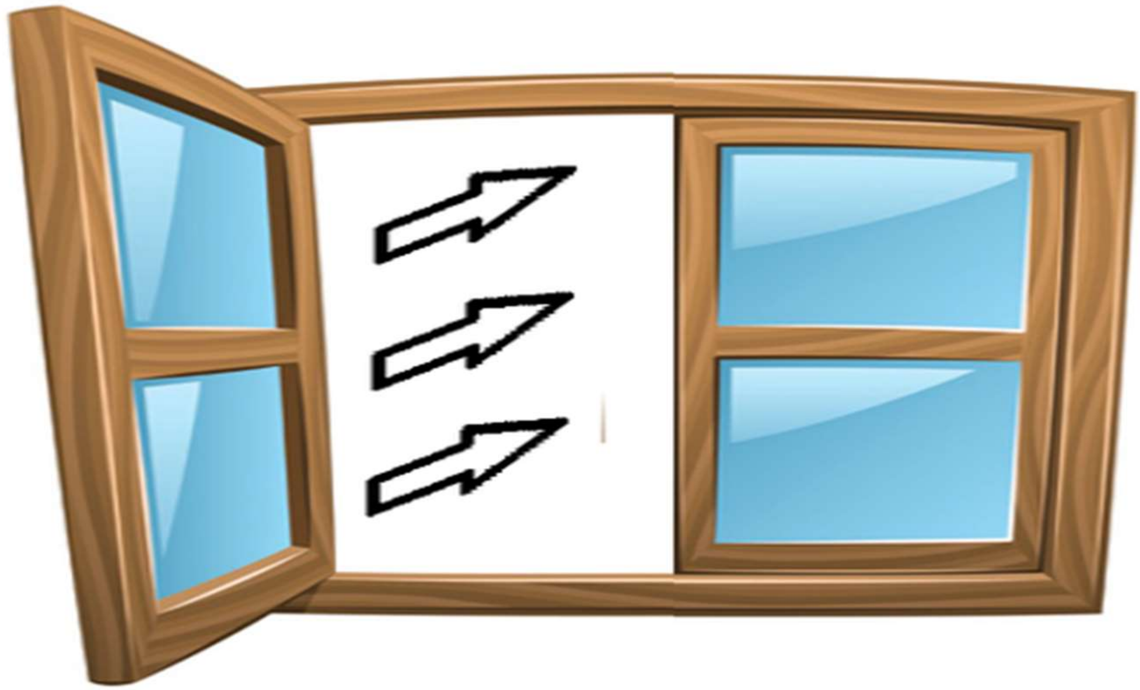
What is Wrong with HFCs (and the earlier refrigerants)?

This is Effectively Earth's Outgoing Thermal Radiation Window

8 to 11 Microns



R410A Closes Part of that Window



Refrigerant Leakage

What percentage of new systems leak?

- Accidentally leaking systems are not illegal are not tracked or reported
- Many technicians are trained to ineffective standards for line set building and testing. Many know the steps but don't really have a standard for what passes or fails.

Selling refrigerant is very profitable

Our Current Best Practice is flawed

One technician x 1oz R410A per service call x 5 service calls per day x 5 days a week

=

1.63 tons of carbon equivalent -R410a

(1 oz R410 x 5 jobs x 5 days x 2088 lbs carbon eq ÷ 2000lbs per ton = 1.63 tons)

(.529 tons of carbon equivalent – R32)

This is a conservative estimate


Rigorous standards for practice are needed as we dramatically raise the volume of refrigerant we introduce to the built environment.

Line Set Assembly, Refrigerant Charge, and Leakage

Leakage is very Prevalent—we have to do better

2018 ASHRAE study found significant leakage rates in flare and compression type fittings.*

Leak testing under pressure is a critical step to identifying failed fittings.

* *Assessment of Leakage Rate and Durability of Field-made Mechanical Joints for Systems Using Low-GWP Flammable Refrigerants* (ASHRAE RP-1808)

Flare Installation

Flares are often required

- Cutters and reamer
- Flare tool
- Don’t use line set nuts
- Refrigerant oil on mating surfaces
- Torque wrench (not always guidance on wet or dry flair nut threads)
- Pressure test at 450 PSI (overnight best) - bubble test for leaks at joints
- Evacuate to 100 to 200 microns (holds below 300 for 15 minutes)
- Adjust charge

Flare Installation

- ✓Flare
- ❑Cutters and reamer
- ❑Flare tool
- ❑Don't use line set nuts
- ❑Refrigerant oil on mating surfaces
- ❑Torque wrench (not always guidance on wet or dry flair nut threads)
- ❑Pressure test at 450 PSI (overnight best) - bubble test for leaks at joints
- ❑Evacuate to 100 to 200 microns (holds below 300 for 15 minutes)
- ❑Adjust charge

Flare Installation

Flare Installation

- ✓Flare
- ✓Cutters and reamer

❑Flare tool

- ❑Don’t use line set nuts
- ❑Refrigerant oil on mating surfaces
- ❑Torque wrench (not always guidance on wet or dry flair nut threads)
- ❑Pressure test at 450 PSI (overnight best) - bubble test for leaks at joints
- ❑Evacuate to 100 to 200 microns (holds below 300 for 15 minutes)
- ❑Adjust charge

Flare Installation

Flare tools

Press-on Fittings

1/2" ZoomLock SAE Flare (PZK-F8-HNBR)

Press-on fittings seem promising, although fittings like these still showed failures in third-party testing. **Leak checking is still critical before putting the system into service.**

Flare Installation

Navac cordless flaring tool

This tool has good reviews and may improve the quality and durability for field manufactured flair connections.

Compression Fitting

In early research, fittings like this did not perform well enough. More research is needed.

Flare Installation

I have no information about the success of these yet. I can imagine how they could cause problems. Research is needed.

Flare Installation

- ✓Flare
- ✓Cutters and reamer
- ✓Flare tool

- ❑Don’t use line set nuts
- ❑Refrigerant oil on mating surfaces
- ❑Torque wrench (not always guidance on wet or dry flair nut threads)
- ❑Pressure test at 450 PSI (overnight best) - bubble test for leaks at joints
- ❑Evacuate to 100 to 200 microns (holds below 300 for 15 minutes)
- ❑Adjust charge

Flare Installation

- ✓Flare
- ✓Cutters and reamer
- ✓Flare tool
- ✓Don’t use line set nuts
- ❑**Refrigerant oil on mating surfaces**
- ❑Torque wrench (not always guidance on wet or dry flair nut threads)
- ❑Pressure test at 450 PSI (overnight best) - bubble test for leaks at joints
- ❑Evacuate to 100 to 200 microns (holds below 300 for 15 minutes)
- ❑Adjust charge

Flare Installation

Flare Installation

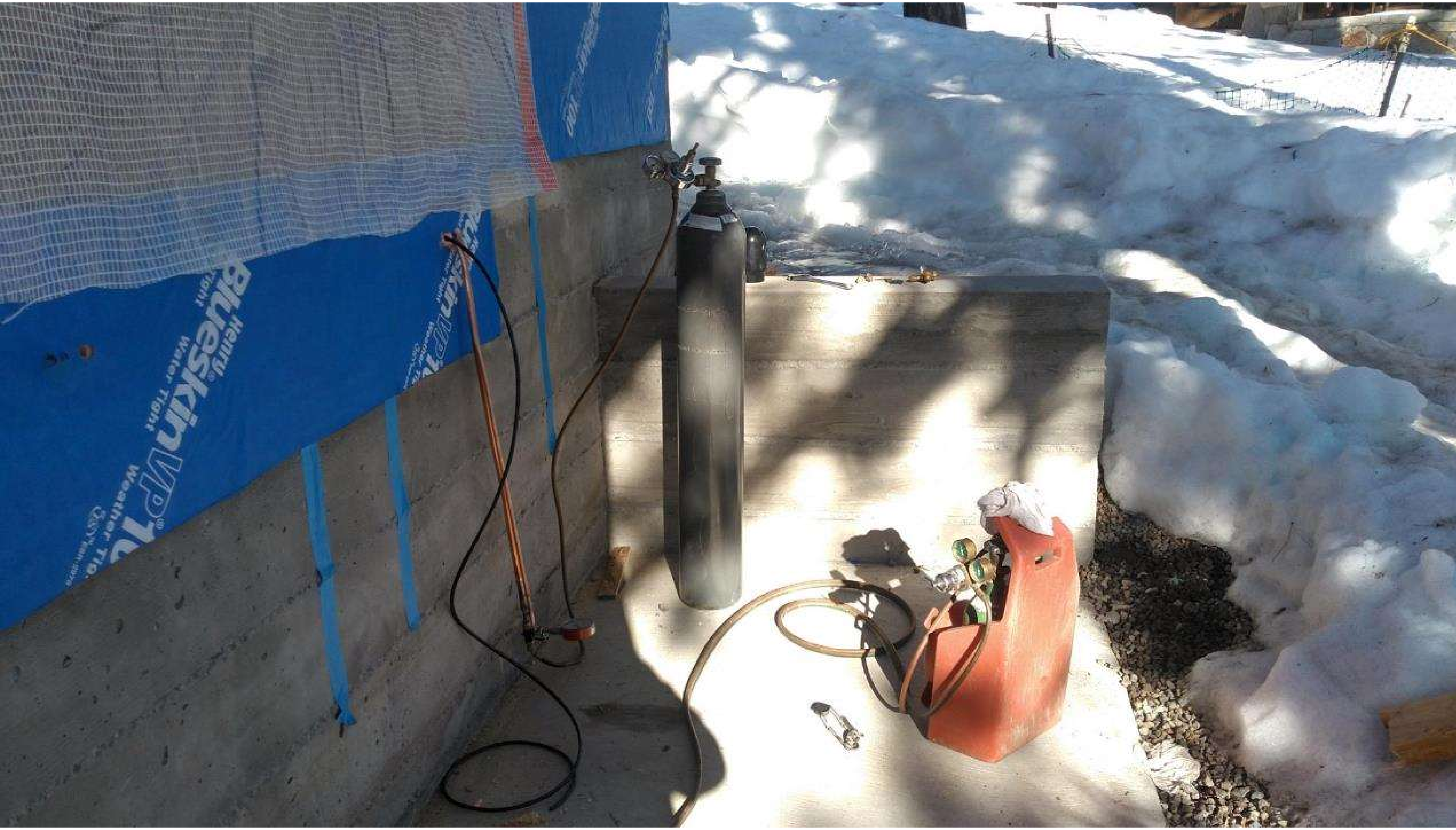
- ✓Flare - Never Braze
- ✓Cutters and reamer
- ✓Flare tool
- ✓Don’t use line set nuts
- ✓Refrigerant oil on mating surfaces
- ❑Torque wrench
- ❑Pressure test at 450 PSI (overnight best) - bubble test for leaks at joints
- ❑Evacuate to 100 to 200 microns (holds below 300 for 15 minutes)
- ❑Adjust charge

Flare Installation


Flare Nut Sizing Chart
YELLOW JACKET

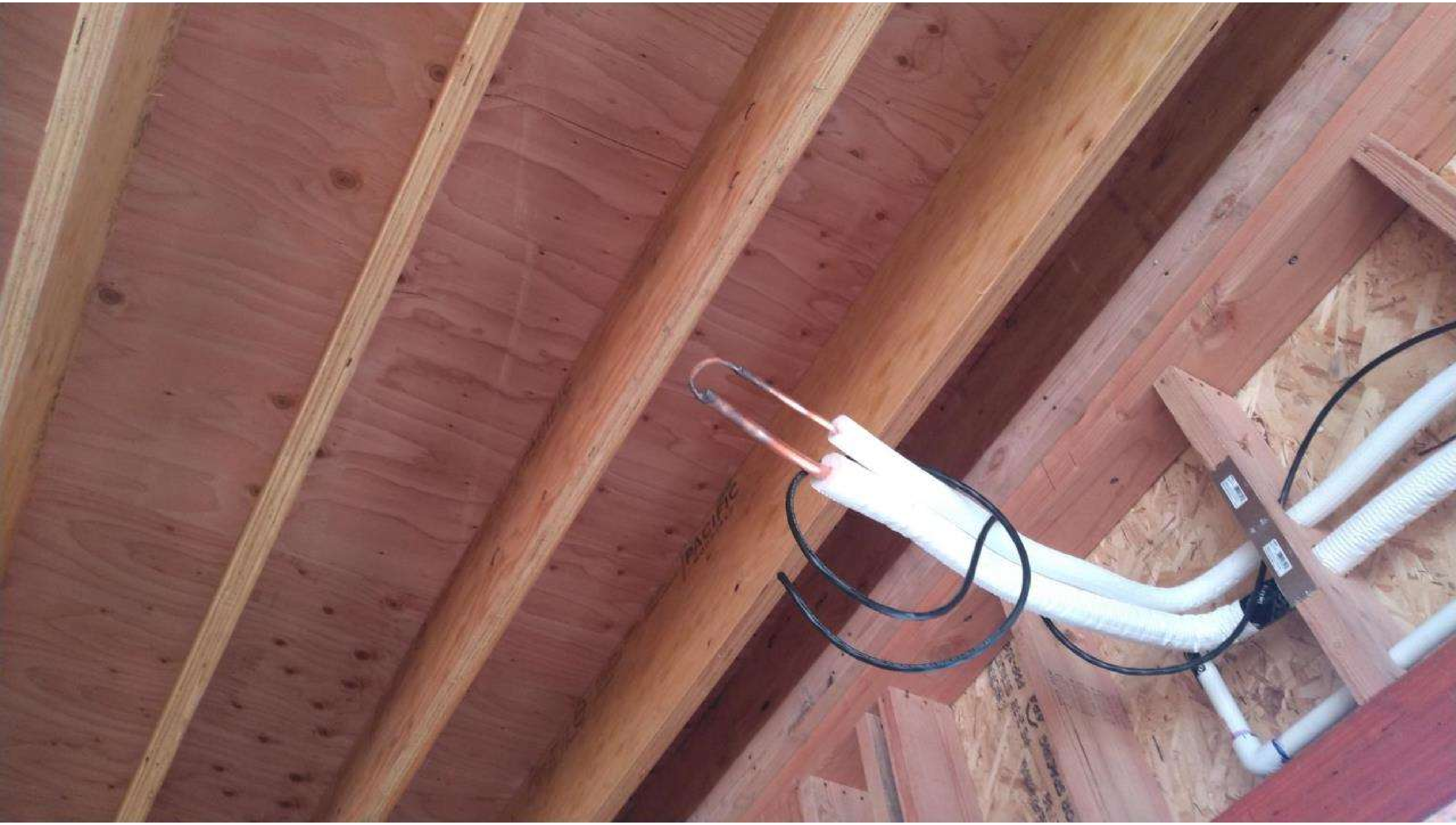
Flare Installation

- ✓Flare
- ✓Cutters and reamer
- ✓Flare tool
- ✓Don’t use line set nuts
- ✓Refrigerant oil on mating surfaces
- ✓Torque wrench (not always guidance on wet or dry flair nut threads)
- ❑Pressure test at 450 - 600 PSI - bubble test for leaks at joints
- ❑Evacuate to 100 to 200 microns (holds below 300 for 15 minutes)
- ❑Adjust charge

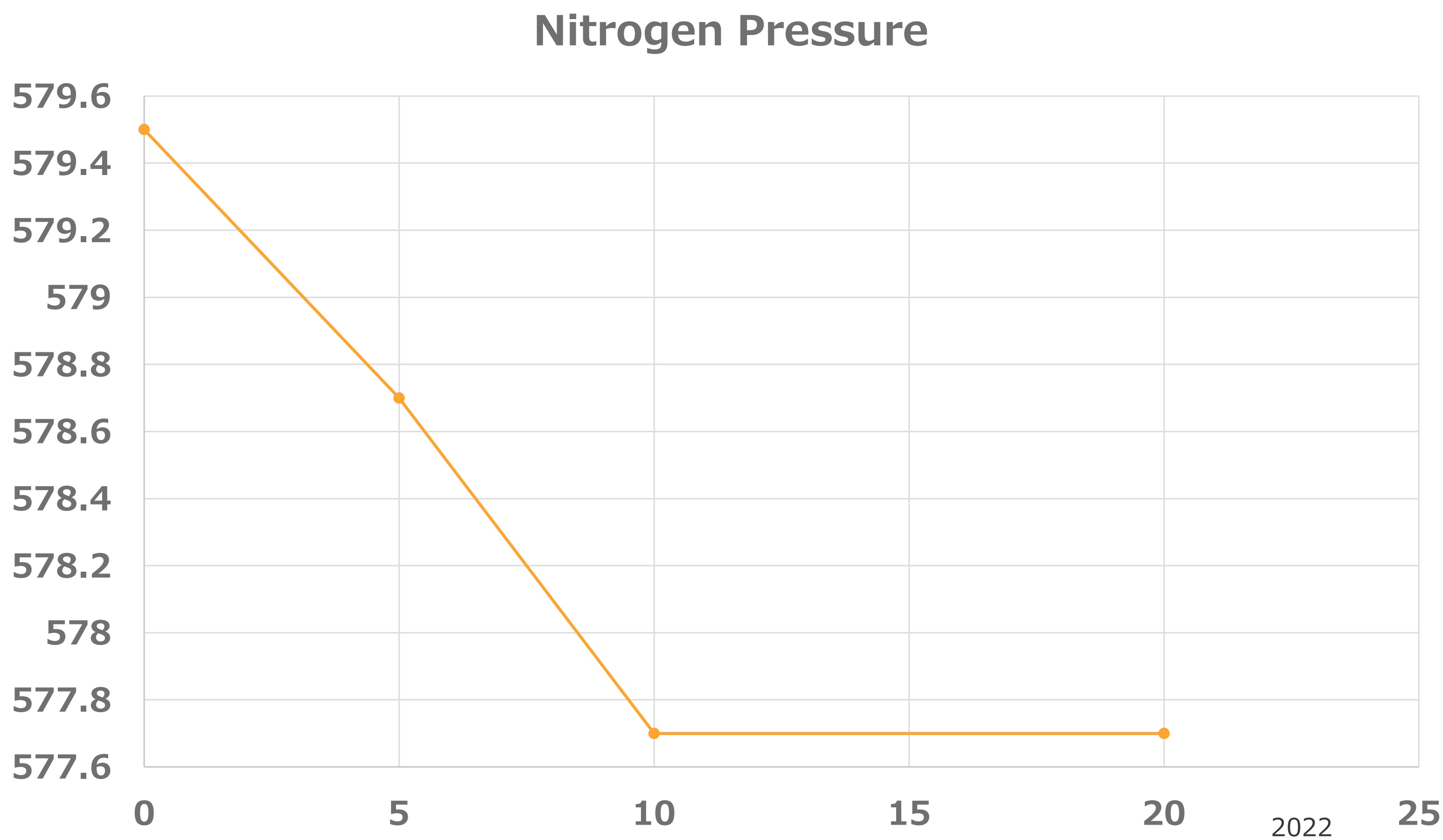

Henry
Blueskin VP10
Water Tight
Weather Tight

Installation

On jobs where you rough in and come back later for finish: leave your line set pressurized with nitrogen.


PACIFIC

Installation



Installation

Installation

Installation

- ✓Flare
- ✓Cutters and reamer
- ✓Flare tool
- ✓Don’t use line set nuts
- ✓Refrigerant oil on mating surfaces
- ✓Torque wrench (not always guidance on wet or dry flair nut threads)
- ✓Pressure test at 450 PSI (overnight best) - bubble test for leaks at joints
- ❑Evacuate to 100 to 200 microns (holds below 300 for 15 minutes)
- ❑Adjust charge

Installation

Installation

PASS	146.0 Microns	0.0 Microns/s
Decay Test Result	**Final Vacuum**	**Avg. Decay Rate**
0:31:01	0:09:56	0:40:58
Time to Ultimate P/D	**Time in Decay**	**Total Elapsed Time**

Customer
Chase

Equipment
Make: Fujitsu
Model: AOU9RLFC
Serial: KYN008018

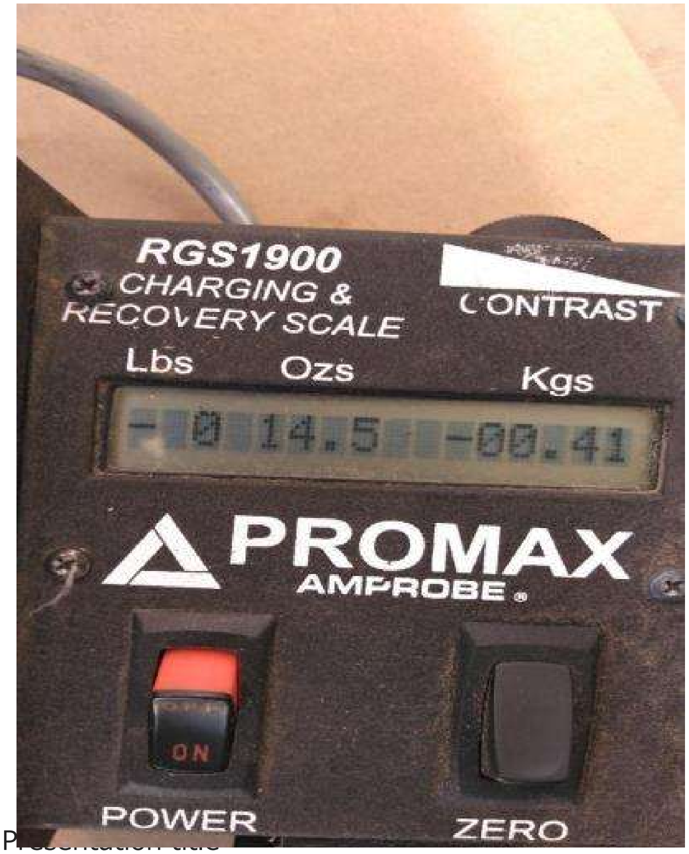
Other Stats	Values
Ultimate Pull Down:	112.8 Microns
Avg. Ambient Temp:	18.0°C
Device Name:	BluVac+ Pro
Date:	11/23/2020
Start Time:	11:23:14 AM
End Time:	12:04:12 PM

Installation

- ✓Flare
- ✓Cutters and reamer
- ✓Flare tool
- ✓Don’t use line set nuts
- ✓Refrigerant oil on mating surfaces
- ✓Torque wrench (not always guidance on wet or dry flair nut threads)
- ✓Pressure test at 450 PSI (overnight best) - bubble test for leaks at joints
- ✓Evacuate to 100 to 200 microns (holds below 300 for 15 minutes)

❑**Adjust charge**

Installation



For mini splits charge adjustment is primarily weighing refrigerant in

Some manufacturers have models where you can check super-heat and sub-cool.

Legacy systems use super- heat and sub-cool

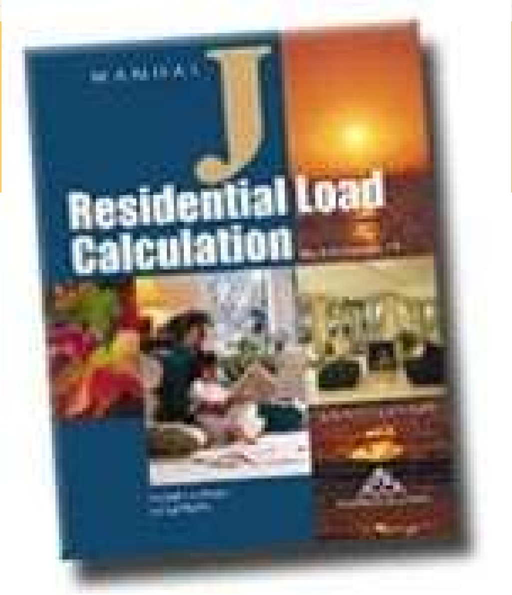
5. Design and Installation

PERFORMANCE FACTORS AND CHECK NUMBERS

Design and Installation

- Houses have gotten better; we need to downsize capacity
- Industry standard practices **are inadequate**—result in a 50% loss of HVAC capacity
- Commissioning during and after install is necessary for high performance systems
  - Manual J load calculation
  - Room by room airflow balance
  - Total airflow at dry climate level
  - Duct leakage at zero
  - Conductive losses at zero
  - Line set tested to zero leakage standard before startup
  - Charge set by appropriate method – super-heat and sub-cool to manufacturer’s targets

Load Calculations!!!



https://www.acca.org/standards/approved-software

All heating or cooling equipment should be sized *for the specific house* based on its construction and orientation, using a heating and cooling load calculation

Current Options

Wright Soft Manual J,D,S…

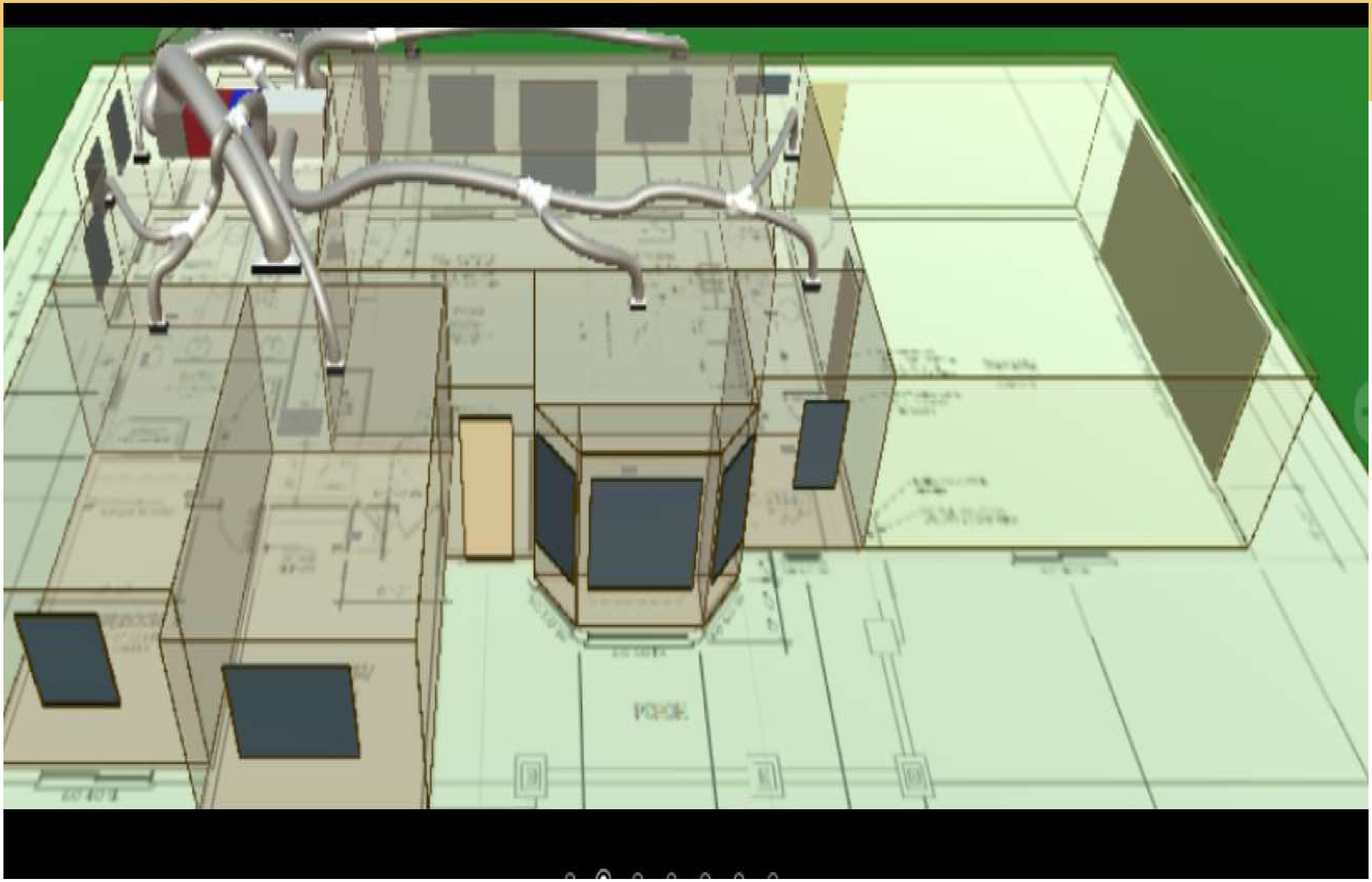
https://www.wrightsoft.com/

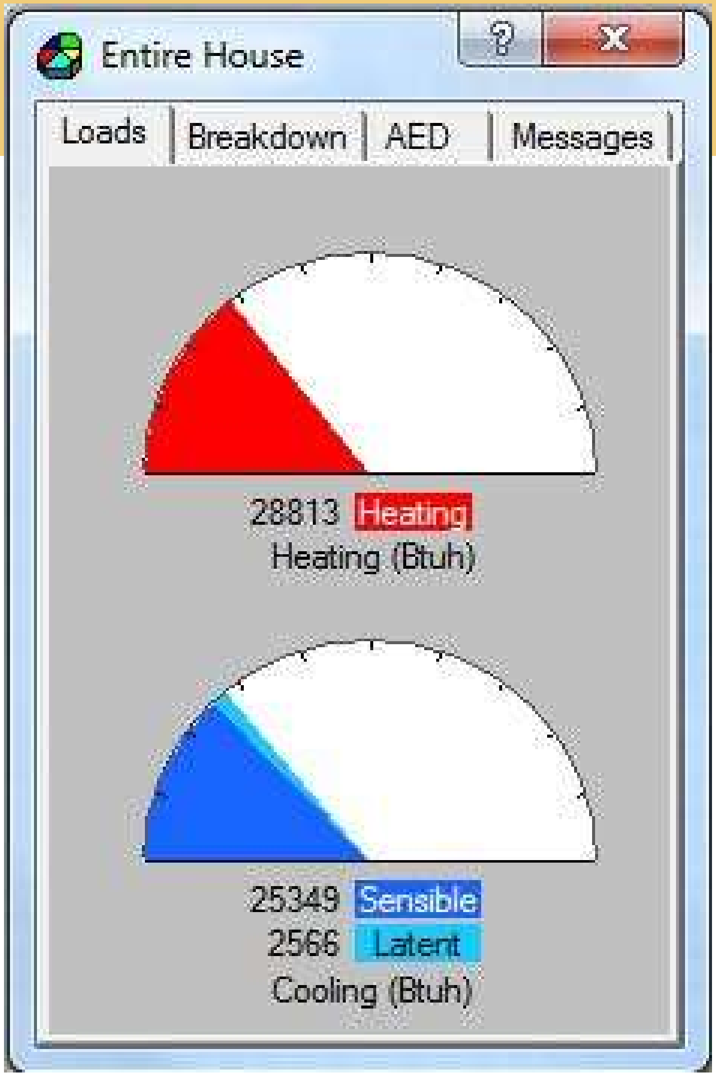
Elite Manual J,D,S…

https://www.elitesoft.com/web/hvacr/elite_rhvacw_info.html

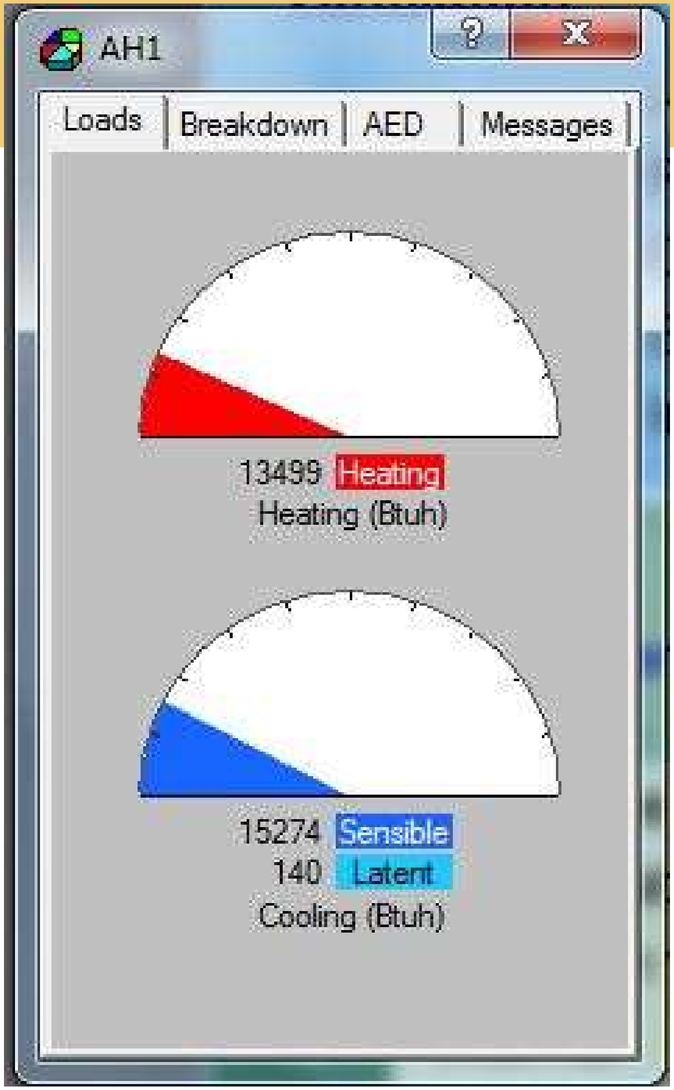
Kwik Model J,D,S…

https://kwikmodel.com/

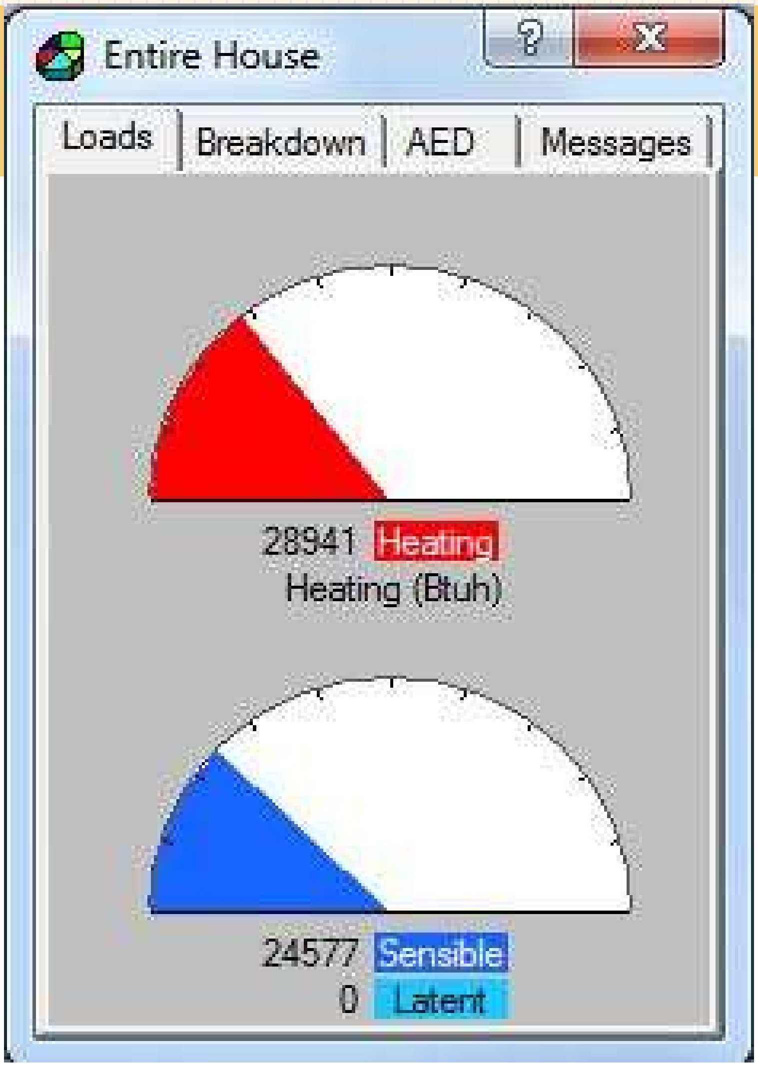




2,000 square feet
1970s vintage 2-story
Partial retrofit
ACH_{50} 6



2,800 square feet
New construction 2014
Well-insulated
ACH_{50} 1



5,000 square feet
New construction 2014
Well-insulated
ACH_{50} 2

Equipment Sizing Based on Manufacturer's Expanded Data

Expanded Cooling Data — GSXC160361C*+CA*F3137*6A*+EEP+TXV High Stage

		Outdoor Ambient Temperature											
		65ºF				75ºF				85ºF			
		Entering Indoor Wet Bulb Temperature											
Airflow		59	63	67	71	59	63	67	71	59	63	67	71
	MBh	35.8	36.3	37.4	-	35.5	36.0	37.0	-	34.5	35.0	36.1	-
	S/T	0.61	0.53	0.40	-	0.61	0.54	0.40	-	0.64	0.56	0.43	-
	ΔT	20	18	15	-	20	18	15	-	21	19	15	-
1000	Lo PR	122	123	127	-	129	131	134	-	136	137	140	-
	Hi PR	245	246	247	-	283	284	286	-	323	325	326	-
	Amps	7.2	7.1	7.1	-	8.2	8.1	8.1	-	9.3	9.3	9.2	-
	KW	2.06	2.06	2.05	-	2.29	2.29	2.28	-	2.54	2.54	2.54	-
	MBh	36.2	36.7	37.8	-	35.9	36.4	37.5	-	35.0	35.5	36.5	-
	S/T	0.66	0.58	0.45	-	0.66	0.59	0.46	-	0.69	0.61	0.48	-
	ΔT	19	17	14	-	19	17	14	-	20	18	14	-
1130	Lo PR	124	125	128	-	131	133	136	-	138	139	142	-
	Hi PR	246	247	249	-	285	286	288	-	325	326	328	-
	Amps	7.2	7.2	7.2	-	8.2	8.2	8.2	-	9.3	9.3	9.3	-
	KW	2.07	2.07	2.06	-	2.30	2.30	2.29	-	2.56	2.55	2.55	-
	MBh	36.7	37.2	38.3	-	36.4	36.9	37.9	-	35.4	35.9	37.0	-
	S/T	0.69	0.61	0.48	-	0.69	0.62	0.49	-	0.72	0.64	0.51	-
	ΔT	19	17	13	-	18	17	13	-	19	17	13	-
1250	Lo PR	125	127	130	-	133	134	137	-	139	141	144	-
	Hi PR	248	249	251	-	287	288	289	-	327	328	330	-
	Amps	7.2	7.2	7.2	-	8.2	8.2	8.2	-	9.4	9.3	9.3	-
	KW	2.08	2.08	2.07	-	2.31	2.31	2.30	-	2.56	2.56	2.56	-
	MBh	35.8	36.3	37.4	39.0	35.5	36.0	37.1	38.7	34.6	35.1	36.1	37.8
	S/T	0.73	0.66	0.52	0.38	0.74	0.66	0.53	0.39	1.00	0.69	0.55	0.41
	ΔT	25	23	19	15	24	23	19	15	25	23	19	16
1000	Lo PR	122	124	127	132	129	131	134	139	136	137	141	146
	Hi PR	245	246	248	252	283	284	286	290	324	325	326	331
	Amps	7.1	7.1	7.1	7.2	8.1	8.1	8.1	8.2	9.3	9.3	9.2	9.3
	KW	2.06	2.05	2.05	2.07	2.29	2.28	2.28	2.30	2.54	2.54	2.54	2.55
	MBh	36.2	36.7	37.8	39.4	35.9	36.4	37.5	39.1	35.0	35.5	36.6	38.2
	S/T	0.79	0.71	0.58	0.44	0.79	0.72	0.58	0.44	1.00	0.74	0.61	0.47
	ΔT	24	22	18	14	23	22	18	14	24	22	18	15
1130	Lo PR	124	125	128	133	131	133	136	141	138	139	142	147
	Hi PR	247	248	249	254	285	286	288	292	326	327	328	333
	Amps	7.2	7.2	7.2	7.2	8.2	8.2	8.2	8.2	9.3	9.3	9.3	9.4
	KW	2.07	2.06	2.06	2.08	2.30	2.30	2.29	2.31	2.55	2.55	2.55	2.57
	MBh	36.7	37.2	38.3	39.9	36.4	36.9	38.0	39.6	35.5	36.0	37.0	38.7
	S/T	0.82	0.74	0.61	0.47	0.82	0.75	0.61	0.47	1.00	0.77	0.64	0.50
	ΔT	23	21	17	14	23	21	17	14	23	21	17	14
1250	Lo PR	125	127	130	135	133	134	137	143	139	141	144	149
	Hi PR	248	249	251	255	287	288	290	294	327	328	330	334
	Amps	7.2	7.2	7.2	7.3	8.2	8.2	8.2	8.3	9.3	9.3	9.3	9.4
	KW	2.08	2.07	2.07	2.09	2.31	2.30	2.30	2.32	2.56	2.56	2.56	2.57

		Outdoor Ambient Temperature											
		95ºF				105ºF				115ºF			
		Entering Indoor Wet Bulb Temperature											
Airflow		59	63	67	71	59	63	67	71	59	63	67	71
	MBh	32.9	33.4	34.5	-	31.0	31.5	32.5	-	29.2	29.7	30.7	-
	S/T	0.66	0.58	0.45	-	1.00	0.60	0.47	-	1.00	0.65	0.52	-
	ΔT	20	18	15	-	20	18	15	-	21	19	16	-
1000	Lo PR	141	143	146	-	147	148	151	-	154	155	158	-
	Hi PR	367	368	370	-	414	415	417	-	464	465	467	-
	Amps	10.5	10.5	10.5	-	11.8	11.8	11.8	-	13.4	13.4	13.4	-
	KW	2.82	2.82	2.82	-	3.13	3.13	3.13	-	3.50	3.50	3.49	-
	MBh	33.4	33.9	34.9	-	31.4	31.9	33.0	-	29.6	30.1	31.2	-
	S/T	0.71	0.63	0.50	-	1.00	0.66	0.52	-	1.00	0.71	0.57	-
	ΔT	19	17	14	-	19	17	14	-	20	18	15	-
1130	Lo PR	143	145	148	-	148	150	153	-	155	157	160	-
	Hi PR	369	370	372	-	416	417	419	-	466	467	469	-
	Amps	10.5	10.5	10.5	-	11.9	11.9	11.9	-	13.5	13.5	13.4	-
	KW	2.83	2.83	2.83	-	3.14	3.14	3.14	-	3.51	3.51	3.50	-
	MBh	33.8	34.3	35.4	-	31.9	32.4	33.4	-	30.1	30.6	31.7	-
	S/T	1.00	0.66	0.53	-	1.00	0.69	0.55	-	1.00	0.74	0.60	-
	ΔT	18	17	13	-	18	16	13	-	19	17	14	-
1250	Lo PR	145	146	149	-	150	152	155	-	157	158	161	-
	Hi PR	371	372	373	-	417	419	420	-	468	469	470	-
	Amps	10.6	10.6	10.5	-	11.9	11.9	11.9	-	13.5	13.5	13.5	-
	KW	2.84	2.84	2.84	-	3.15	3.15	3.15	-	3.52	3.51	3.51	-
	MBh	32.9	33.5	34.5	36.1	31.0	31.5	32.6	34.2	29.2	29.7	30.8	32.4
	S/T	1.00	0.71	0.57	0.43	1.00	0.73	0.60	0.45	1.00	1.00	0.65	0.51
	ΔT	24	23	19	15	24	22	19	15	25	24	20	16
1000	Lo PR	141	143	146	151	147	148	151	157	154	155	158	163
	Hi PR	367	368	370	374	414	415	417	421	464	465	467	471
	Amps	10.5	10.5	10.4	10.5	11.8	11.8	11.8	11.9	13.4	13.4	13.4	13.5
	KW	2.82	2.82	2.82	2.83	3.13	3.13	3.13	3.14	3.50	3.49	3.49	3.51
	MBh	33.4	**33.9**	35.0	36.6	31.4	31.9	33.0	34.6	29.6	30.1	31.2	32.8
	S/T	1.00	**0.76**	0.63	0.49	1.00	0.78	0.65	0.51	1.00	1.00	0.70	0.56
	ΔT	23	**22**	18	14	23	21	18	14	24	22	19	15
1130	Lo PR	143	**145**	148	153	148	150	153	158	155	157	160	165
	Hi PR	369	**370**	372	376	416	417	419	423	466	467	469	473
	Amps	10.5	**10.5**	10.5	10.6	11.9	11.9	11.8	11.9	13.5	13.4	13.4	13.5
	KW	2.83	**2.83**	2.83	2.84	3.14	3.14	3.14	3.15	3.51	3.50	3.50	3.52
	MBh	33.9	34.4	35.4	37.1	31.9	32.4	33.5	35.1	30.1	30.6	31.7	33.3
	S/T	1.00	0.79	0.66	0.52	1.00	0.81	0.68	0.54	1.00	1.00	0.73	0.59
	ΔT	23	21	17	14	22	20	17	13	24	22	18	14
1250	Lo PR	145	146	149	155	150	152	155	160	157	158	161	167
	Hi PR	371	372	374	378	418	419	420	425	468	469	471	475
	Amps	10.6	10.5	10.5	10.6	11.9	11.9	11.9	12.0	13.5	13.5	13.5	13.5
	KW	2.84	2.84	2.83	2.85	3.15	3.15	3.15	3.16	3.52	3.51	3.51	3.53

Goodman legacy heat pump data

Capacity at typical design conditions

NOTE: these data are not tied to design conditions

Capacity

Nominal Cooling	9,000 Btu
Min-Max Cooling	3,100–12,000 Btu
Nominal Heating	12,000 Btu
Min-Max Heating	3,100-22,000 Btu

Fujitsu submittal sheet data

Much better—we need expanded data!!

Fujitsu *Design and Technical Manual* expanded data table

6. CAPACITY TABLE

6-1. COOLING CAPACITY

■ MODEL: ASU9RLS3

AFR	489

		Indoor temperature																	
	°FDB	64			70			75			80			85			90		
	°FWB	54			60			63			67			71			73		
Outdoor temperature	°FDB	TC	SHC	IP	TC	SHC	IP	TC	SHC	IP	TC	SHC	IP	TC	SHC	IP	TC	SHC	IP
	15	8.33	8.06	0.19	9.29	8.11	0.19	10.25	8.87	0.20	10.57	9.53	0.20	11.17	9.50	0.20	11.81	10.07	0.21
	23	8.16	7.88	0.22	9.09	7.91	0.22	10.03	8.65	0.23	10.35	9.31	0.22	10.94	9.28	0.22	11.56	9.91	0.23
	32	7.99	7.69	0.22	8.90	7.75	0.23	9.81	8.45	0.24	10.13	9.16	0.23	10.70	9.09	0.23	11.32	9.68	0.24
	41	7.81	7.58	0.24	8.71	7.61	0.24	9.60	8.28	0.25	9.90	8.97	0.24	10.47	8.90	0.24	11.07	9.50	0.25
	50	7.64	7.36	0.22	8.51	7.41	0.22	9.38	8.07	0.24	9.68	8.76	0.23	10.24	8.70	0.23	10.83	9.26	0.24
	59	7.47	7.24	0.27	8.32	7.27	0.27	9.16	7.91	0.28	9.46	8.57	0.28	10.01	8.51	0.28	10.58	9.08	0.28
	67	8.42	8.15	0.34	9.38	8.18	0.35	10.33	8.94	0.36	10.67	9.63	0.36	11.28	9.59	0.36	11.93	10.18	0.37
	77	8.01	7.74	0.39	8.93	7.77	0.39	9.85	8.49	0.40	10.16	9.15	0.40	10.74	9.11	0.41	11.35	9.73	0.41
	87	7.57	7.29	0.44	8.45	7.36	0.44	9.31	8.01	0.45	9.58	8.67	0.45	10.16	8.63	0.46	10.74	9.18	0.46
	95	7.09	6.88	0.48	7.91	6.91	0.49	8.73	7.53	0.50	9.00	8.15	0.50	9.55	8.12	0.51	10.06	8.63	0.51
	104	6.00	5.67	0.45	6.68	6.16	0.46	7.36	6.71	0.46	7.60	7.26	0.46	8.05	7.22	0.47	8.52	7.70	0.47
	115	5.52	5.33	0.45	6.17	5.71	0.46	6.78	6.22	0.46	6.99	6.74	0.46	7.43	6.71	0.47	7.84	7.15	0.47

AFR : Air Flow Rate (CFM)
TC : Total Capacity (kBtu/h)
SHC : Sensible Heat Capacity (kBtu/h)
IP : Input Power (kW)

Ducts or No Ducts

- Air Filtration proven effective
- Uniform Comfort
- Can deliver to small rooms
- Quiet
- Traditional Aesthetic
- Can be optimized for dry climate
- Can be commissioned
- Can be adjusted to improve performance

- Higher rated efficiency
- No Duct losses
- Quiet Compressor – Outside
- Significantly less expensive project
- Less Mechanical space necessary
- High rate of lost refrigerant
- Can't be optimized for dry climate
- Cannot be commissioned

Ducts

No Ducts

Performance Factors with Check Numbers

- Equipment Capacity, smallest adequate equipment. Total capacity not to exceed 12,000 Btus/hr per 1000 square feet of floor area
- Duct Leakage less than 20 cfm_{25}
- Duct Conduction limited – Conditioned space or R-38 ducts
- Room by room airflow within 10% of Manual D or eq. design, grills specified for throw and sound. Returns specified for filtration and low velocity

Performance Factors with Check Numbers

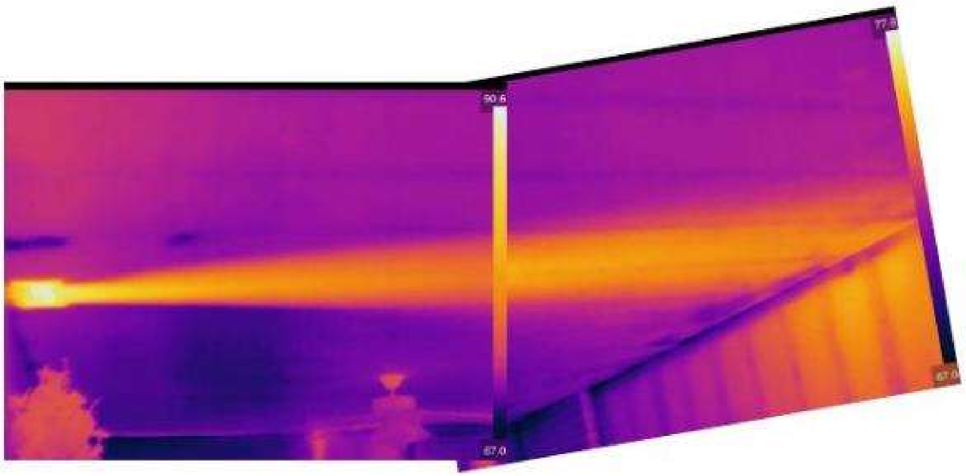
- Duct Velocities between 300 fpm and 500 fpm
- System Airflow 500-700 cfm per 12,000 Btu of input capacity
- Fan Power at 5 or more cfm per watt
- Refrigerant charge. Line set swept with nitrogen, Nitrogen pressure test at 450 - 600 psi passed, vacuum test at under 300 microns passed, charge adjusted to super heat and sub cool. Manufacturer’s targets or 5 degrees for both.

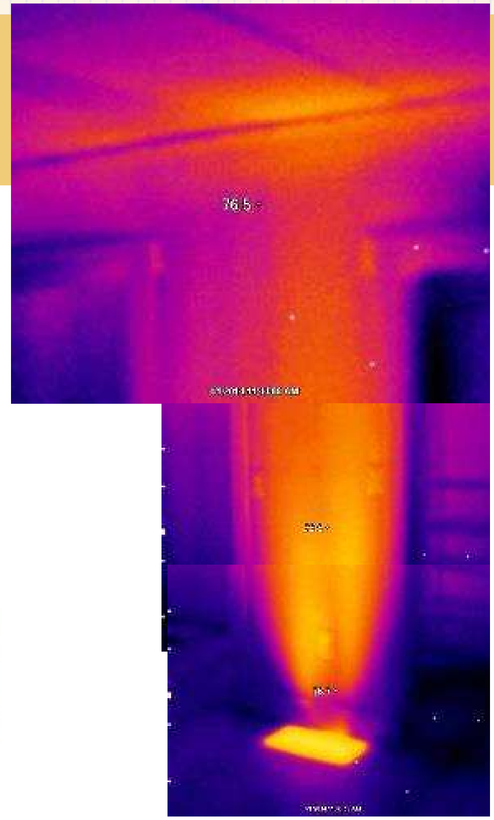
Duct Leakage

Duct Conduction

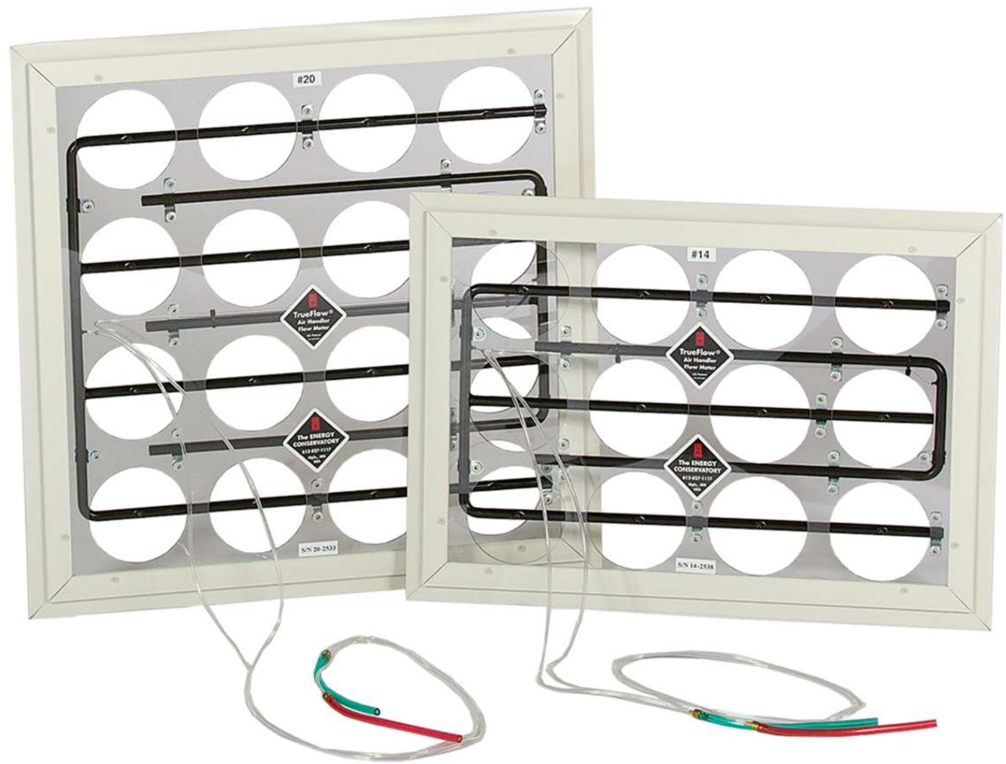
Duct Conduction

Room by Room Airflow





System Airflow



Goodman 30K Heat Pump Air Handler with In-line Hydronic Coil and 24 KBtu Heat Pump

Room Name		Dinning	kitchen	Office	M bed	M bath	living	guest bed	guest bath					
Test condition	tap or speed set	Supply1	Supply 2	Supply 3	Supply 4	Supply 5	Supply 6	Supply 7	Supply 8	TOTALS	Supply static	Return Static	Total Static	Watt
plus 10%		334	99	80	167	96	161	152	73	1162				
minus 10%		276	82	66	138	79	133	125	60	960				
Manual J Target		304	90	73	152	87	146	138	66	1056				
balance 1 2/4/2016	C minus 5%	290	105	98	163	83	125	171	80	1115	0.2	0.1	0.3	
balance 2	C minus 10%	276	87	96	160	83	122	165	80	1069	0.862	0.0636	0.9256	
balance 3 final 2/5/2016	C minus 10%	284	105	72	167	85	150	138	66	1067	0.0953	0.0654	0.1607	174
balance 4										0			0	
balance 5										0			0	
balance 6										0			0	
final balance	C minus 10%	284	105	72	167	85	150	138	66	1067	0.0953	0.0654	0.1607	174
										0			0	

Dry climate airflow target met: measured airflow greater than 450 cfm per ton.

Refrigerant Charge

Charge to the manufacturer's super-heat and sub-cool targets.

In some cases, mini-splits are charged by weigh-in.

Refrigerant Charge

For service calls, learn non-invasive system evaluation techniques to avoid unnecessary refrigerant release.

Measuring airflow, air temperature, and power consumption can tell you far more about the performance of a system than refrigerant charge will.

6. Heat Pump Water Heaters

EASY ELECTRIFICATION OPTION

Refrigerant Charge

- Selection – Equipment Type & Refrigerant Options
- Sizing – Think Tank
- Installation – Location, Location, Location
- Commissioning & Performance

System Type – Unitary Hybrid

Unitary Non Hybrid (Heat Pump Only)

Stiebel Eltron

Refrigerants

All of the unitary systems use high GWP refrigerants.

One Split System Option

Sanden CO_2 Heat Pump

Refrigerant

GWP 1

!!!

Sizing

All heat pump water heaters have an hourly output of 12 to 15 KBtu.

This is significantly less than even a small gas water heater and roughly the same as an older electric resistance water heater.

This is not a problem.

To minimize customer issues, install the largest tank that the budget and the space will allow. (If necessary, further increases in available capacity can be achieved by using a higher tank temperature and a mixing valve.)

Commissioning and Performance

- Adequate air volume
- Equipment location
- Resistance heat
- Recirculation systems

Location, Location, Location

What matters most is...

Is the space large enough to provide the heat pump system with enough ambient air for heat exchange?

- Check the manufacturer’s specifications. Available air volume is more important than any other physical location detail.
- If ambient air volume is limited, use a unit that can be ducted to a space with adequate air volume.

Adequate Air Volume – Duct Kits

Equipment Location

Keeping adequate air volume in mind

- Locate the equipment as close to the water uses as possible.
- To get hot water to the tap, the system has to displace roughly twice the standing volume of water that is in the pipes between the tank and the tap.
- Learn about structured plumbing – it’s on YouTube. Look for Gary Klein.

https://www.youtube.com/watch?v=hiY09Ps1SS8&list=PLc5H3yZAD9ZPLS7a9DJGokao4Q8OjXfKw

Resistance Heat

- **Resistance heat has a large impact on system efficiency.**
- **Some manufacturers INCORRECTLY label the mode with resistance heat as the "efficiency" mode.**

Differences in aCOP between water heaters are highly confounded by differences in draw profiles, as well as other differences in operating conditions, which makes an average COP for an individual unit difficult to interpret. Compared to the Figure 17 graph of system aCOP, Figure 18 is much more orderly because it has used the definition of hpCOP which excludes resistance element use. Consequently, we can conclude that resistance heat, used for whatever reason, is a large influence in the variability and difference in performance between sites. Moreover, it is possible conclude to that the GeoSpring had the most efficient heat pump, followed by the Voltex, and then by the ATI. Likewise, lab tests showed the same finding.

Figure 18. Estimated hpCOP as a Function of Daily Draw

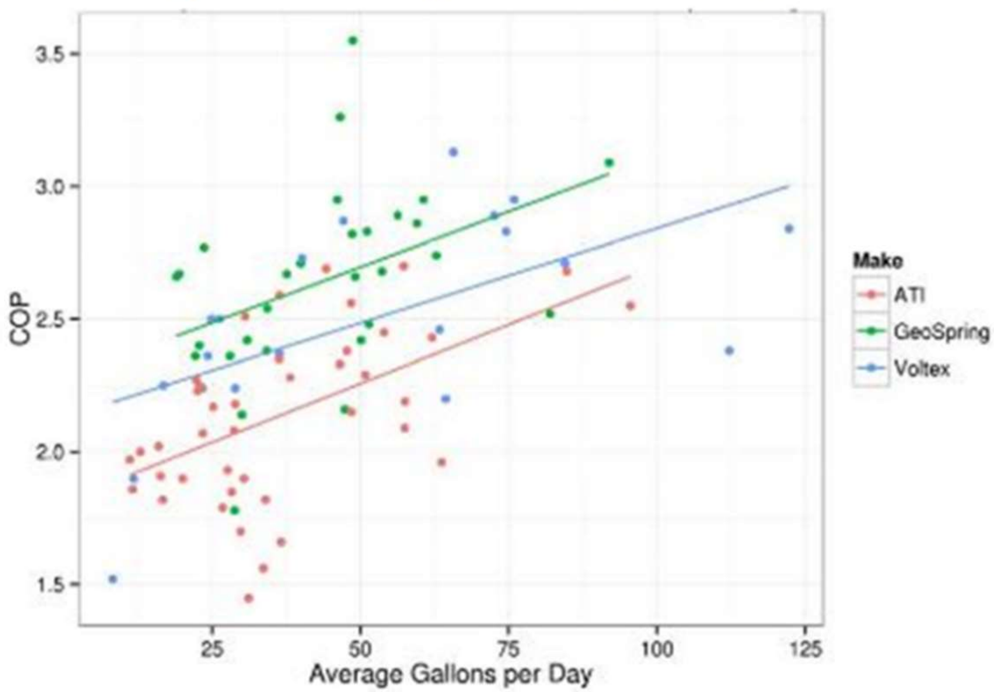
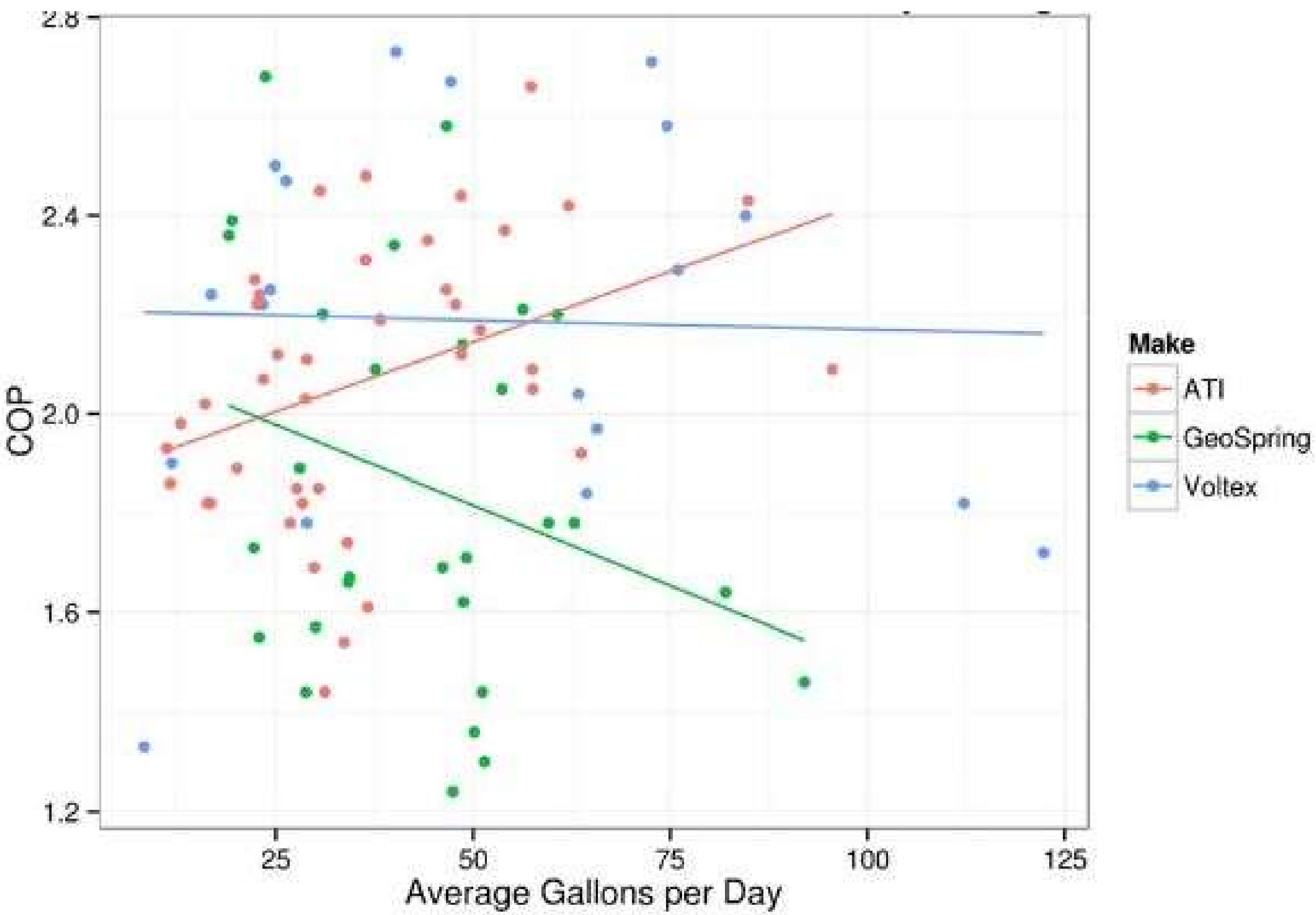


Figure 17. aCOP as a Function of Daily Draw



Recirculation and Tank Temperature

- **Heat pump tanks are stratified by design.**
  - The heat pump pulls cold water off the bottom, heats it and deposits the heated water at the top of the tank
- **Heat pump efficiency is higher when the unheated water is colder.**
- **Recirculation systems de-stratify the tank.**
  - To minimize destratification, use ***on-demand*** recirculation.

Questions

?

Closing

- Continuing Education Units Available
  - Contact itzel.torres@ventura.org for AIA HSW LUs
- Coming to Your Inbox Soon!
  - Slides, Recording, & Survey – Please Take It and Help Us Out!
- **Upcoming HPF Courses:**
  - **Water Heating Distribution Best Practices – Gary Klein (10/11)**
  - **How to Assess a Home for Electrification – Ann Edminster (11/15)**
- Regularly Scheduled Programming:
  - 9/22: National Association of REALTORS Green Designation
  - 9/27: Home Remodeling – Fire Resiliency & Electrification
  - 9/29: CEA Exams
  - 9/30: Green Real Estate Marketing
  - 10/3: Solar PV: Technology and Valuation
  - 10/4: Water Heating Distribution Best Practices

Thank you!

For more info:
3c-ren.org

For questions:
info@3c-ren.org

3C REN
TRI-COUNTY REGIONAL ENERGY NETWORK
SAN LUIS OBISPO • SANTA BARBARA • VENTURA