A Closer Look at Heat Pumps

Hot Air

Fan

Cool Air

Warm Air

Warm Air

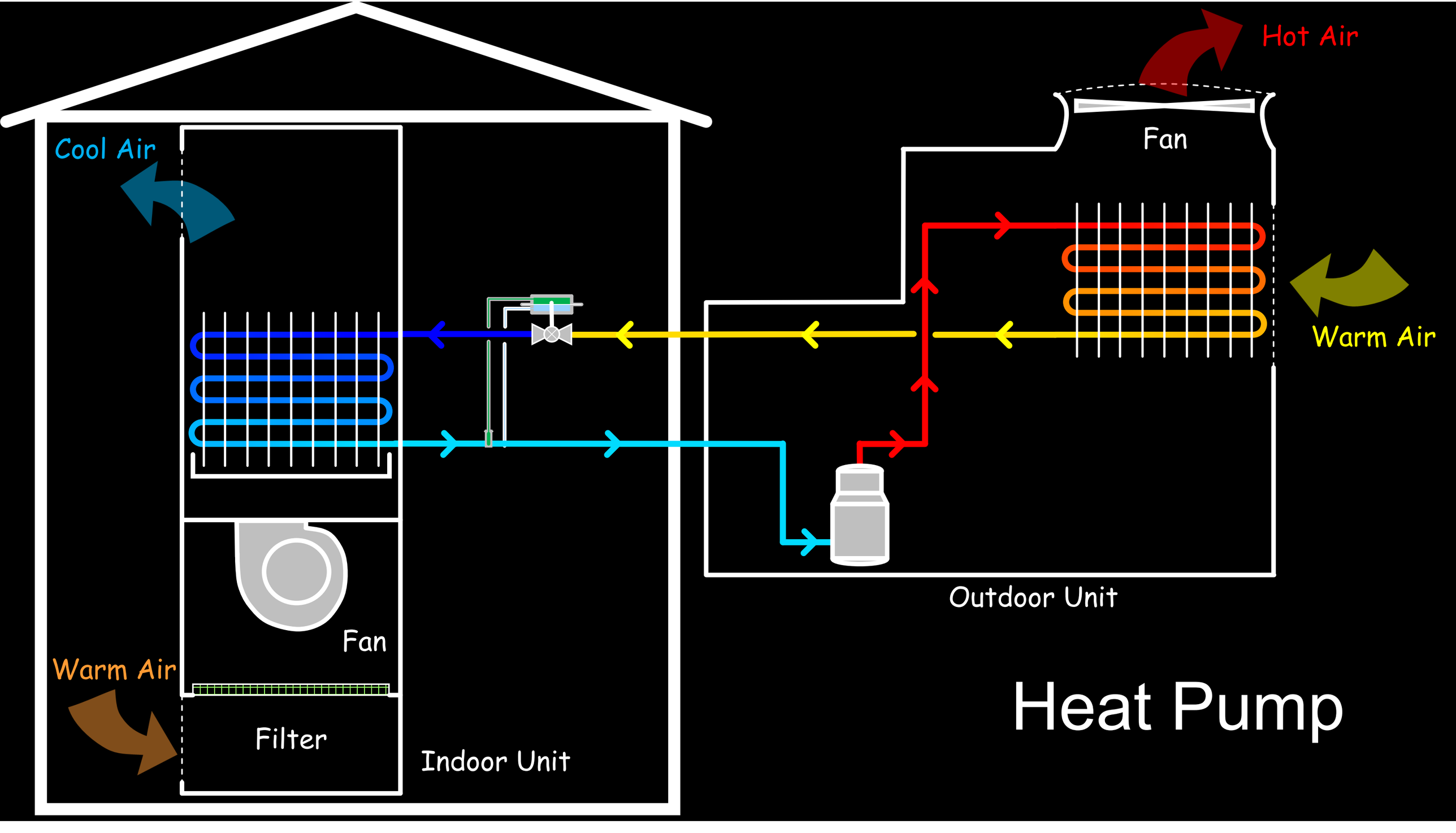
Fan

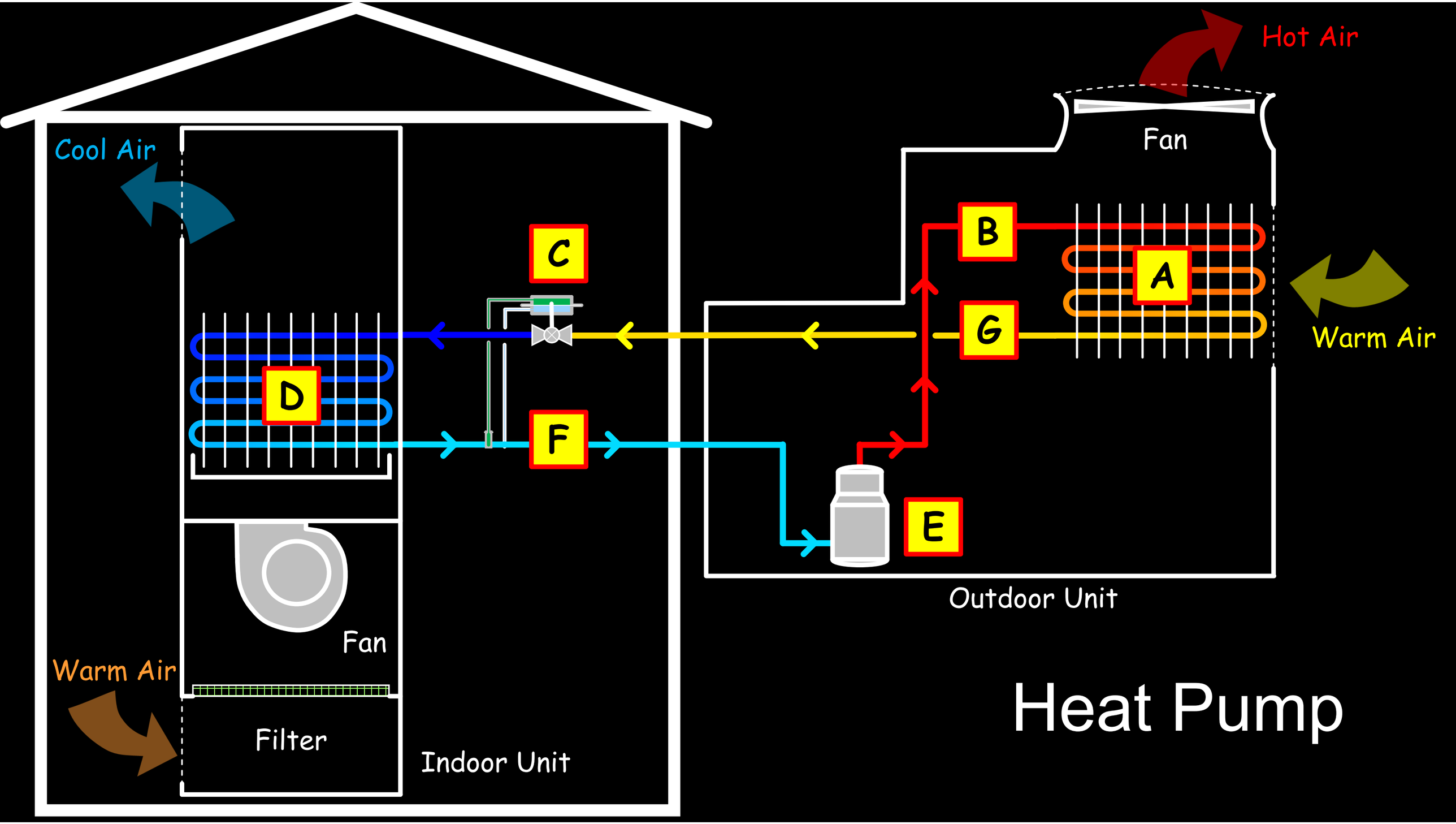
Filter

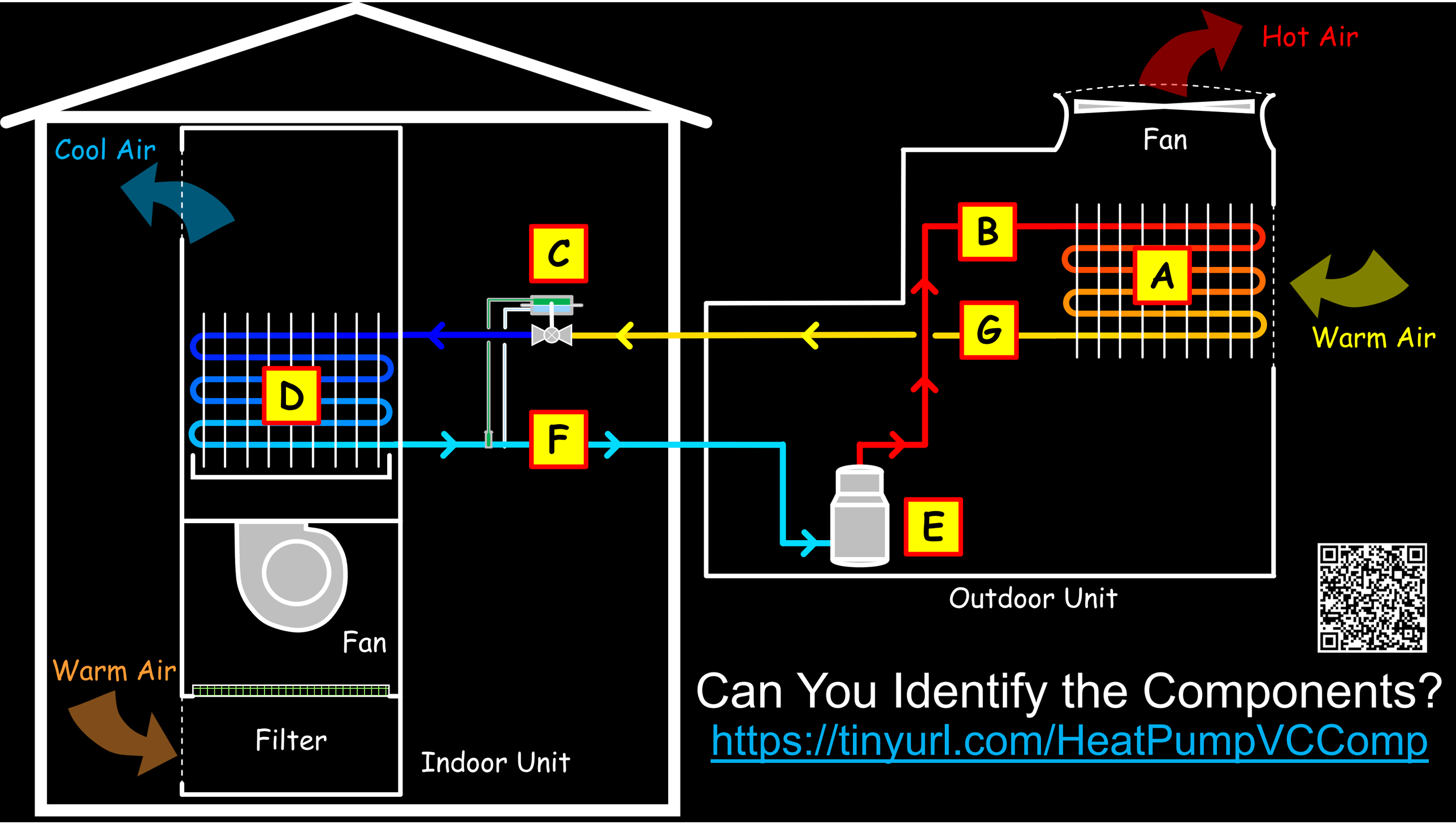
Indoor Unit

Outdoor Unit

Conventional Air Conditioner

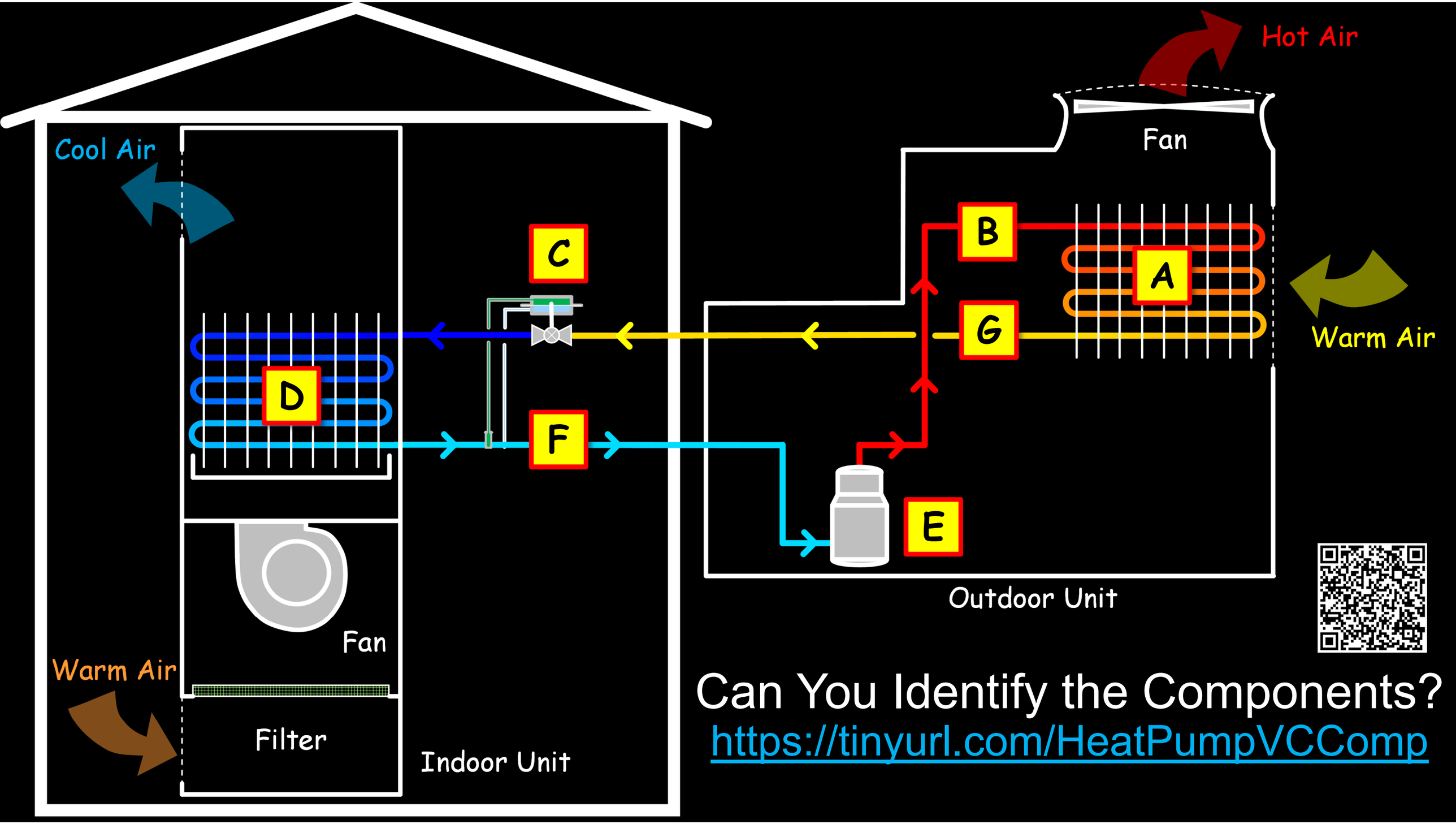

Hot Air
Fan
Cool Air
Warm Air
Fan
Warm Air
Filter
Indoor Unit
Outdoor Unit
Heat Pump


Hot Air
Fan
Cool Air
B
A
C
G
Warm Air
D
F
E
Outdoor Unit
Fan
Warm Air
Filter
Indoor Unit
Heat Pump



Can You Identify the Components?

https://tinyurl.com/HeatPumpVCComp


Hot Air
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Can You Identify the Components?
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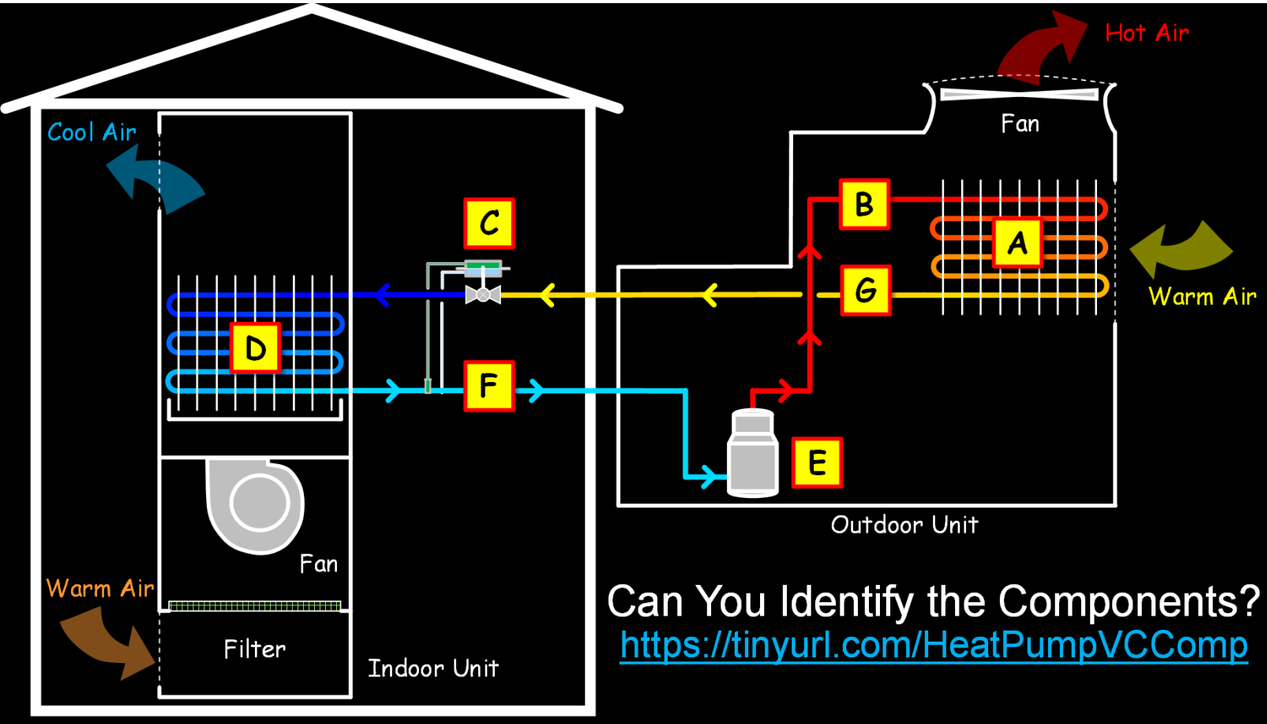


Can You Identify the Components?
https://tinyurl.com/HeatPumpVCComp

The Components

A Condenser

B Hot Gas Line

C Expansion Device

D Evaporator

E Compressor

F Suction Line

G Liquid Line

A Few Definitions

Heat Pump – Thermodynamic Definition

- A heat pump extracts heat from a source and transfers it to a sink at a higher temperature

A Few Definitions

Air Conditioner – Industry Definition

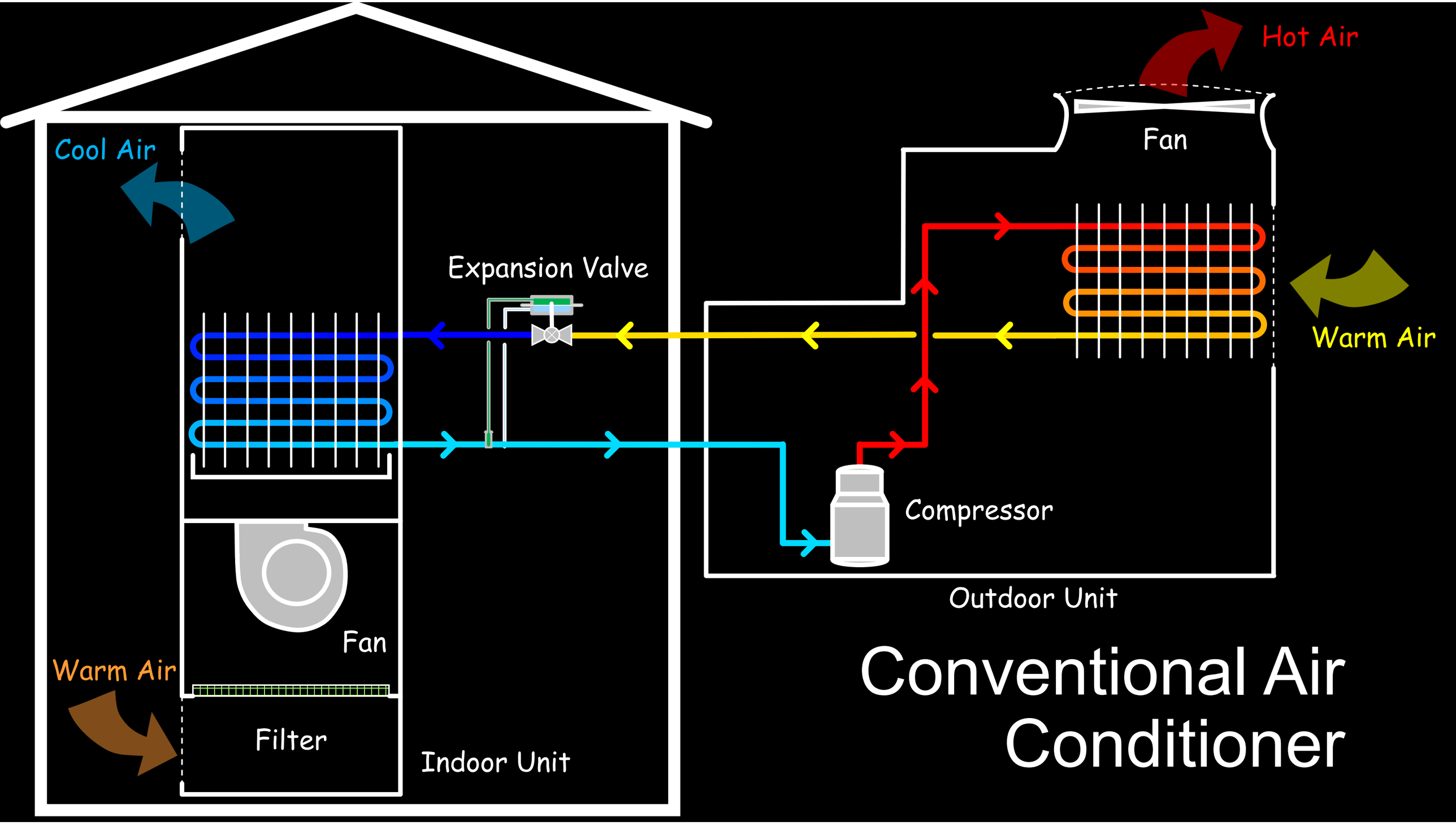
- An air conditioner moves heat from inside the occupied zone to an area outside the occupied zone to remove energy from the occupied zone

A Few Definitions

Heat Pump – Industry Definition

- A heat pump:
  - Moves heat from an area outside the occupied zone into the occupied zone to add energy to the occupied zone, or
  - moves heat from inside the occupied zone to an area outside the occupied zone to remove energy from the occupied zone

depending on what is needed to maintain the zone set point


Hot Air
Fan
Cool Air
Expansion Valve
Warm Air
Compressor
Outdoor Unit
Fan
Warm Air
Filter
Indoor Unit
Conventional Air Conditioner

Expansion Valve

Fan

Fan

Filter

Indoor Unit

Compressor

Outdoor Unit

Making it a Heat Pump

Fan

Expansion Valve

Reversing Valve

Compressor

Outdoor Unit

Fan

Filter

Indoor Unit

Making it a Heat Pump

Expansion Valve

Fan

Reversing Valve

Expansion Valve with
Check Valve Bypass

Compressor

Outdoor Unit

Fan

Filter

Indoor Unit

Making it a Heat Pump

Fan

Reversing Valve

Expansion Valve with Check Valve Bypass

Compressor

Outdoor Unit

Expansion Valve with Check Valve Bypass

Fan

Filter

Indoor Unit

Making it a Heat Pump

Fan

Reversing Valve

Expansion Valve with Check Valve Bypass

Compressor

Outdoor Unit

Expansion Valve with Check Valve Bypass

Fan

Filter

Indoor Unit

Making it a Heat Pump

Hot Air

Fan

Cool Air

Warm Air

Reversing Valve

Expansion Valve with Check Valve Bypass

Expansion Valve with Check Valve Bypass

Compressor

Outdoor Unit

Fan

Warm Air

Filter

Indoor Unit

Heat Pump in Cooling Mode

Fan

Reversing Valve

Expansion Valve with Check Valve Bypass

Compressor

Outdoor Unit

Expansion Valve with Check Valve Bypass

Fan

Filter

Indoor Unit

Heat Pump Transitioning

Fan

Reversing Valve

Expansion Valve with Check Valve Bypass

Compressor

Outdoor Unit

Expansion Valve with Check Valve Bypass

Fan

Filter

Indoor Unit

Heat Pump Transitioning

Cold Air

Fan

Hot Air

Reversing Valve

Cool Air

Expansion Valve with Check Valve Bypass

Compressor

Outdoor Unit

Expansion Valve with Check Valve Bypass

Fan

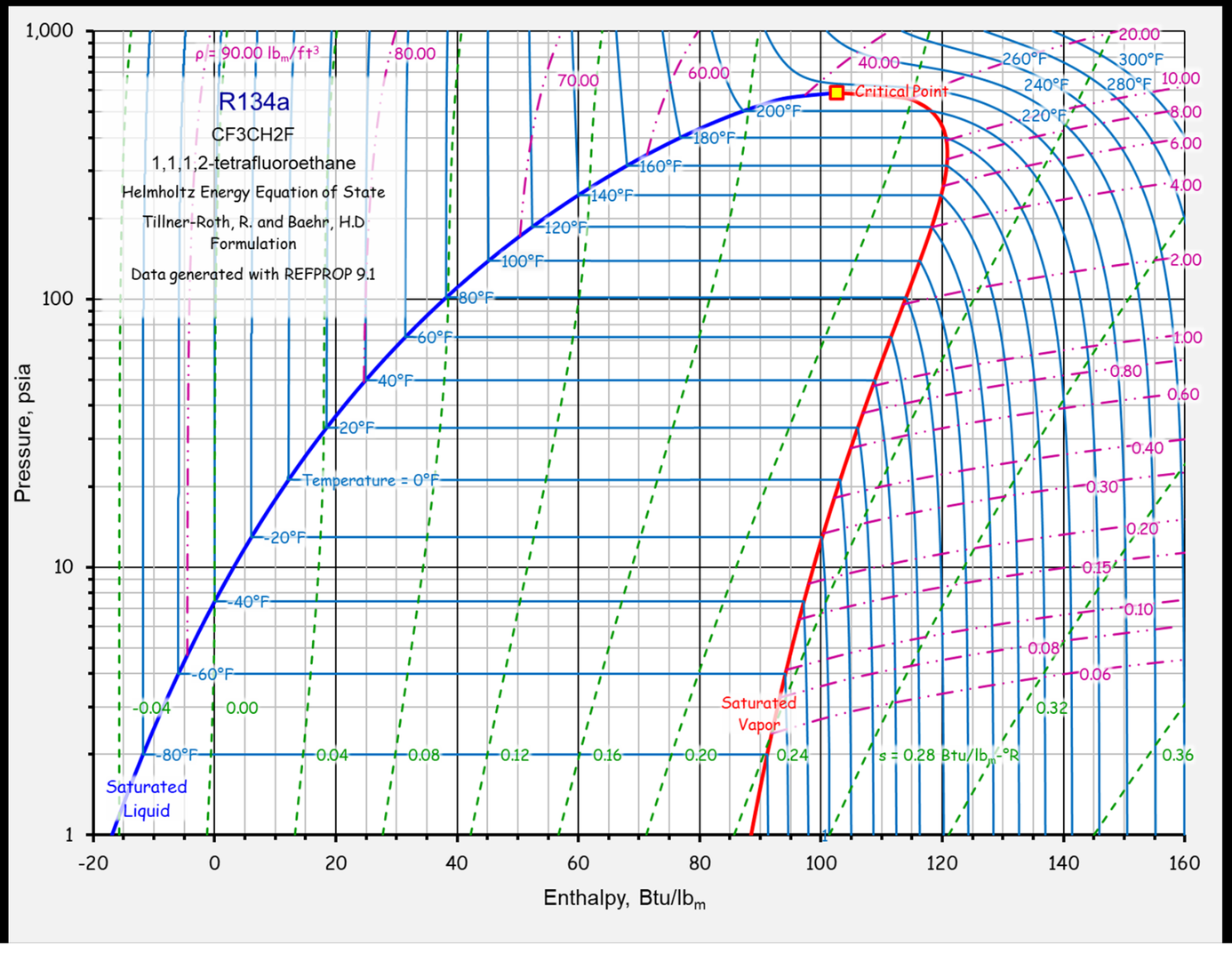
Cool Air

Filter

Indoor Unit

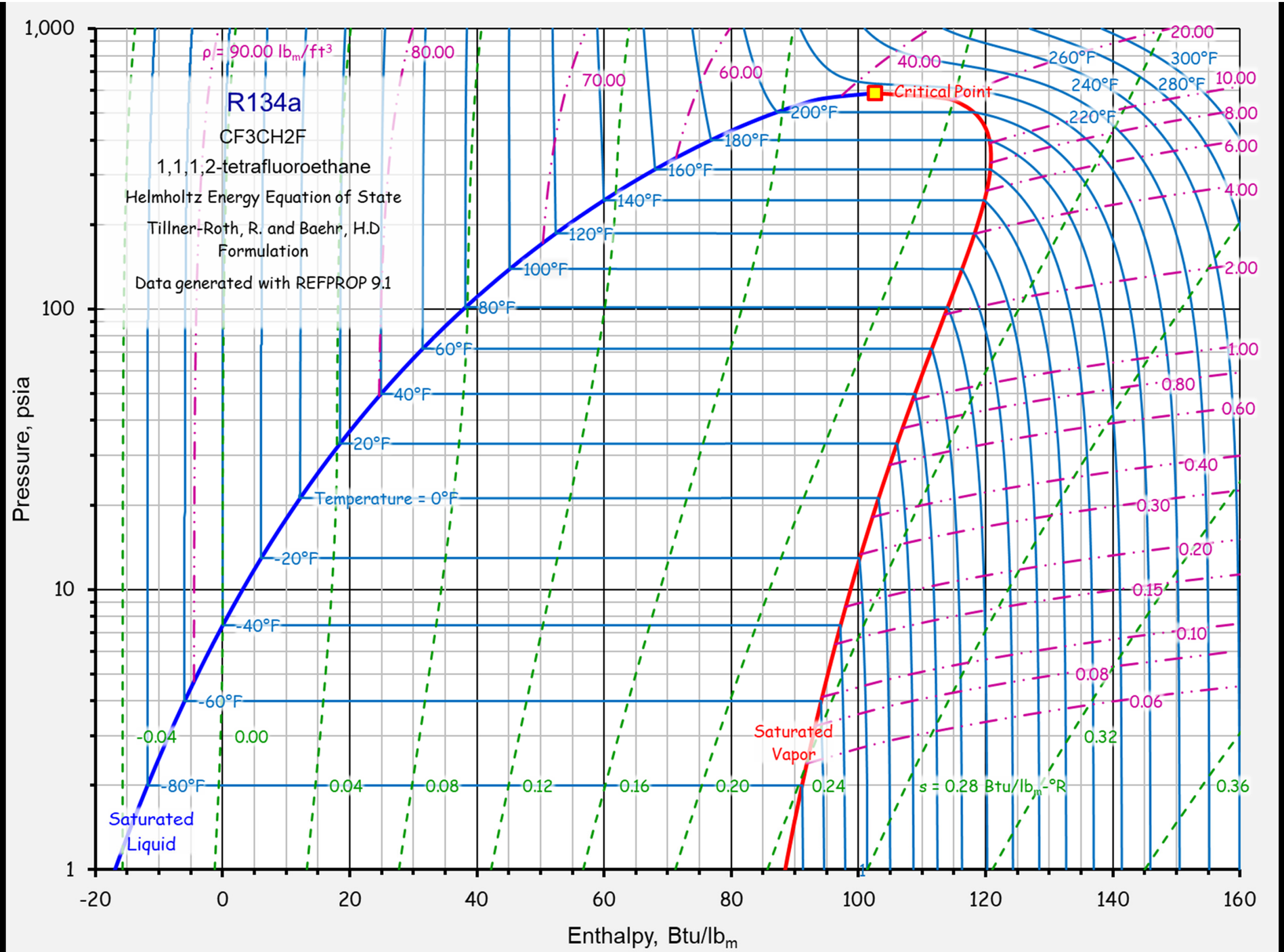
Heat Pump in Heating Mode

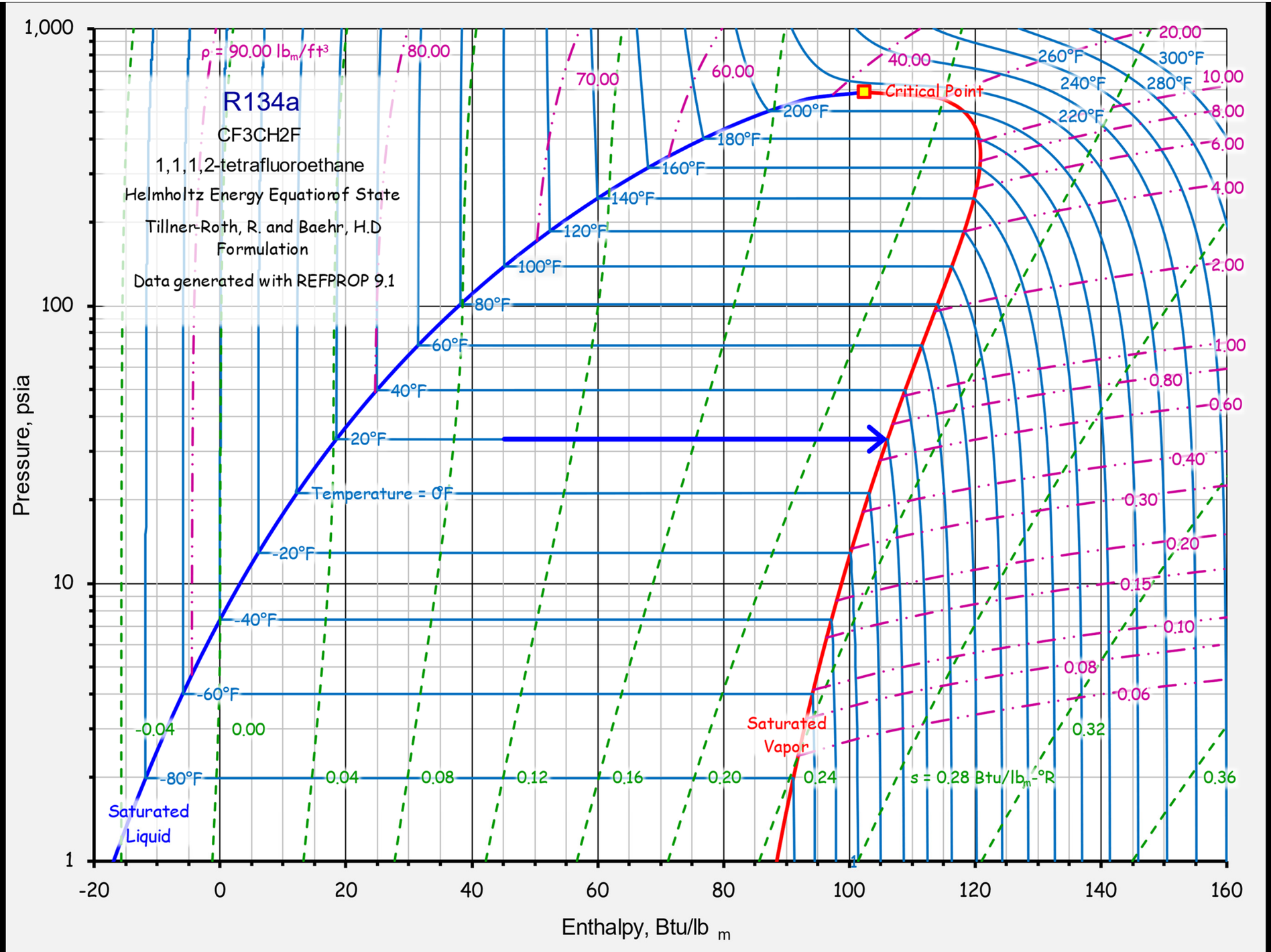
The Pressure-Enthalpy (p-h) Diagram



- Understanding a p-h diagram
- https://tinyurl.com/SporlanPHBulletin

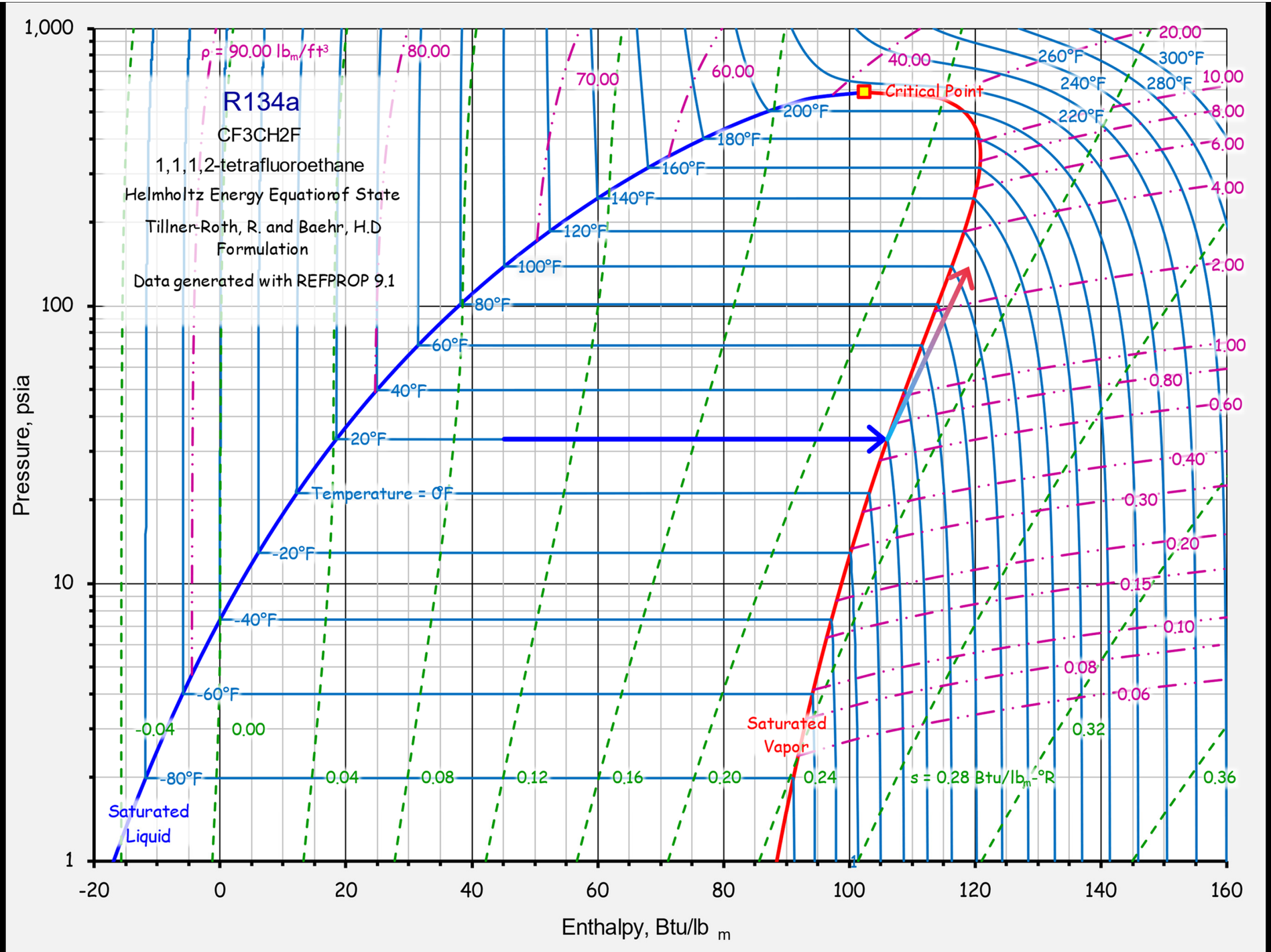
The Pressure-Enthalpy (p-h) Diagram – Theoretical Cycle



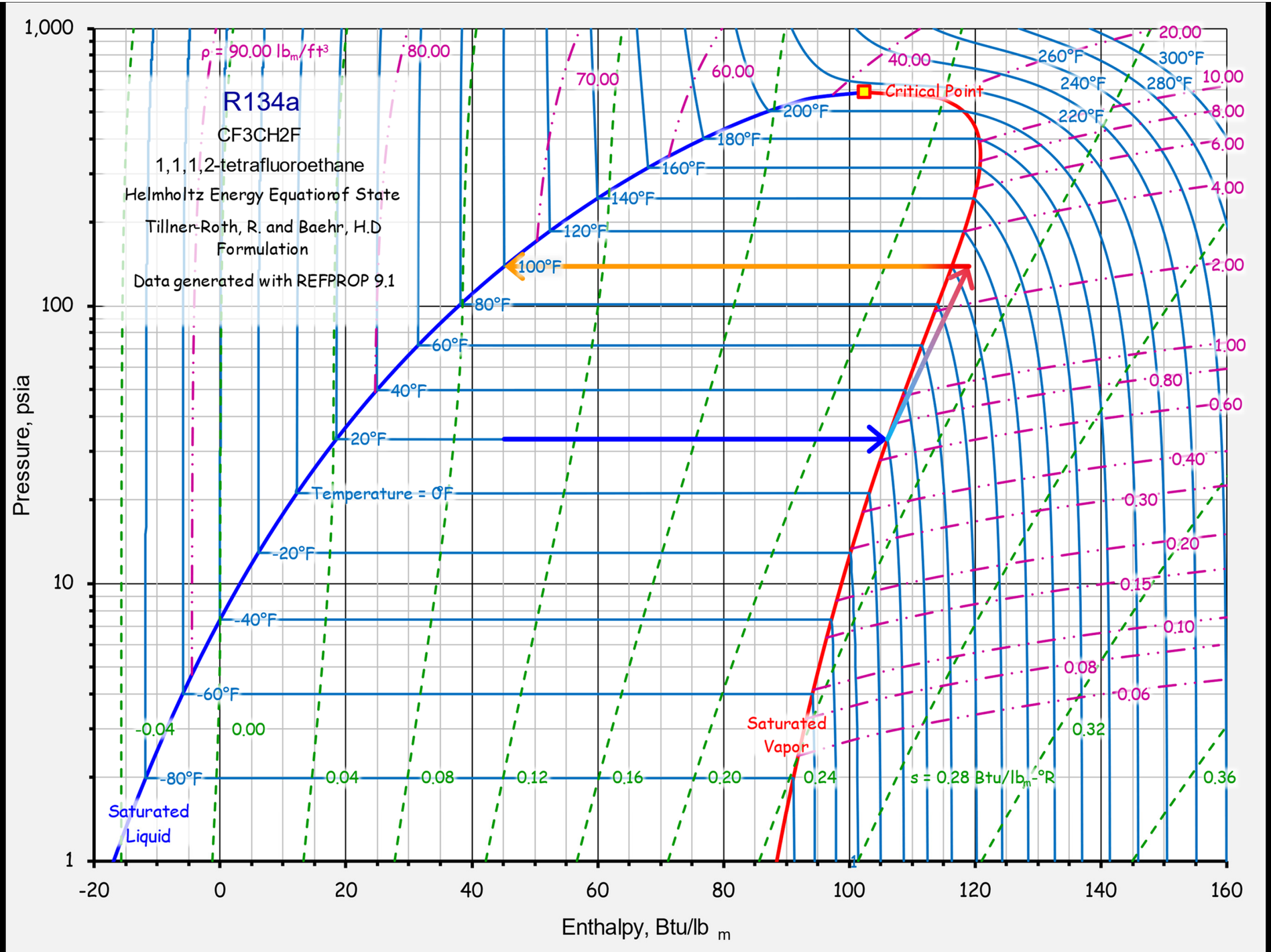


Evaporation

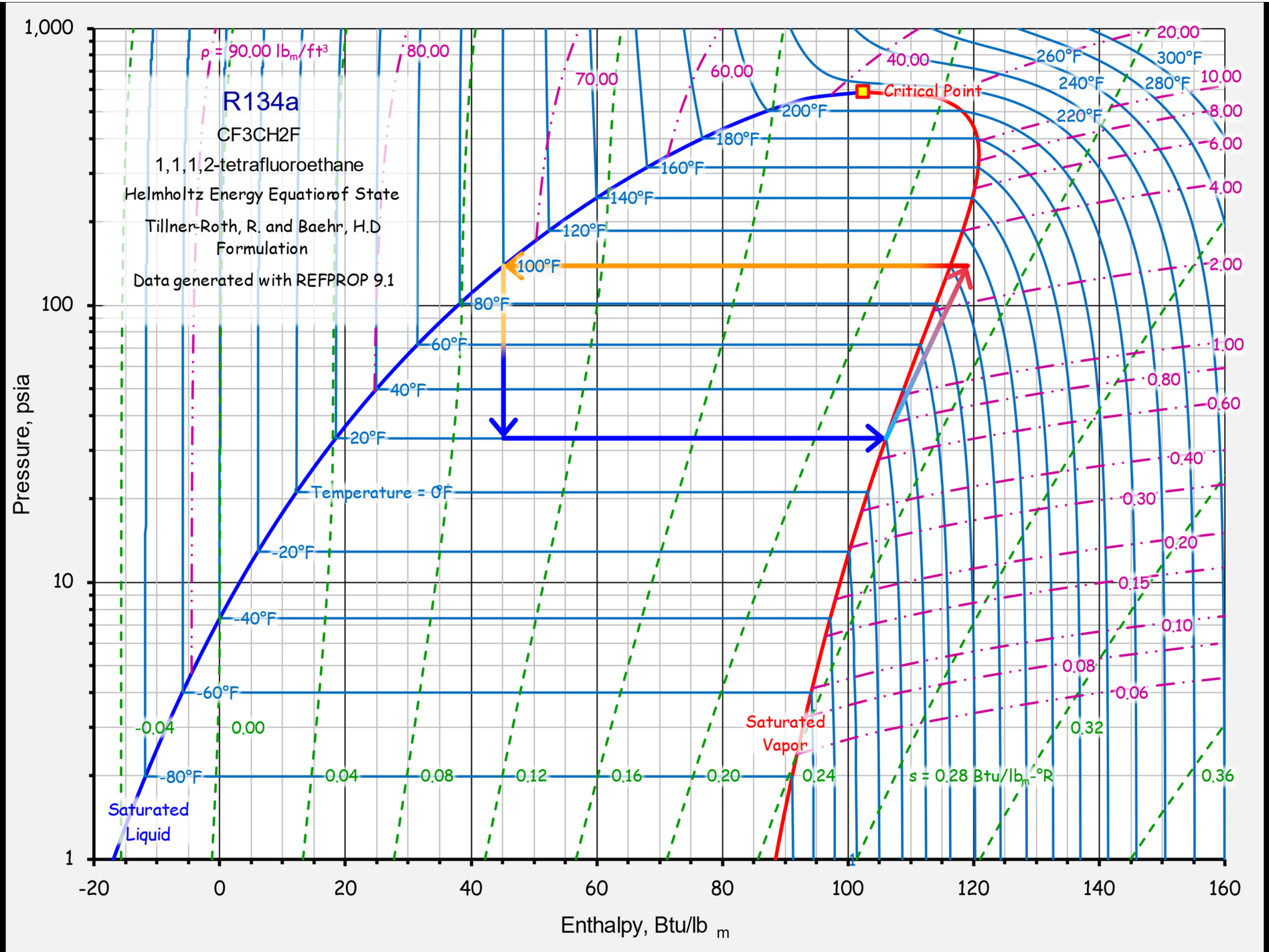
Compression



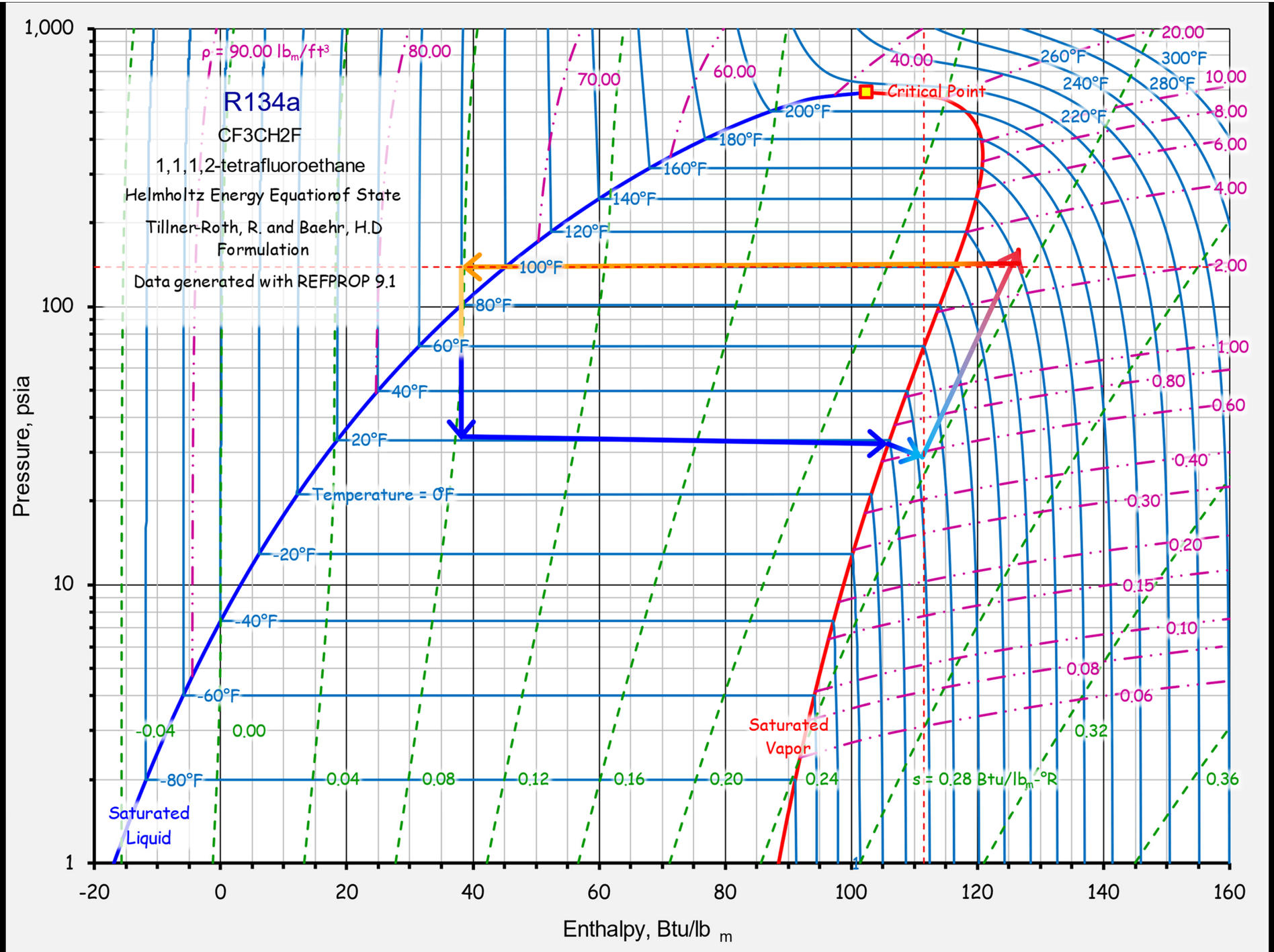
Condensation

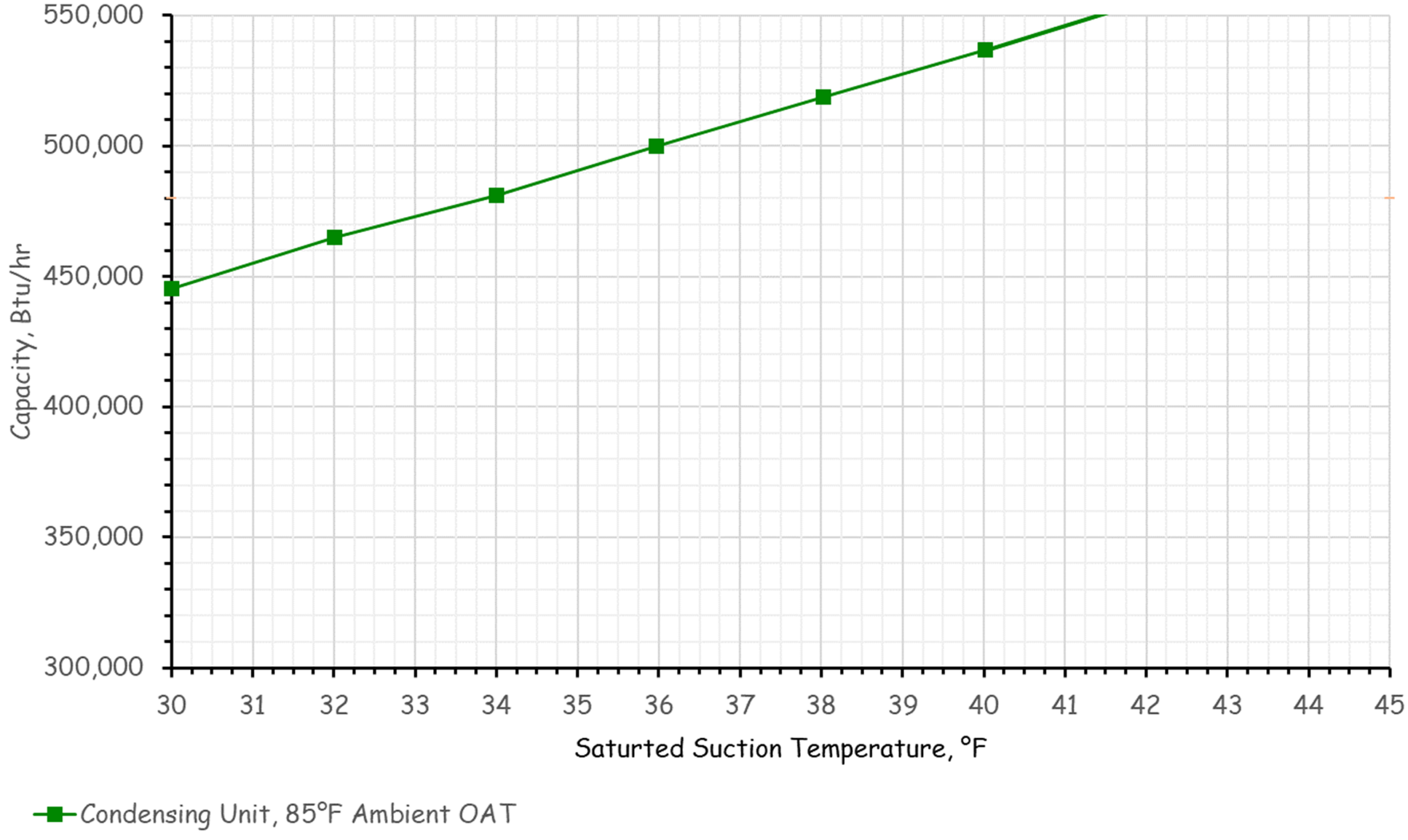


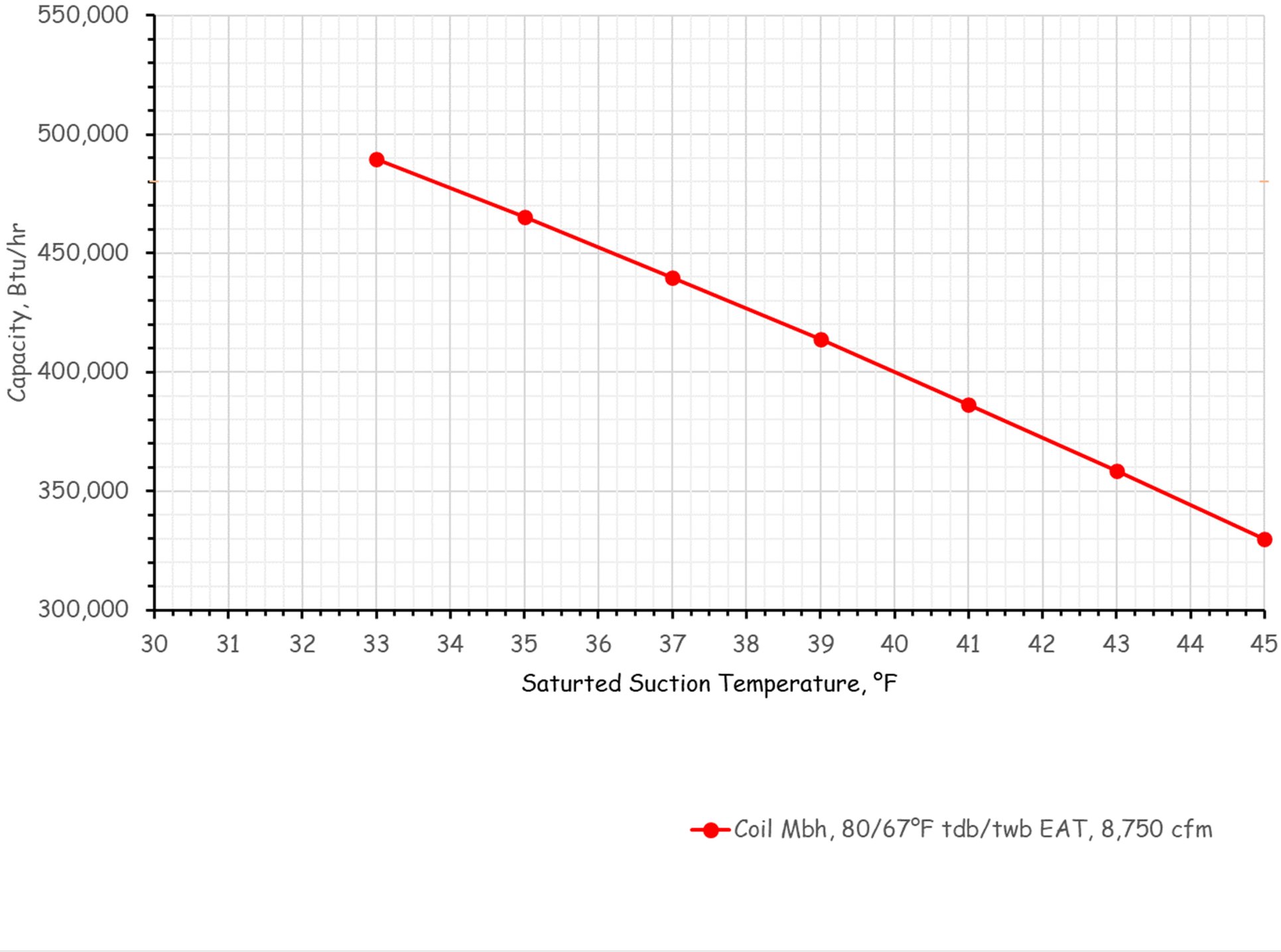
Expansion

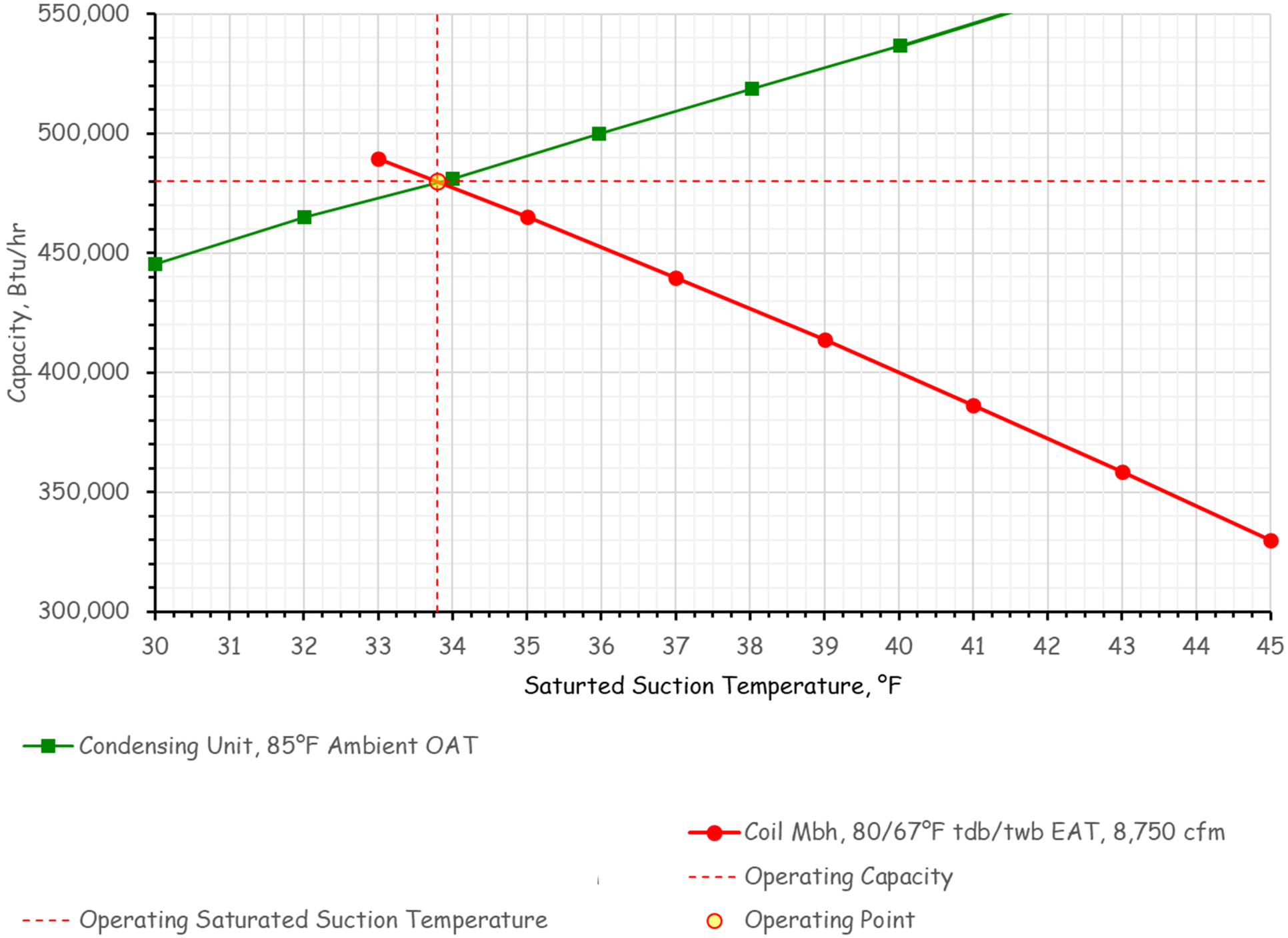

R134a
CF3CH2F
1,1,1,2-tetrafluoroethane
Helmholtz Energy Equation of State
Tillner-Roth, R. and Baehr, H.D
Formulation
Data generated with REFPROP 9.1
ρ = 90.00 lbm/ft3
80.00
70.00
60.00
40.00
20.00
Critical Point
260°F
300°F
240°F
280°F
220°F
200°F
180°F
160°F
140°F
120°F
100°F
80°F
60°F
40°F
20°F
Temperature = 0°F
-20°F
-40°F
-60°F
-80°F
10.00
8.00
6.00
4.00
2.00
1.00
0.80
0.60
0.40
0.30
0.20
0.15
0.10
0.08
0.06
-0.04
0.00
0.04
0.08
0.12
0.16
0.20
0.24
0.32
0.36
s = 0.28 Btu/lbm-°R
Saturated
Liquid
Saturated
Vapor
1,000
100
10
1
Pressure, psia
-20
0
20
40
60
80
100
120
140
160
Enthalpy, Btu/lb m

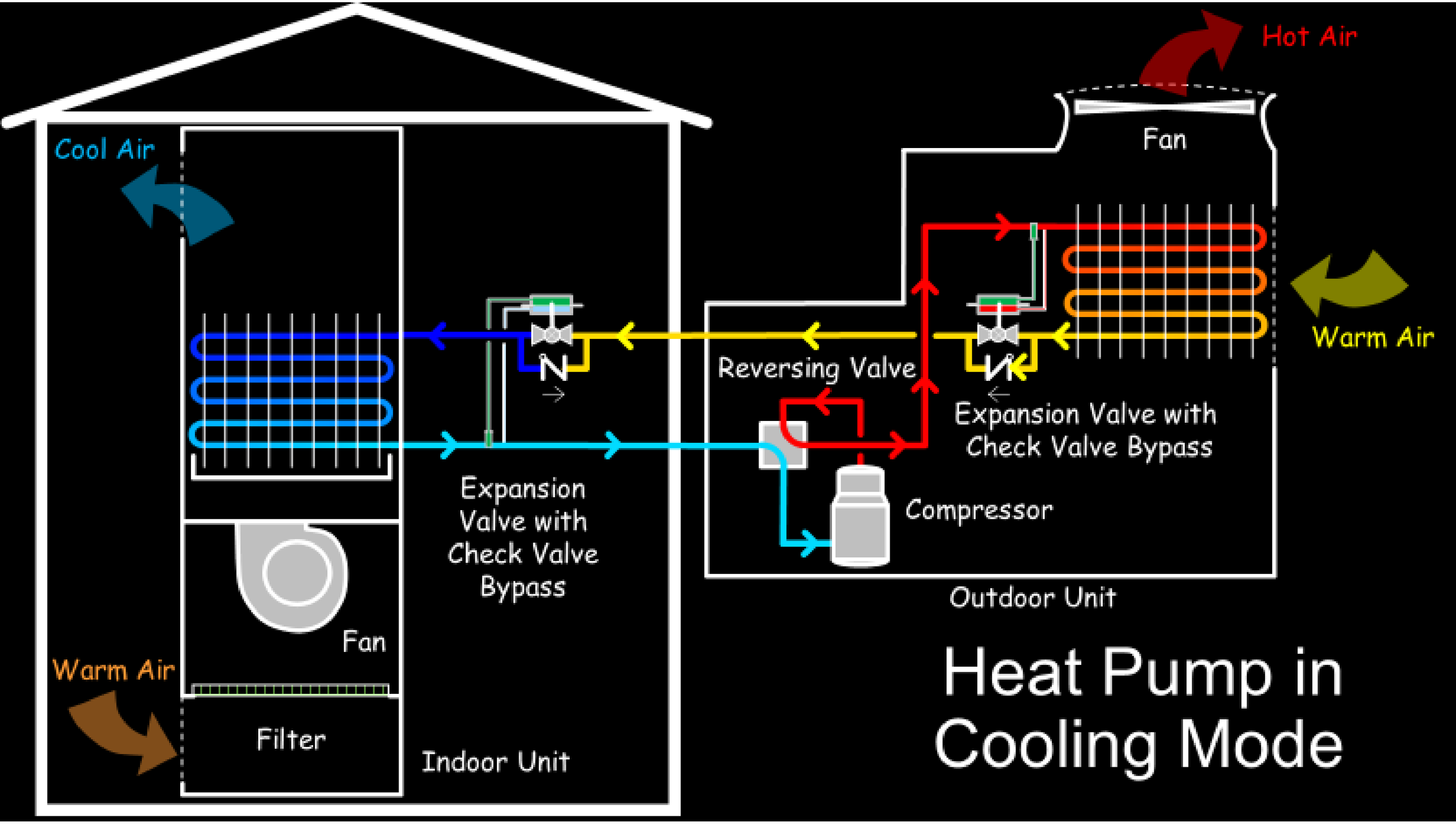
The Pressure-Enthalpy (p-h) Diagram – Actual Cycle

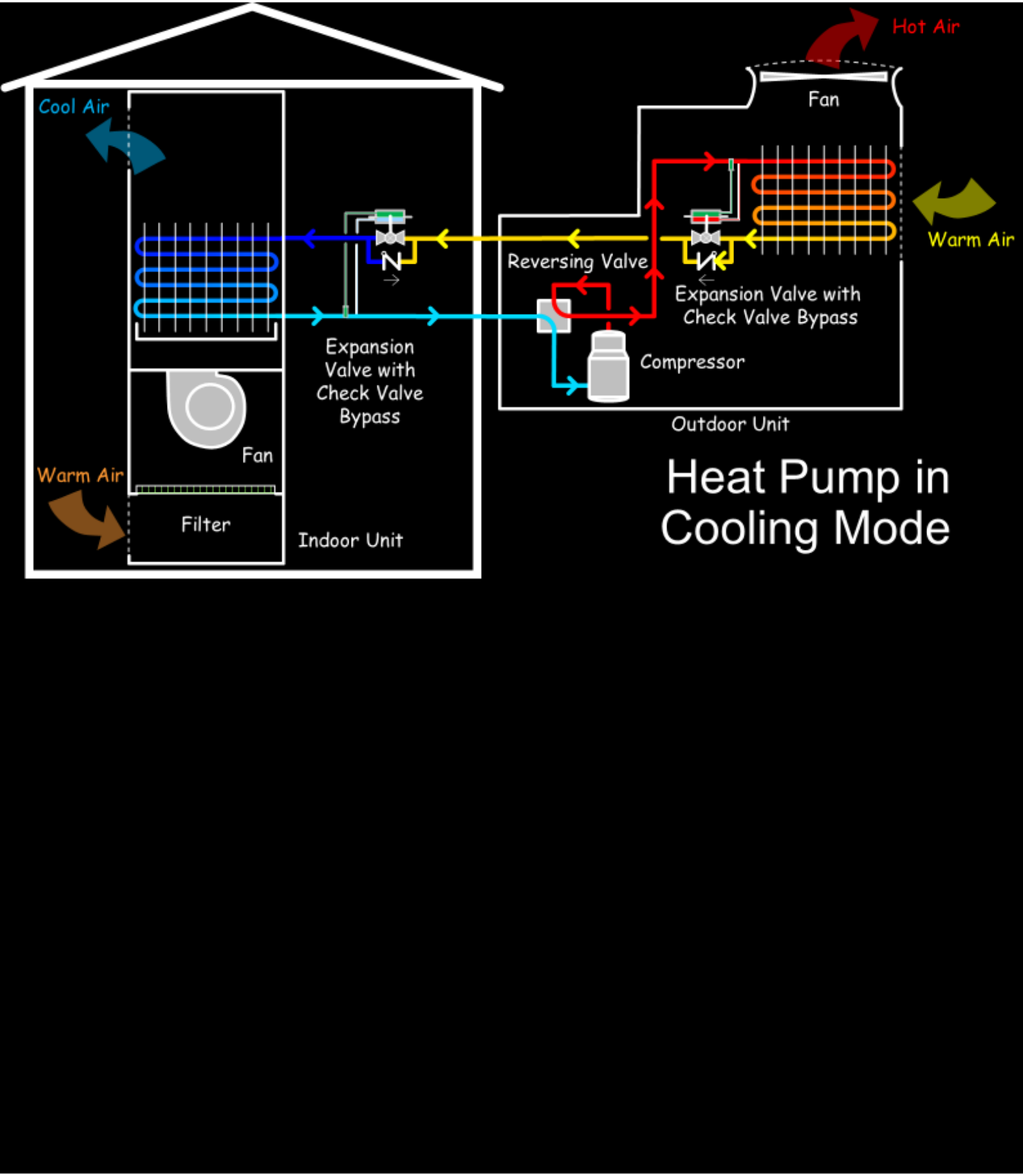


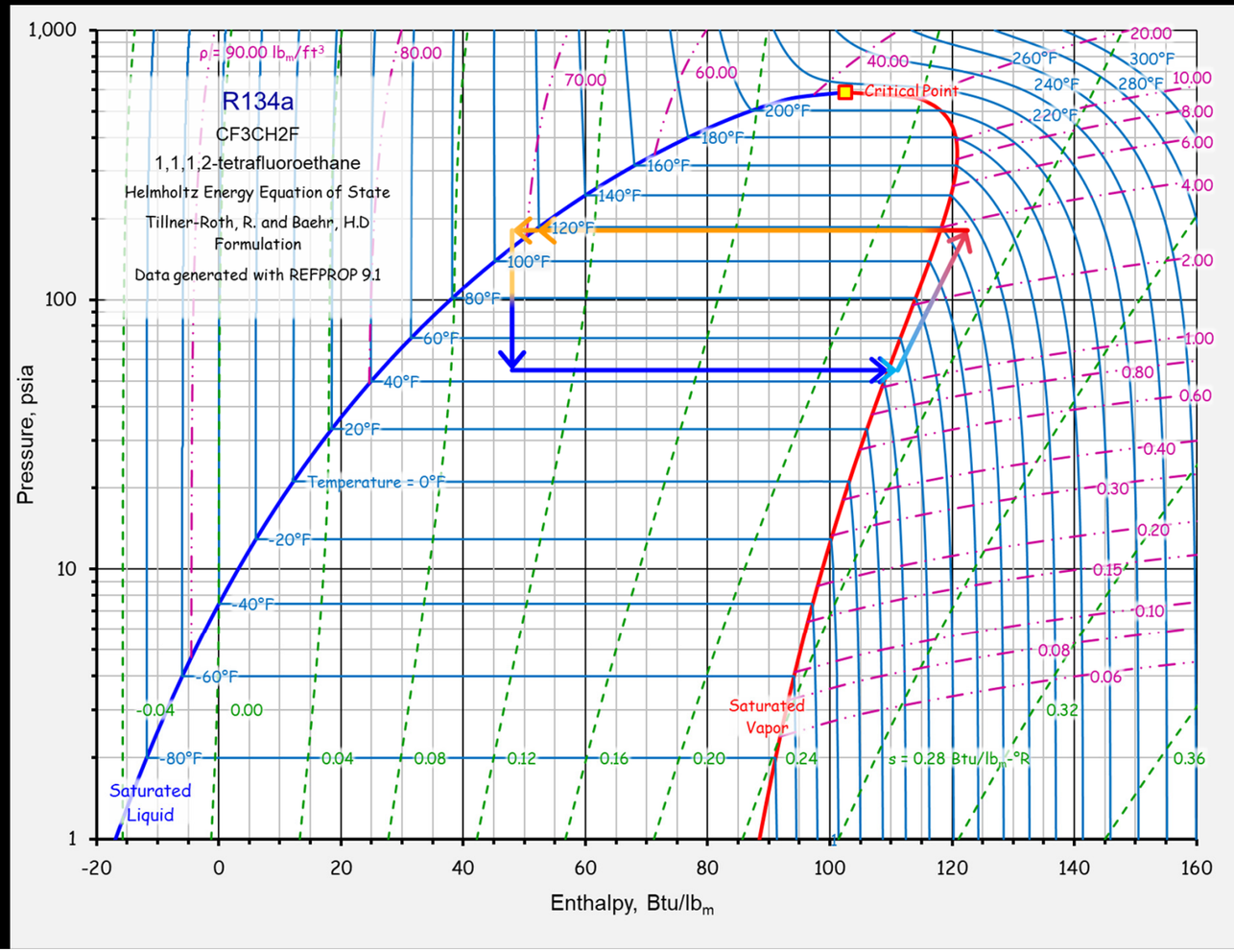

550,000
500,000
450,000
400,000
350,000
300,000
Capacity, Btu/hr
30
31
32
33
34
35
36
37
38
39
40
41
42
43
44
45
Saturted Suction Temperature, °F
Condensing Unit, 85°F Ambient OAT

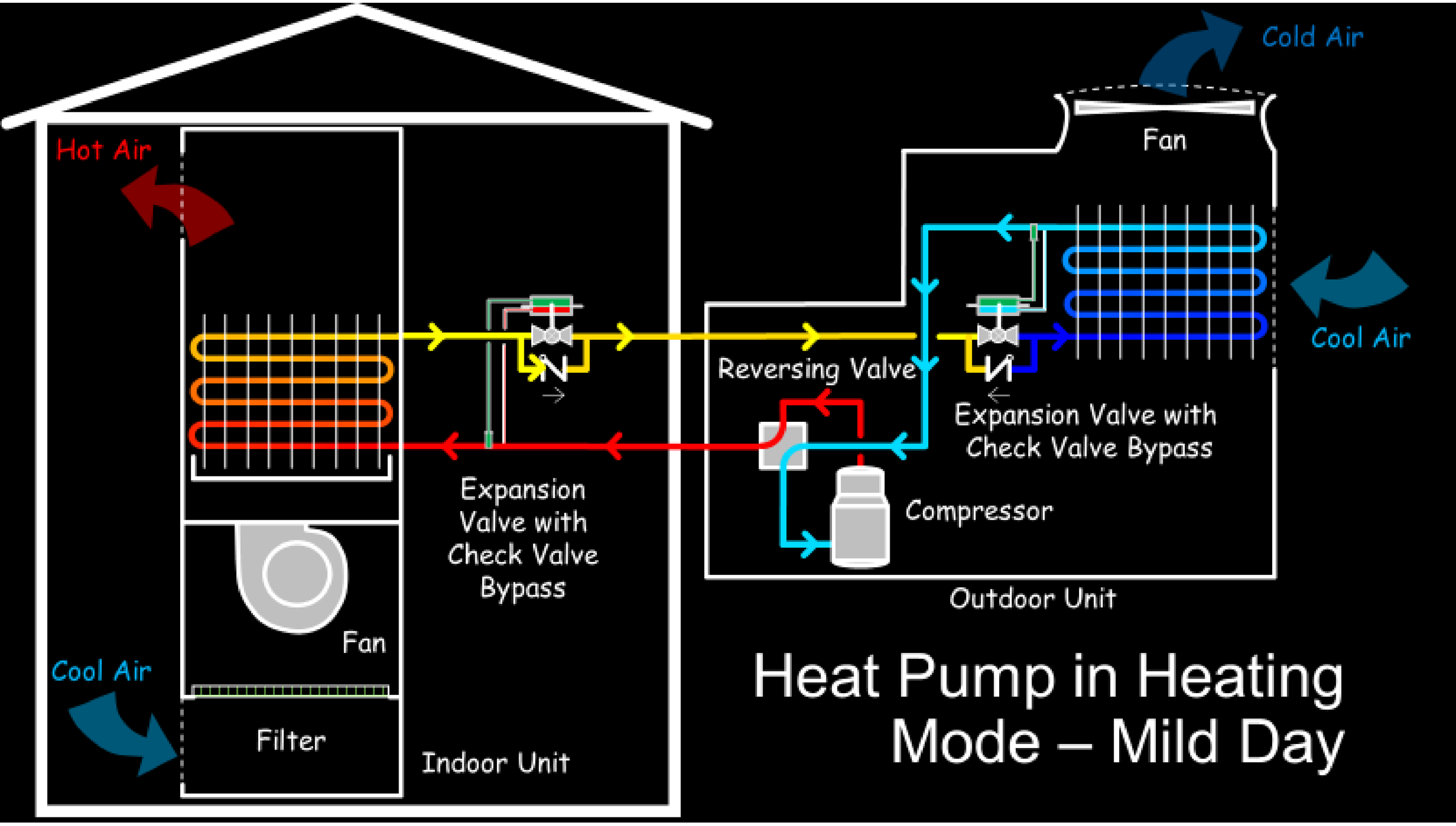

550,000
500,000
450,000
400,000
350,000
300,000
Capacity, Btu/hr
30
31
32
33
34
35
36
37
38
39
40
41
42
43
44
45
Saturted Suction Temperature, °F
Coil Mbh, 80/67°F tdb/twb EAT, 8,750 cfm

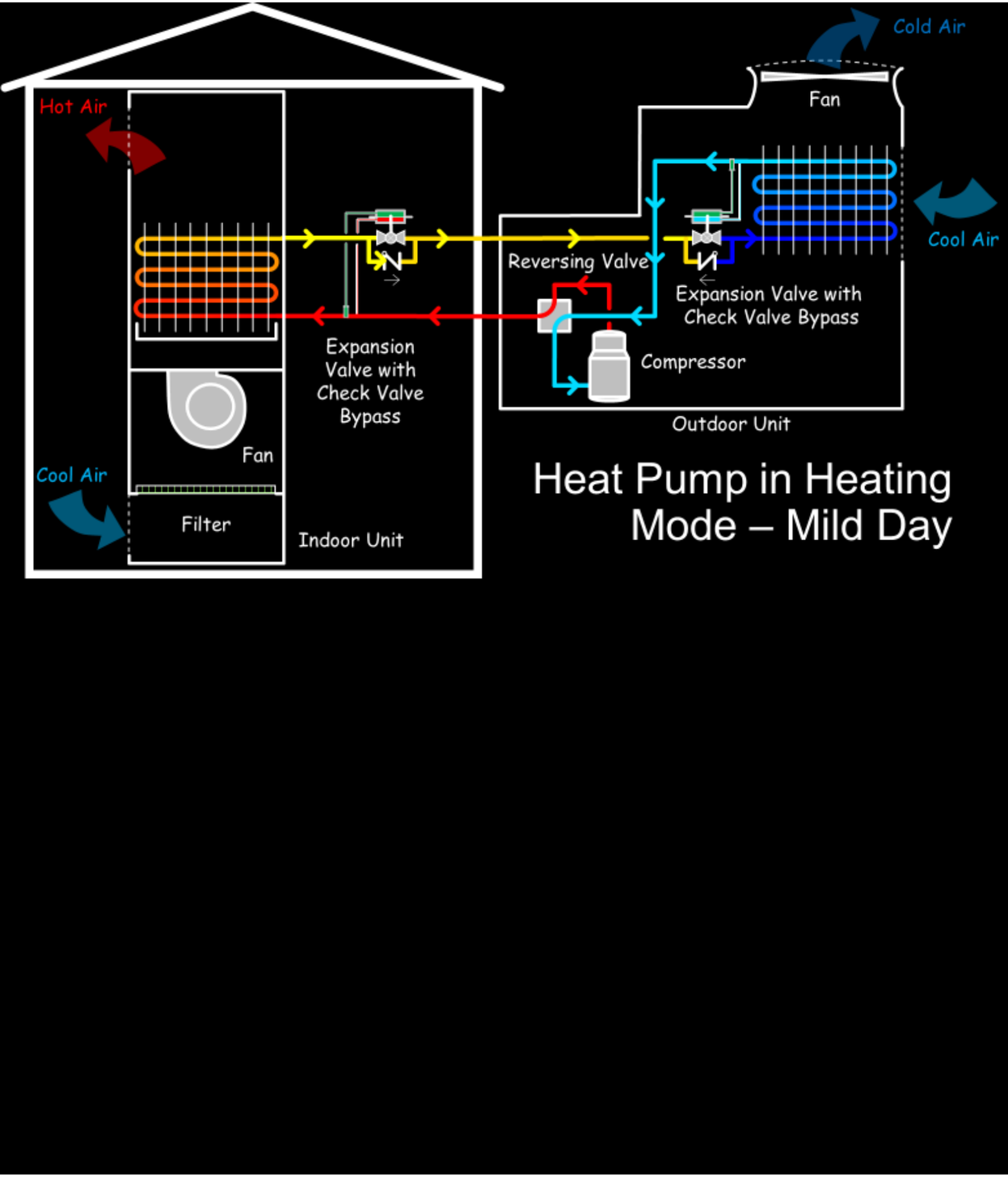

550,000
500,000
450,000
400,000
350,000
300,000
Capacity, Btu/hr
30
31
32
33
34
35
36
37
38
39
40
41
42
43
44
45
Saturted Suction Temperature, °F
Condensing Unit, 85°F Ambient OAT
Coil Mbh, 80/67°F tdb/twb EAT, 8,750 cfm
Operating Capacity
Operating Saturated Suction Temperature
Operating Point

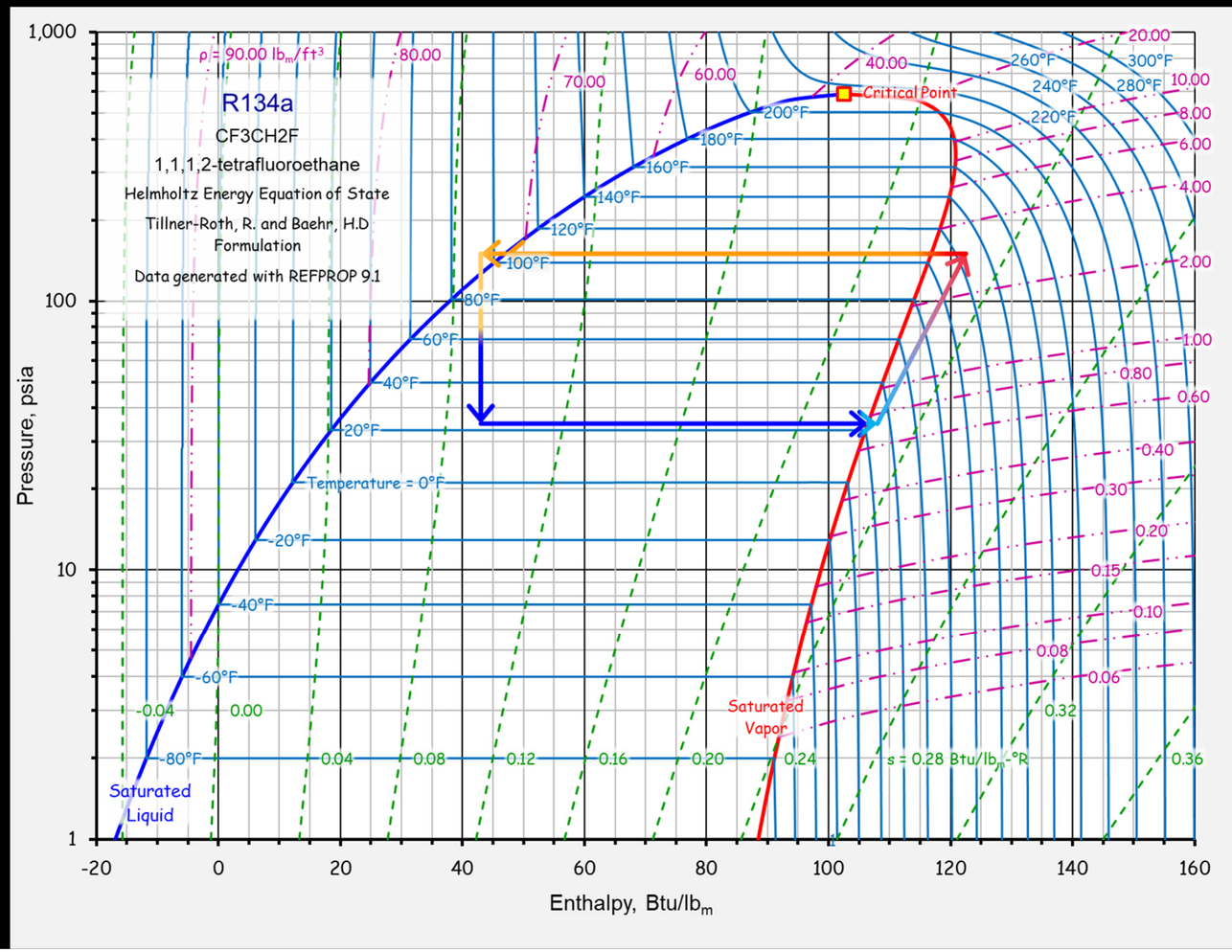

Hot Air
Fan
Cool Air
Warm Air
Reversing Valve
Expansion Valve with Check Valve Bypass
Compressor
Outdoor Unit
Expansion Valve with Check Valve Bypass
Fan
Warm Air
Filter
Indoor Unit
Heat Pump in Cooling Mode


Hot Air
Fan
Cool Air
Warm Air
Reversing Valve
Expansion Valve with Check Valve Bypass
Compressor
Outdoor Unit
Expansion Valve with Check Valve Bypass
Fan
Warm Air
Filter
Indoor Unit
Heat Pump in Cooling Mode


ρ = 90.00 lbm/ft3
R134a
CF3CH2F
1,1,1,2-tetrafluoroethane
Helmholtz Energy Equation of State
Tillner-Roth, R. and Baehr, H.D
Formulation
Data generated with REFPROP 9.1
Critical Point
Saturated Liquid
Saturated Vapor
Temperature = 0°F
s = 0.28 Btu/lbm-°R
Pressure, psia
Enthalpy, Btu/lbm
1,000
100
10
1
-20
0
20
40
60
80
100
120
140
160


Cold Air
Fan
Hot Air
Reversing Valve
Cool Air
Expansion Valve with Check Valve Bypass
Expansion Valve with Check Valve Bypass
Compressor
Outdoor Unit
Fan
Cool Air
Filter
Indoor Unit
Heat Pump in Heating Mode – Mild Day


Cold Air
Fan
Hot Air
Cool Air
Reversing Valve
Expansion Valve with Check Valve Bypass
Compressor
Expansion Valve with Check Valve Bypass
Fan
Cool Air
Filter
Indoor Unit
Outdoor Unit
Heat Pump in Heating Mode – Mild Day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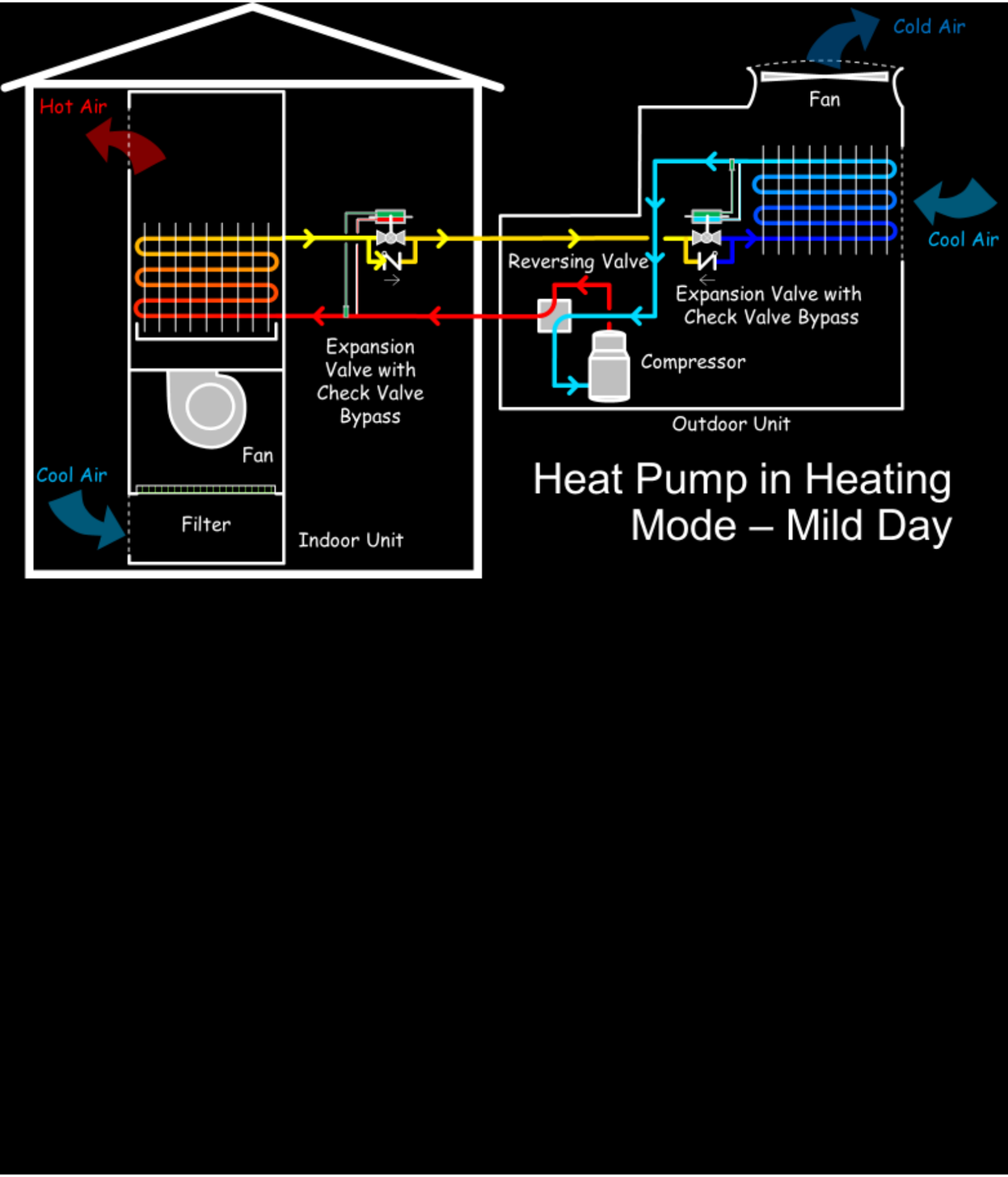
Saturated Liquid
Saturated Vapor
Pressure, psia
Enthalpy, Btu/lbm
s = 0.28 Btu/lbm-°R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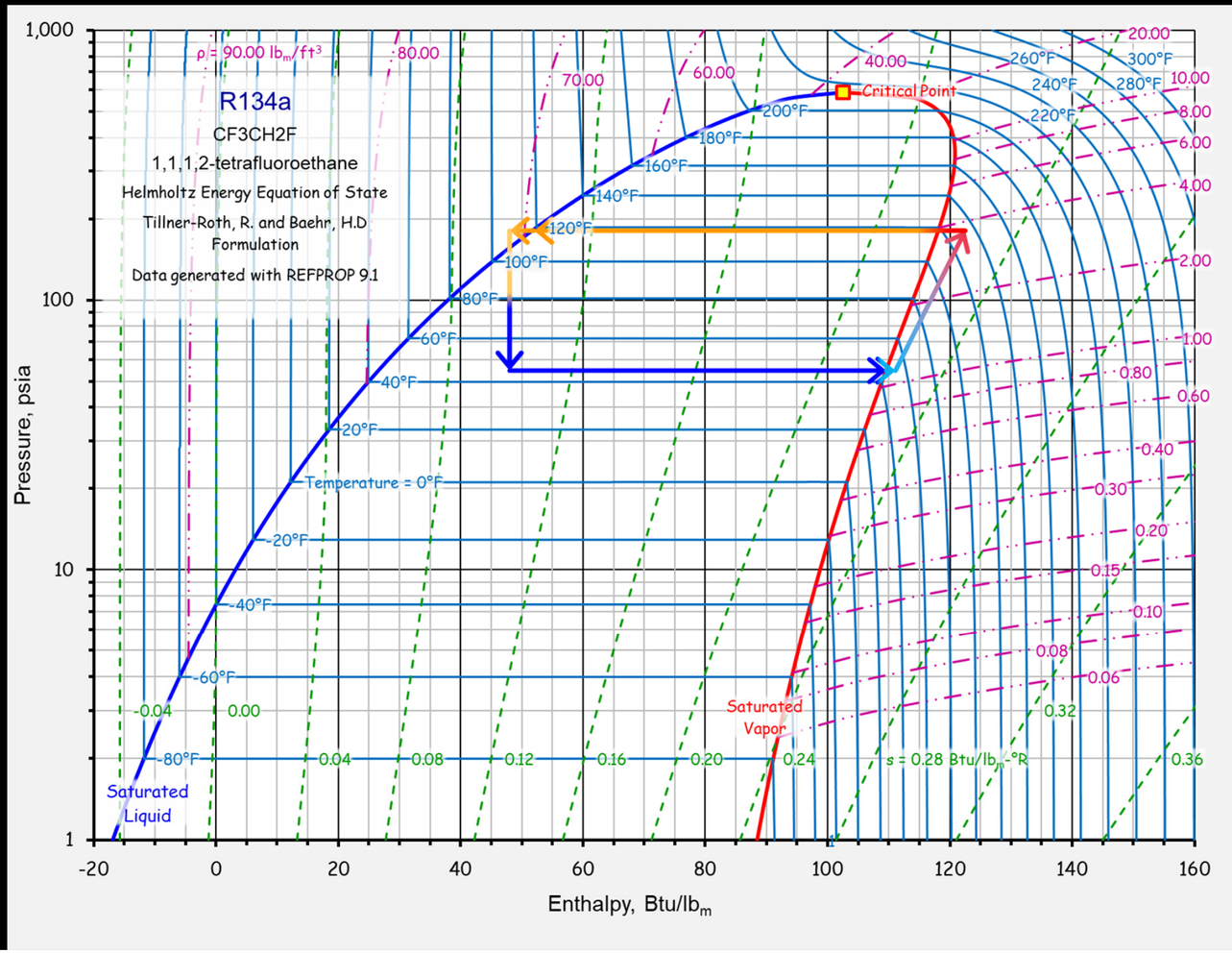
Filter
Indoor Unit
Outdoor Unit
Heat Pump in Heating Mode – Mild Day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Saturated Vapor
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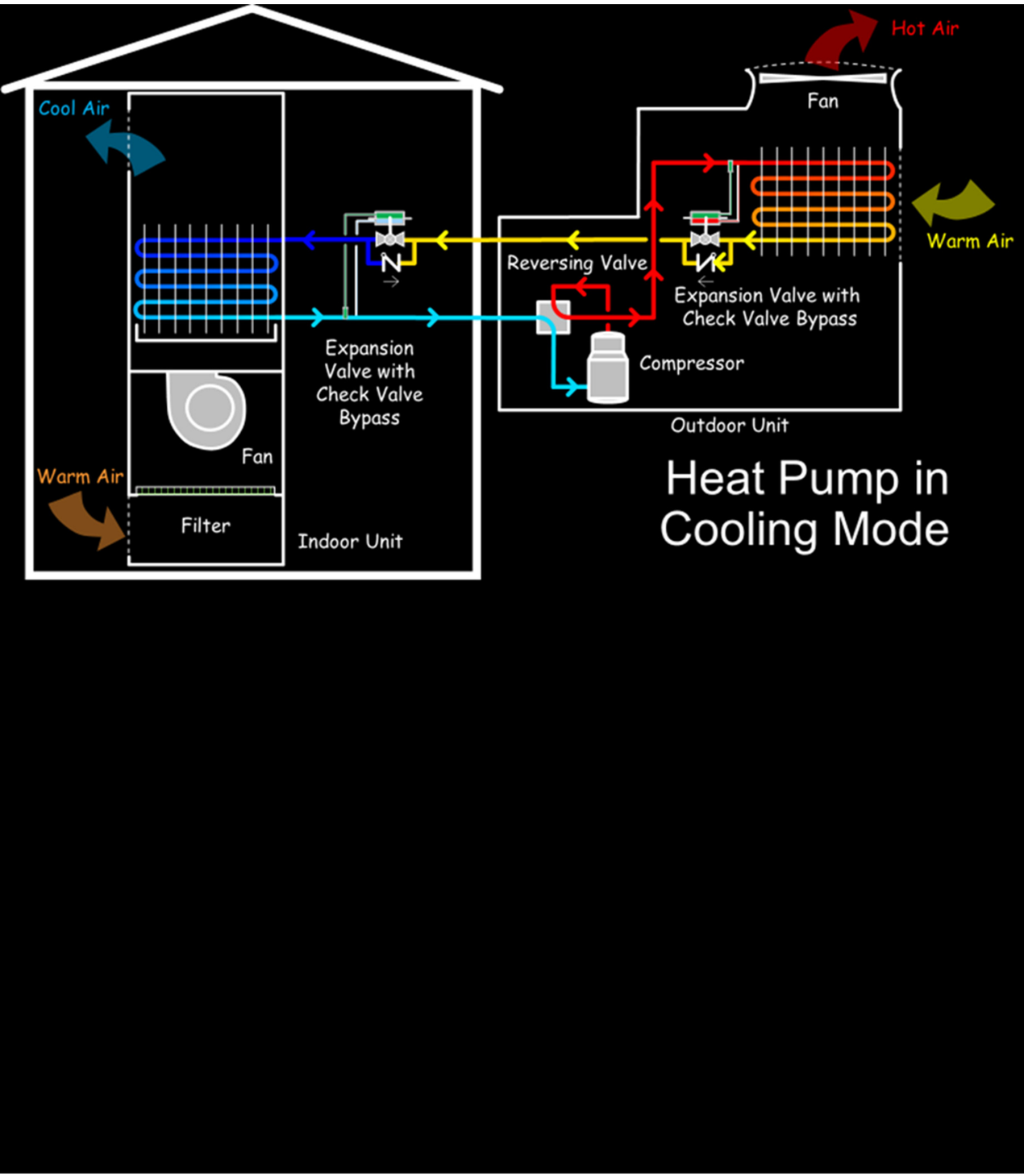
Pressure, psia
Enthalpy, Btu/lbm
1,000
100
10
1
-20
0
20
40
60
80
100
120
140
160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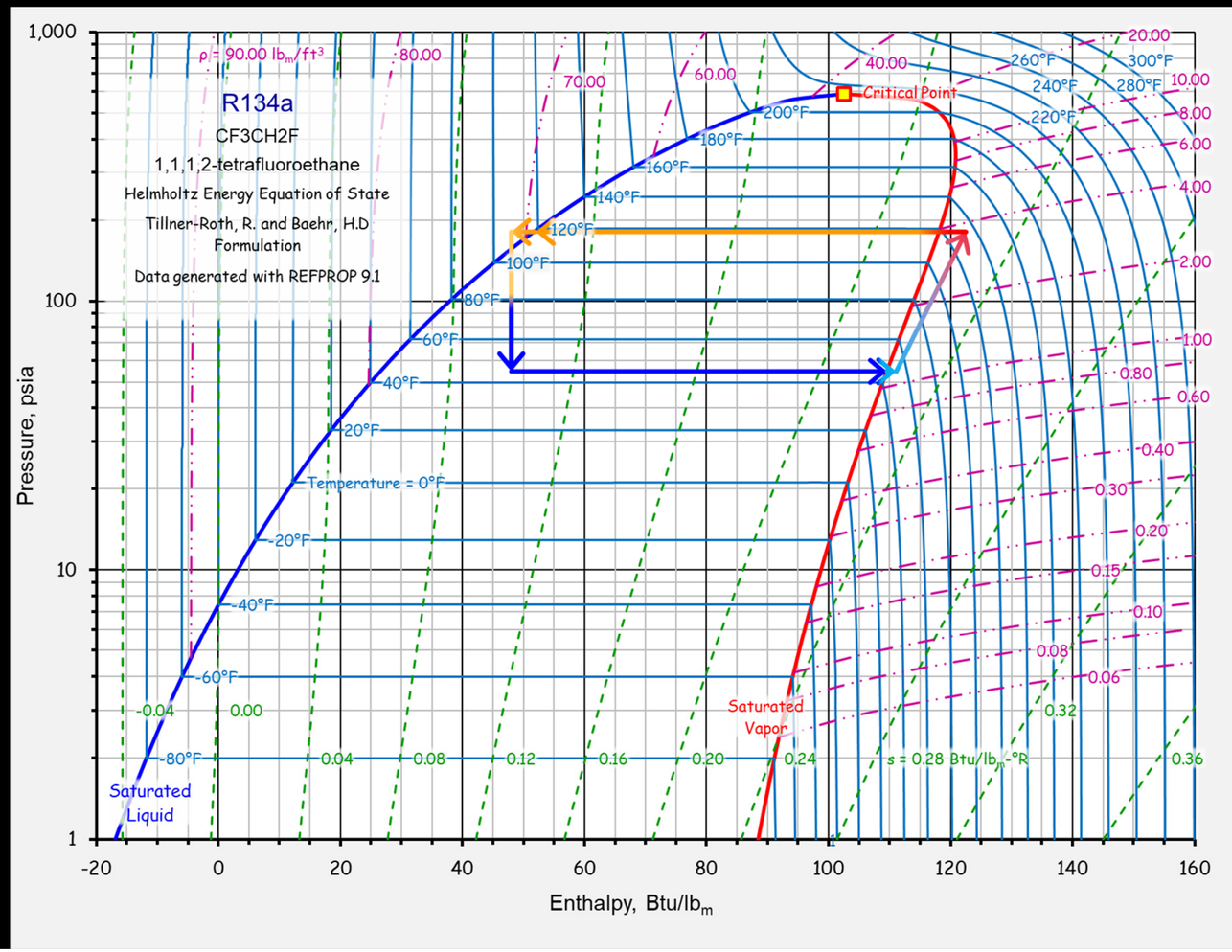
Fan
Warm Air
Filter
Indoor Unit
Heat Pump in Cooling Mode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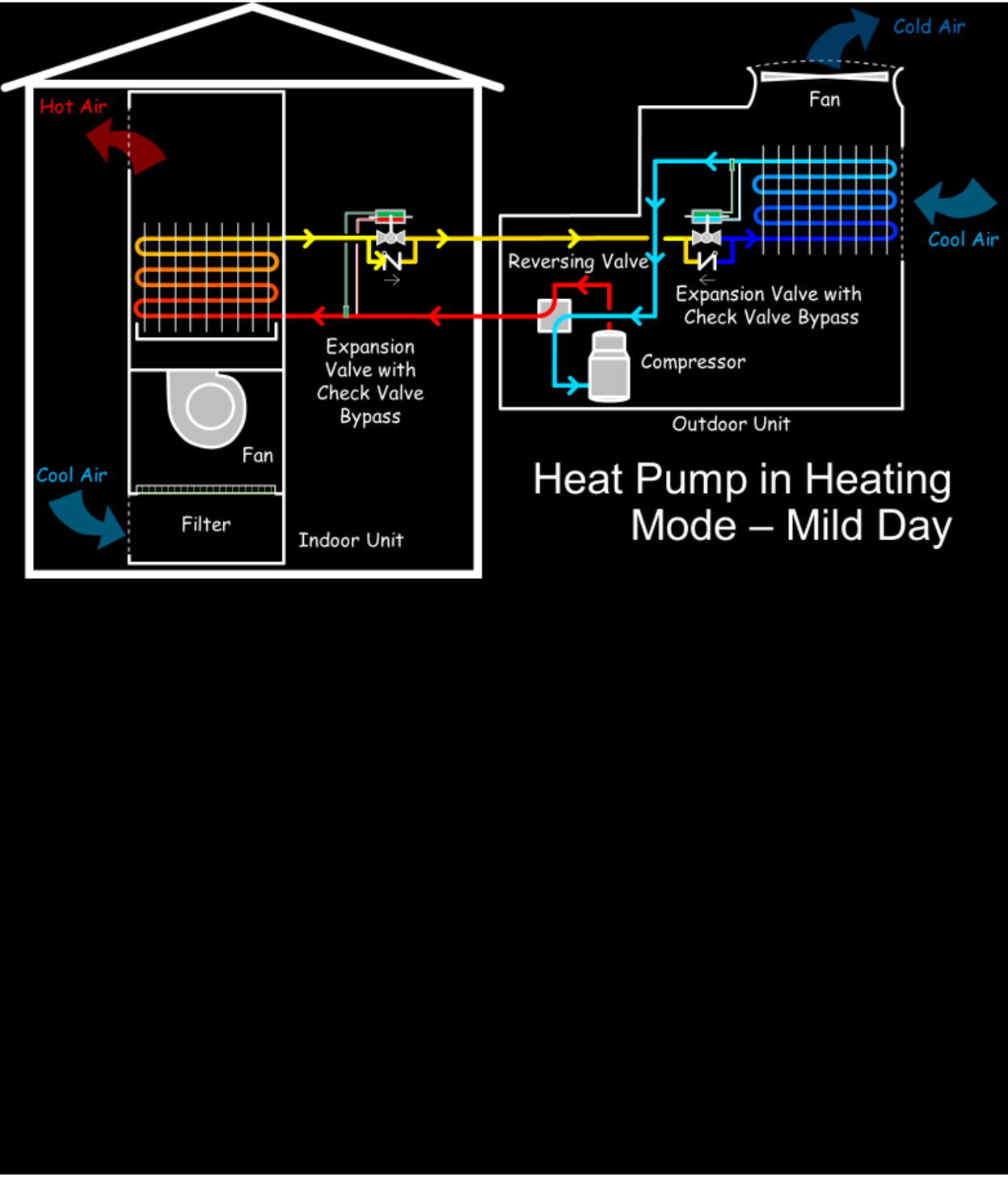
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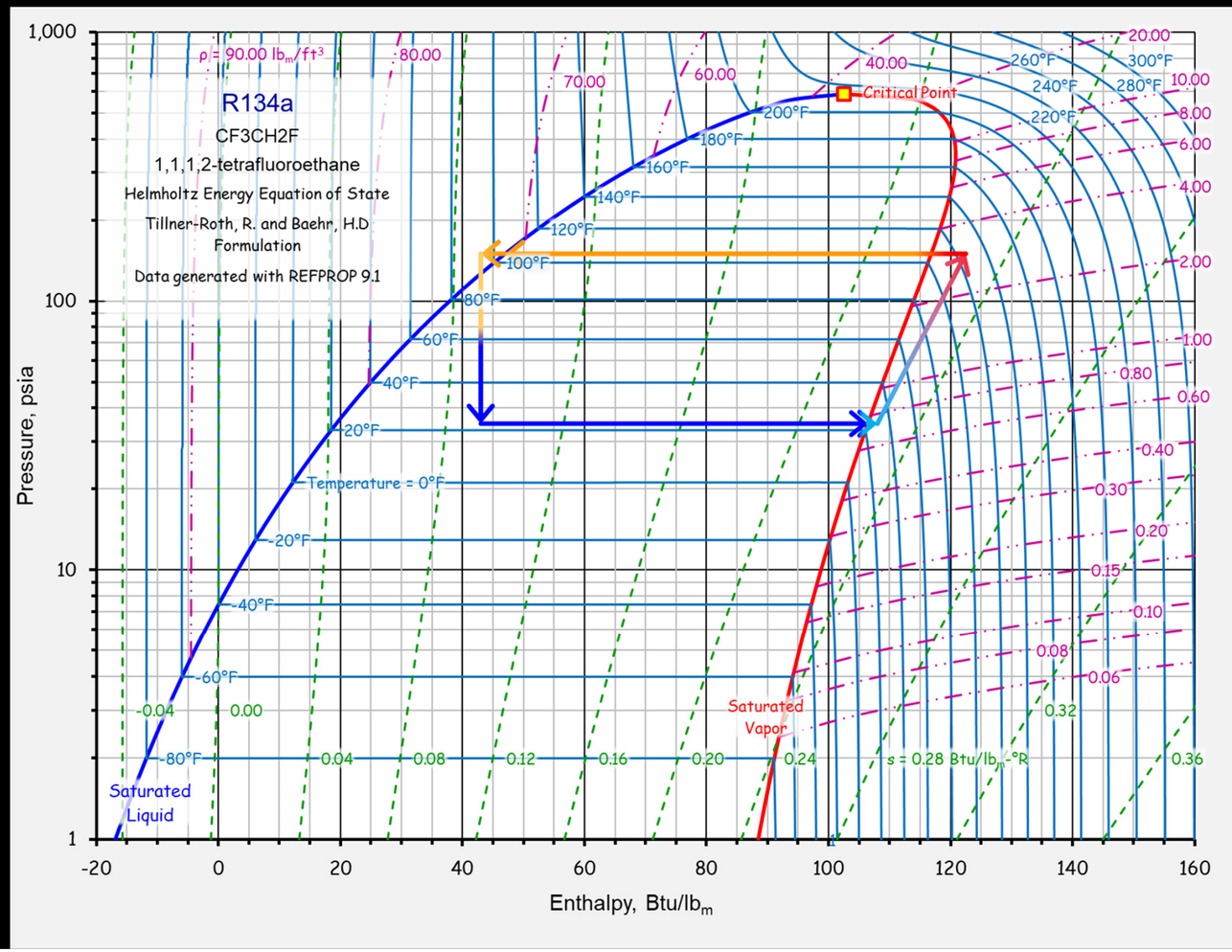
Filter
Indoor Unit
Outdoor Unit
Heat Pump in Heating Mode – Mild Day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1,1,1,2-tetrafluoroethane
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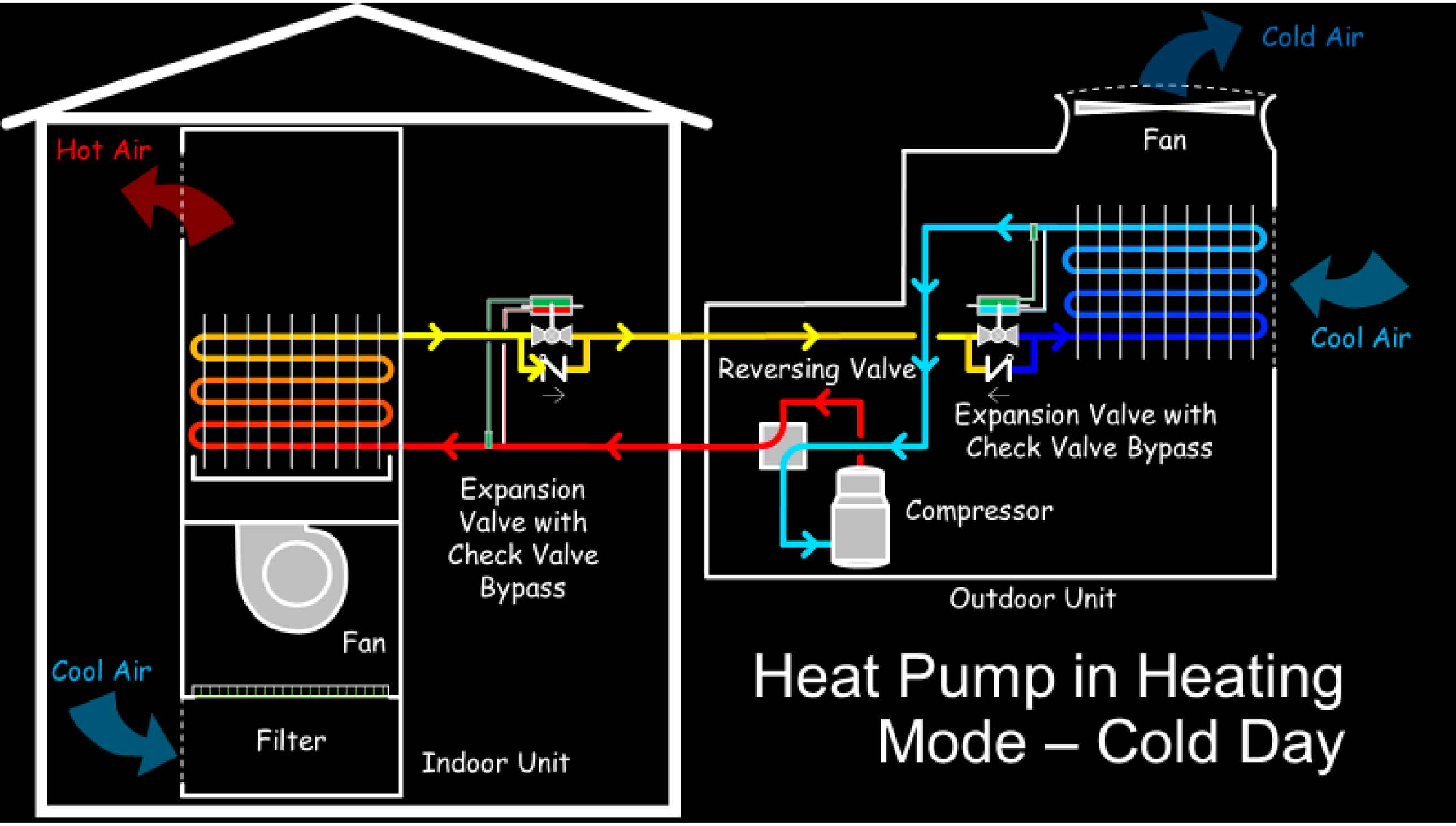
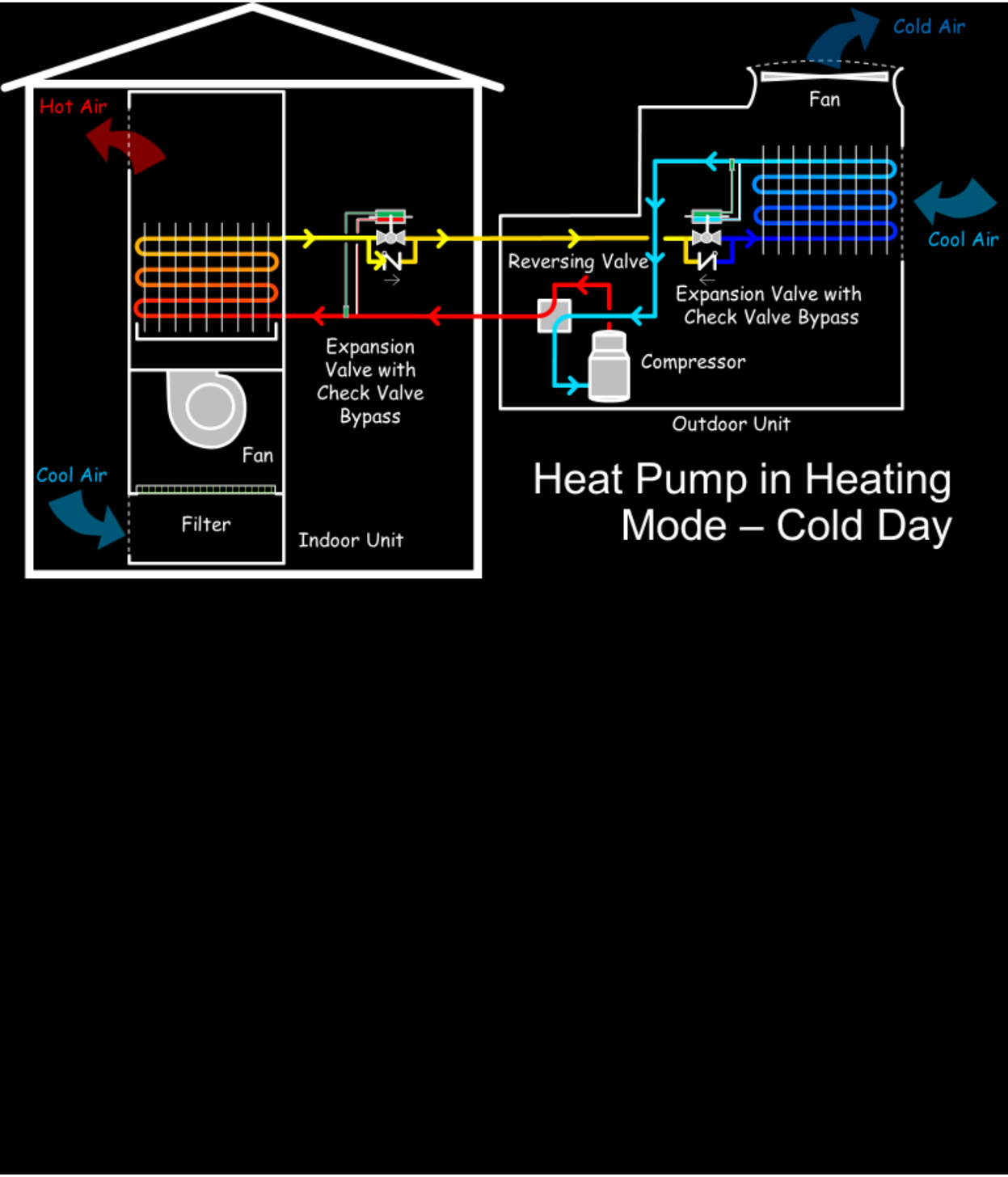
Saturated Vapor
Pressure, psia
Enthalpy, Btu/lbm
s = 0.28 Btu/lbm-°R


Cold Air
Fan
Hot Air
Reversing Valve
Cool Air
Expansion Valve with Check Valve Bypass
Expansion Valve with Check Valve Bypass
Compressor
Outdoor Unit
Fan
Cool Air
Filter
Indoor Unit
Heat Pump in Heating Mode – Cold Day


Cold Air
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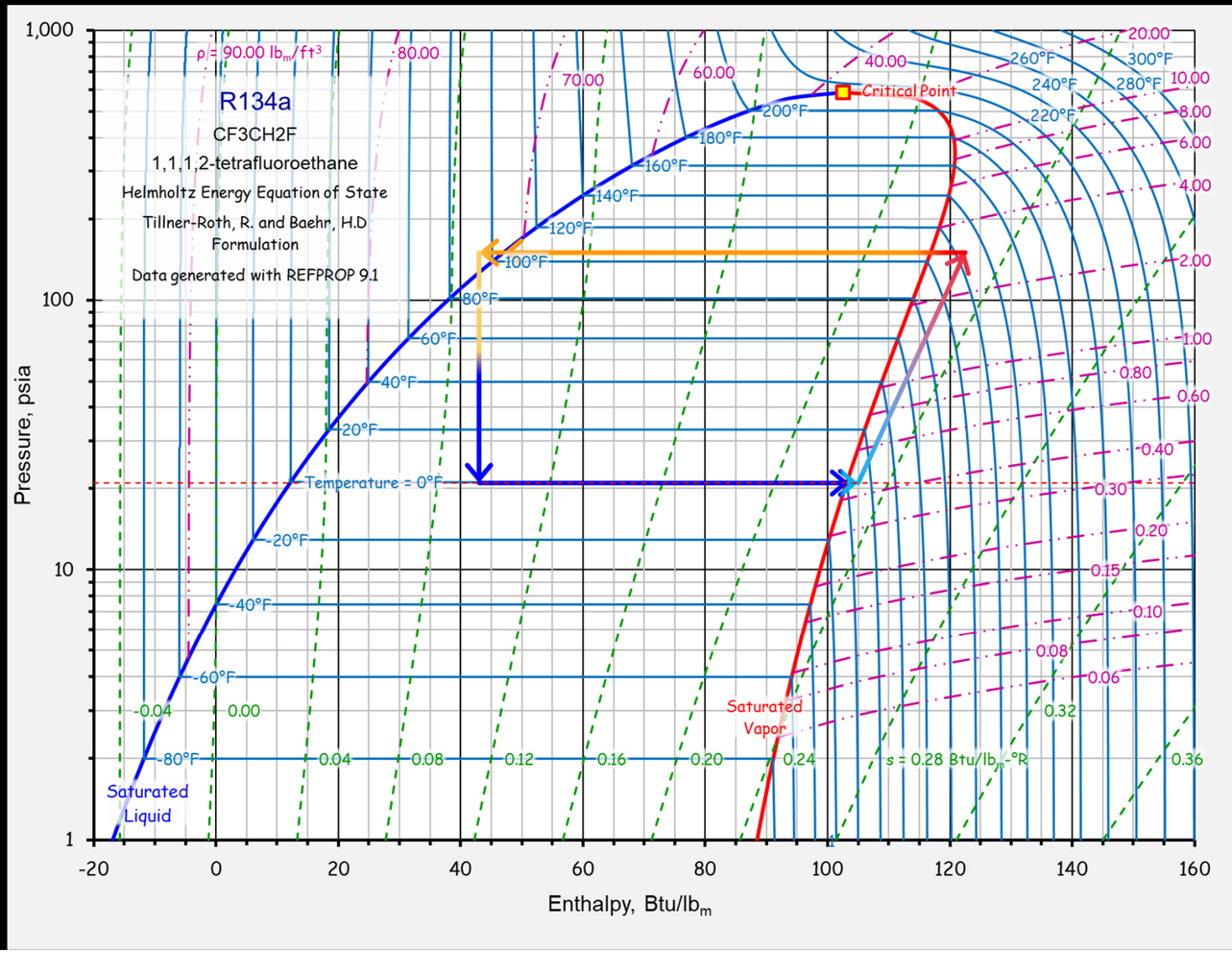
Hot Air
Cool Air
Reversing Valve
Expansion Valve with Check Valve Bypass
Compressor
Expansion Valve with Check Valve Bypass
Fan
Cool Air
Filter
Indoor Unit
Outdoor Unit
Heat Pump in Heating Mode – Cold Day


ρ = 90.00 lbm/ft3
R134a
CF3CH2F
1,1,1,2-tetrafluoroethane
Helmholtz Energy Equation of State
Tillner-Roth, R. and Baehr, H.D
Formulation
Data generated with REFPROP 9.1
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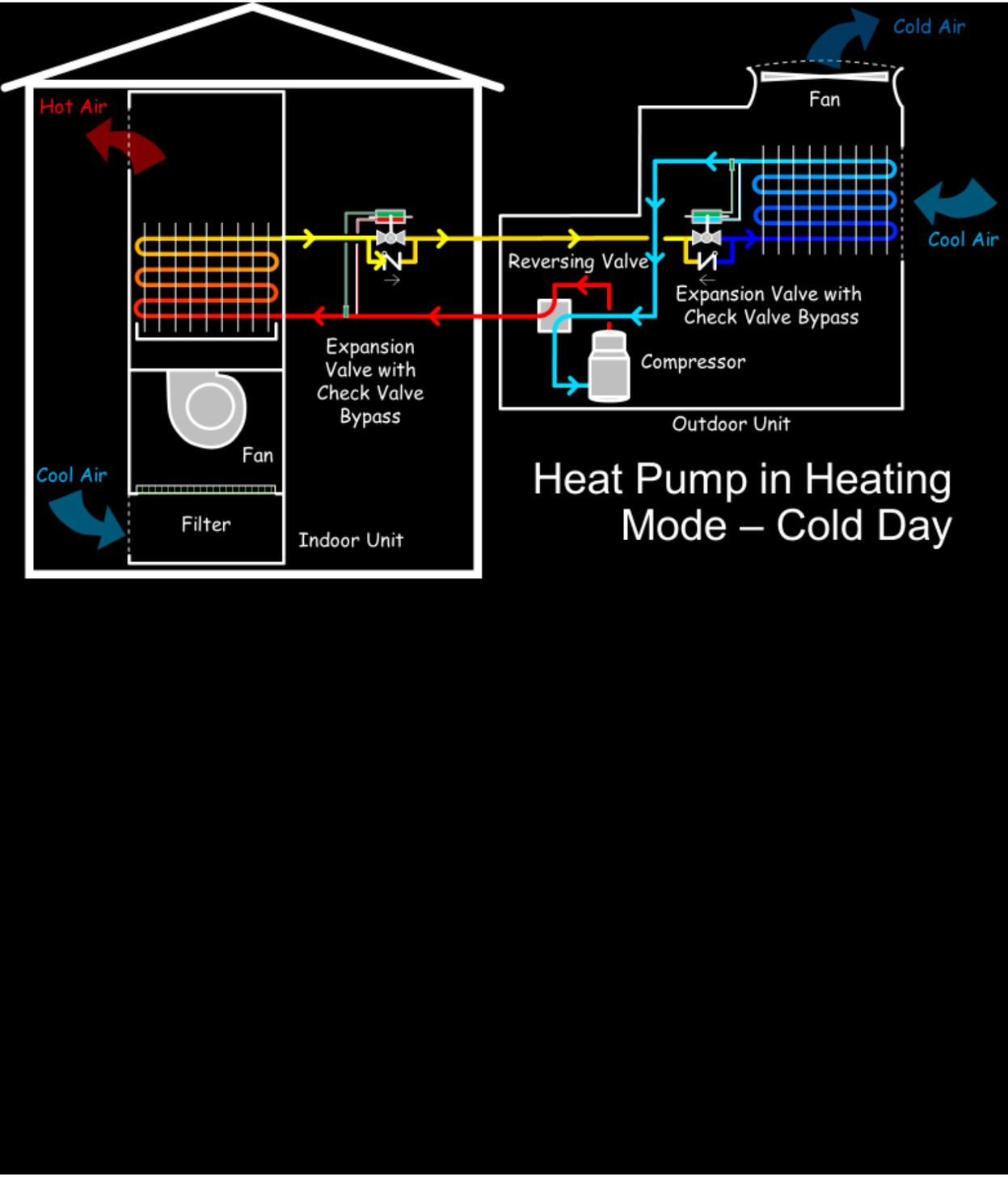
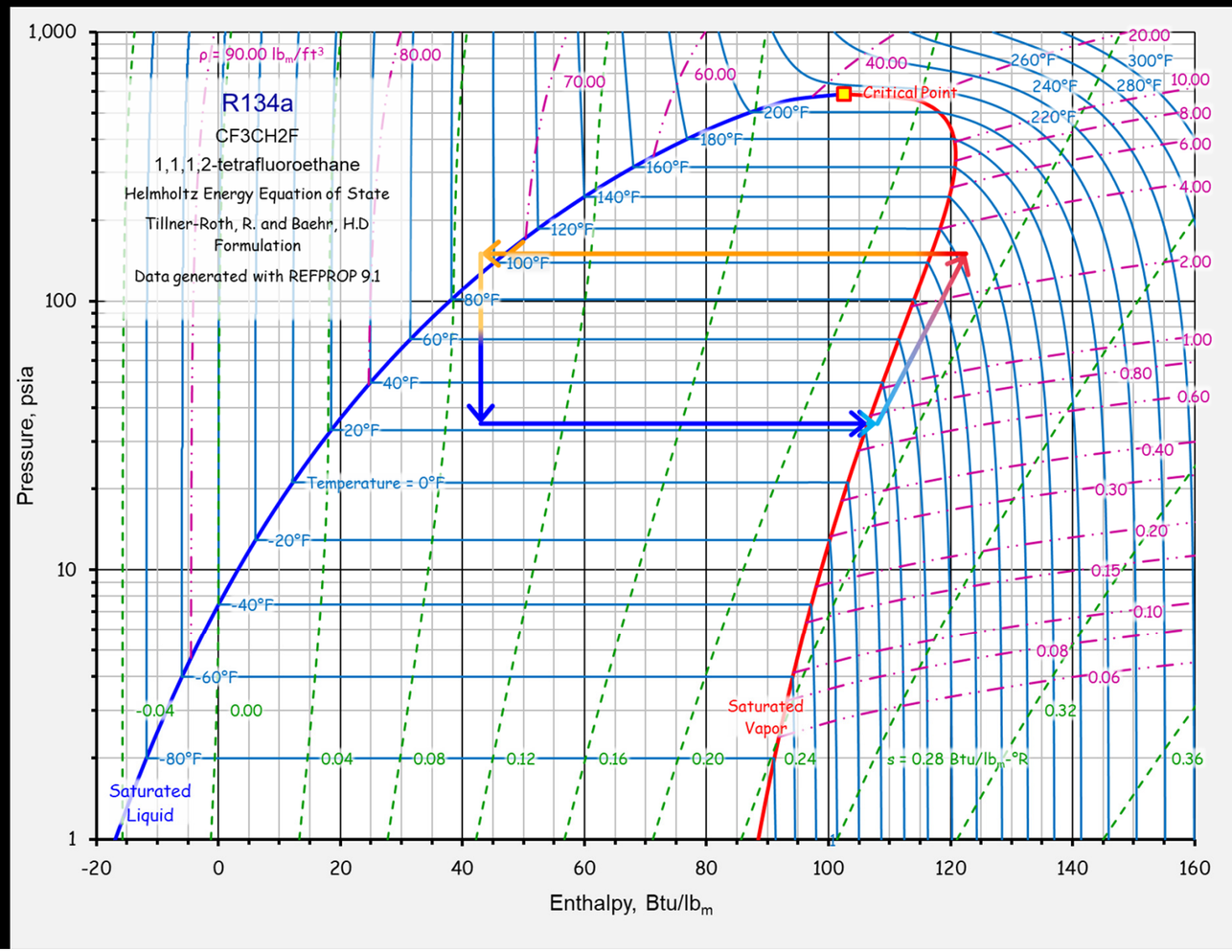
Saturated Vapor
Temperature = 0°F
s = 0.28 Btu/lbm-°R
Pressure, psia
Enthalpy, Btu/lbm
1,000
100
10
1
-20
0
20
40
60
80
100
120
140
160


Cold Air
Fan
Hot Air
Cool Air
Reversing Valve
Expansion Valve with Check Valve Bypass
Expansion Valve with Check Valve Bypass
Compressor
Outdoor Unit
Fan
Cool Air
Filter
Indoor Unit
Heat Pump in Heating Mode – Cold Day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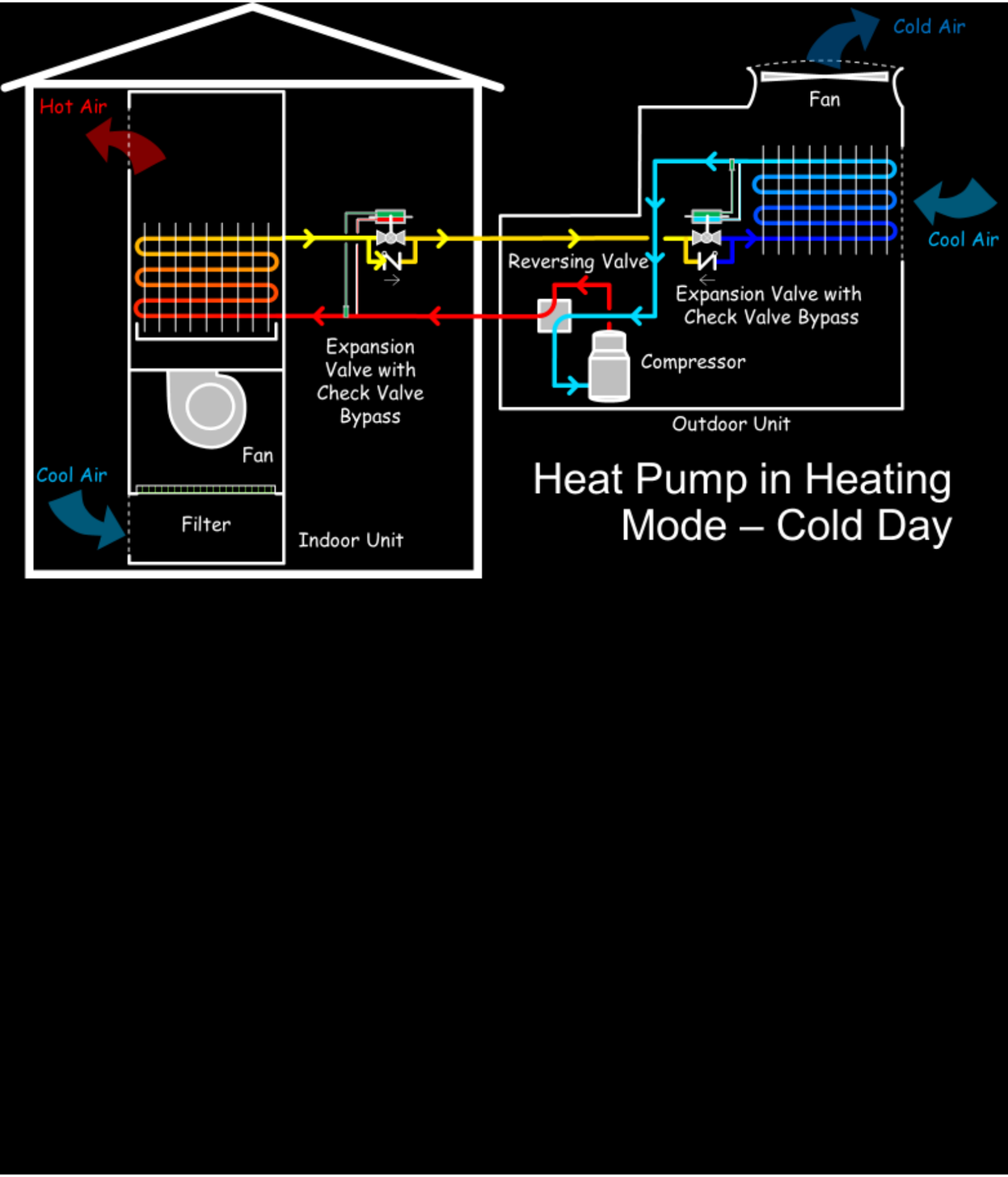
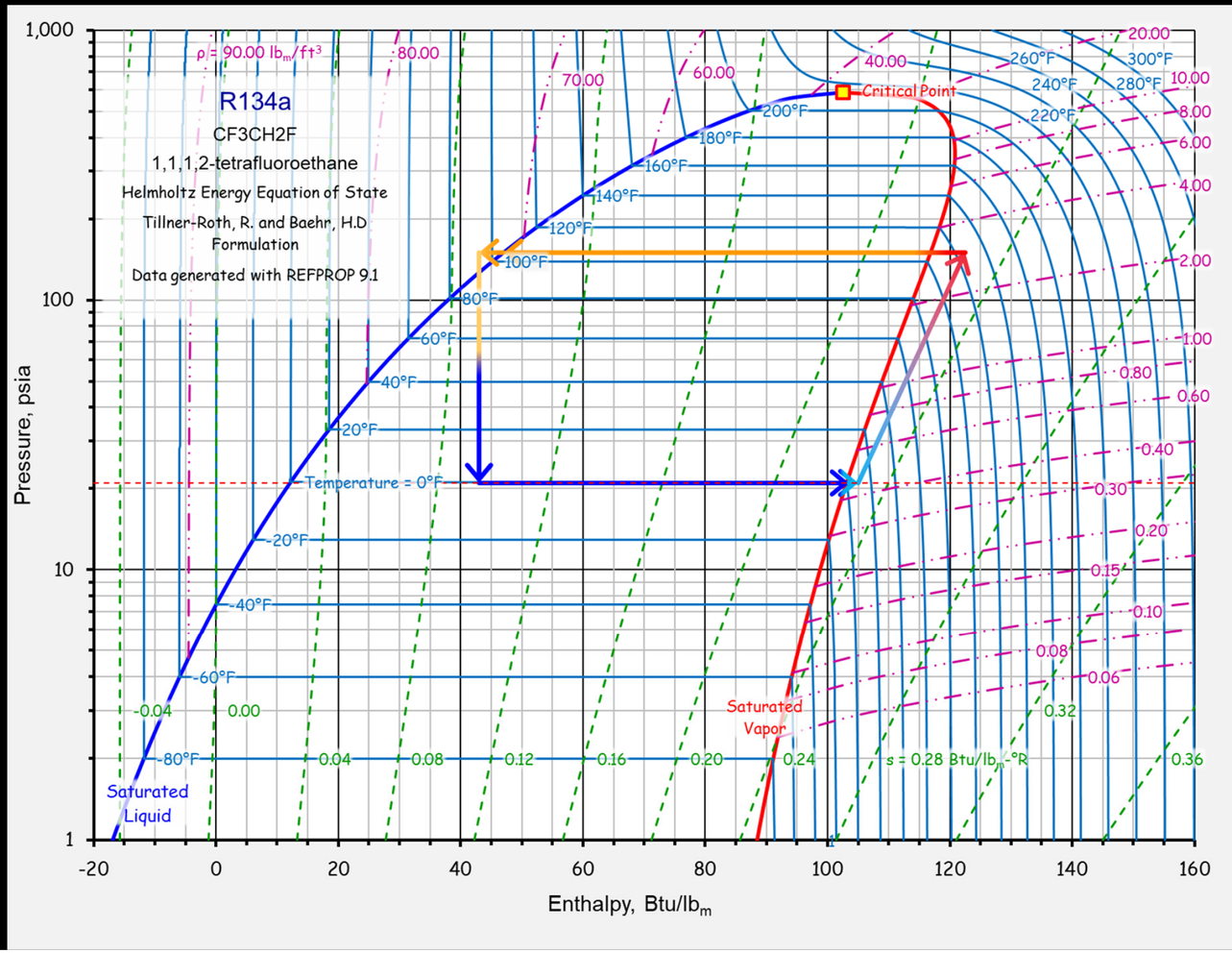
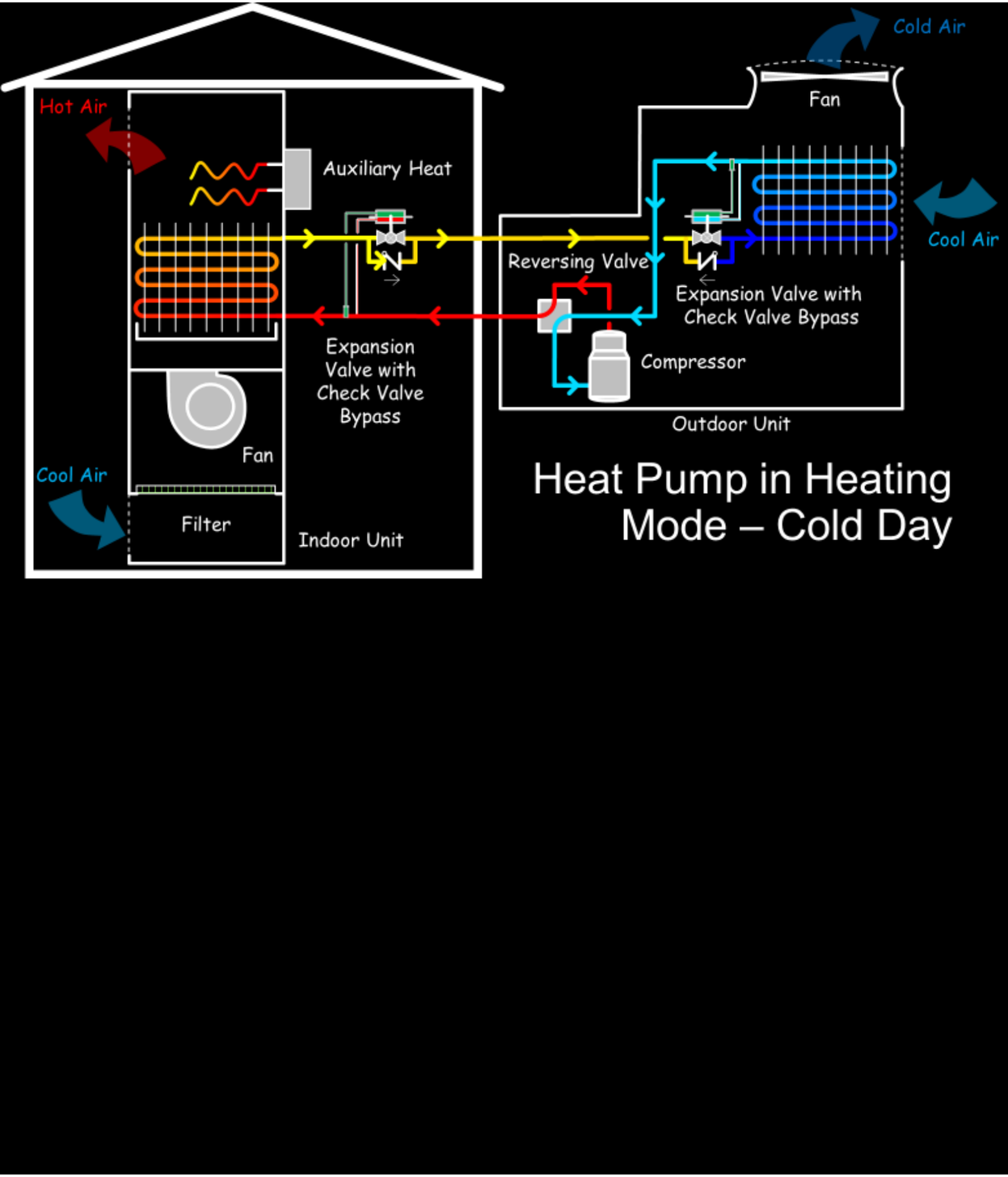
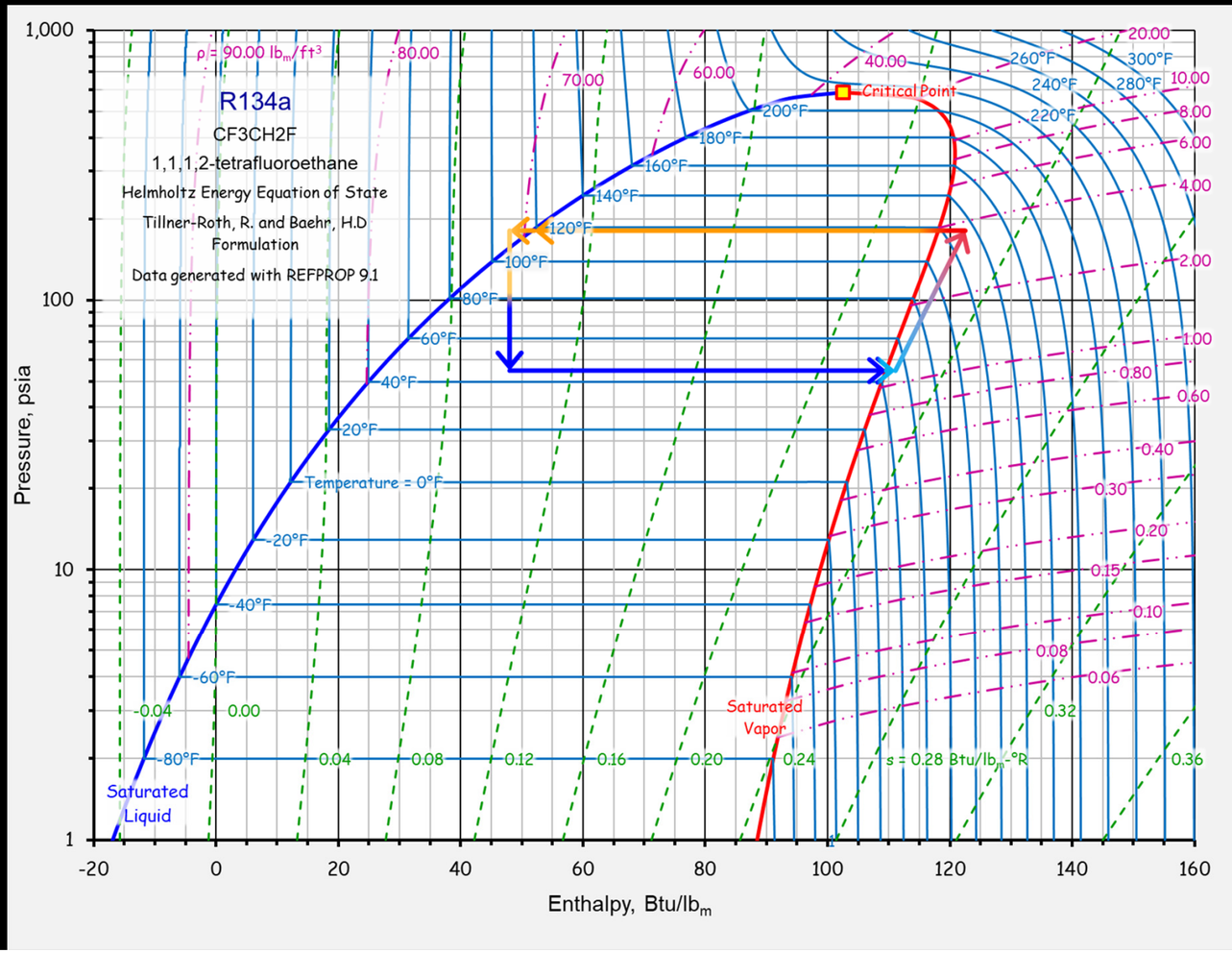
R134a
CF3CH2F
1,1,1,2-tetrafluoroethane
Helmholtz Energy Equation of State
Tillner-Roth, R. and Baehr, H.D
Formulation
Data generated with REFPROP 9.1
Critical Point
Saturated Liquid
Saturated Vapor
Temperature = 0°F
s = 0.28 Btu/lbm-°R
Pressure, psia
Enthalpy, Btu/lbm
1,000
100
10
1
-20
0
20
40
60
80
100
120
140
160


Cold Air
Fan
Hot Air
Cool Air
Reversing Valve
Expansion Valve with Check Valve Bypass
Compressor
Expansion Valve with Check Valve Bypass
Fan
Cool Air
Filter
Indoor Unit
Outdoor Unit
Heat Pump in Heating Mode – Cold Day


ρ = 90.00 lbm/ft3
R134a
CF3CH2F
1,1,1,2-tetrafluoroethane
Helmholtz Energy Equation of State
Tillner-Roth, R. and Baehr, H.D
Formulation
Data generated with REFPROP 9.1
Critical Point
Saturated Liquid
Saturated Vapor
Temperature = 0°F
s = 0.28 Btu/lbm-°R
Pressure, psia
Enthalpy, Btu/lbm
1,000
100
10
1
-20
0
20
40
60
80
100
120
140
160


Cold Air
Fan
Hot Air
Auxiliary Heat
Cool Air
Reversing Valve
Expansion Valve with Check Valve Bypass
Expansion Valve with Check Valve Bypass
Compressor
Outdoor Unit
Fan
Cool Air
Filter
Indoor Unit
Heat Pump in Heating Mode – Cold Day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R134a
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Saturated Liquid
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Pressure, psia
Enthalpy, Btu/lbm
1,000
100
10
1
-20
0
20
40
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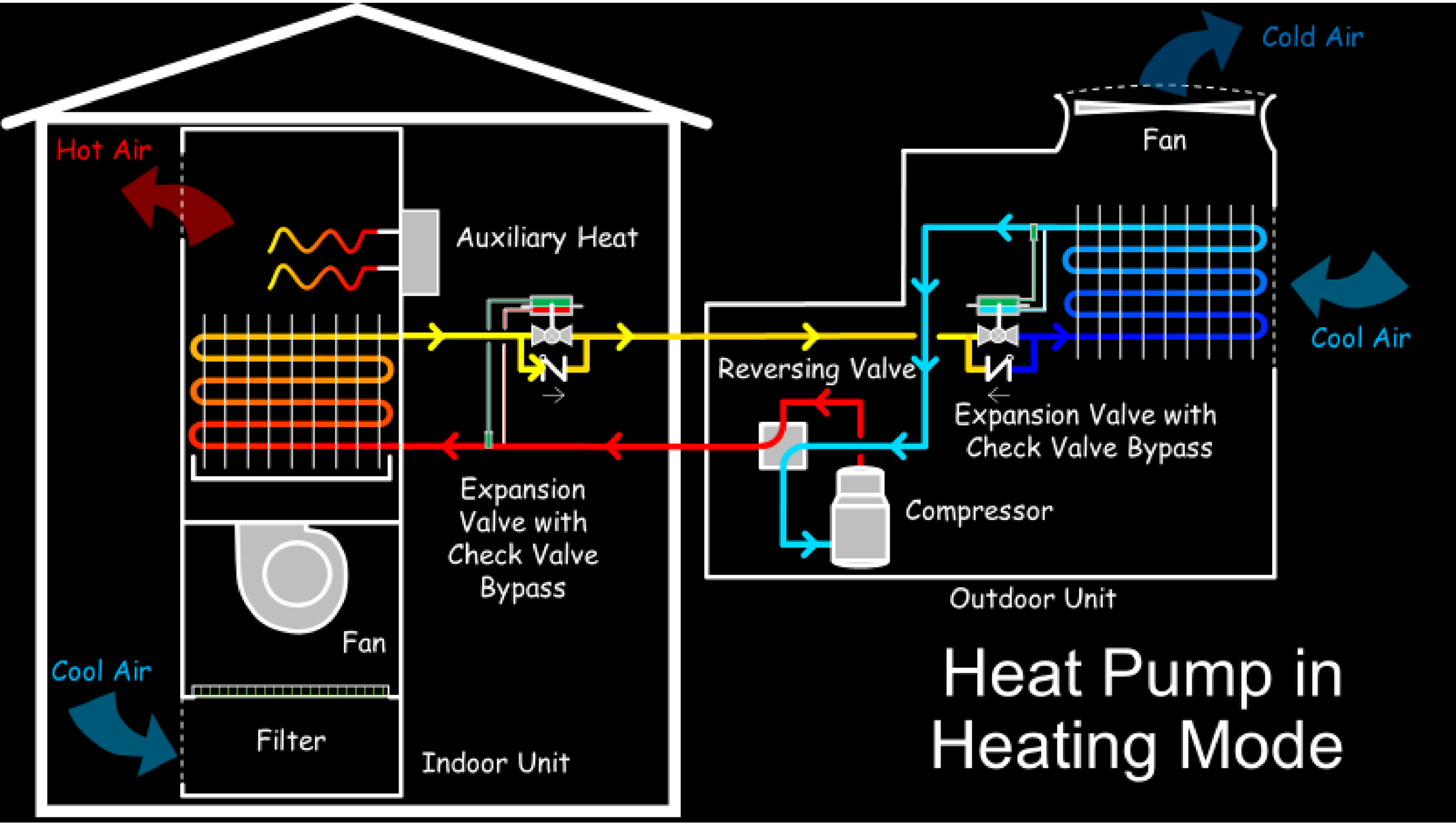
80
100
120
140
160


Cold Air
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Expansion Valve with Check Valve Bypass
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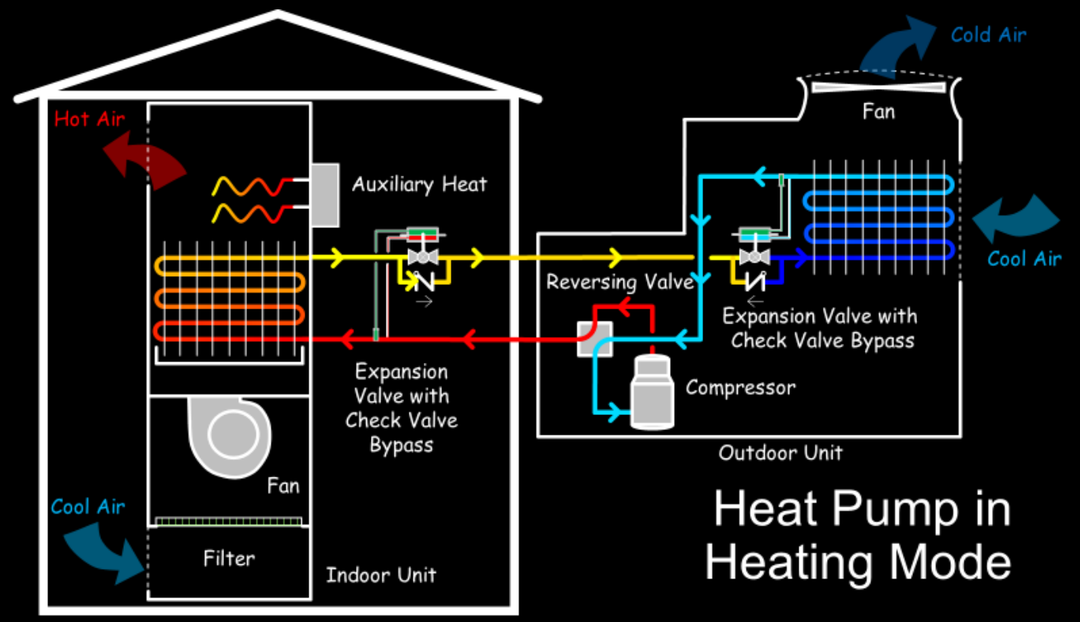
Outdoor Unit
Fan
Cool Air
Filter
Indoor Unit
Heat Pump in Heating Mode

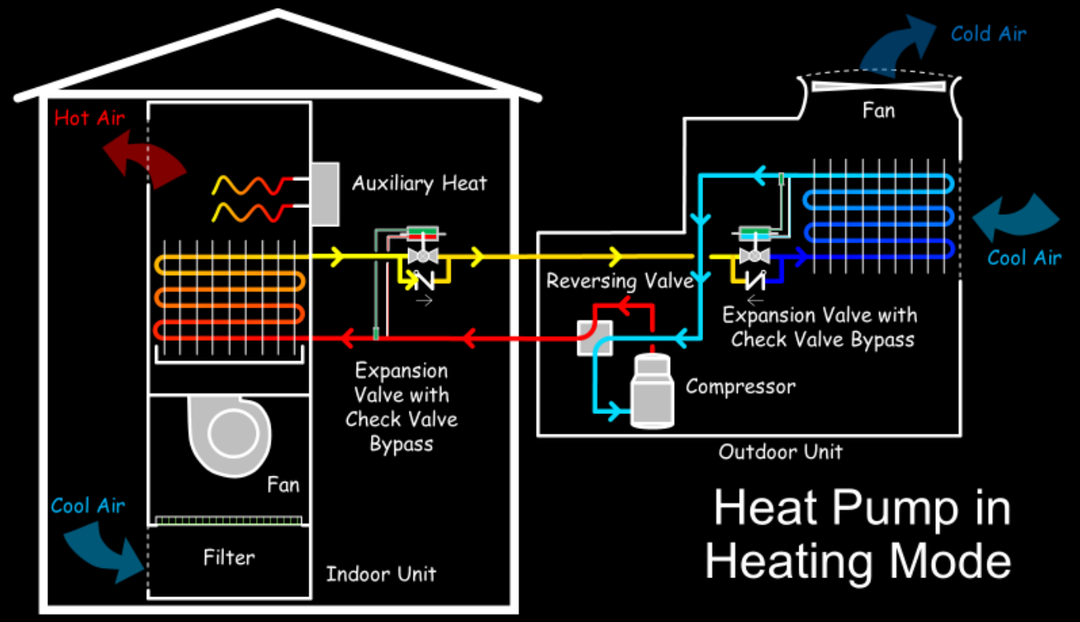
What Happens If:

The cooling coil temperature drops below 32°F and the outdoor air dew point is above 32°F?



What Happens If:

The cooling coil temperature drops below 32°F and the outdoor air dew point is above 32°F?

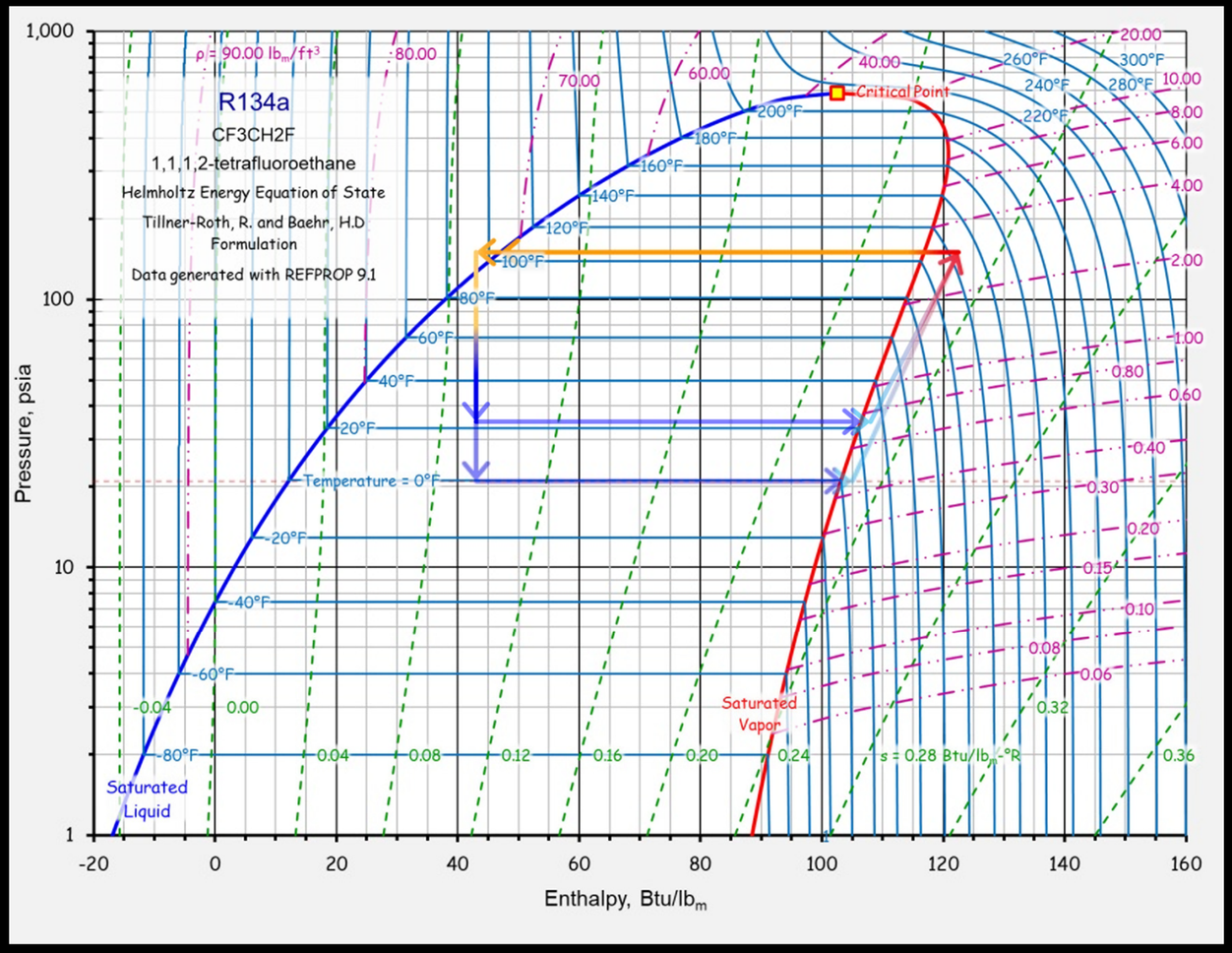


What Happens If:

The cooling coil temperature drops below 32°F and the outdoor air dew point is above 32°F?

What Happens If:

It gets really cold outside?



What Happens If:

It gets really cold outside?

$$Q = U \times A \times \left(t_{Inside} - t_{Outside} \right)$$

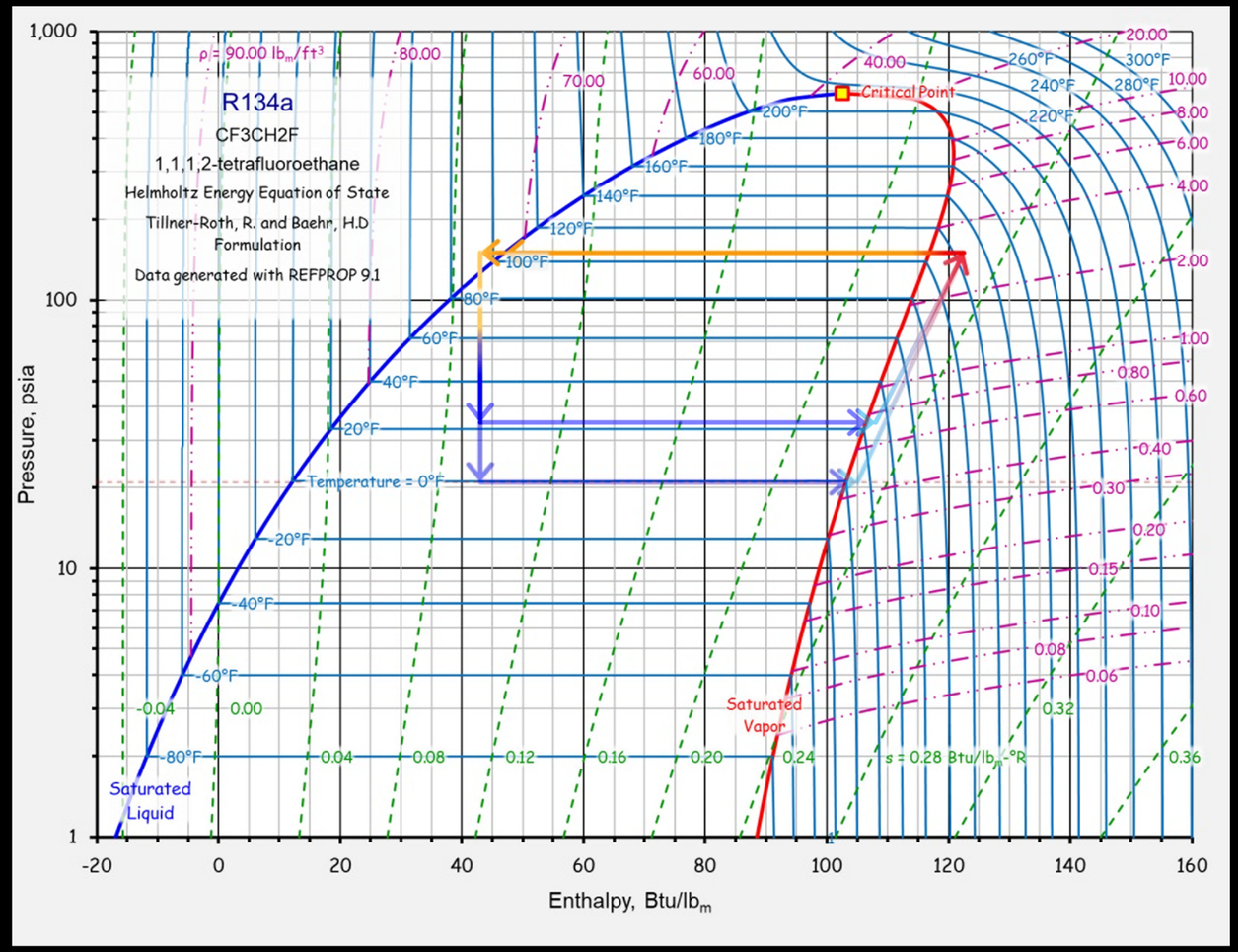
Where:

Q = Heat transfer in Btu/hr

U = Heat transfer coefficient in Btu/hr - square foot - °F

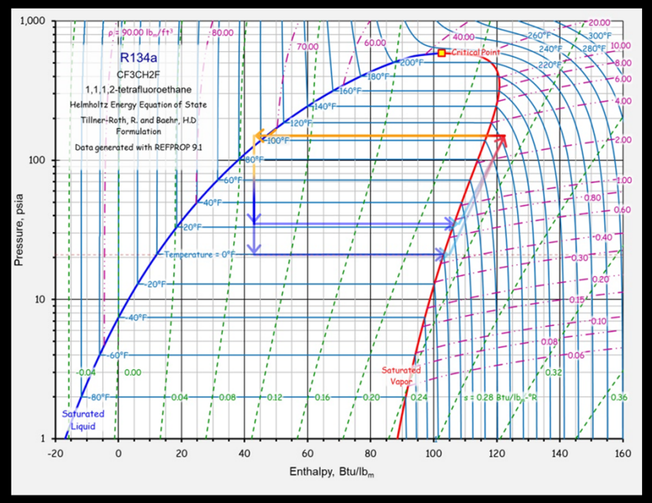
A = Area in square feet

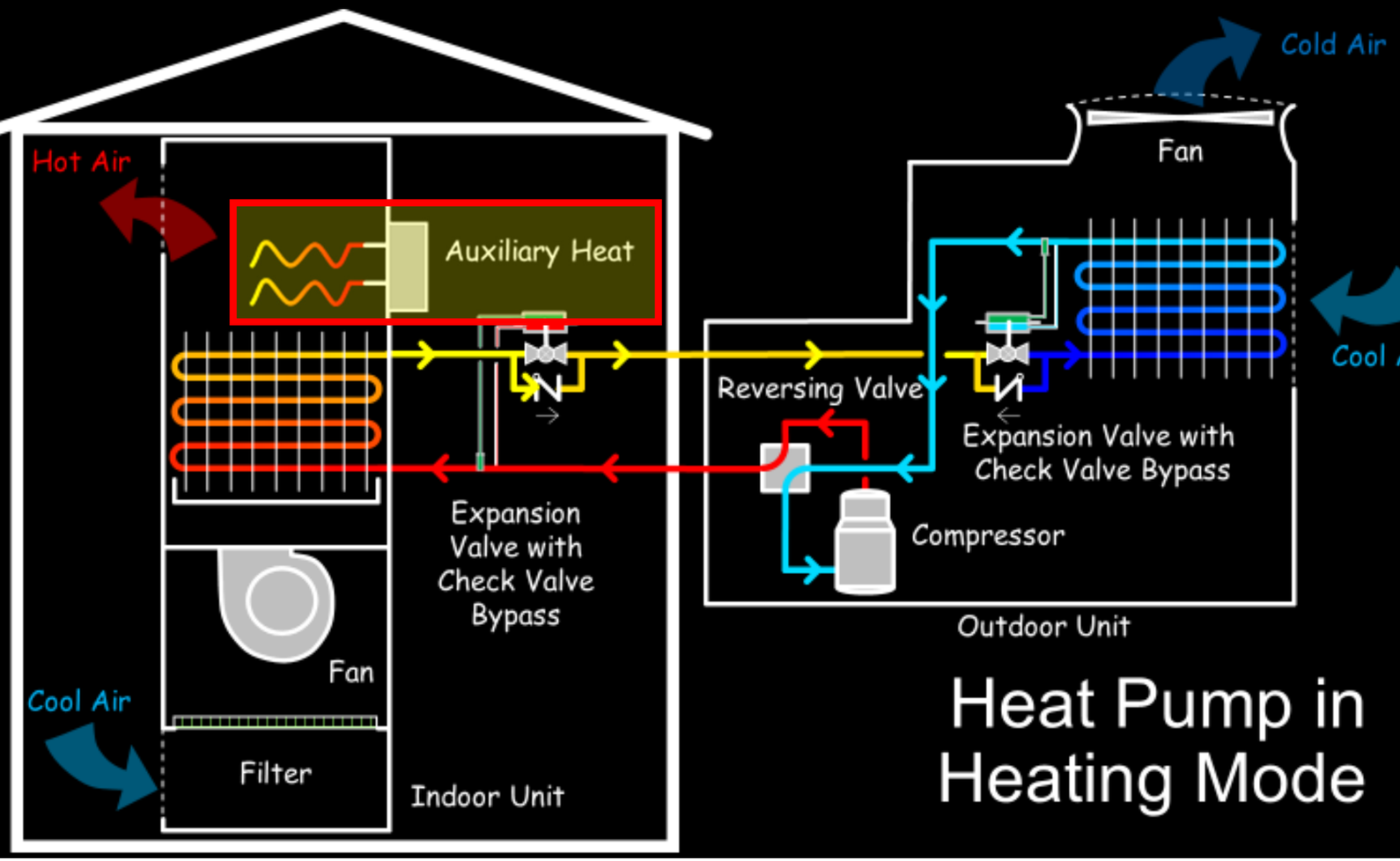
$\left(t_{Inside} - t_{Outside} \right)$ = Inside to outside temperature difference in °F



What Happens If:

It gets really cold outside?





Heat Pump in Heating Mode

Bottom Lines

1. A heat pump's ability to "leverage" the electricity it consumes to *move* heat is compromised as the temperature of the heat source drops
2. The "physics" of the heat source can compound the problem
3. At some point, a heat pump using outdoor air for the heat source may need supplemental heat
   a. As we transition, we still may need to burn something to make heat
   b. Finding heat sources other than outdoor air will minimize the need to burn something
   c. The loads in the building can be the heat source

Question?

Together, Building a Better California