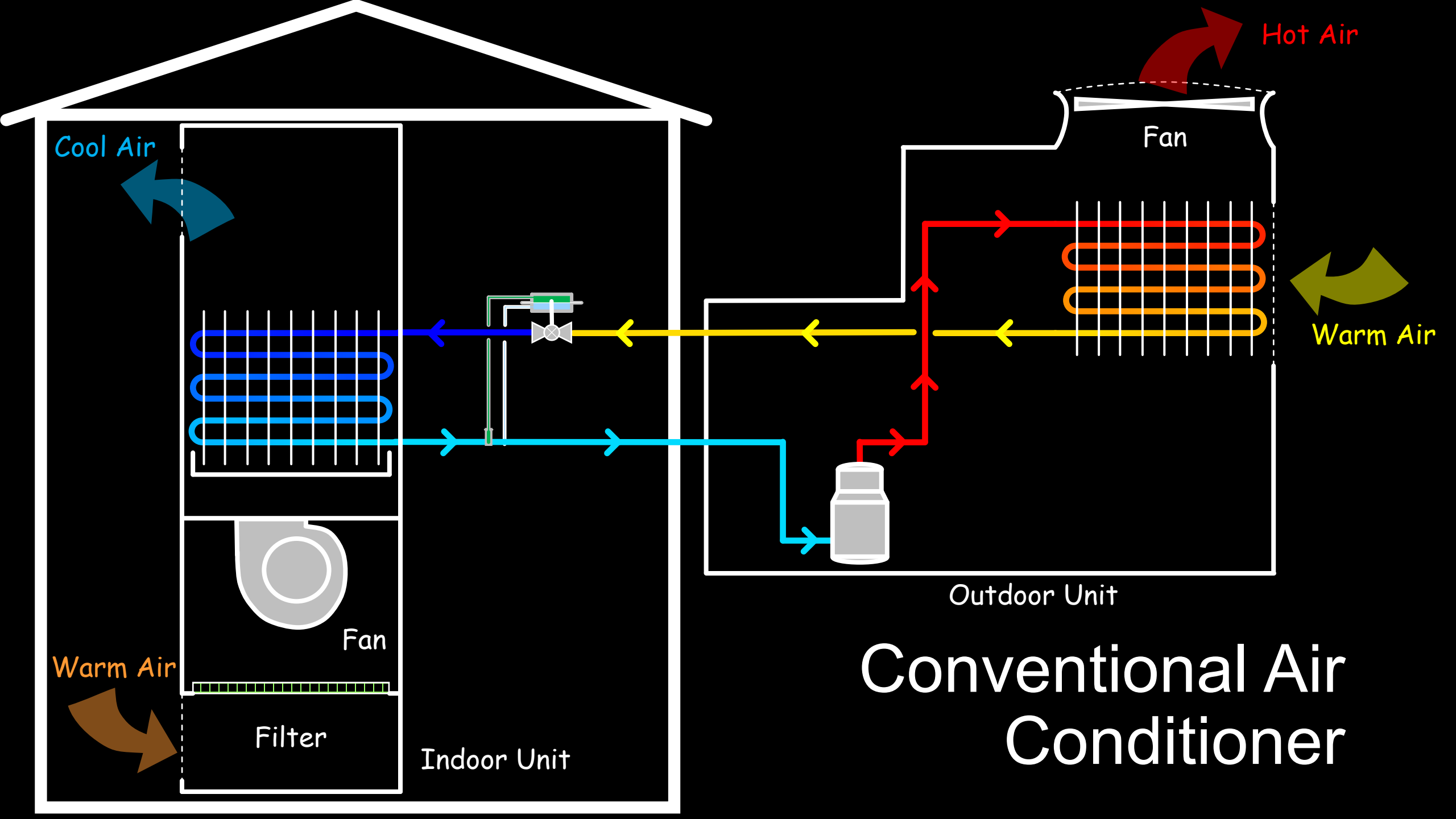
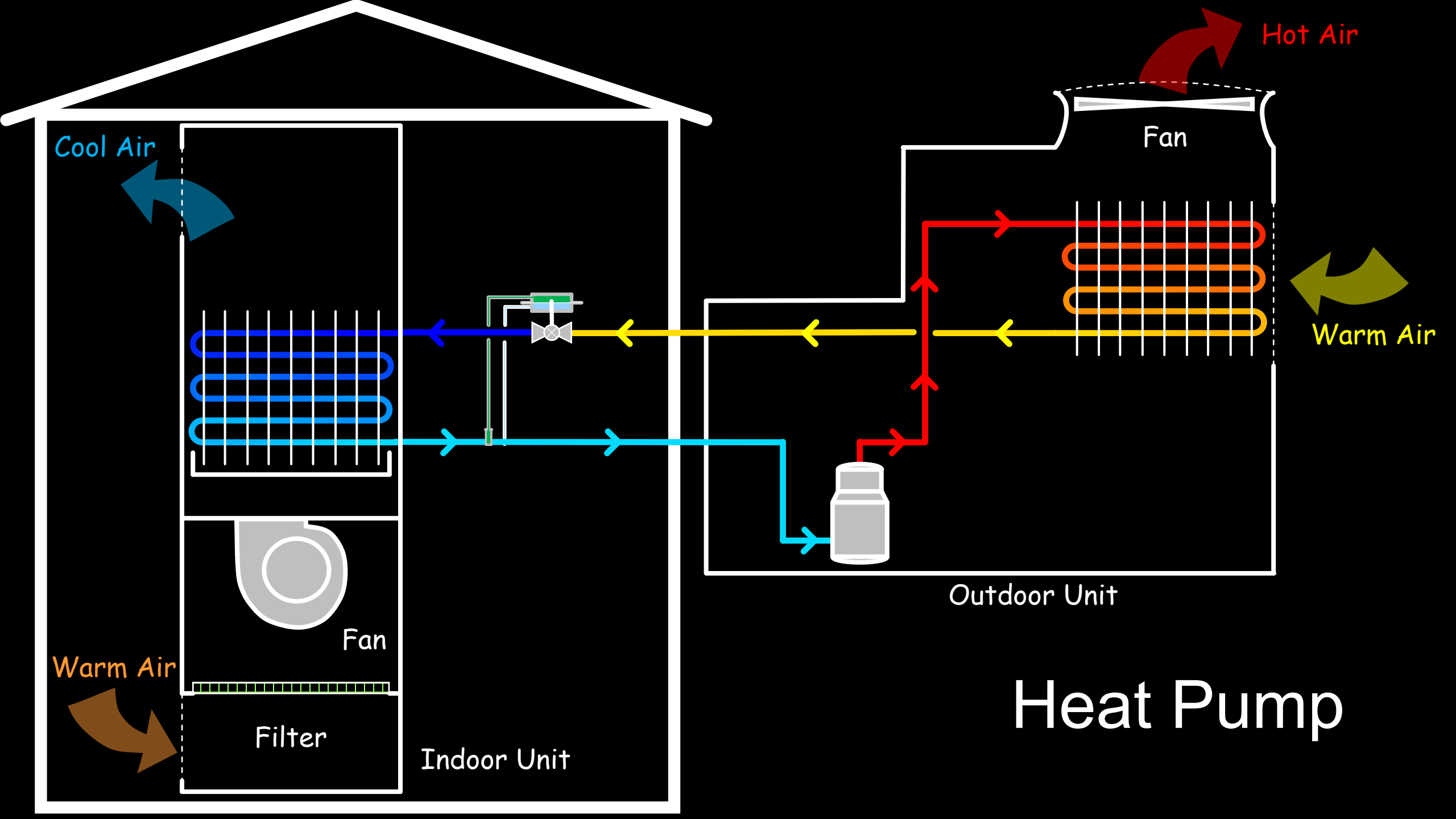
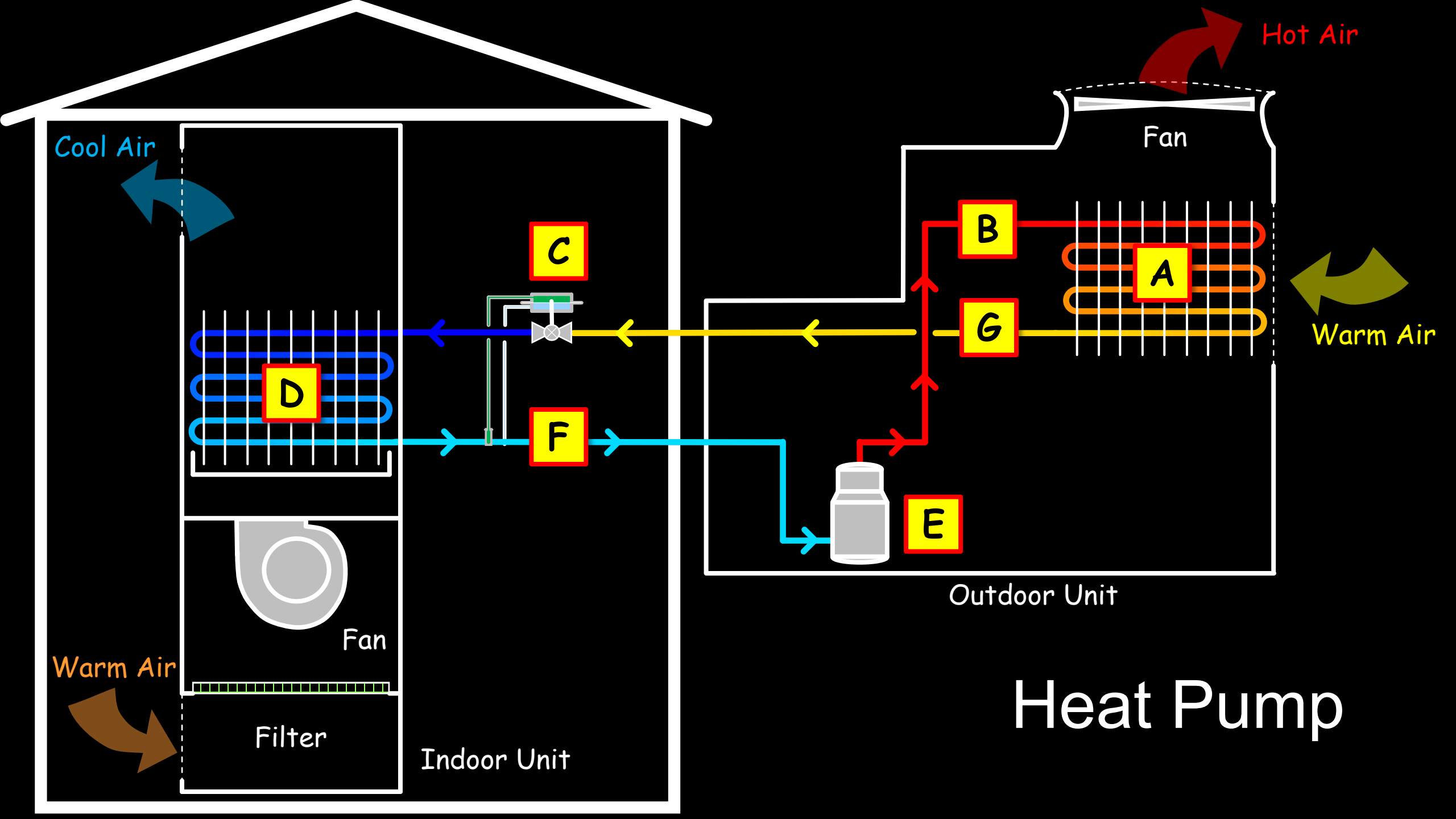
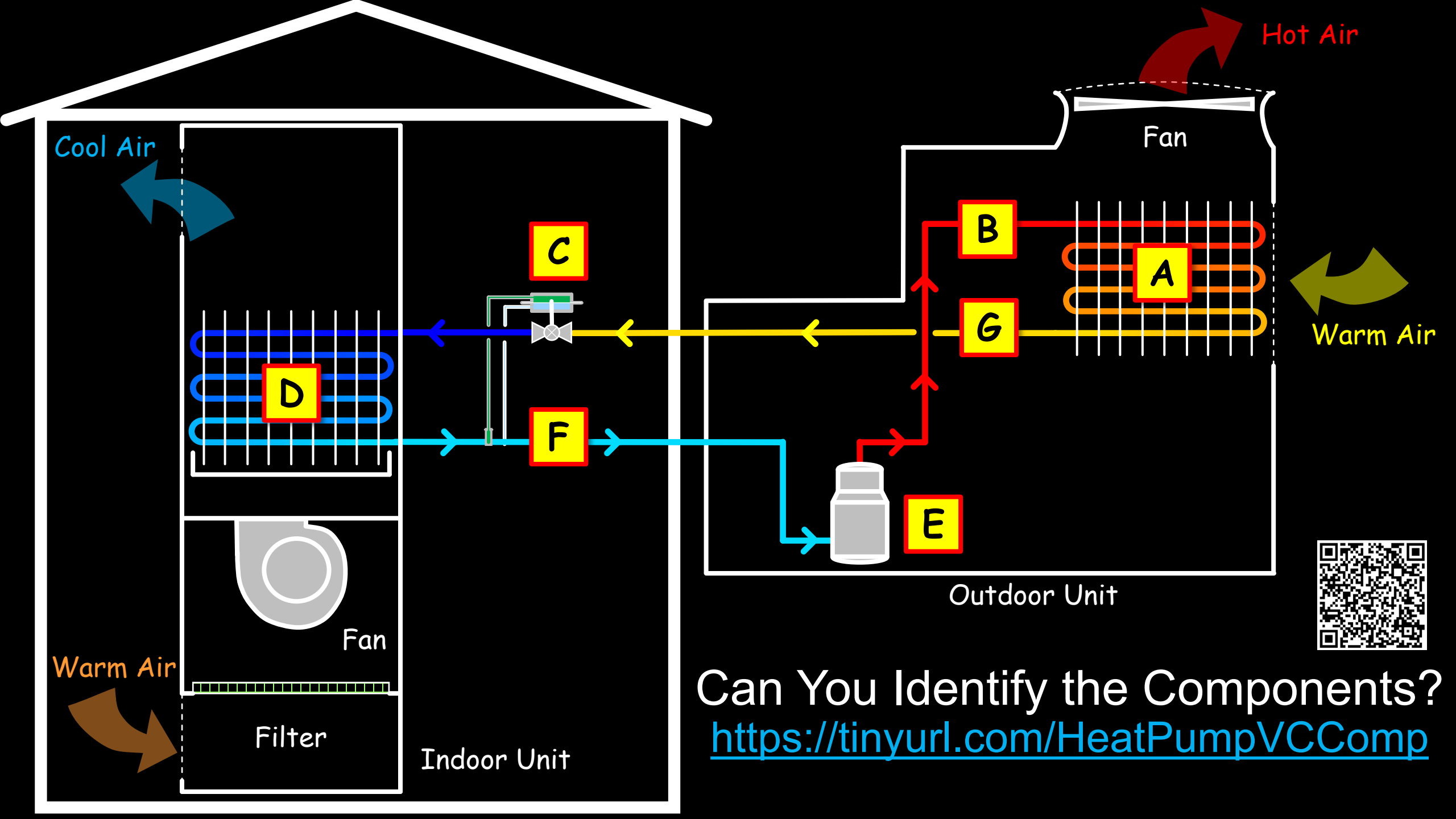
# A Closer Look at Heat Pumps




# Conventional Air Conditioner

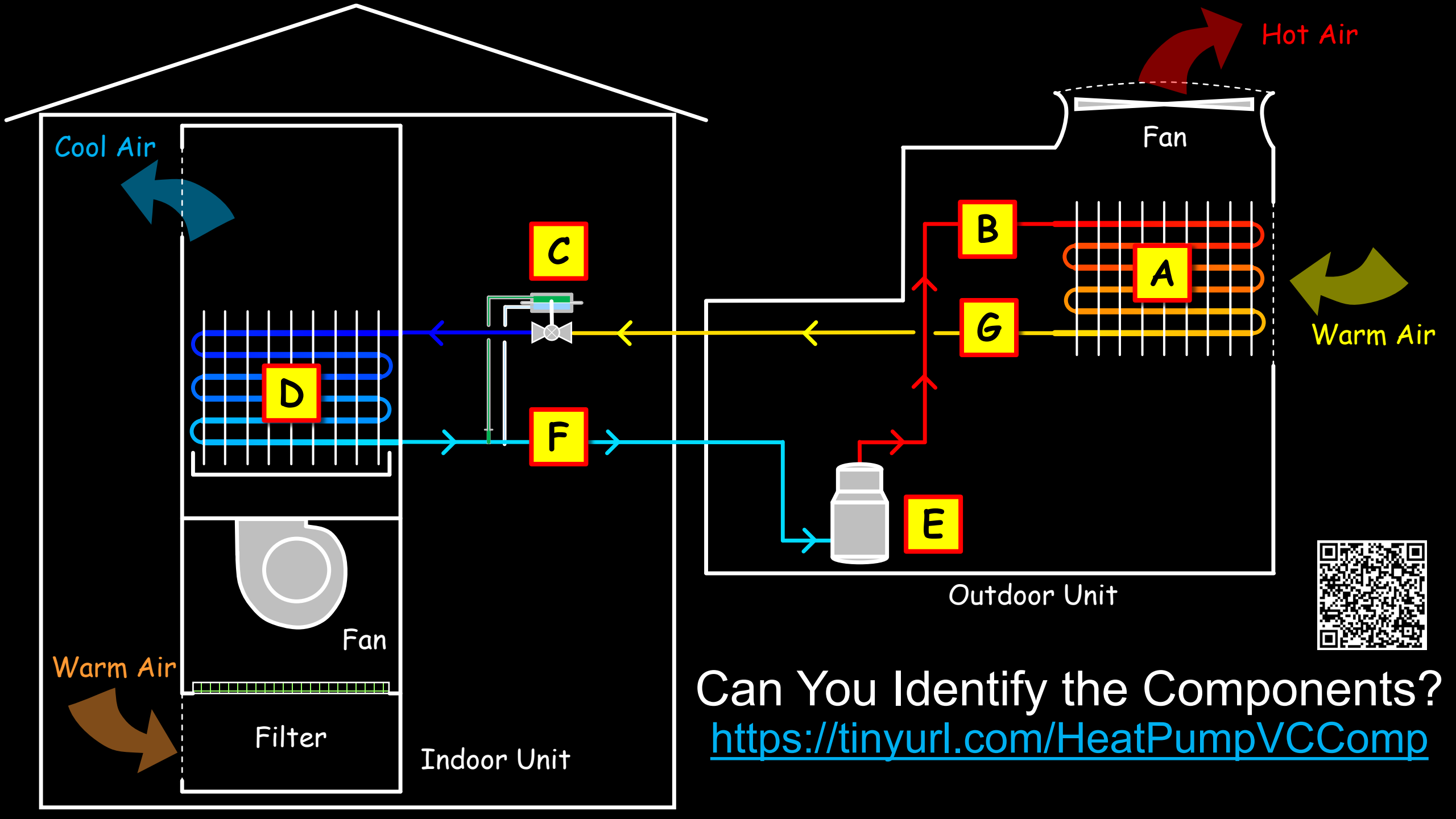

Hot Air
Fan
Cool Air
Warm Air
Outdoor Unit
Fan
Warm Air
Filter
Indoor Unit
Heat Pump


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?

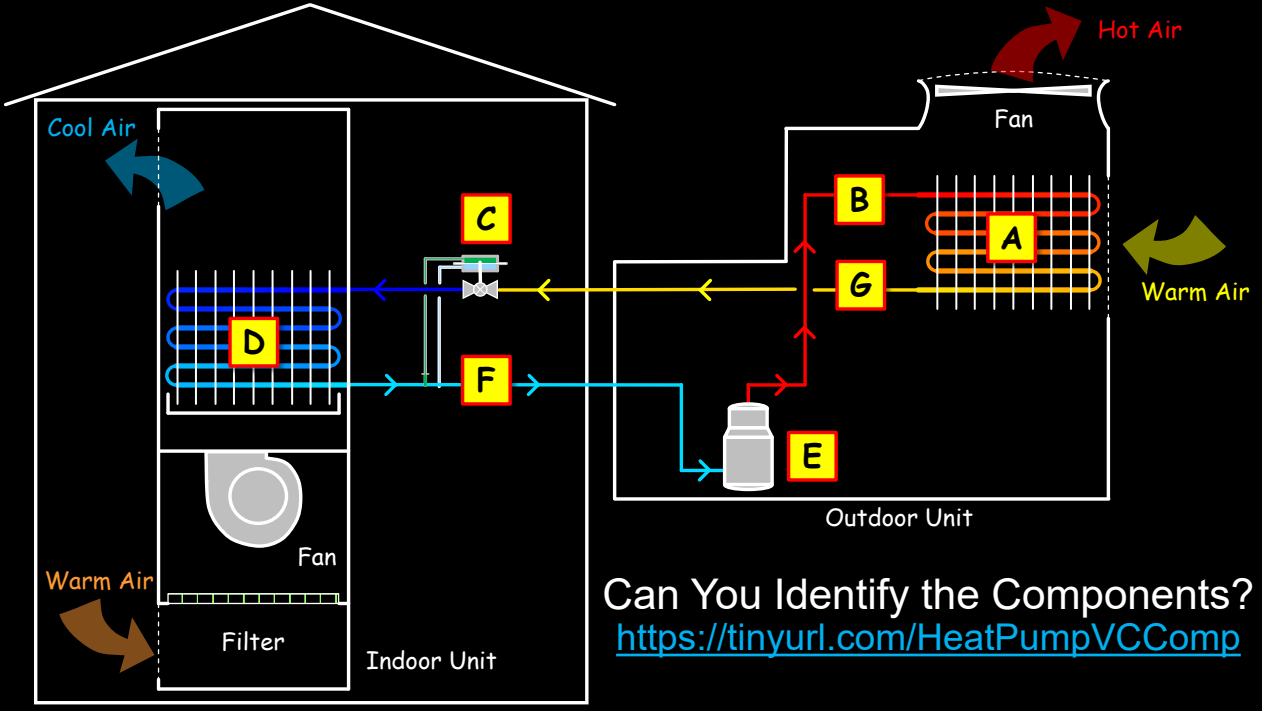
https://tinyurl.com/HeatPumpVCComp




Can You Identify the Components?

https://tinyurl.com/HeatPumpVCComp

# The Components




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

**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

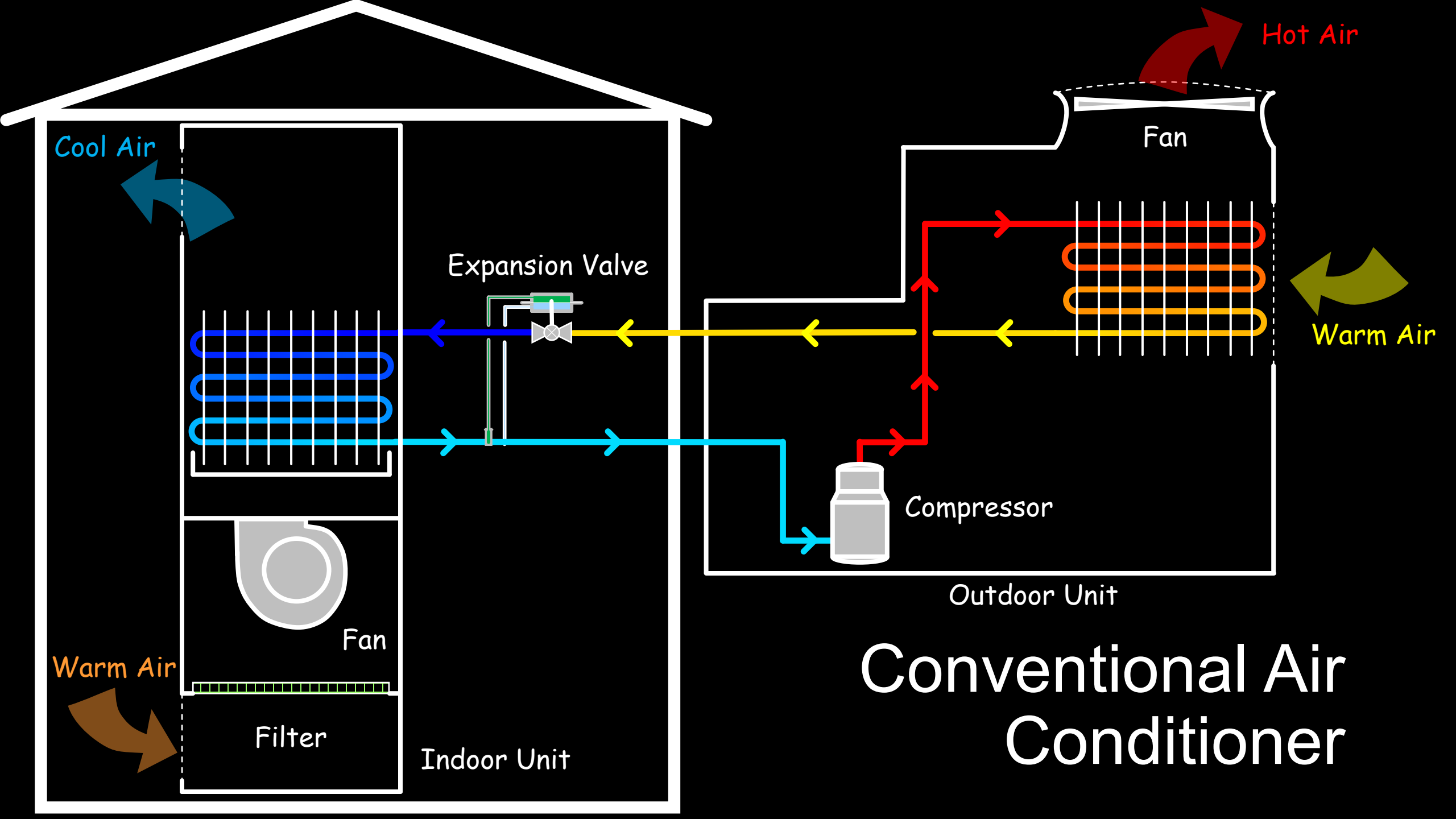
- An air conditioner moves heat from inside the occupied zone to an area outside the occupied zone to remove energy from the occupied zone

# A Few Definitions

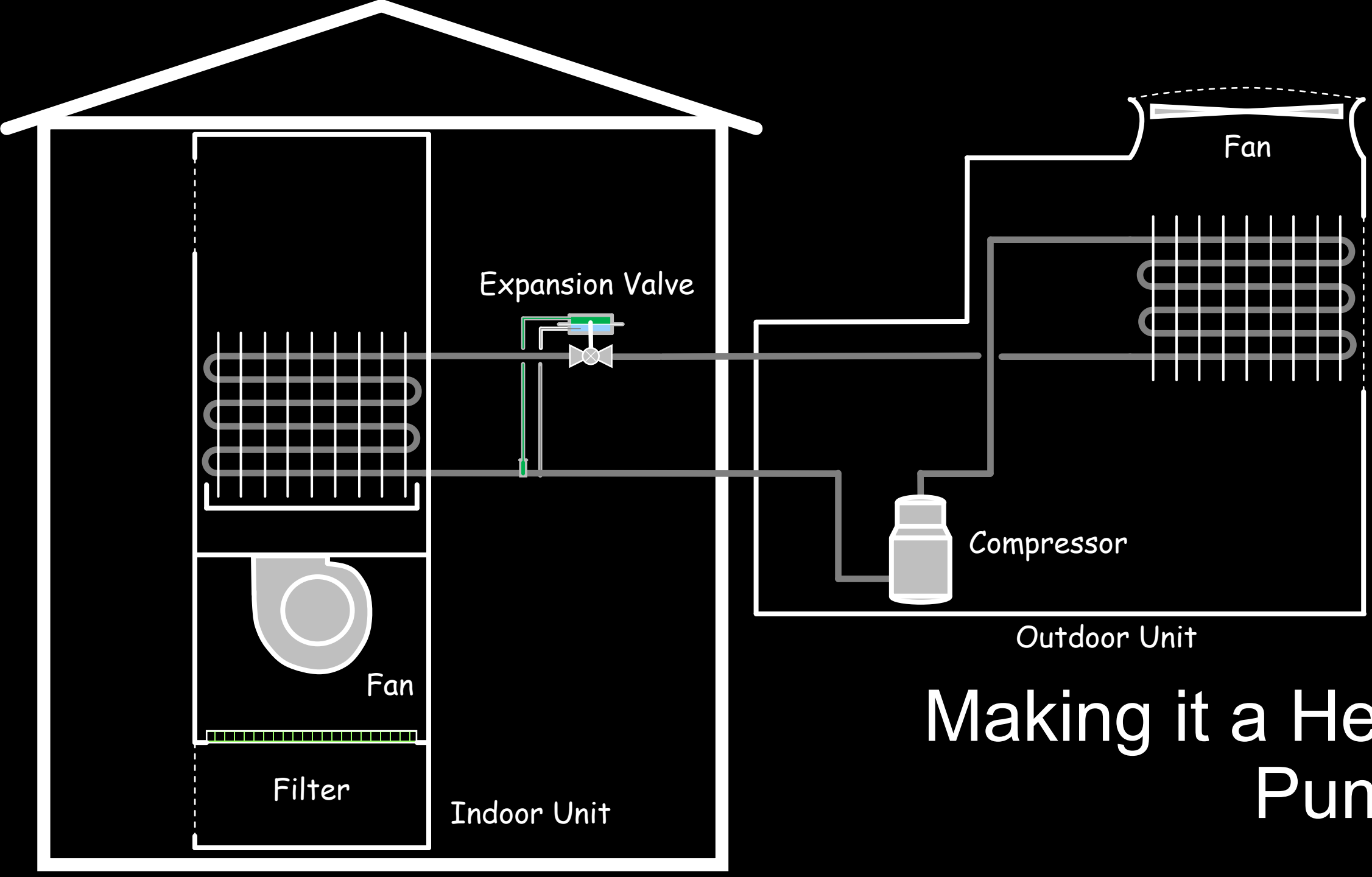
## Heat Pump – Industry Definition

- 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

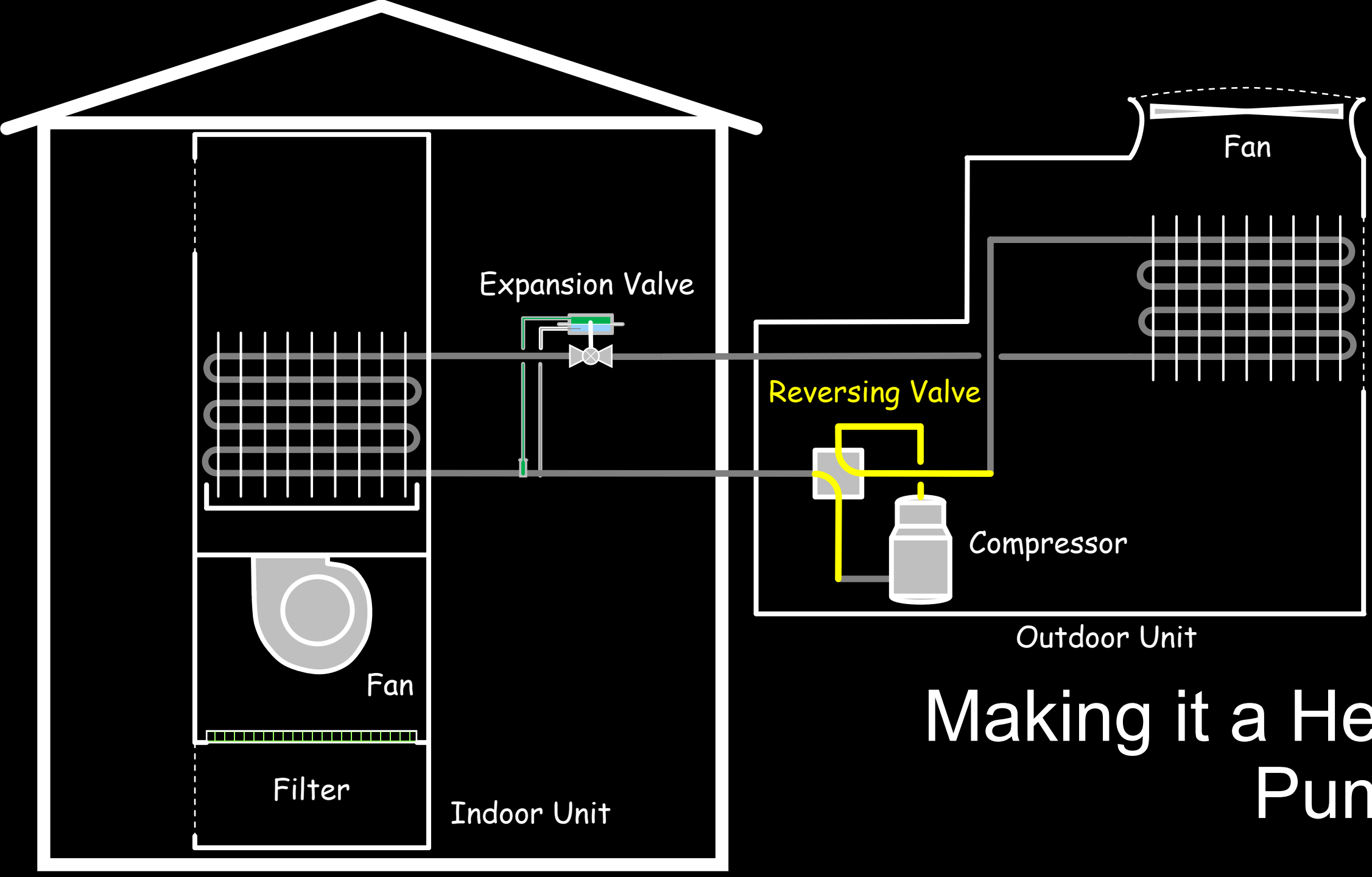
  depending on what is needed to maintain the zone set point



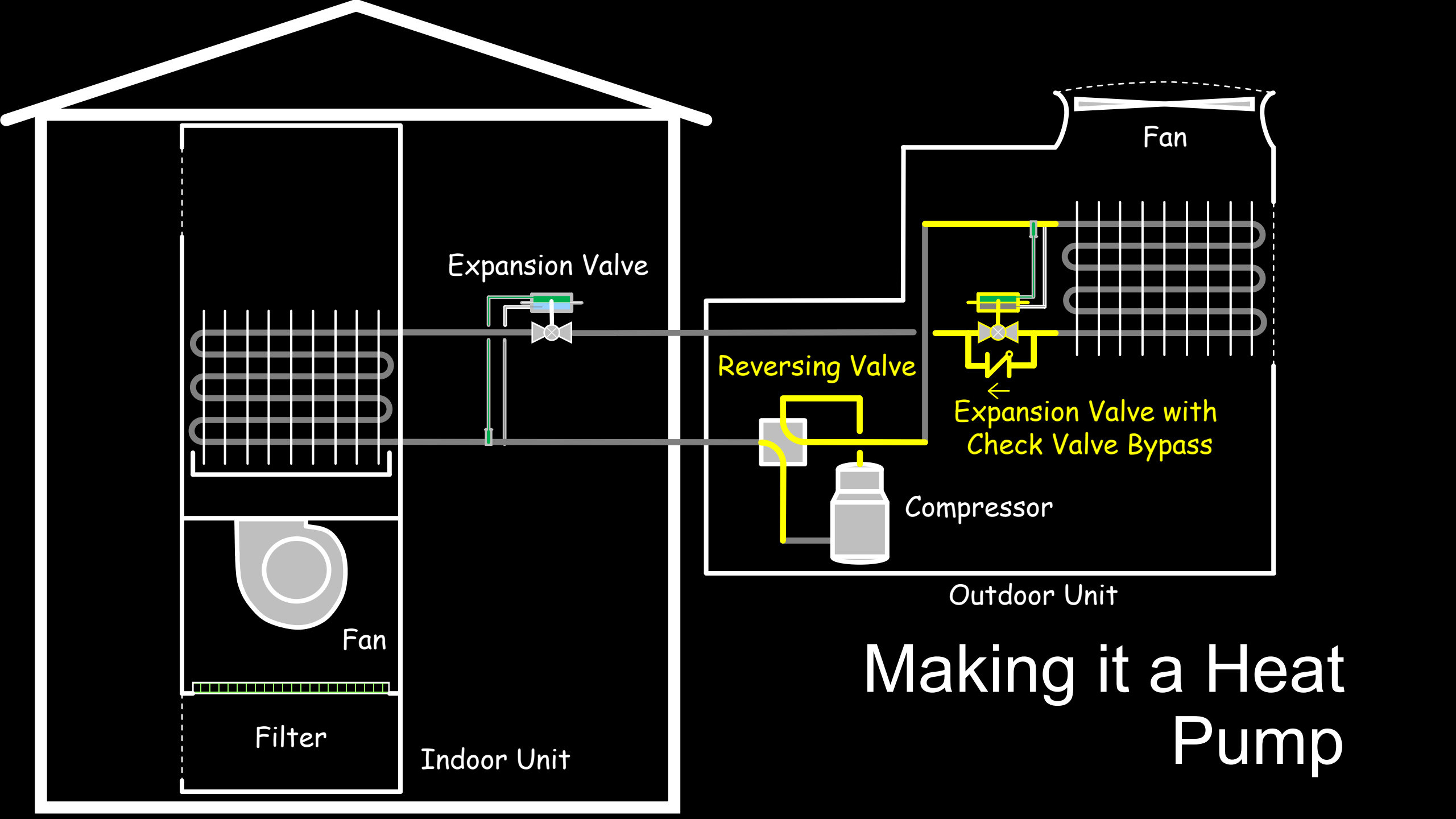

# Conventional Air Conditioner



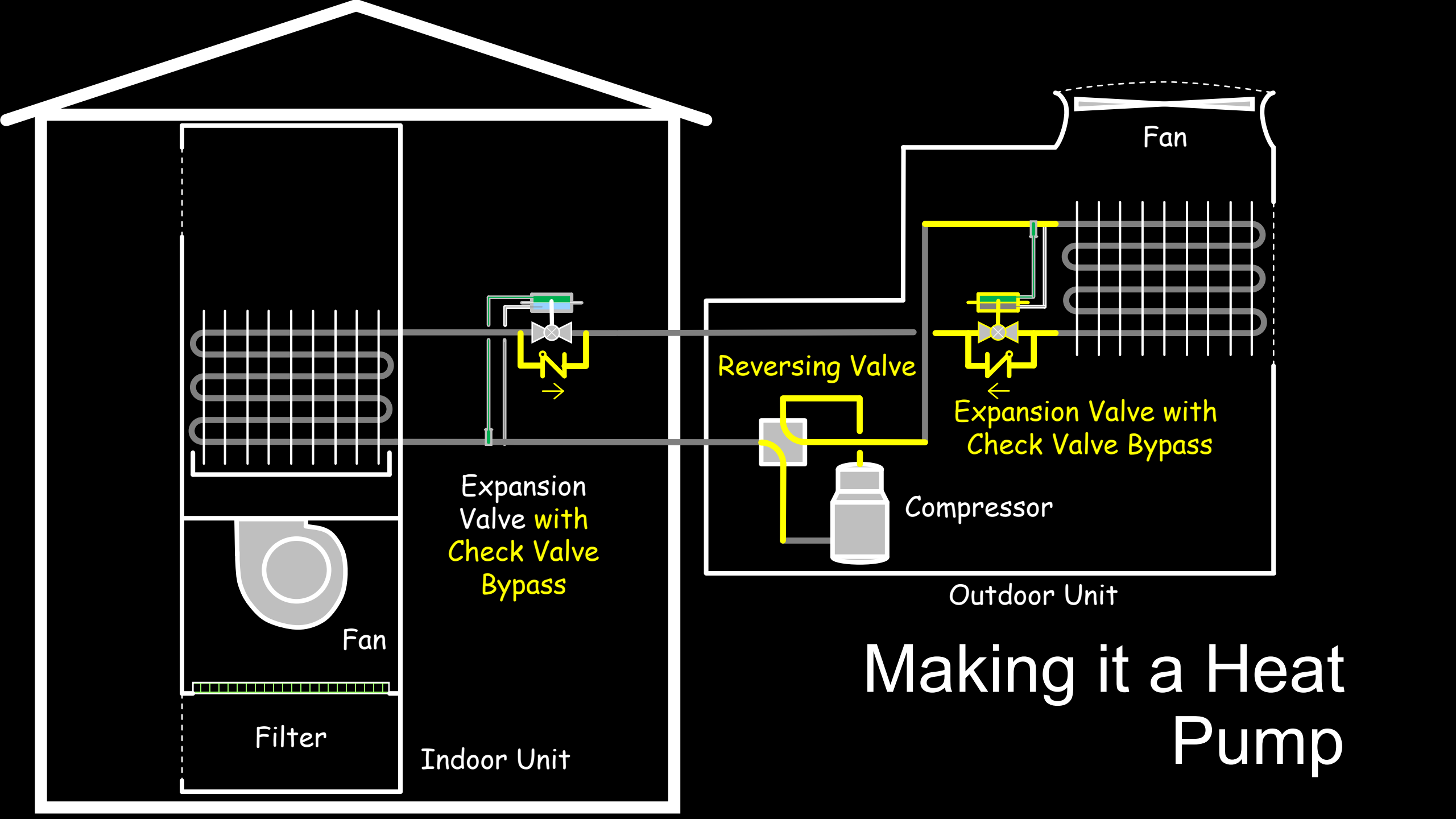

# Making it a Heat Pump



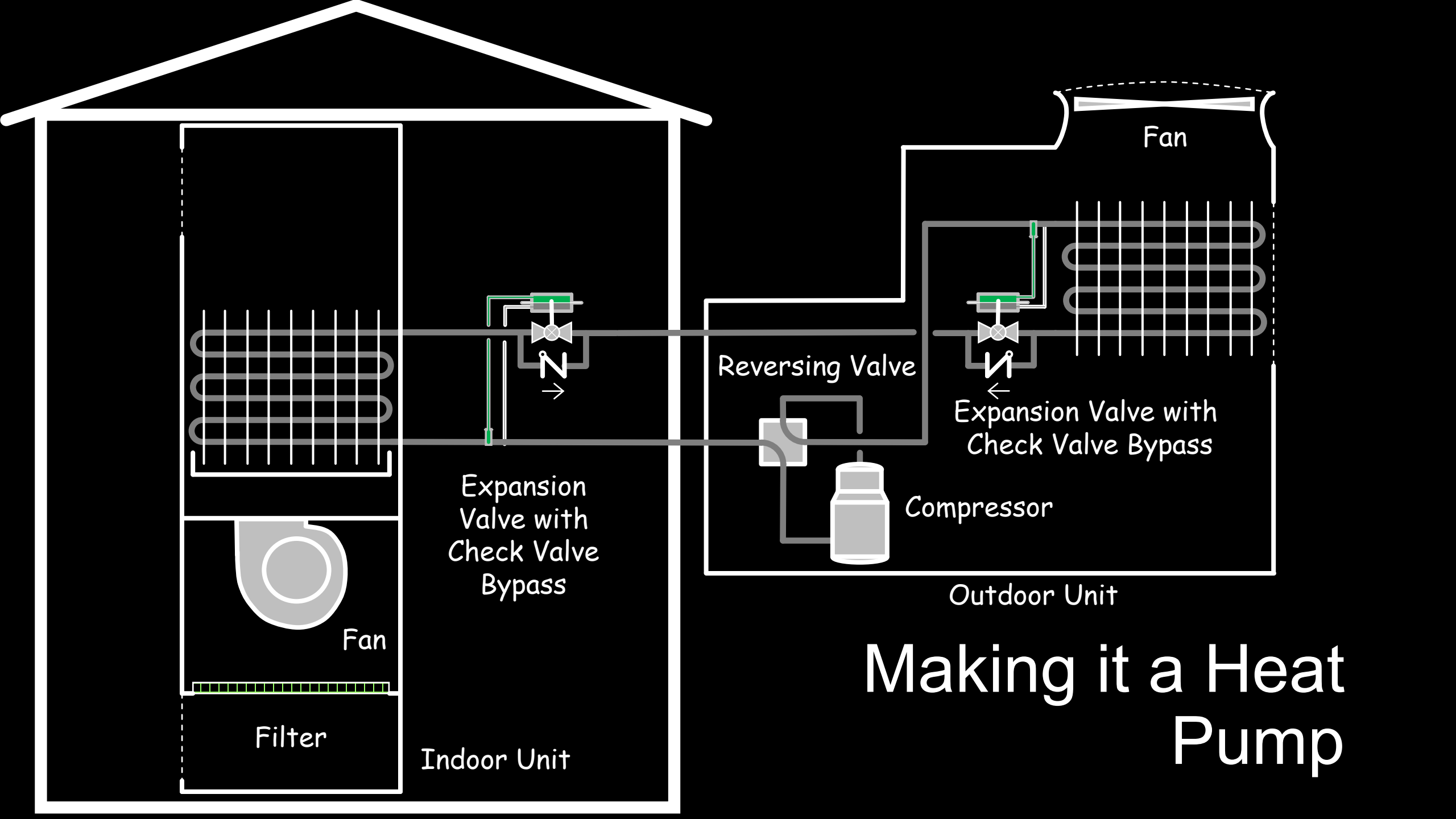

# Making it a Heat Pump



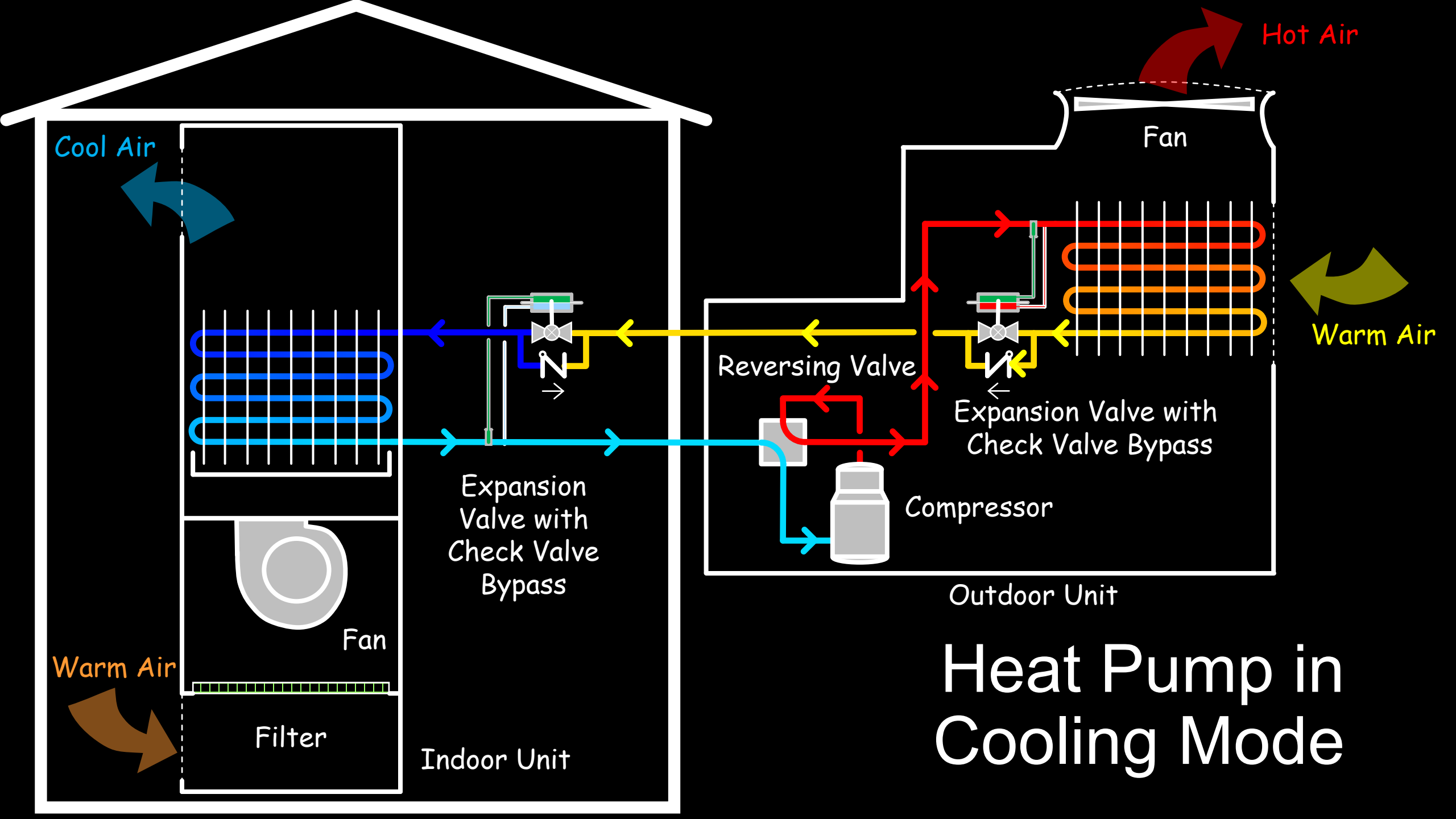

# Making it a Heat Pump



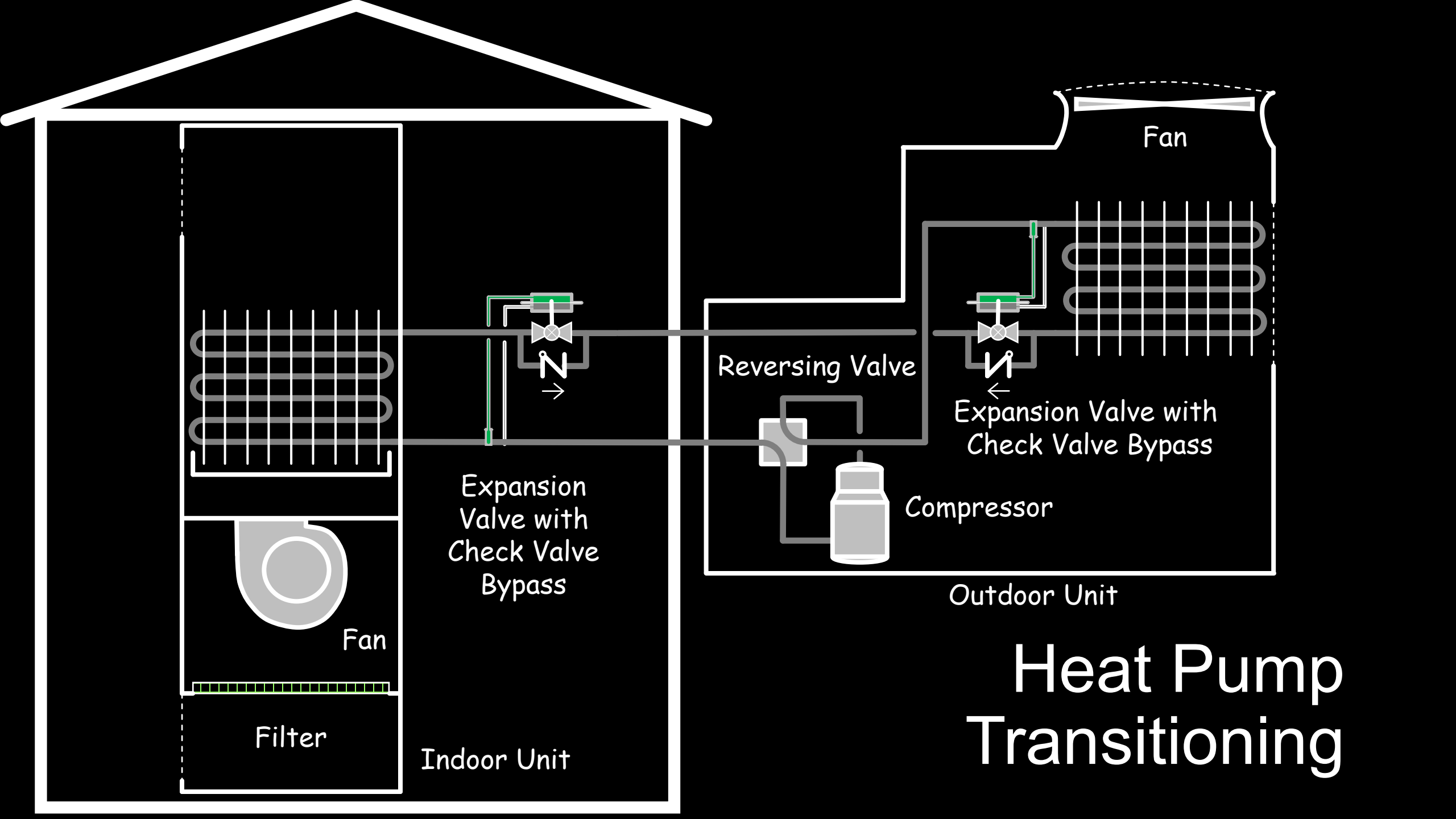

# Making it a Heat Pump



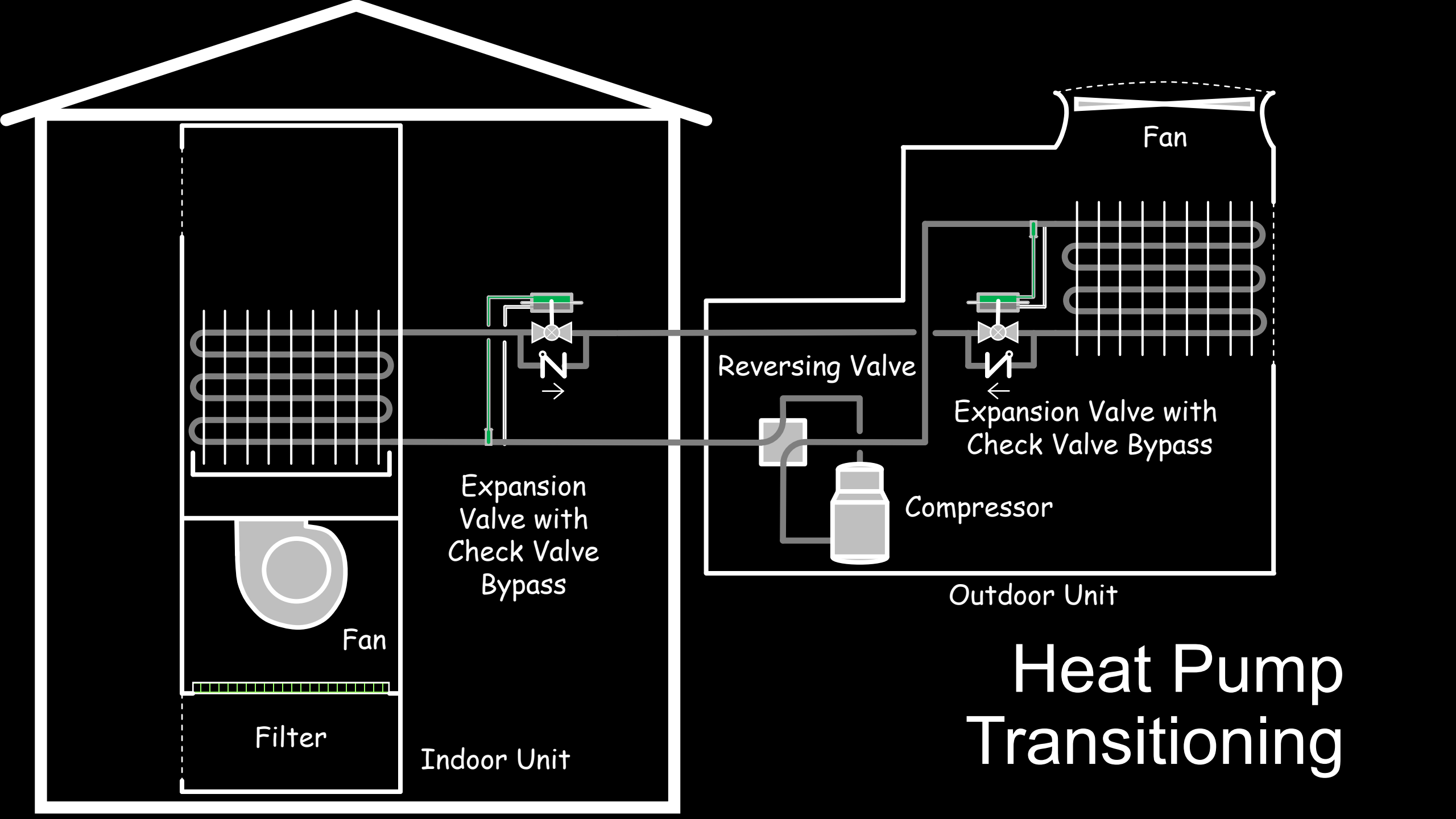

# Making it a Heat Pump



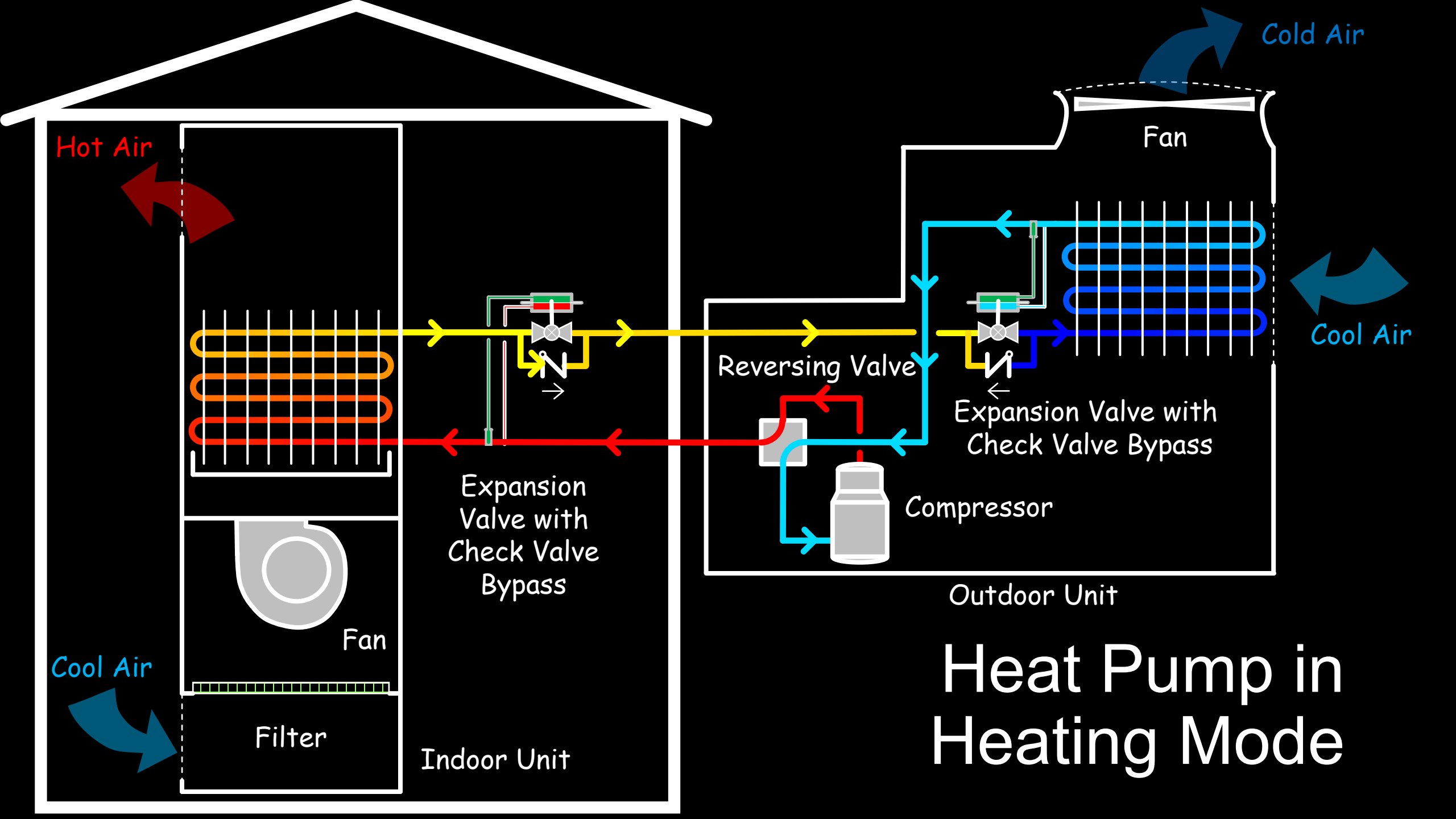

# Heat Pump in Cooling Mode




# Heat Pump Transitioning

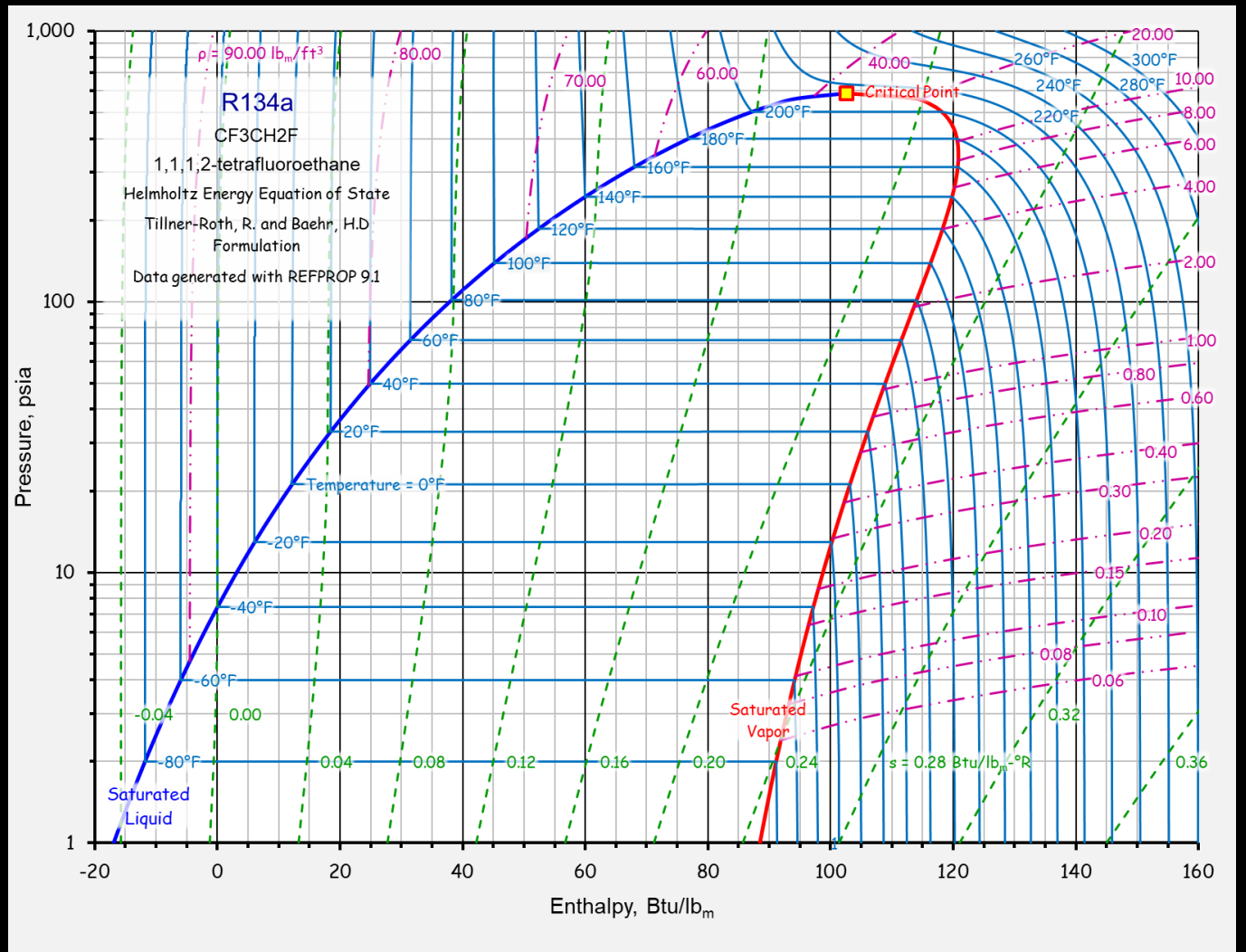



# Heat Pump Transitioning



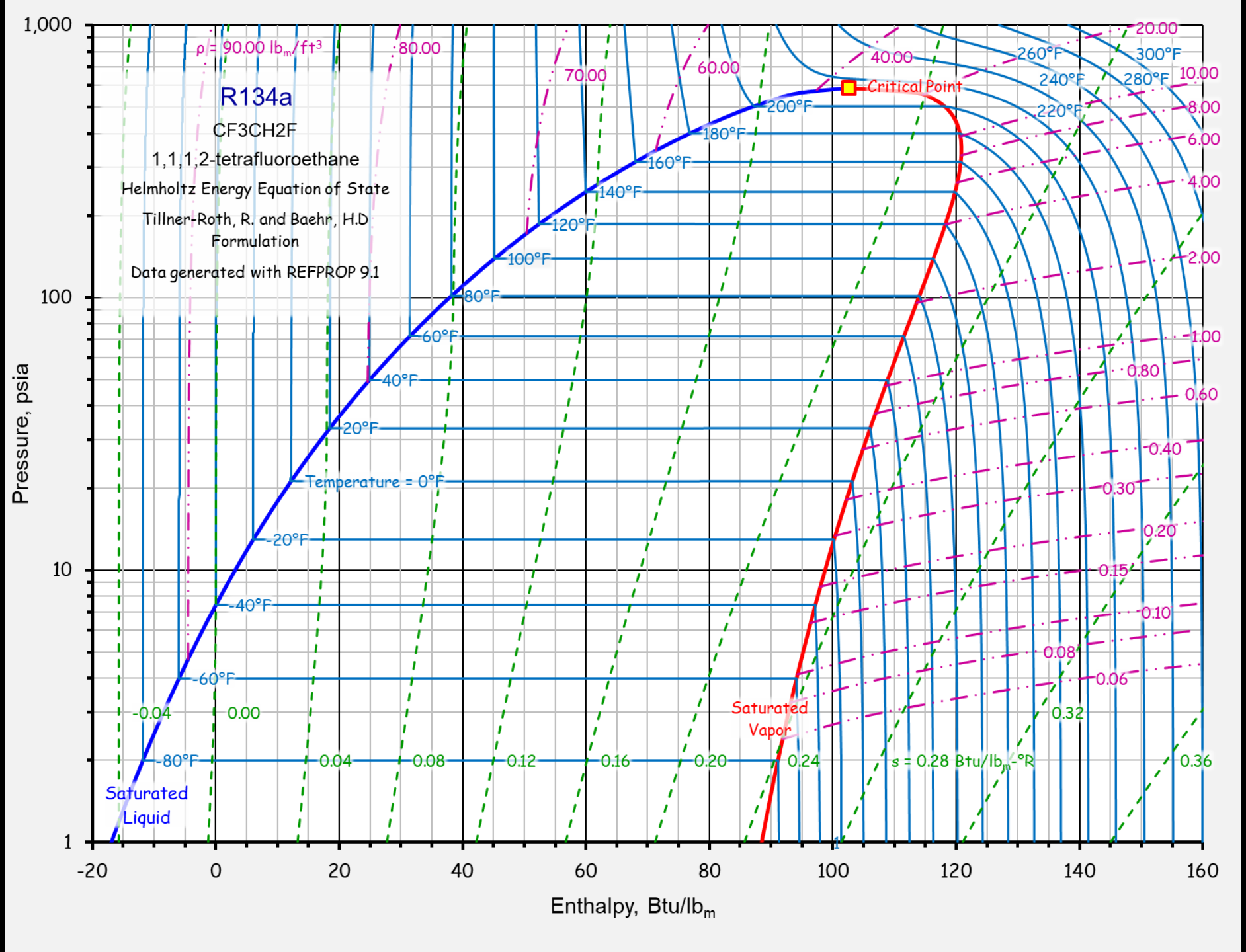

# Heat Pump in Heating Mode

# The Pressure-Enthalpy (p-h) Diagram

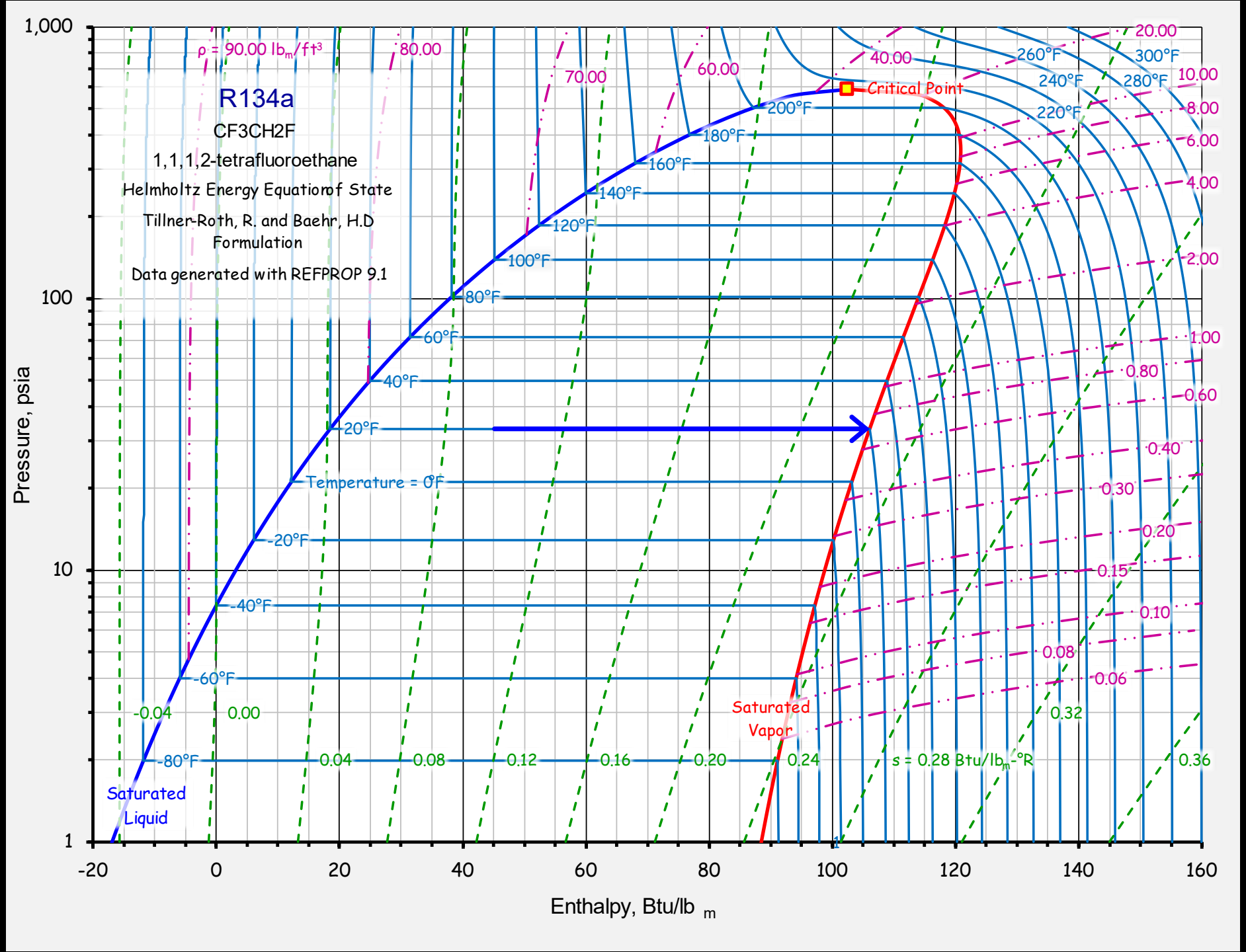



- Principles of Refrigeration, 5th Edition, Roy Dossat
- https://tinyurl.com/SporlanPHBulletin

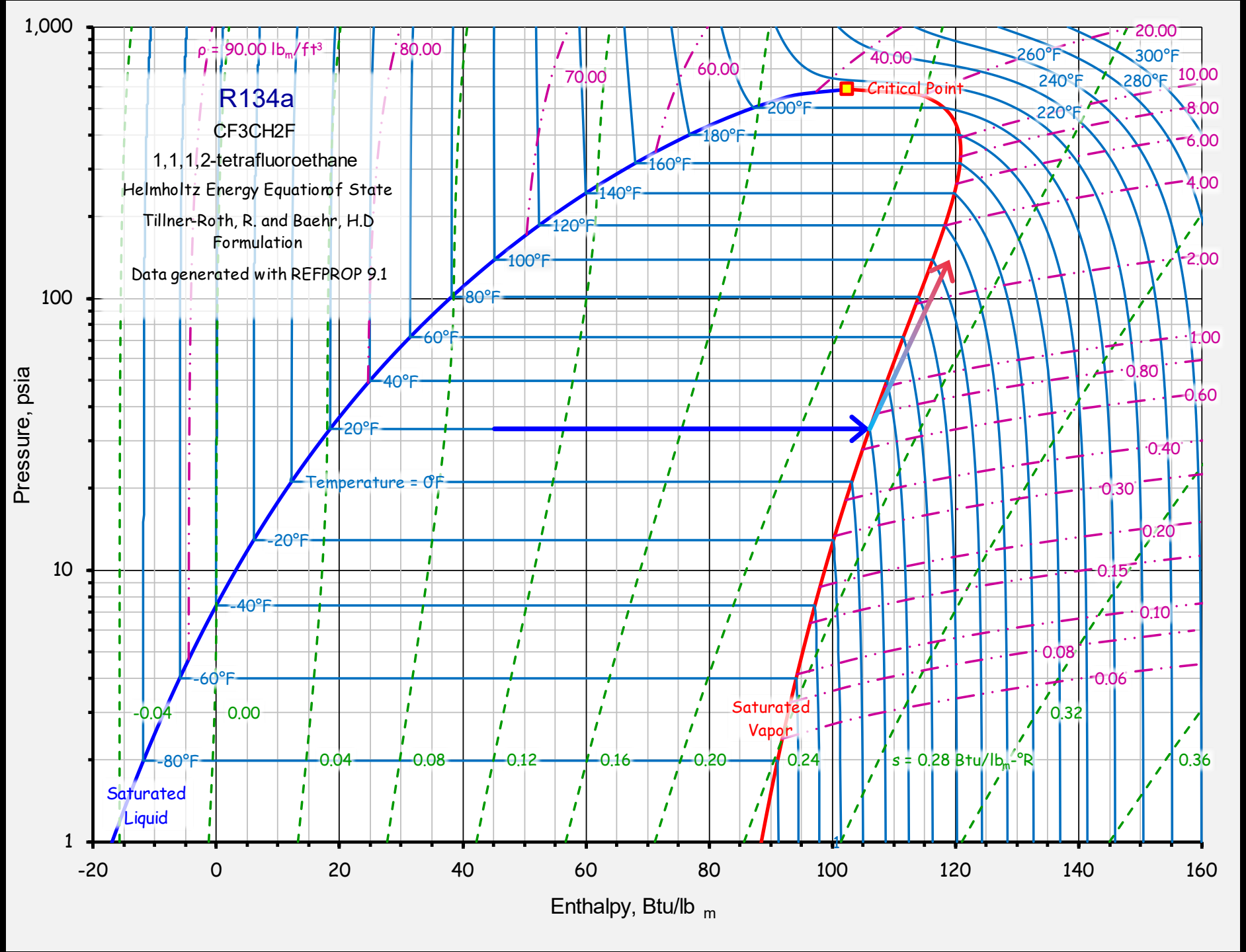
# The Pressure-Enthalpy (p-h) Diagram – Theoretical Cycle



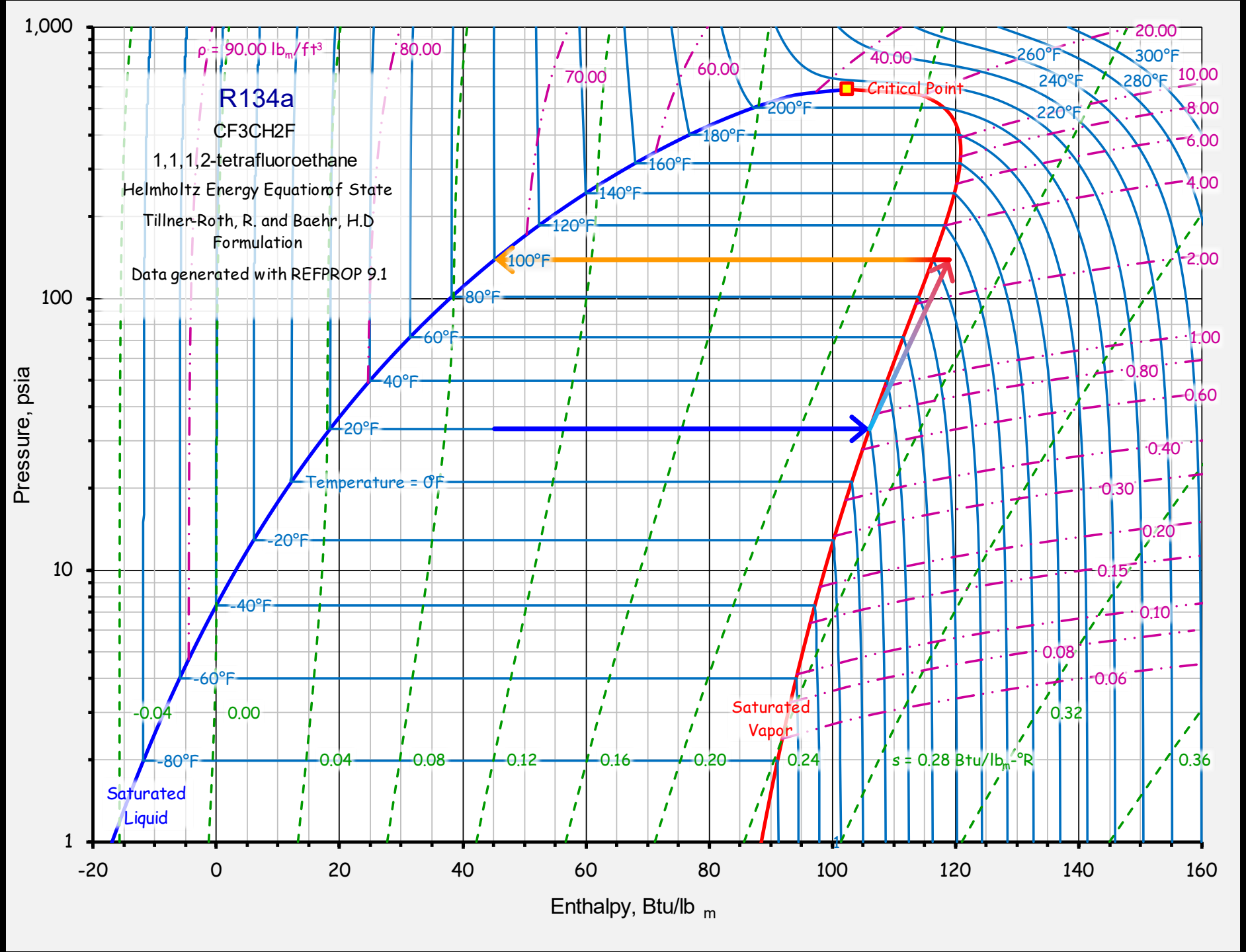
Evaporation

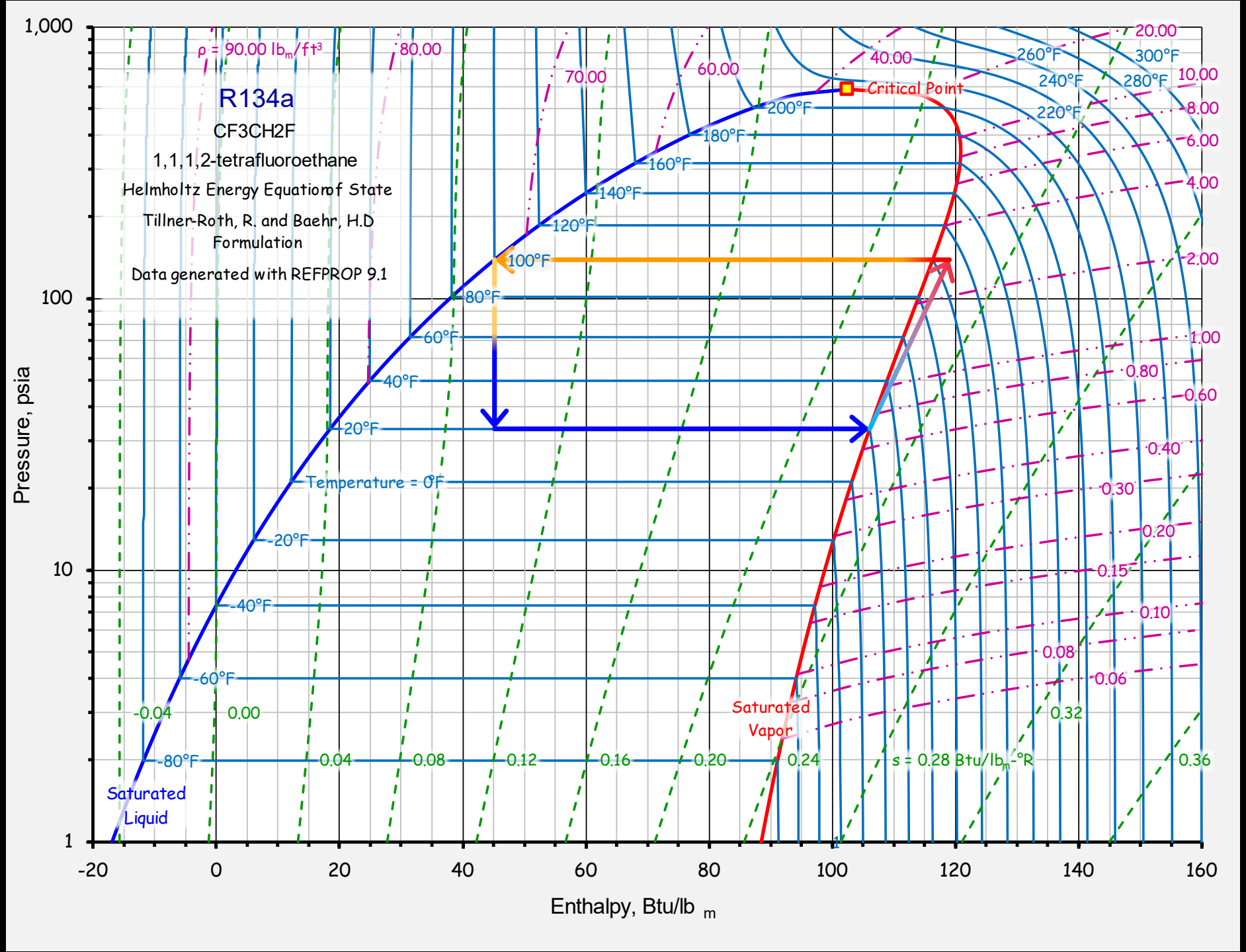


Compression



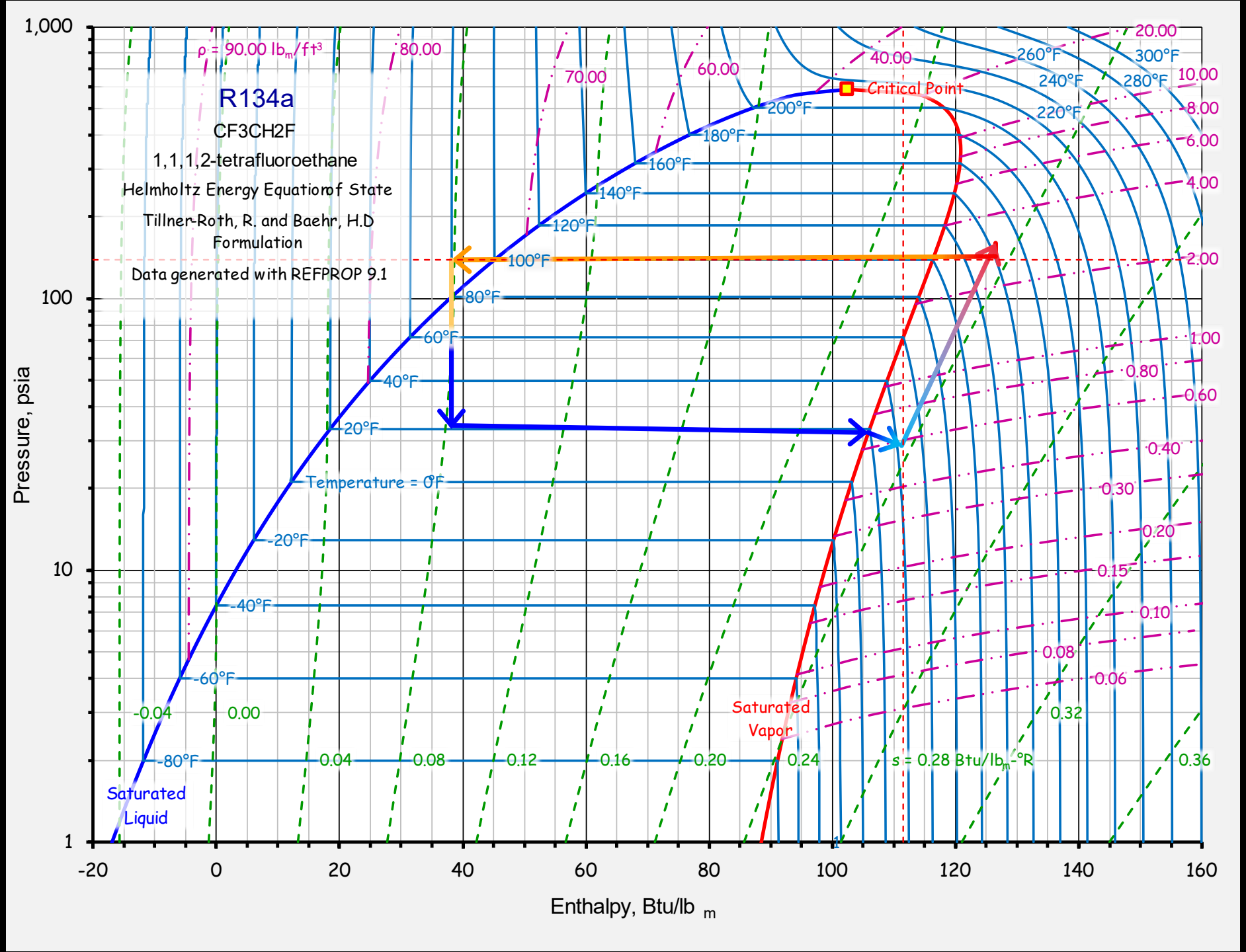
Condensation

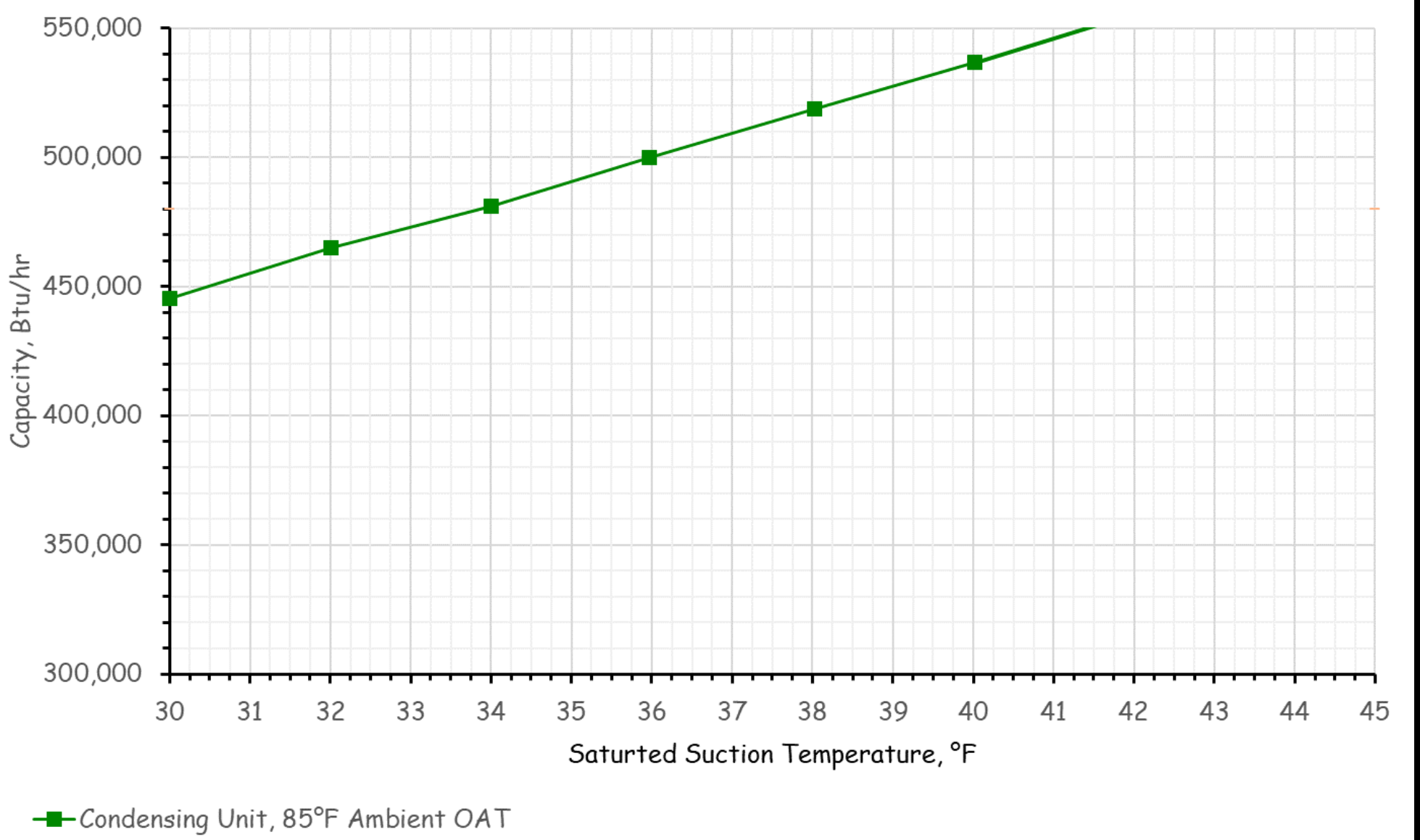


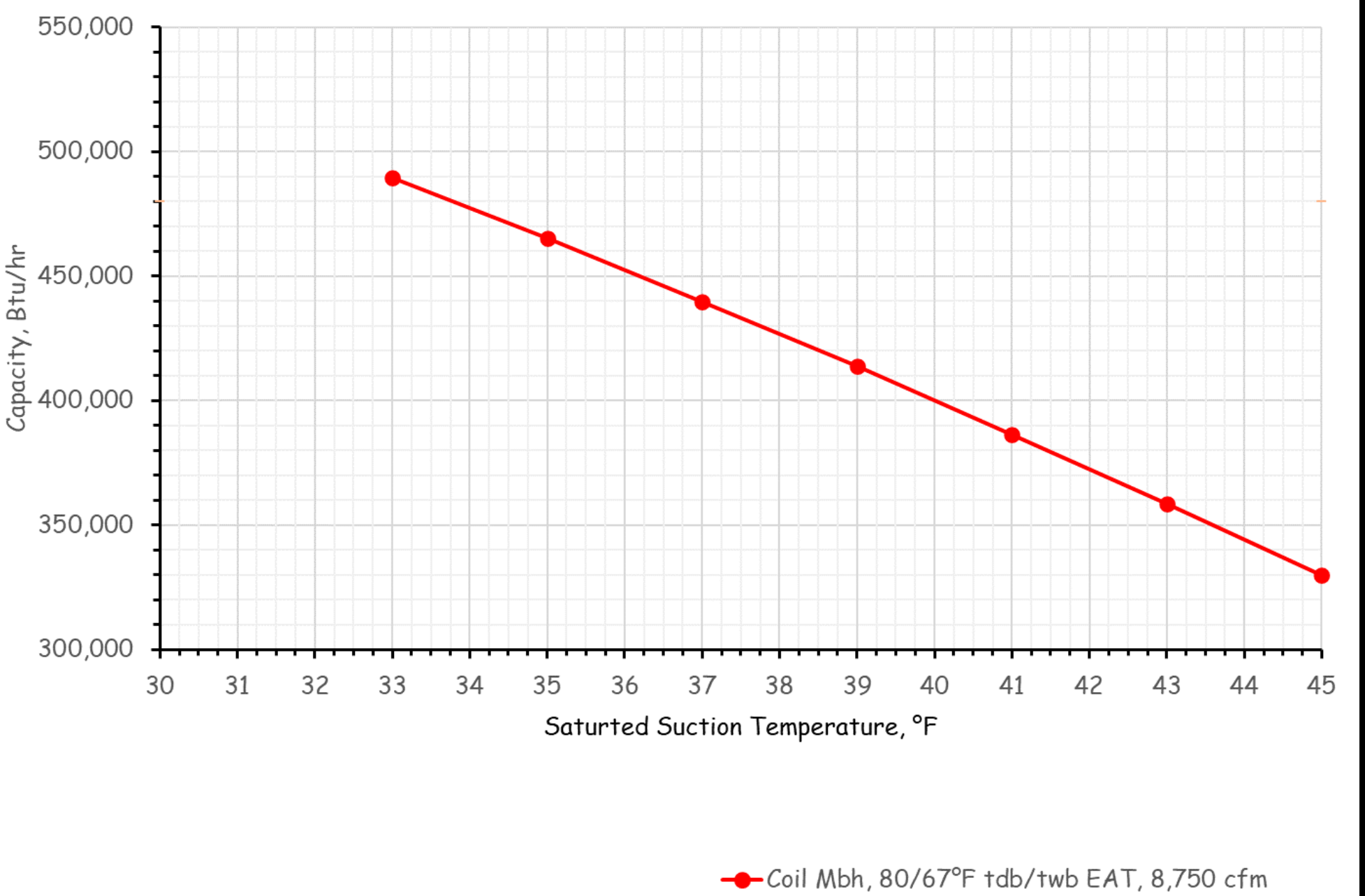

R134a
CF3CH2F
1,1,1,2-tetrafluoroethane
Helmholtz Energy Equationof State
Tillner-Roth, R. and Baehr, H.D
Formulation
Data generated with REFPROP 9.1
ρ = 90.00 lbm/ft³
80.00
70.00
60.00
40.00
Critical Point
20.00
260°F
300°F
240°F
280°F
220°F
10.00
8.00
6.00
4.00
2.00
1.00
0.80
0.60
0.40
0.30
0.20
0.15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

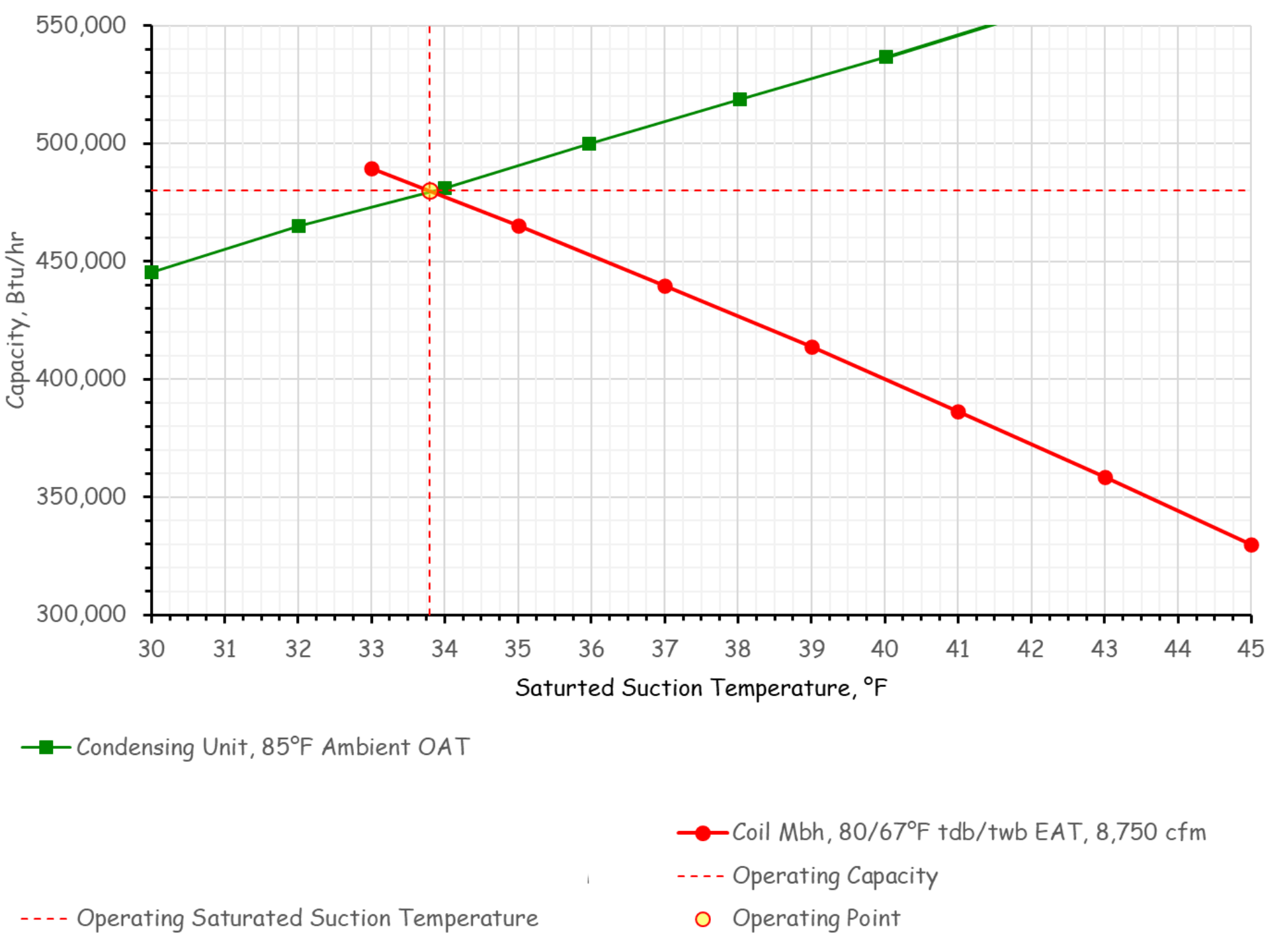
Expansion

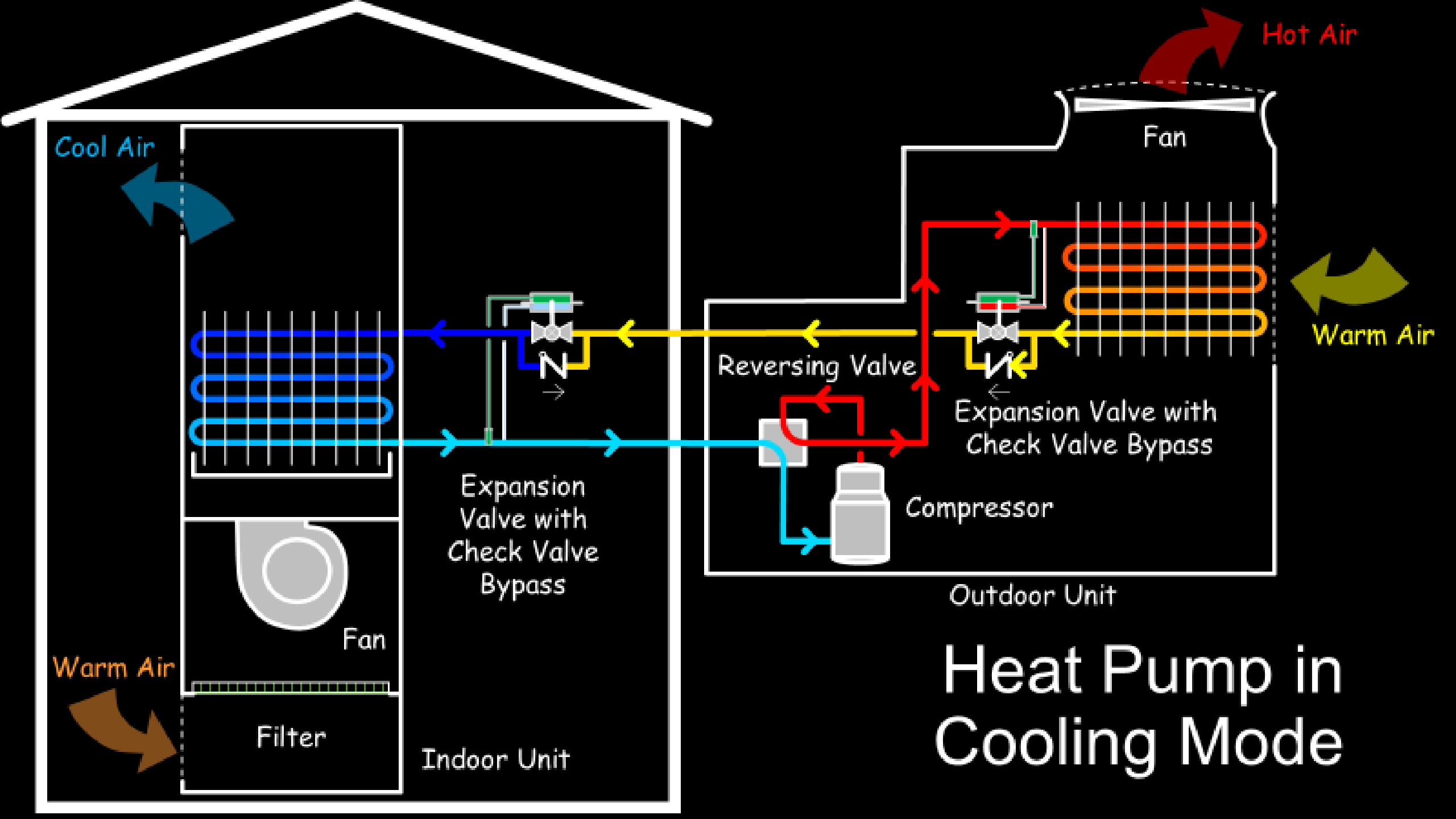
# The Pressure-Enthalpy (p-h) Diagram – Actual Cycle

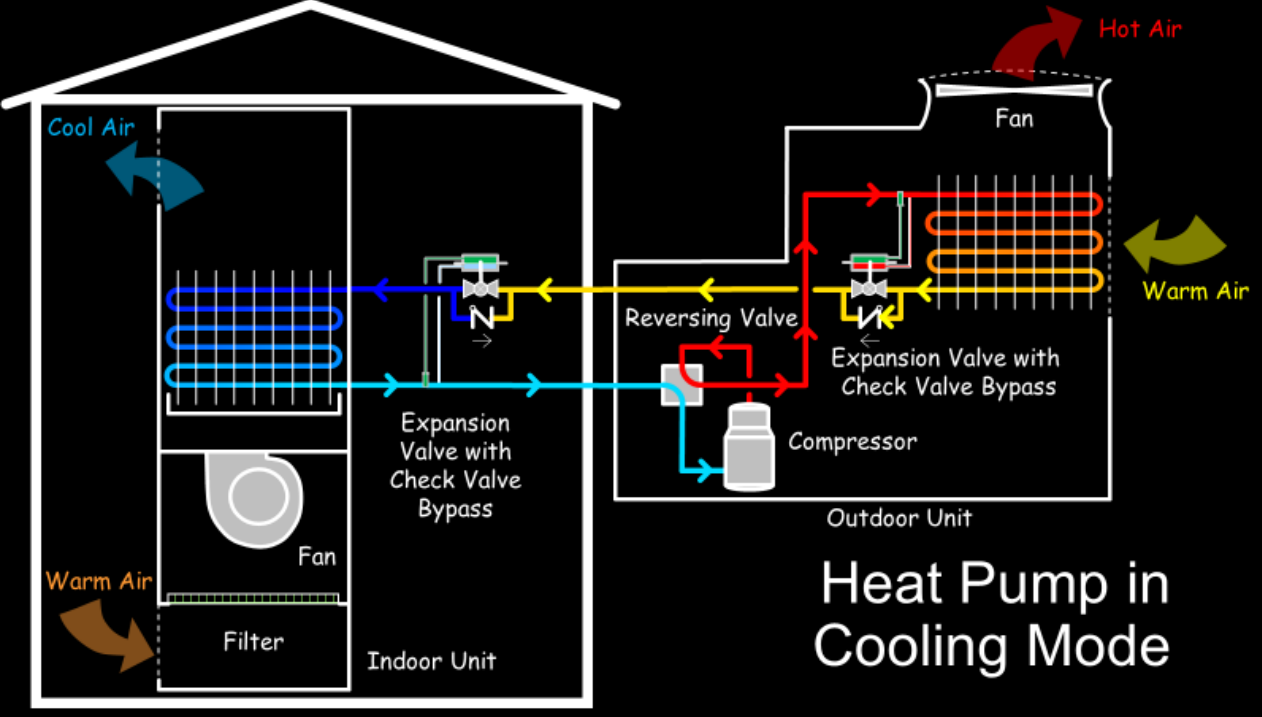



550,000
500,000
450,000
400,000
350,000
300,000
Capacity, Btu/hr
30
31
32
33
34
35
36
37
38
39
40
41
42
43
44
45
Saturted Suction Temperature, °F
Condensing Unit, 85°F Ambient OAT

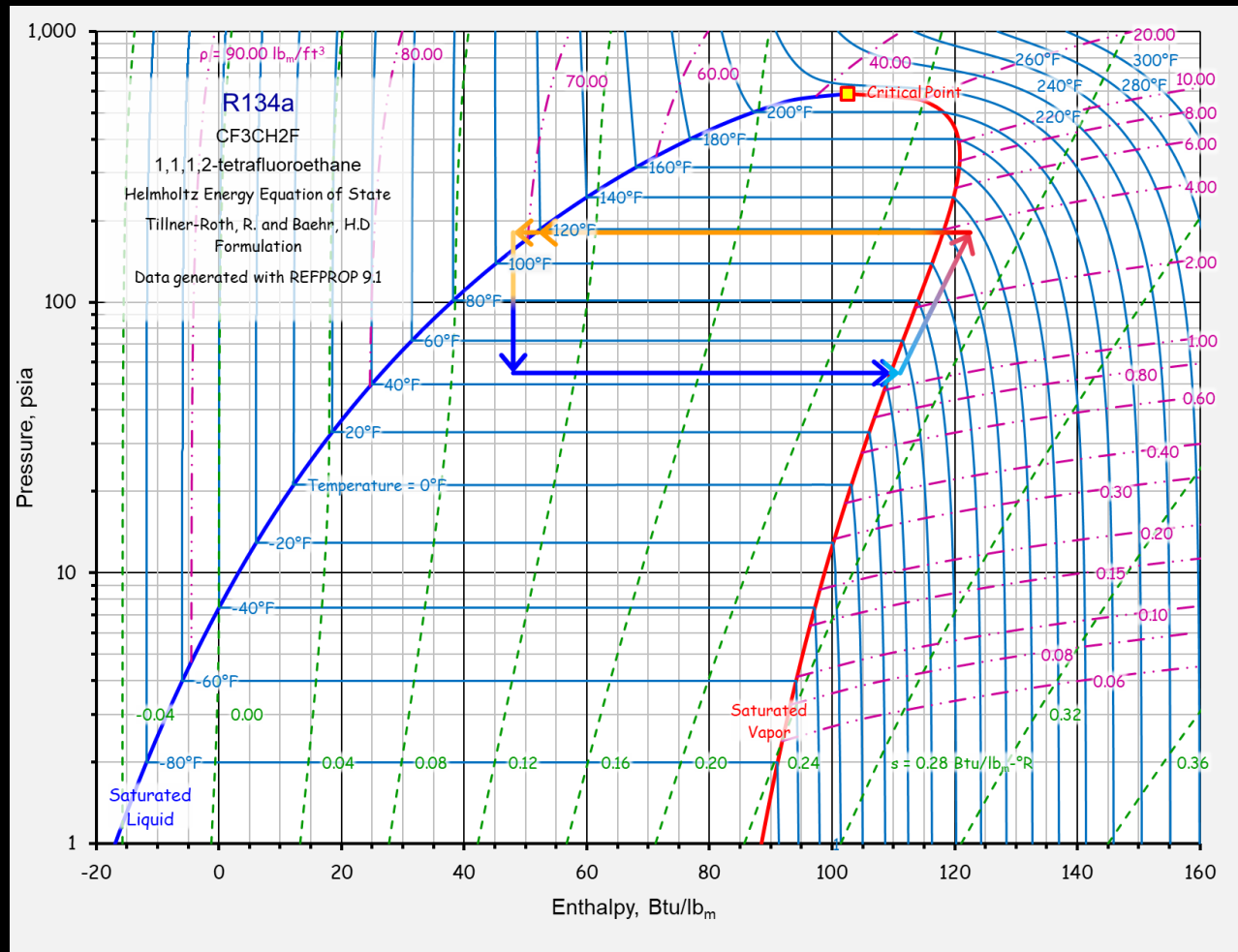

550,000
500,000
450,000
400,000
350,000
300,000
Capacity, Btu/hr
30
31
32
33
34
35
36
37
38
39
40
41
42
43
44
45
Saturted Suction Temperature, °F
Coil Mbh, 80/67°F tdb/twb EAT, 8,750 cfm

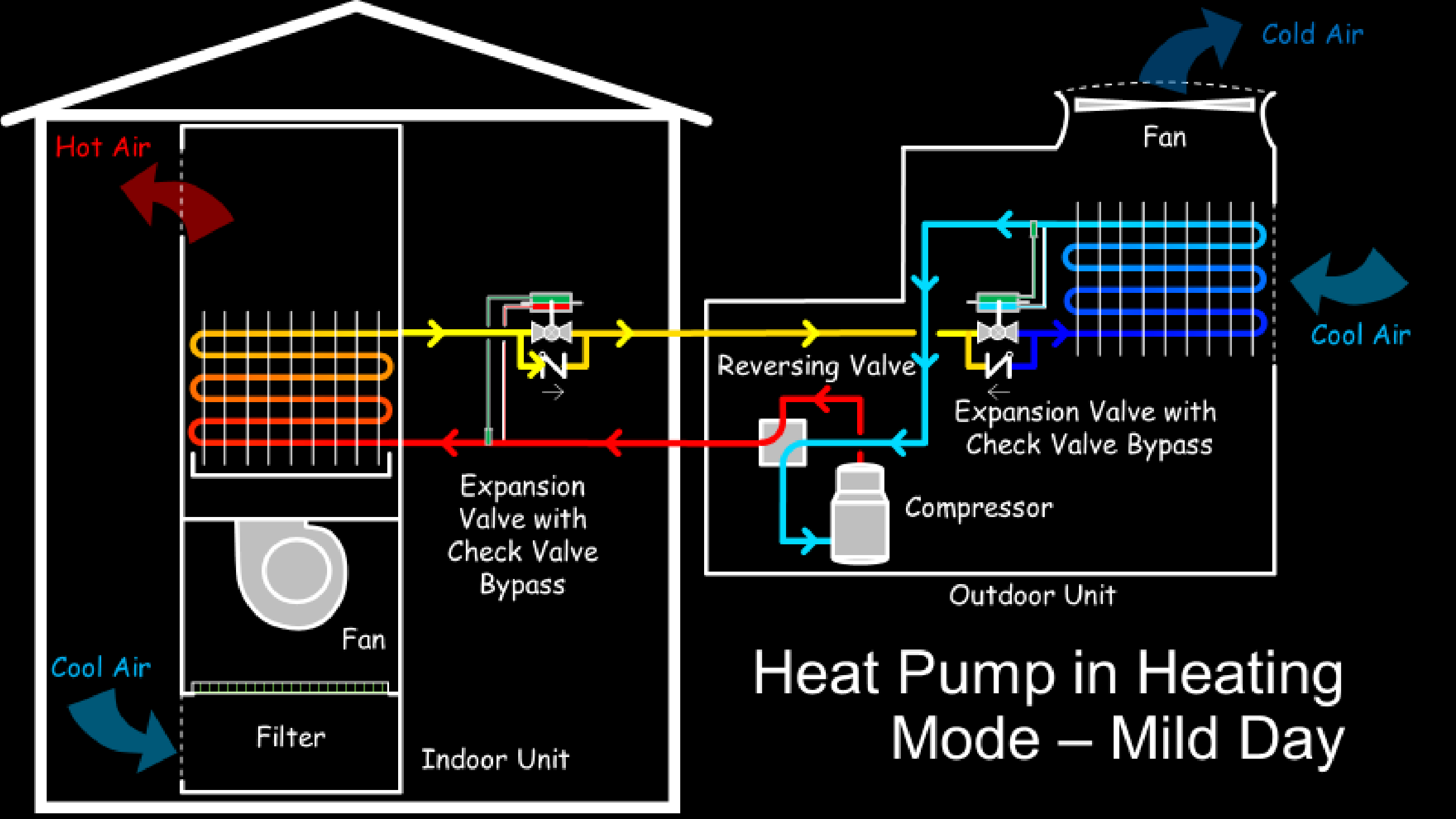

550,000
500,000
450,000
400,000
350,000
300,000
Capacity, Btu/hr
30
31
32
33
34
35
36
37
38
39
40
41
42
43
44
45
Saturted Suction Temperature, °F
Condensing Unit, 85°F Ambient OAT
Coil Mbh, 80/67°F tdb/twb EAT, 8,750 cfm
Operating Capacity
Operating Point
Operating Saturated Suction Temperature


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

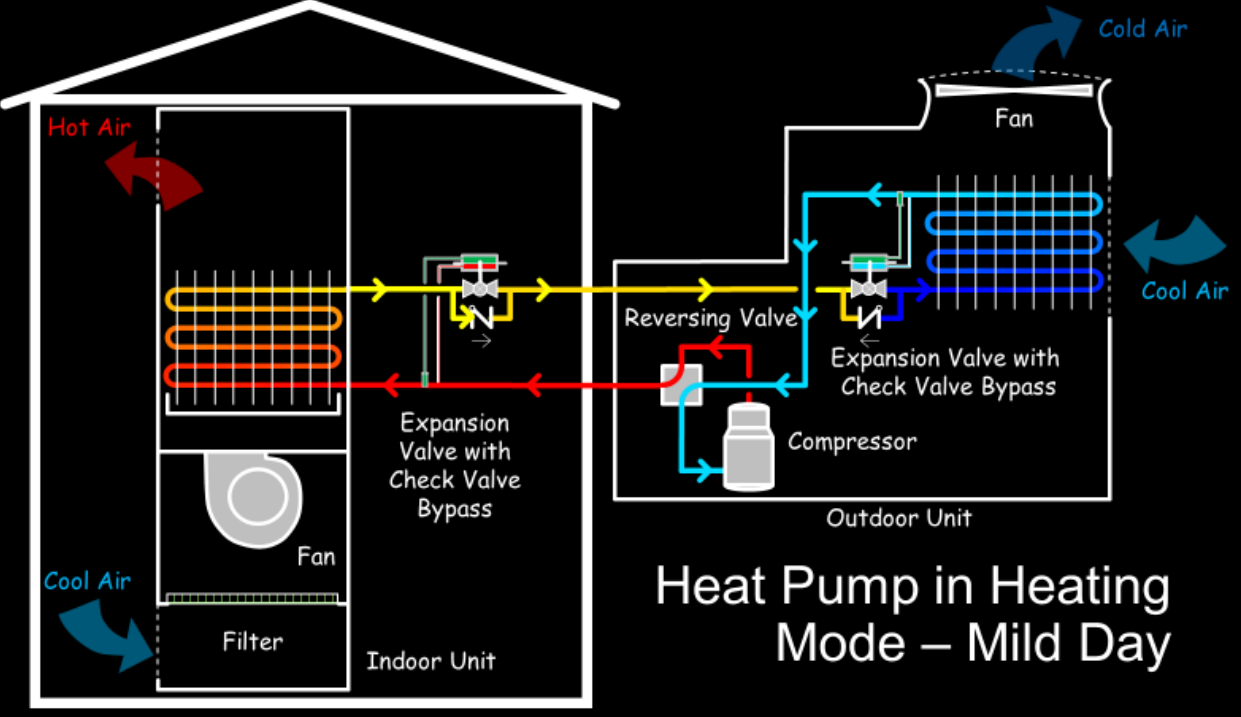



# Heat Pump in Cooling Mode

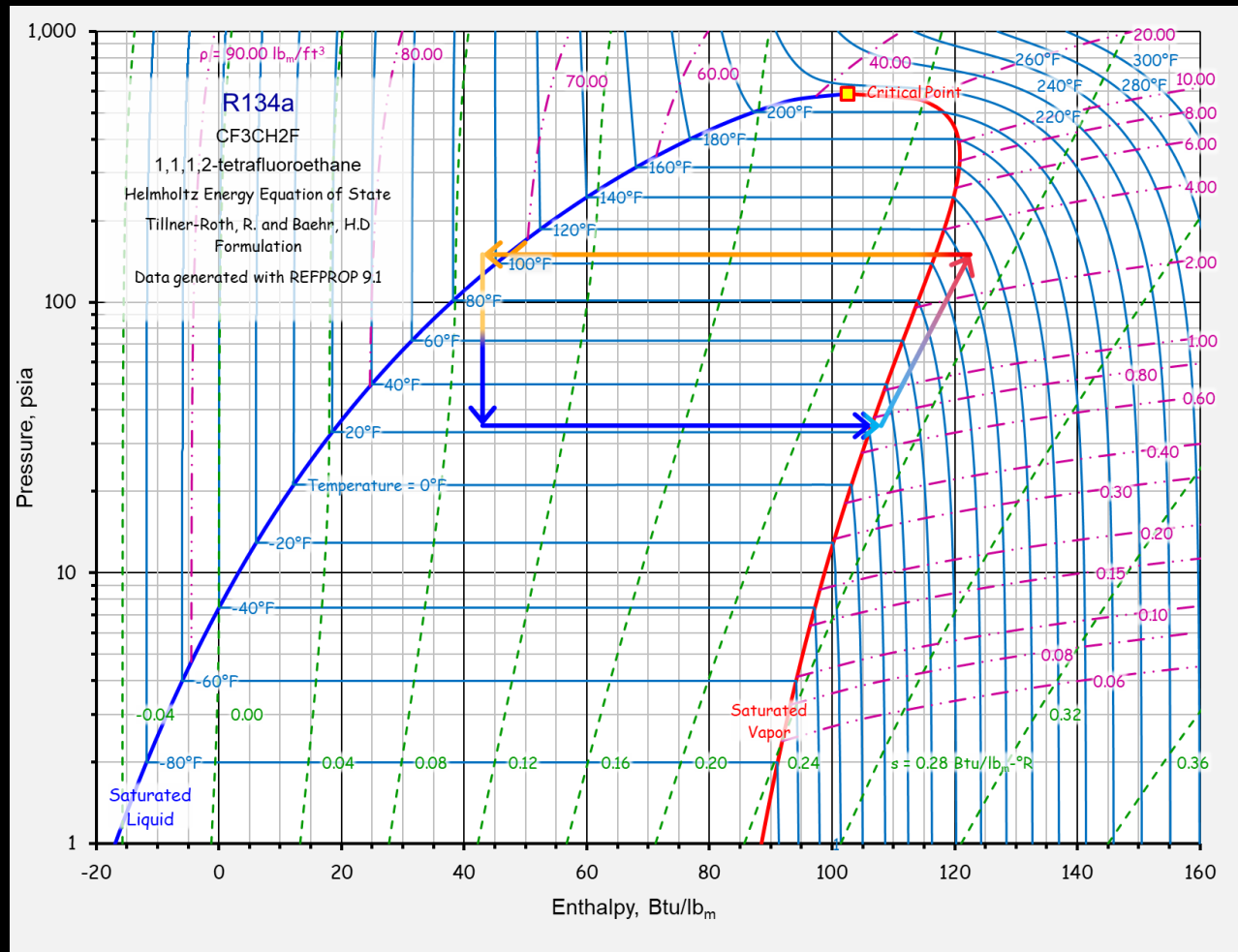


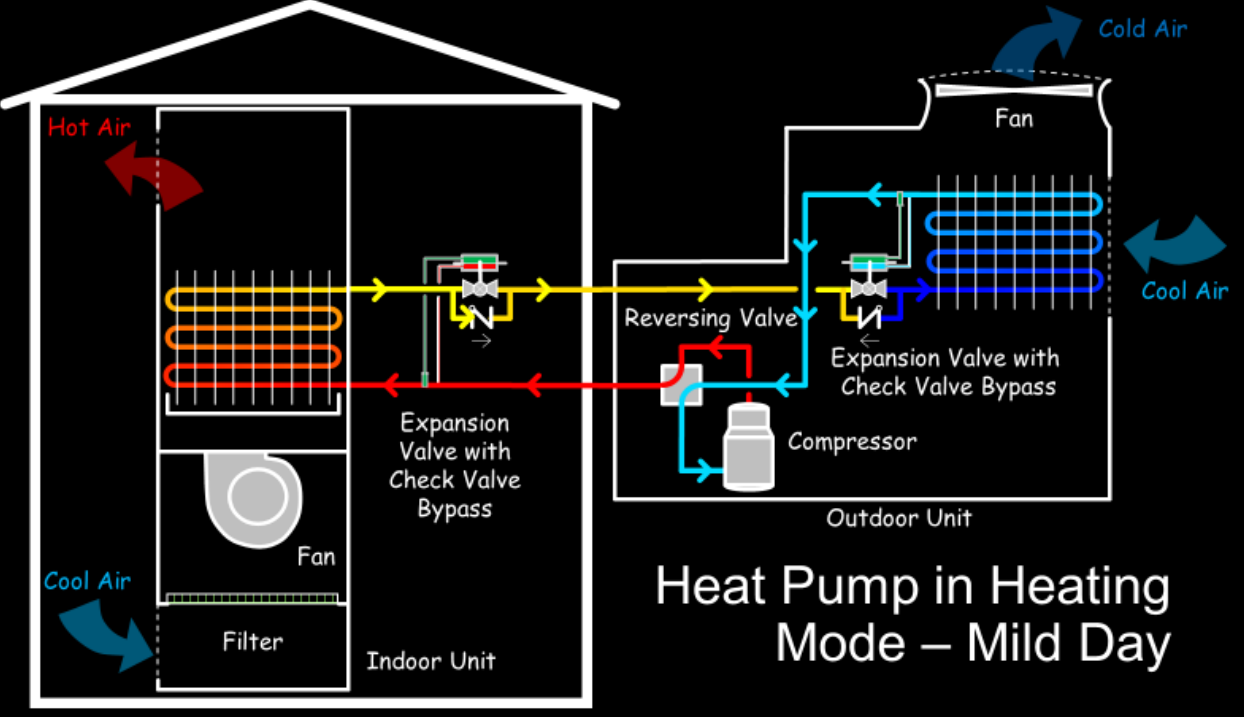



# Heat Pump in Heating Mode – Mild Day

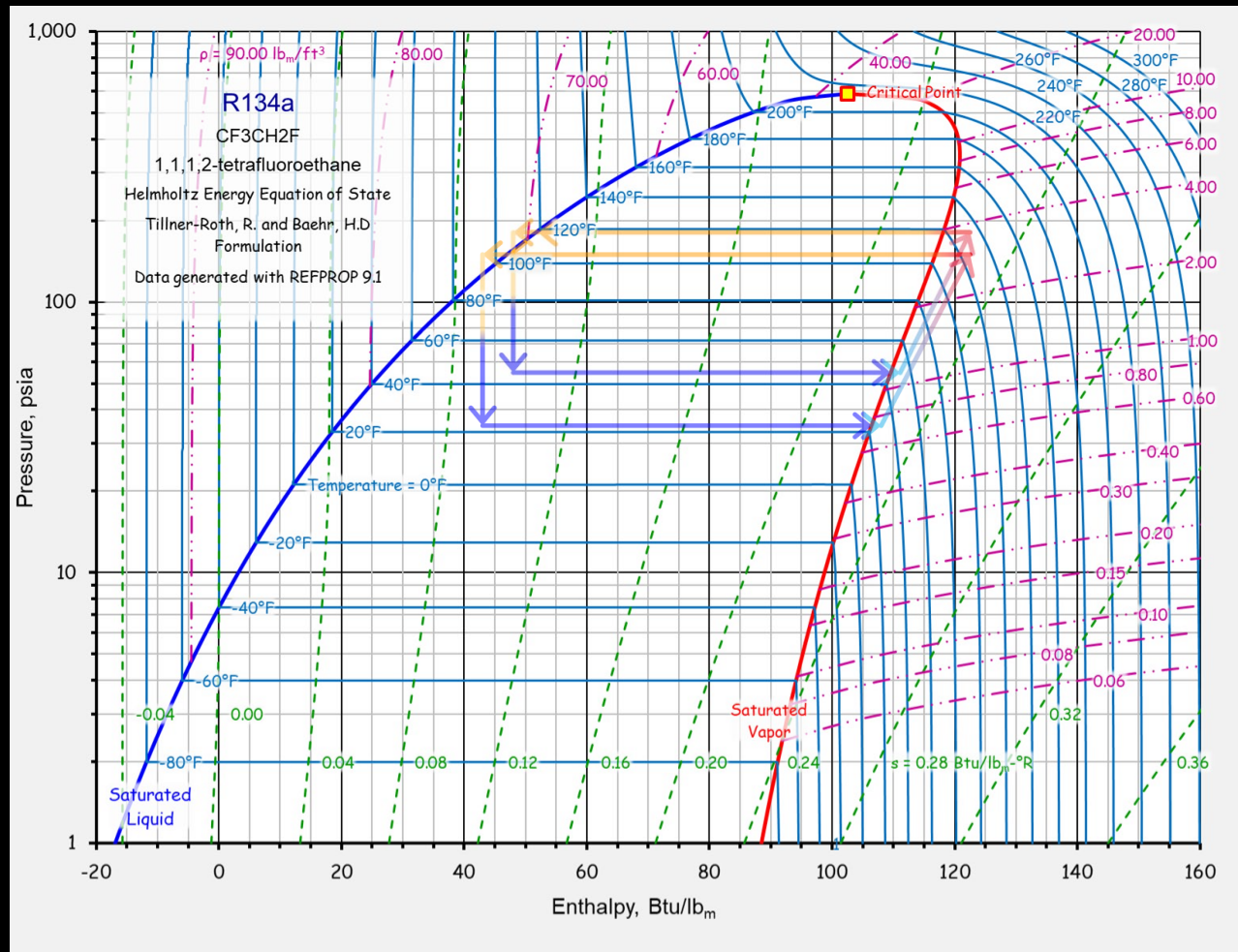


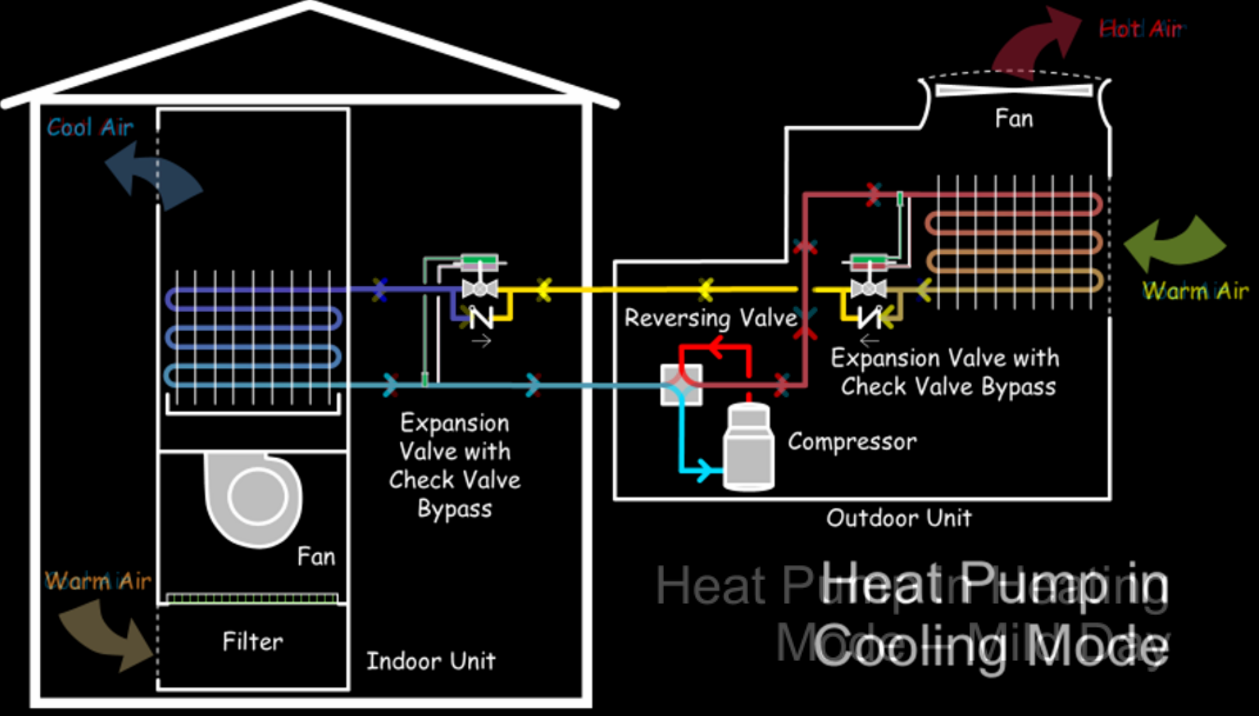

# Heat Pump in Heating Mode – Mild Day

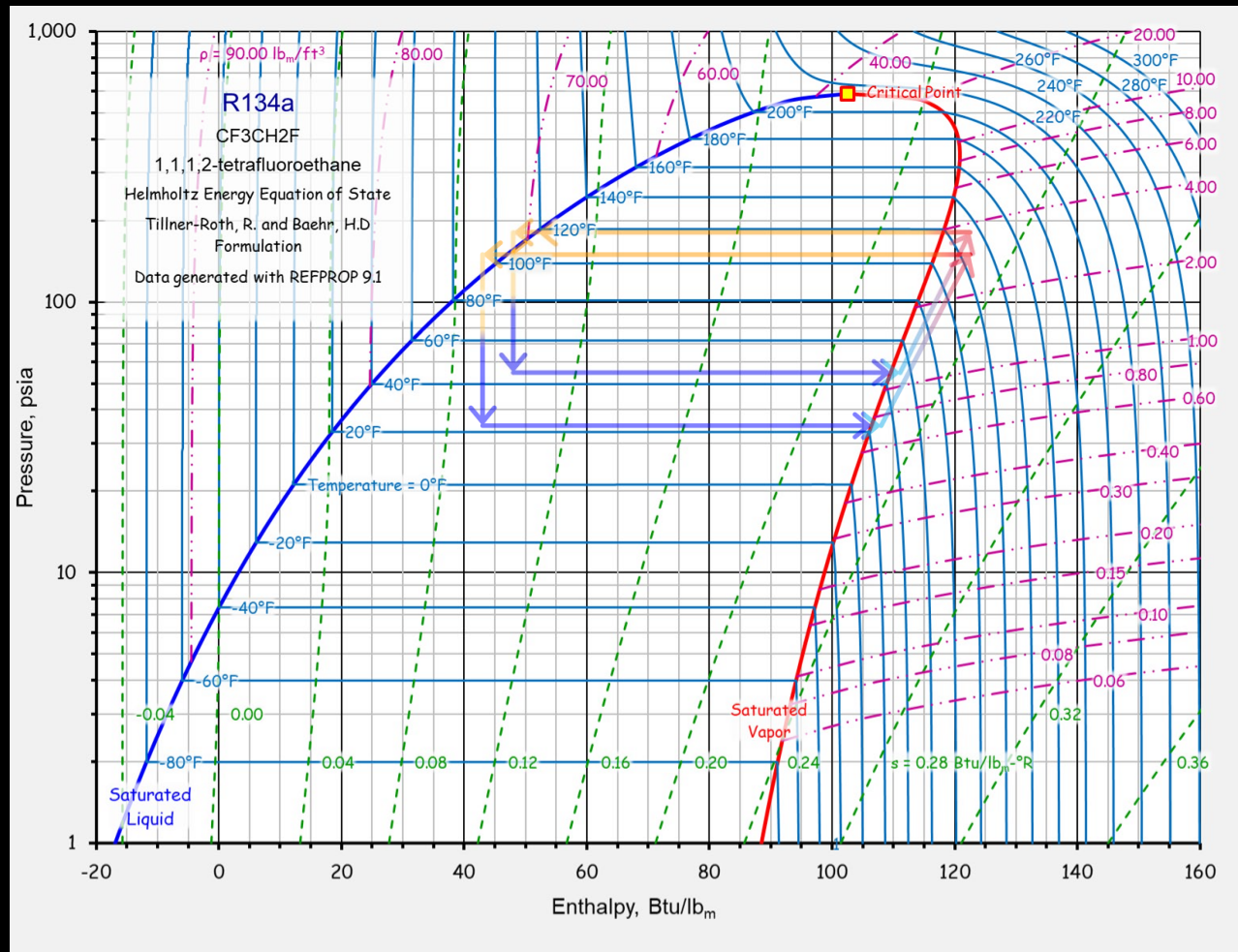


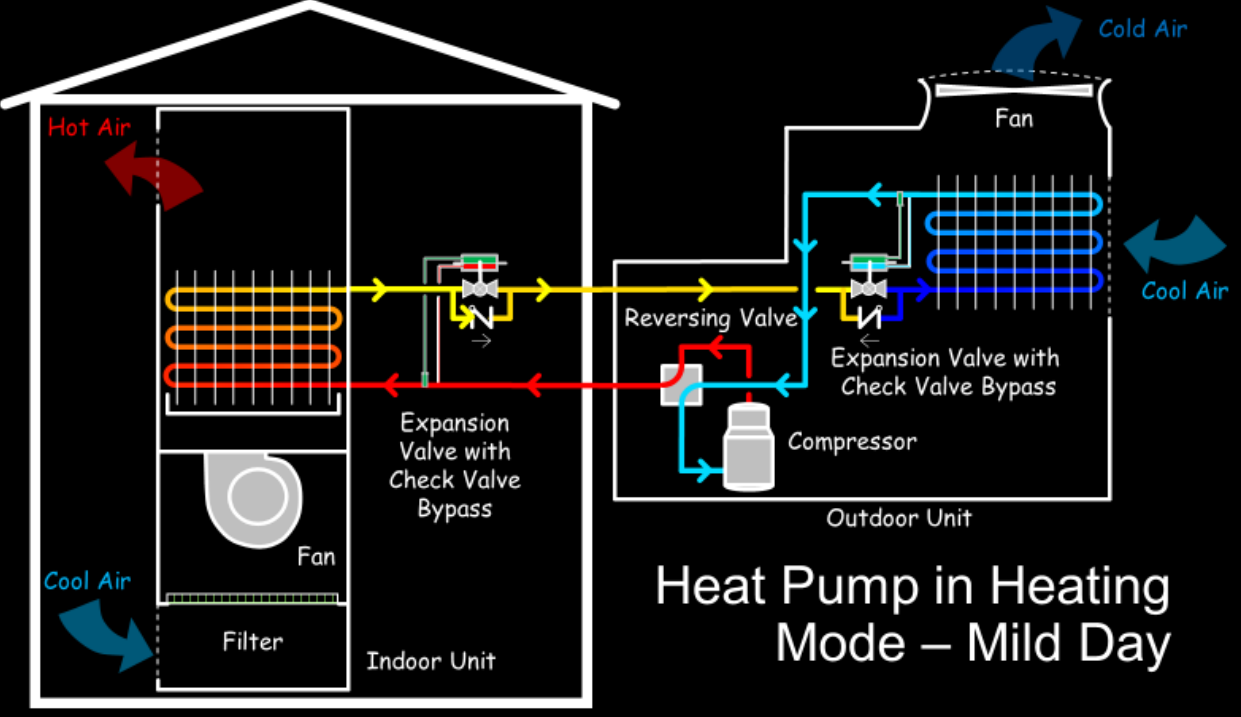



# Heat Pump in Heating Mode – Mild Day

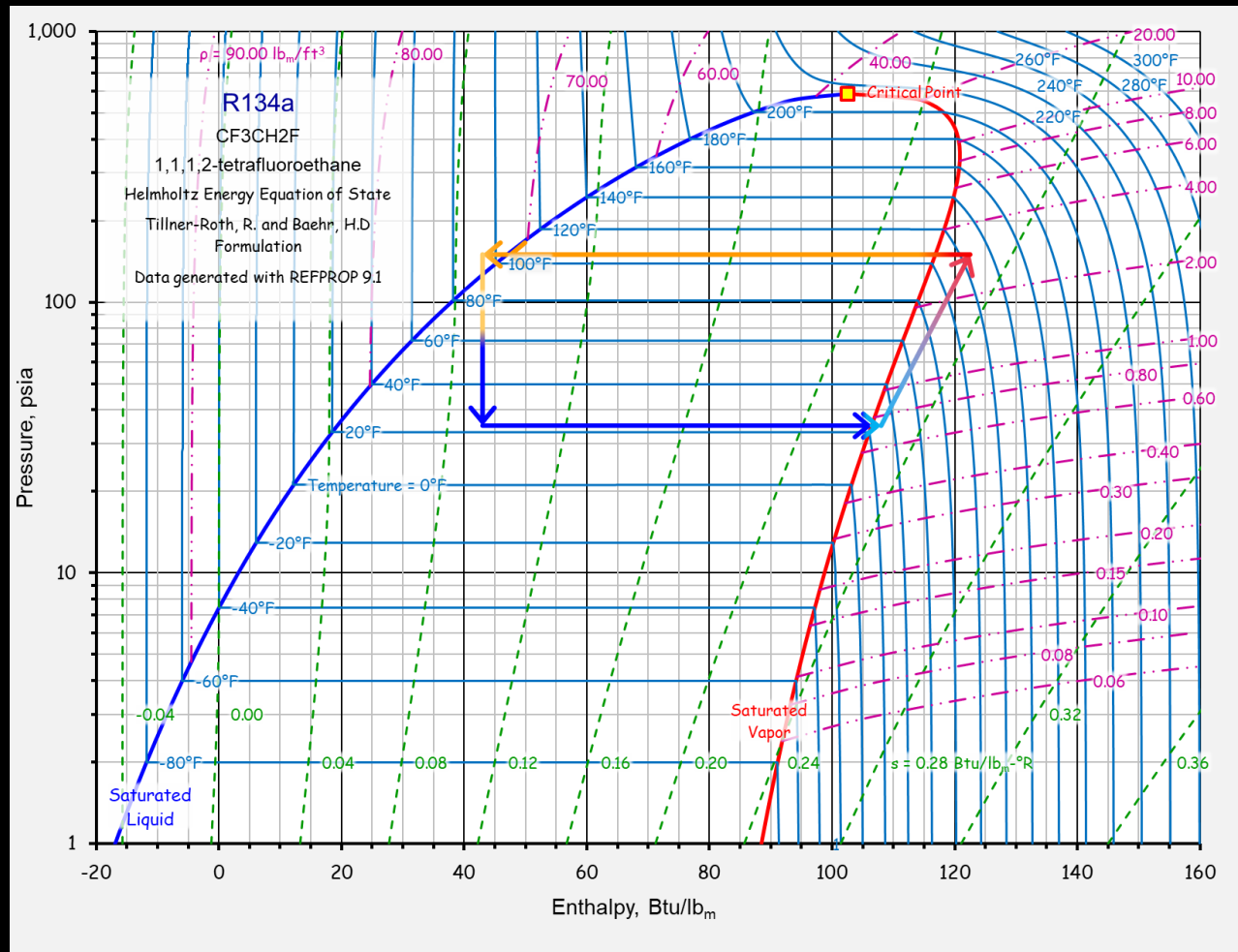


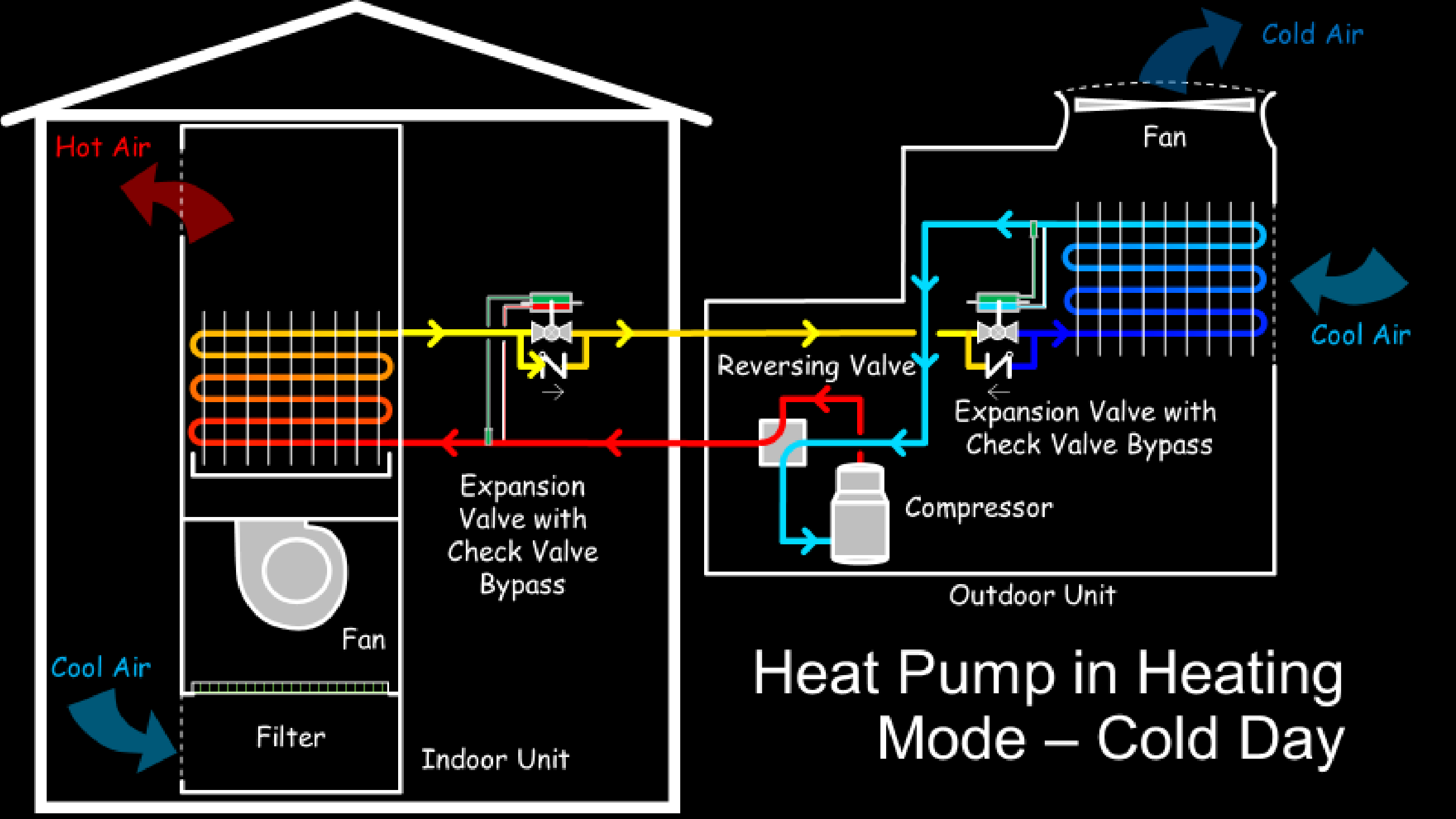

Hot Air
Fan
Cool Air
Warm Air
Reversing Valve
Expansion Valve with Check Valve Bypass
Compressor
Expansion Valve with Check Valve Bypass
Fan
Warm Air
Filter
Indoor Unit
Outdoor Unit
Heat Pump in Cooling Mode


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
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

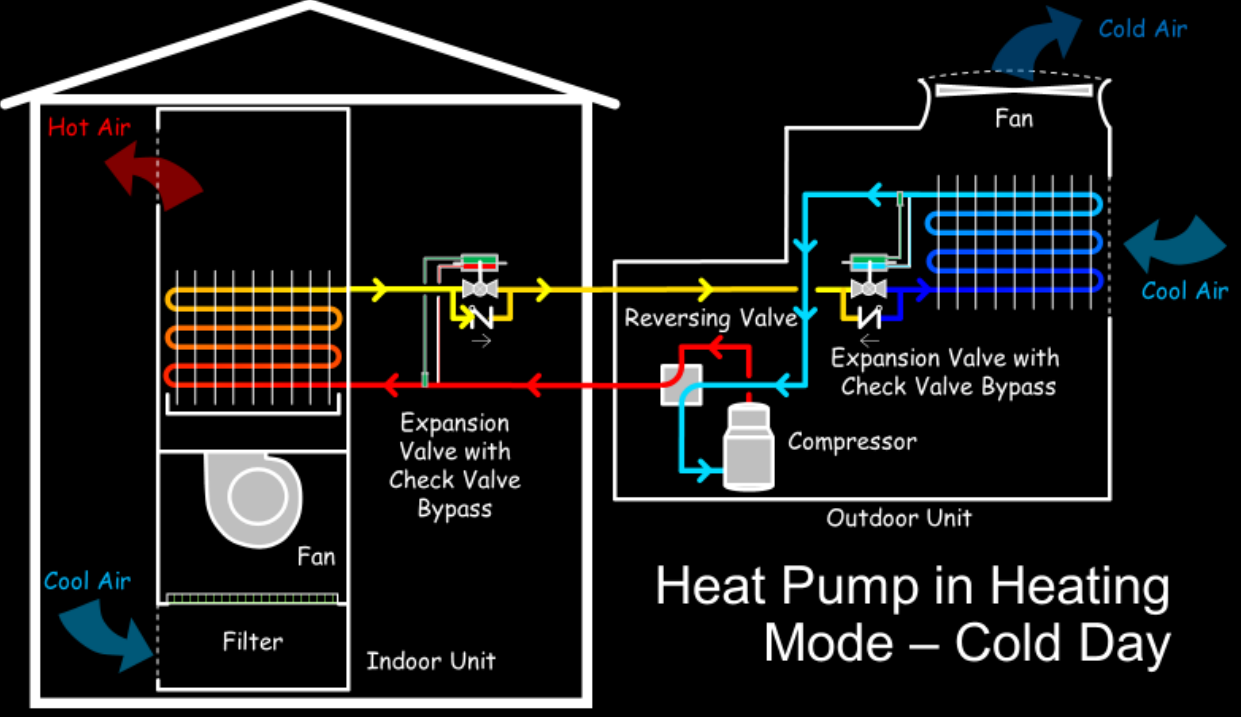



# Heat Pump in Heating Mode – Mild Day

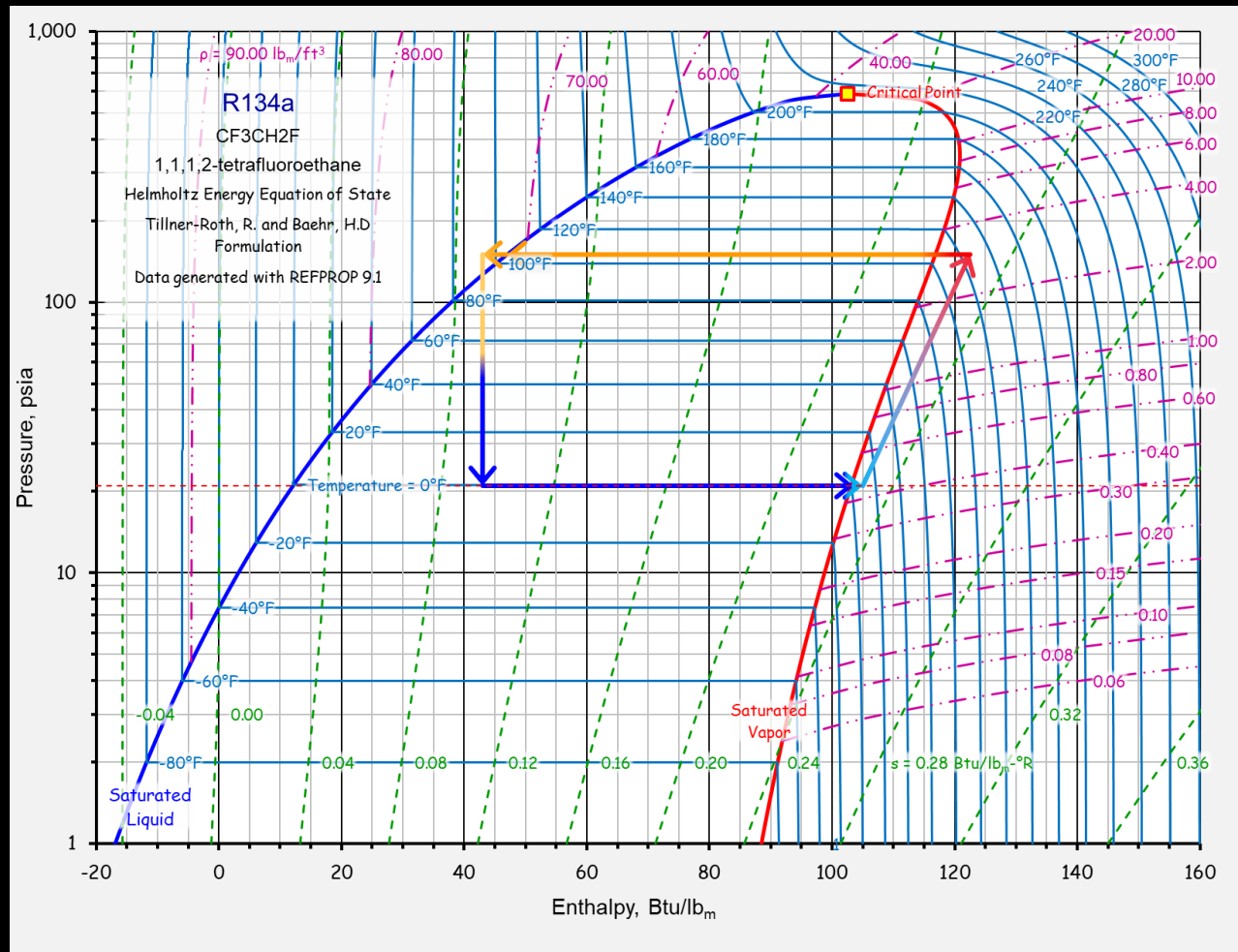


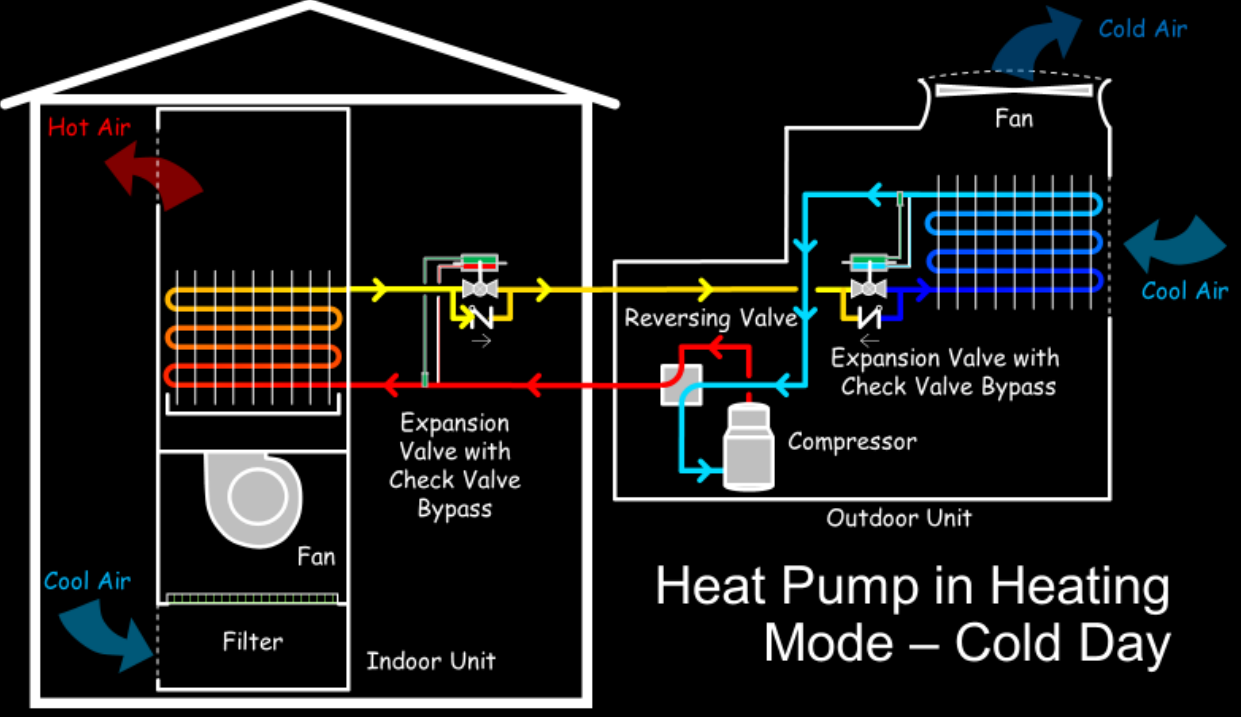



# Heat Pump in Heating Mode – Cold Day

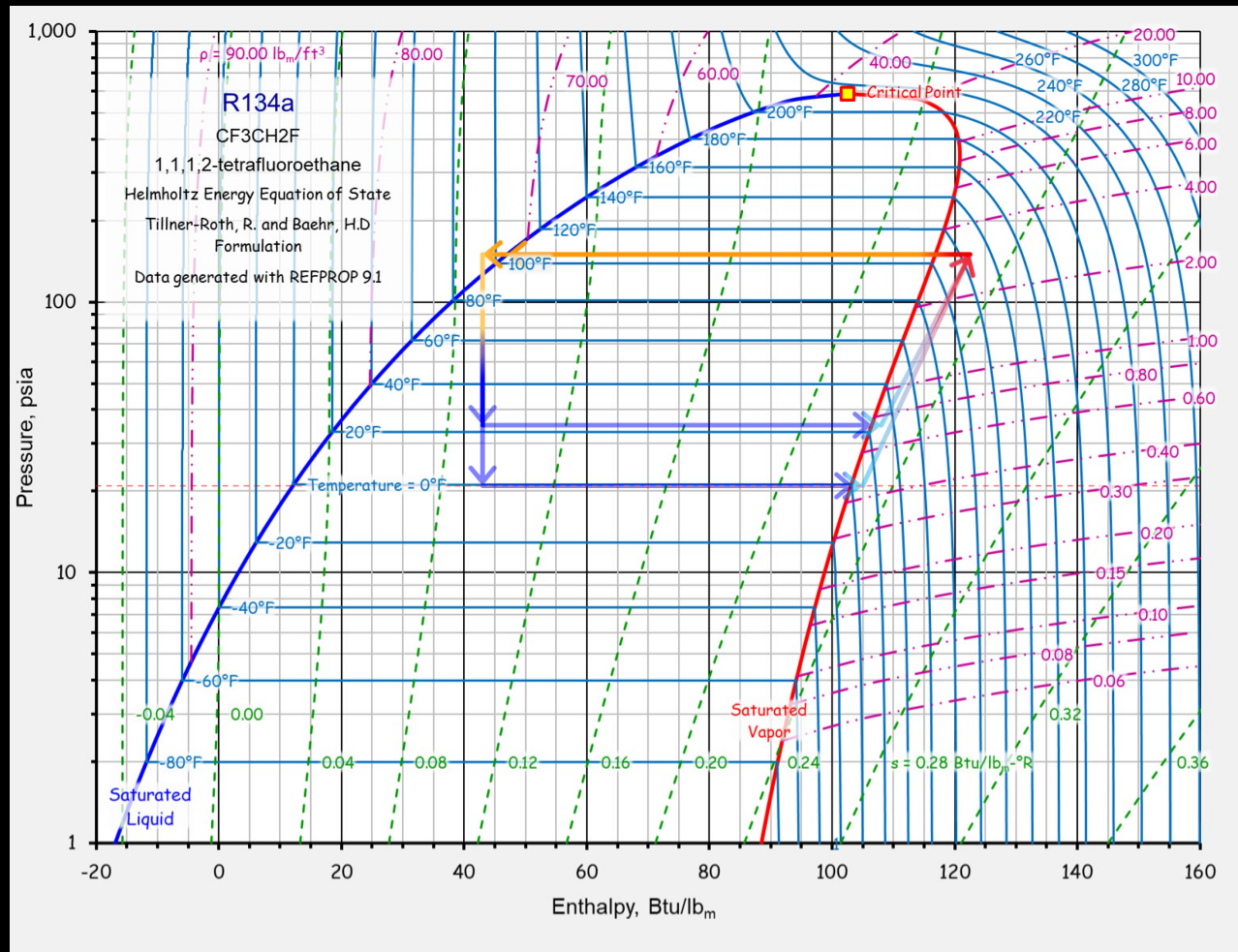


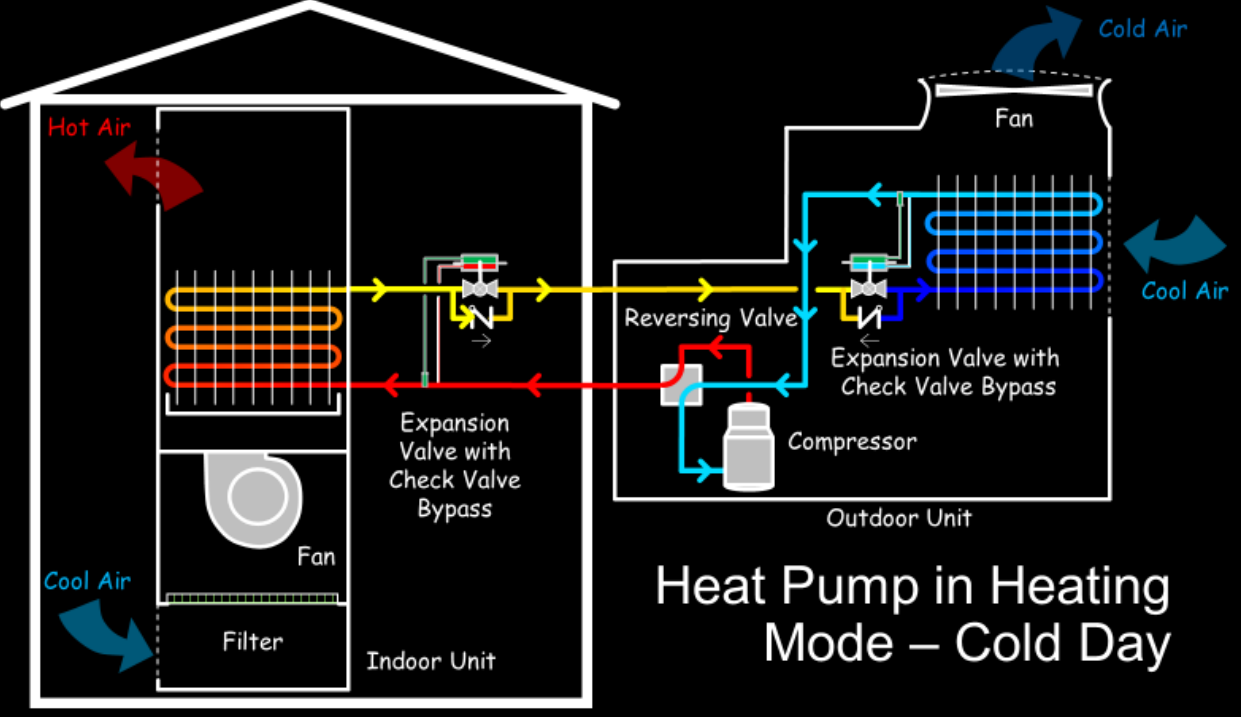

# Heat Pump in Heating Mode – Cold Day



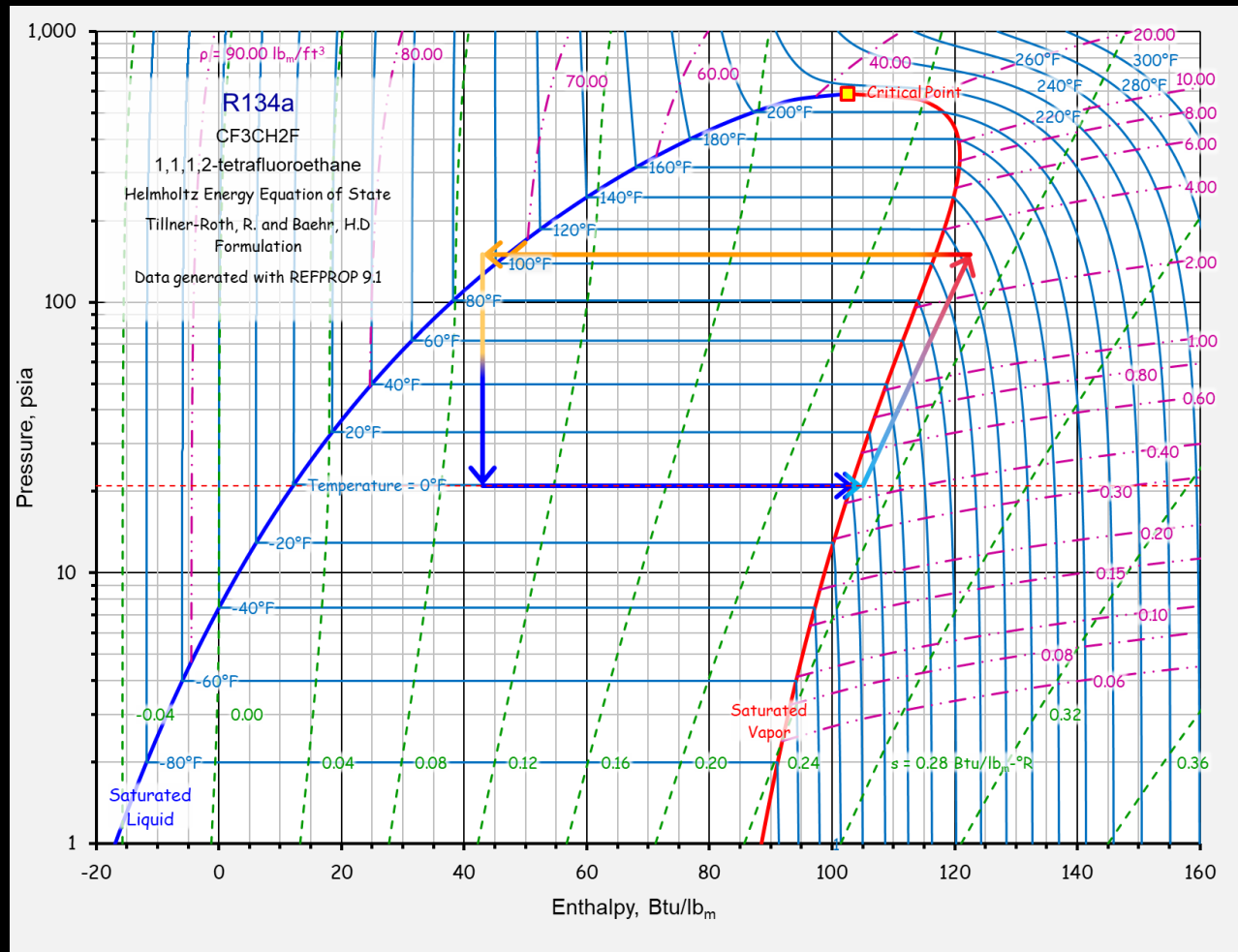


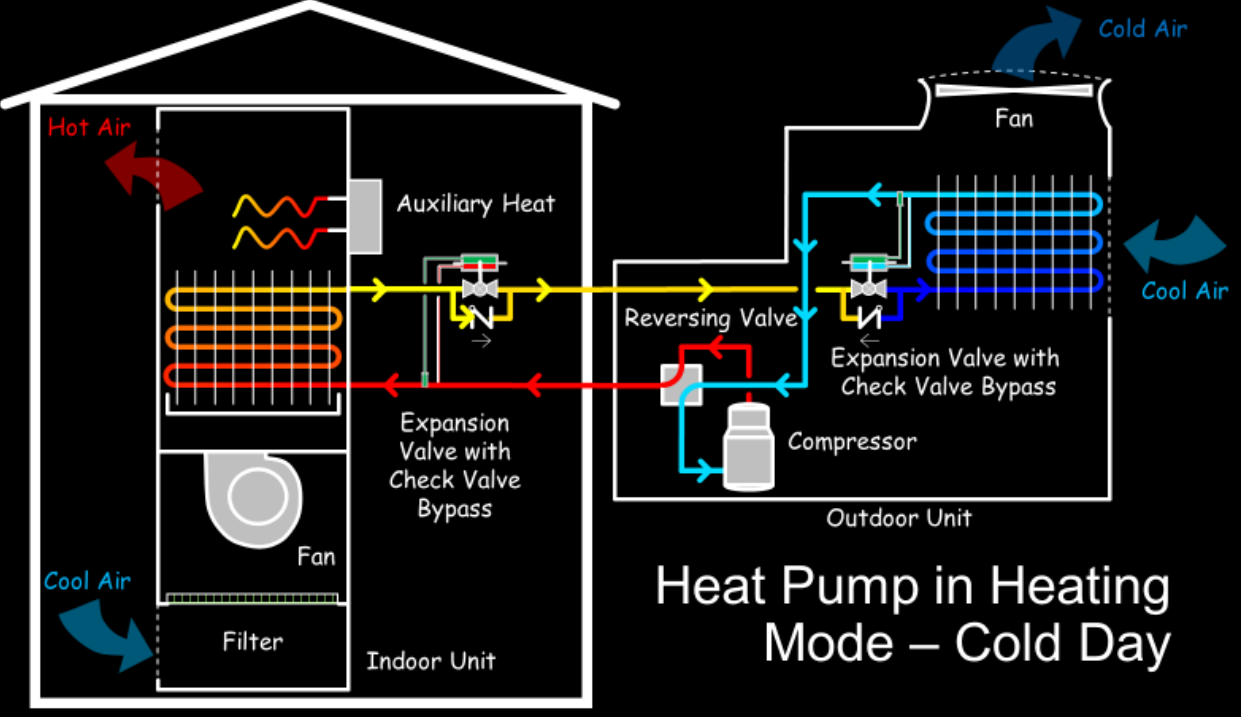

# Heat Pump in Heating Mode – Cold Day



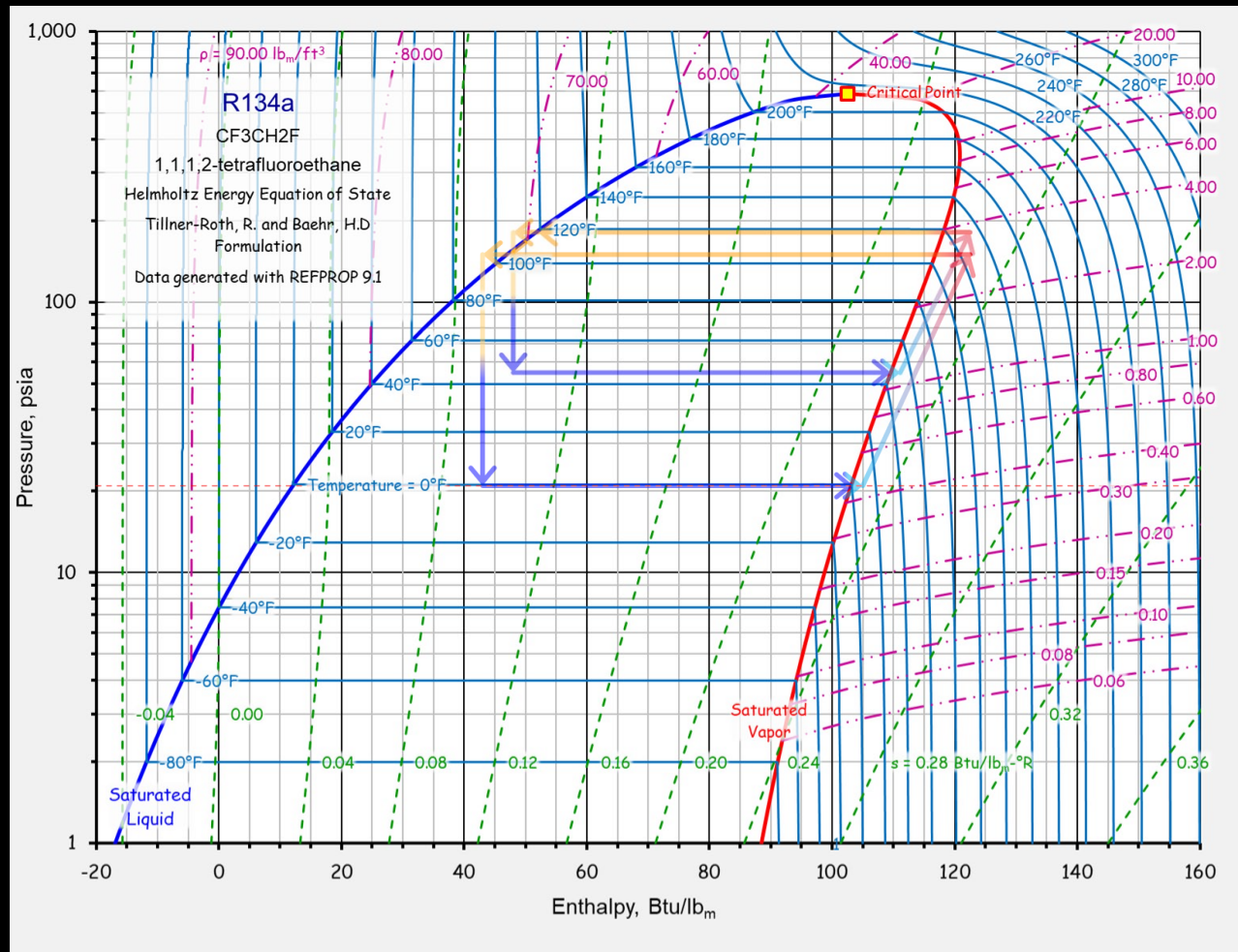


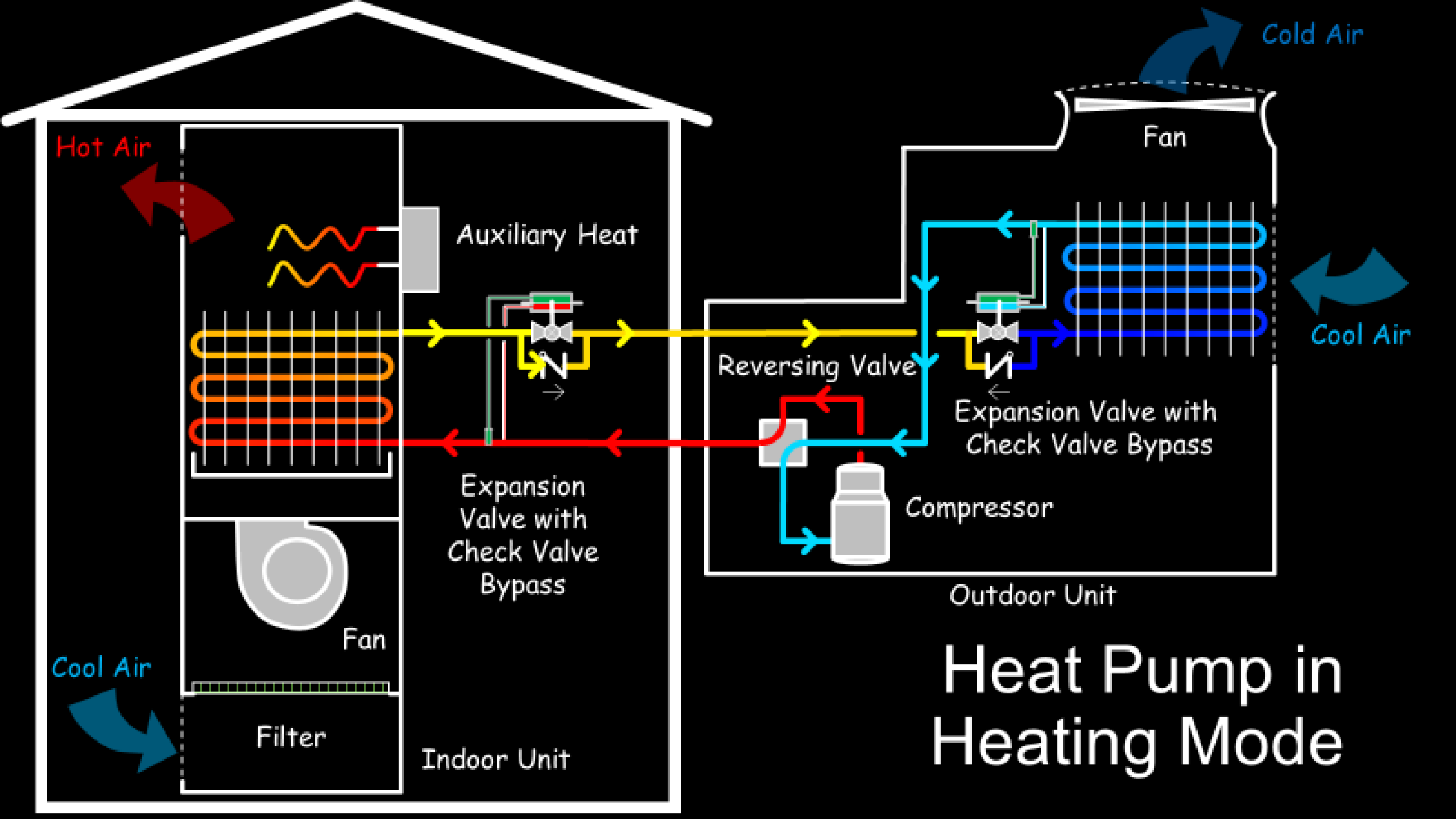

# Heat Pump in Heating Mode – Cold Day





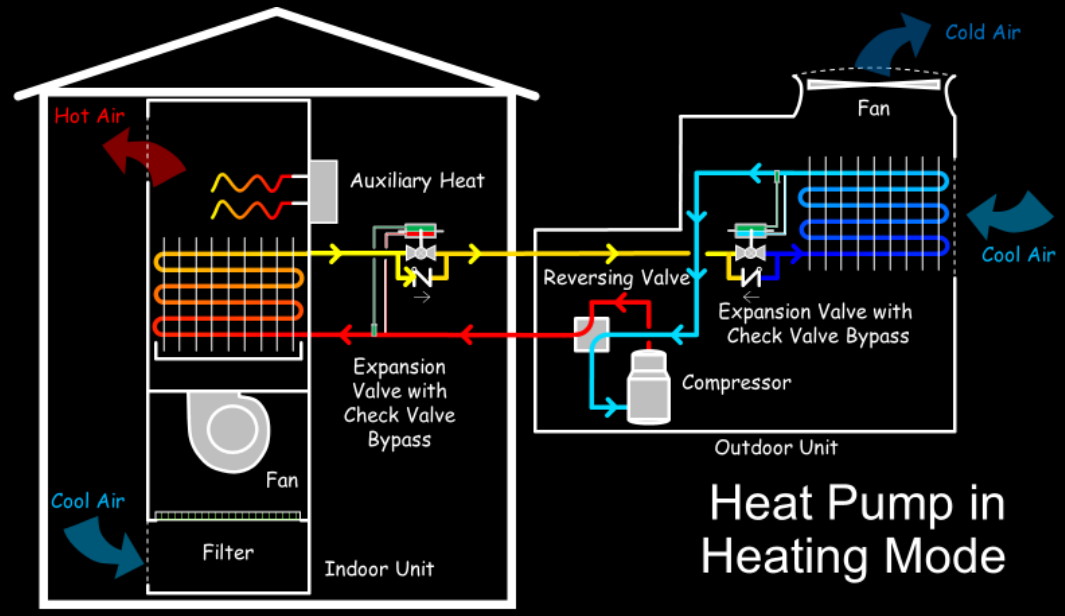

# Heat Pump in Heating Mode – Cold Day




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

# What Happens If:

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



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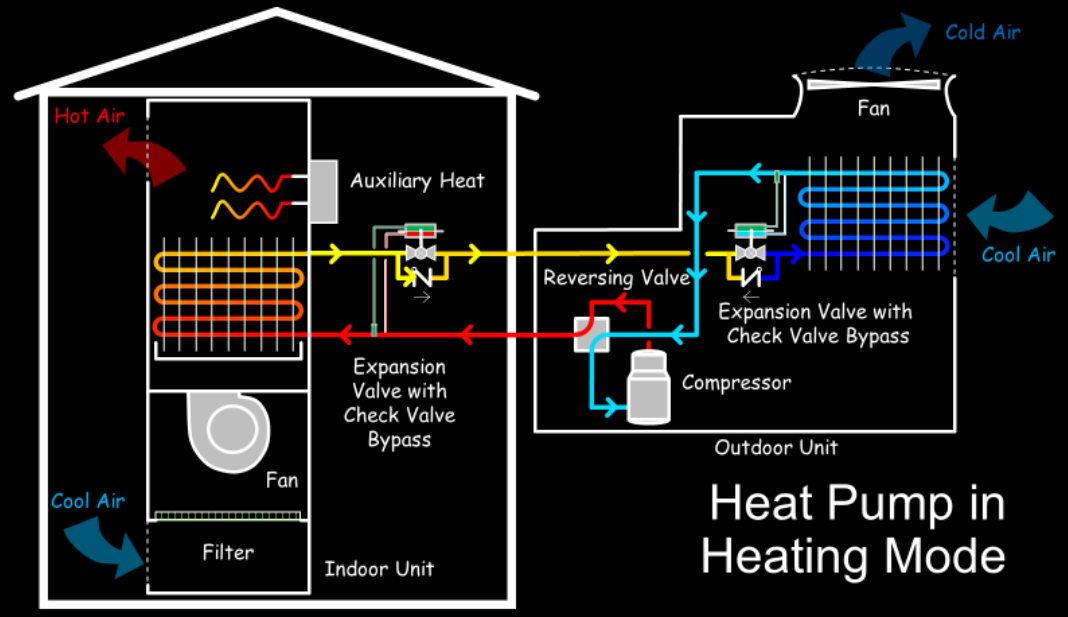


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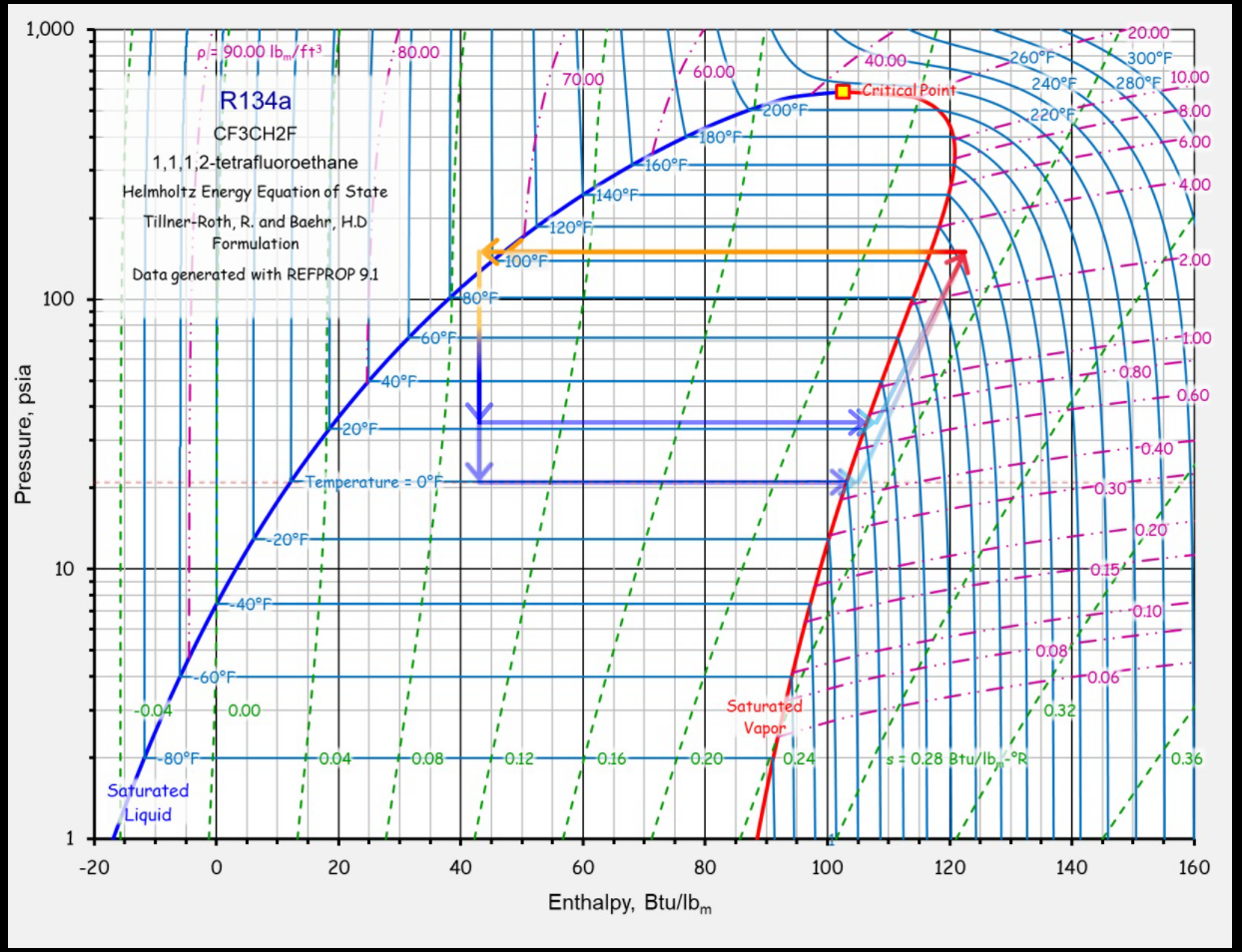
# What Happens If:

It gets really cold outside?



# What Happens If:

## It gets really cold outside?

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

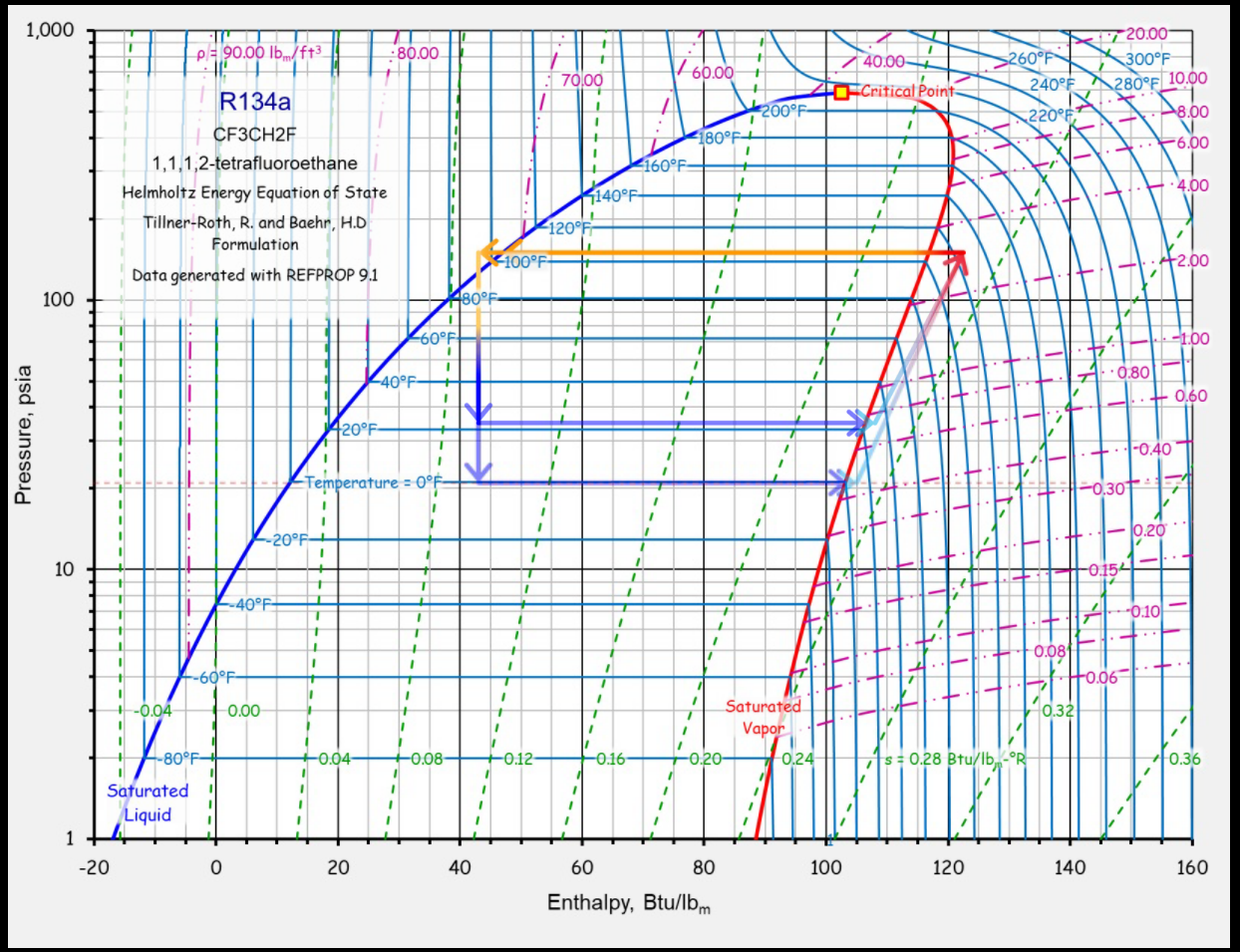
Where:

$Q$ = 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



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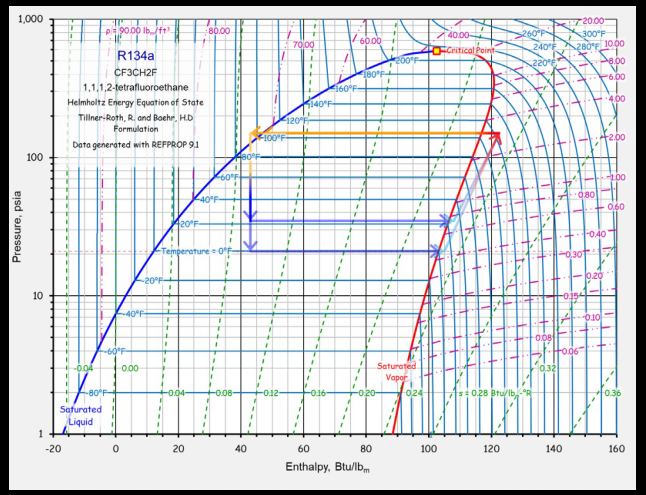


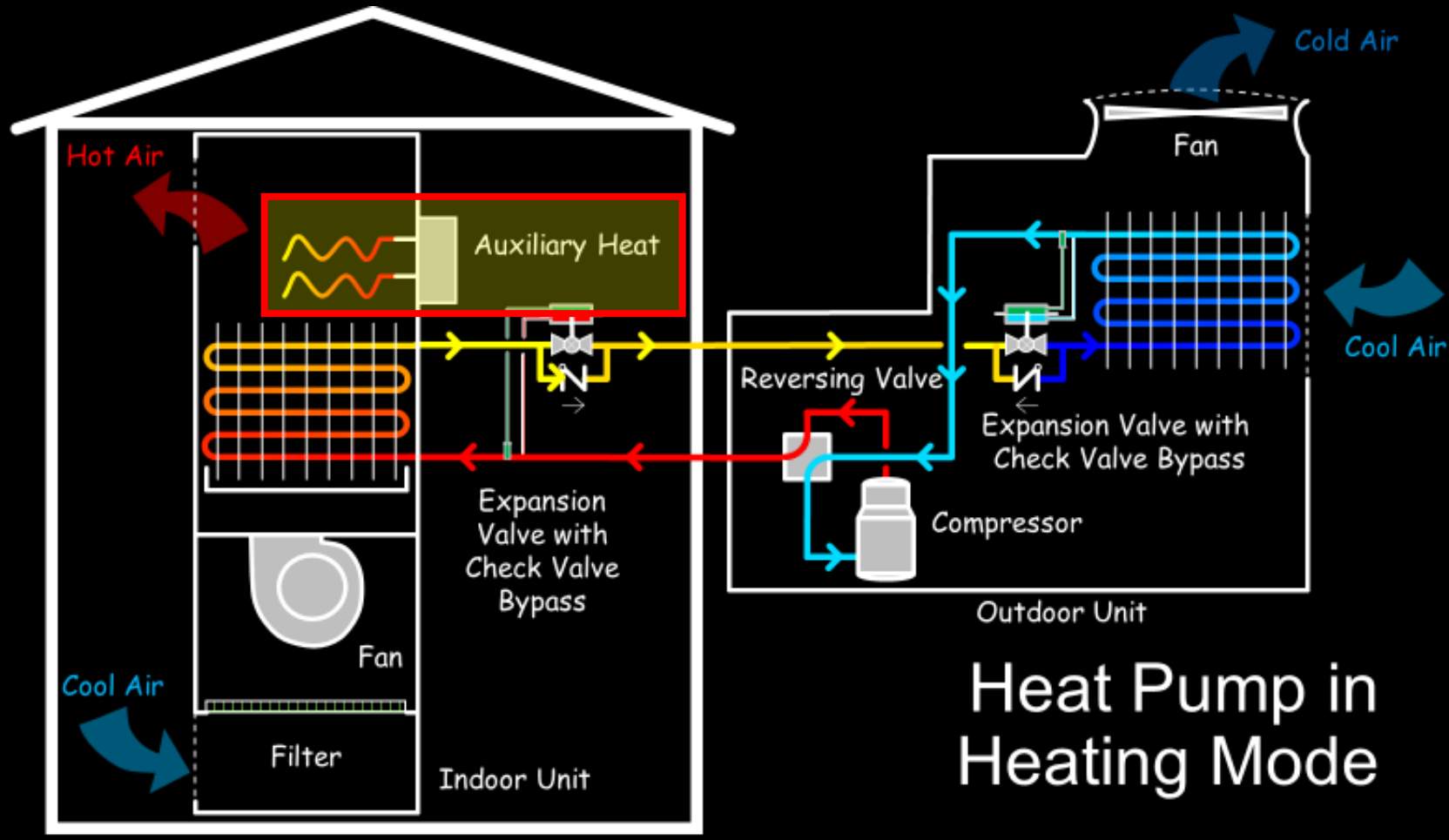

# Bottom Lines

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?

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