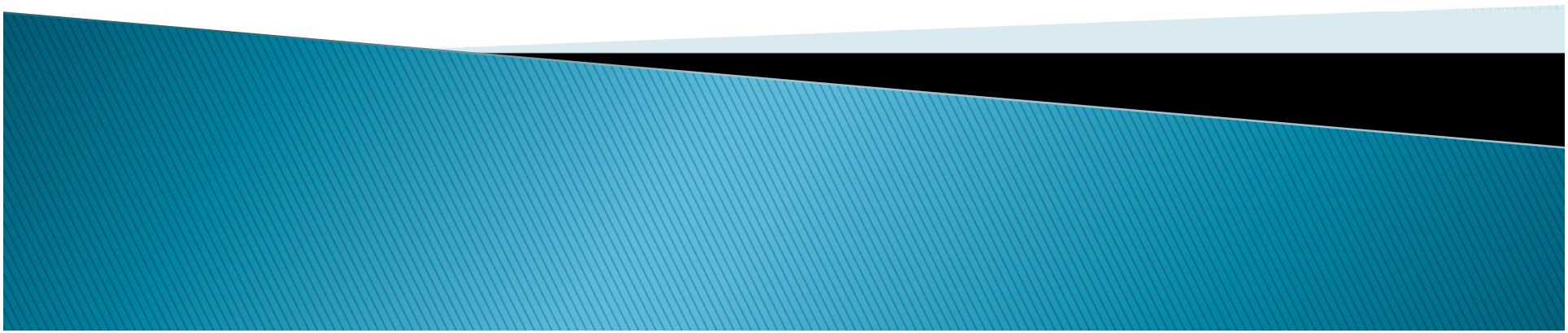
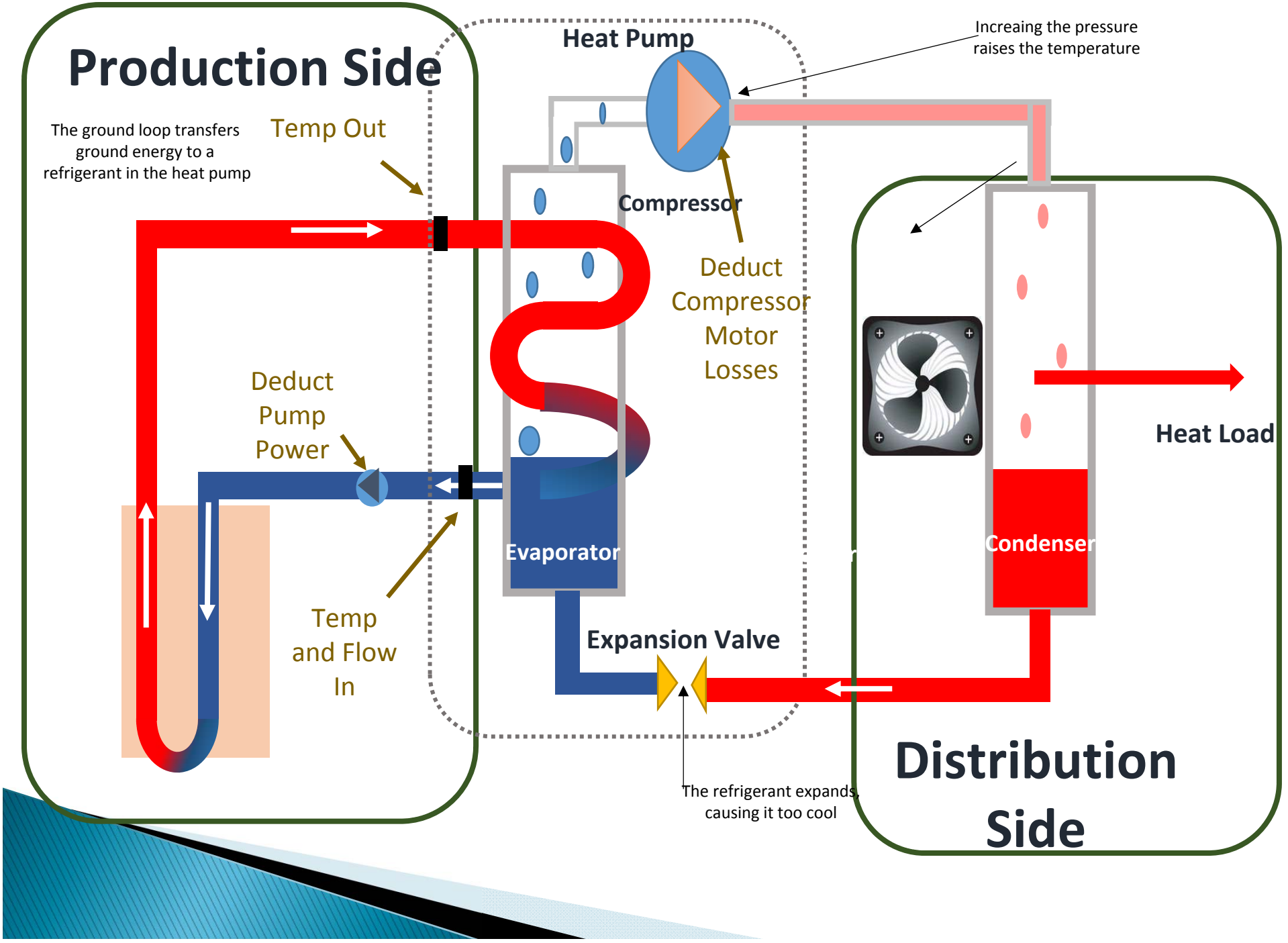
Geothermal Energy

Metering Methods and Options




Production Side
Heat Pump
Increaing the pressure raises the temperature
The ground loop transfers ground energy to a refrigerant in the heat pump
Temp Out
Compressor
Deduct Compressor Motor Losses
Deduct Pump Power
Heat Load
Evaporator
Condenser
Temp and Flow In
Expansion Valve
The refrigerant expands, causing it too cool
Distribution Side

Thermal Metering Production

- Continuous Metering – Ground Loop
  - Temperature sensors installed close to Heat pump HX (loop inflow and outflow)
  - Flow meter near ground loop inflow/outflow to HX
  - Accuracy to **match** EN1434 (ASTM Standard in progress)
- Thermal Generation formula

Q_g = m*cp (To –Ti) in heating mode, m*cp (Ti –To) in cooling mode
Q_g = heat generated/extracted in the ground loop (BTU)
m = mass flow measured near the inlet to the heat pump heat exchanger (lbs/hour)
cp = specific heat of the working fluid (Btu/lb-F)
Ti = ground loop inlet temperature measured near the heat pump heat exchanger (F)
To = collector loop outlet temperature measured near the heat pump heat exchanger (F)

Thermal Metering Adjustments

- Coefficient for Ground Loop Pumping Power
  - Coefficient determines pump energy consumed to produce geothermal energy
  - Method relies on onsite performance test
- Pump Energy Coefficient formula

$dE_p/dQ = V_m * A_m * t / Q_g$

dE_p/dQ = Rate of Energy consumed by ground loop pump per unit of heat generated (Wh/BTU)

V_m = measured voltage at the pump terminals (Volts)

A_m = measured current flow to the pump averaged for the test period (Amps)

Q_g = heat generated/extracted in the ground loop for the test period (BTU)

t = total time in the test period (hours)

Thermal Metering Adjustments

- Coefficient for compressor motor losses
  - Compressor work necessary to raise (lower in cooling mode) heat exchange fluid to effective HX temperature
  - Coefficient determines geothermal share of motor losses
- Motor Loss Allocation formula

F_{cl} = Qg/Qt = (COP−1)/COP = ratio of ground loop heat input (or extraction) to the total heat pump useful heat generated (or extracted)

COP = Qt/Qe = ratio of total heat input to the thermal equivalent of heat pump electrical energy input measured at AHRI standard certification conditions.
COP = EER/3.412 for the cooling season where EER is measured at AHRI standard certification conditions

Thermal Metering Adjustments

- Motor Loss Coefficient formula

$dE_{cl}/dQ = V_m * A_m * t * f_{me} / Qg * F_{cl}$

dE_{cl}/dQ = Rate of electrical and mechanical energy lost by heat pump compressor motor per unit of heat generated (or extracted) by the ground loop (Wh/BTU)

V_m = measured voltage at the compressor motor terminals (Volts)

A_m = measured current flow to the compressor motor averaged for the test period (Amps)

t = total time in the test period (hours)

Q_g = heat generated/extracted in the ground loop for the test period (BTU)

f_{me} = compressor motor energy loss factor (shaft mechanical and electric)

F_{cl} = factor for allocation of compressor electrical and mechanical losses to ground loop generation.

Thermal Metering – Net Useful Energy

- Net Useful Geothermal energy delivered to distribution
  - Gross production continuously metered
  - Pump and Compressor corrections to determine energy to distribution interface
- General Equation for Net Useful Thermal Energy

$Q_u(net) = Q_g - Q_g*dEp/dQ*k - \Sigma_{heating}\ Q_g*dE_{cl}/dQ*k - \Sigma_{cooling}\ Q_g*dE_{cl}/dQ*k$

$Q_u(net)$ = Net useful thermal energy delivered (BTU)

Q_g = useful energy generated/extracted in the ground loop (BTU) in each season

dE_p/dQ= Rate of Energy consumed by ground loop pump per unit of heat generated (Wh/BTU)

dE_{cl}/dQ = Rate of electrical and mechanical energy lost by heat pump compressor per unit of heat generated by the ground loop (Wh/BTU)

k = 3.412 BTU/Wh direct conversion factor

Exceptions and Additions

- Hybrid Air and Geothermal Systems will likely require adjustments for the air heat exchange operation