Heat Pump Systems with Heat Exchange to Liquid and Air

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Agenda

• Heat Pump System Overview
• Challenges to Modeling
• Cooling Mode Model and Results
• Heating Mode Model and Results
• Conclusions
Heat Pump Product Overview

- Compressor
  - Single Speed
  - Multiple Voltage
- Air to Refrigerant HX
- Round Tube – Fin Coil
- Water to Refrigerant HX
  - Tube-in-Tube Type
- 4 way valve
- TXV
- Blower
- Controller
- Switch heating and cooling mode
- Air to Refrigerant HX
  - Round Tube – Fin Coil
Typical Applications

- **Geothermal**
  - Tower
Heat Pump Model Layout

Compressor –
Single Speed
Multiple voltage motors available
- 230 Volt Single Phase
- 230 Volt Three Phase
- 460 Volt Three Phase

Tube in Tube HX
‘COAX’

4 way reversing valve

Water
Refrigerant

Counter flow in Cooling Mode
Parallel flow in Heating Mode
Air to Ref Heat Exchanger

Multi-Circuit –
Round tube expanded into plate fin

54 tubes
7 circuits

In cooling mode
red numbered tubes are the inlets
blue numbered tubes are the outlets

In heating mode (flow is reversed)
red numbered tubes are the outlets
blue numbered tubes are the inlets

Hard to model in GT Power
Could model each tube -> solving time
Broke into 9 equal segments for air flow

Had test data from a coil
with 10 equal segments
Evaporator Only Results

Changes in refrigerant inlet quality and mass flow
Test 1 – EWT of 59 F
Test 2 – EWT of 77 F
Test 3 – EWT of 86 F

Changes in humidity
Test 4 – RH of 80% (lower DB)
Test 5 – RH of 30% (lower WB)

Changes in air flow rate
Test 6 – Increase air flow by 25%
Test 7 – Decrease air flow by 25%

Largest area of concern
Reproducibility more than 5%
Expansion Device - TXV

At low entering water temperature, the pressure difference is very low and the valve maximum open area is not enough to compensate for the demand for increased mass flow.

\[ \dot{m} = C \times A \times \sqrt{\rho_{\text{liq}} \times (P_{\text{discharge}} - P_{\text{suction}})} \]

**Challenge in modeling**
Determine when the TXV switches from fixed superheat control to acting as a fixed orifice.
Cooling Test Matrix

5 variables for ‘Extended Range’ Testing

Baseline Condition
- Water inlet 86 F
- Air inlet 80 F Dry Bulb/66 F Wet Bulb (47% RH)

Enter Water Temp (EWT) – 7 pts
- 30 to 120 F

Dry bulb (DB) – 3 pts
- 70 to 85 F

Wet bulb (WB) – 3 pts
- 60 to 75 F

Air Flow – 2 pts
- nominal 400 cfm/ton

Water Flow – 2 pts
- nominal 3 gpm/ton

- Evaporator Load vs EWT
- Evaporator Load vs Inlet RH (%)
- Evaporator Load vs Air Flow

Test with 15% methanol
Cooling Model Preparation

- Goal is to test 7 points, build an accurate model and then simulate 18 extended range points
- Test limits on
  - Refrigerant mass flow, inlet quality to the evaporator
  - Water volume flow
  - Compressor pressure ratio for mass flow and power consumption
  - Air volume flow and humidity

ISO Points (3 tests)

4 additional tests
- Test 4. High cfm
- Test 5. Low cfm
- Test 6. Hot water and low gpm
  - Highest pressure ratio
  - Run dry (low WB)
- Test 7. Cold water at high gpm
  - Lowest pressure ratio
  - Run wet (low DB)

Find limit of TXV

Individual components are calibrated from the 7 data points
Charge determination done on the 3 ISO Points – set subcooling, calculate charge, average between the 3 points
Cooling Modeling Results

Influence of Entering Water Temperature

Evaporator Load vs EWT

Power Draw vs EWT

Deviation in mass flow – especially at higher pressure ratios

Learned after data analysis
- Extended Range Testing done with 208 Volt 1 phase motor
- Calibration done later with 460 Volt 3 phase motor
Cooling Modeling Results

Influence of humidity

Poor calibration of humidity
A proper circuiting model for the air to refrigerant HX may be the root cause
Heating Mode Test Matrix

4 variables in ‘extended range’ testing

Baseline Condition
Water inlet 68 F
Air inlet 68 F Dry Bulb

Enter Water Temp (EWT) – 6 pts 25 to 110 F
Dry bulb (DB) – 3 pts 64 to 77 F
Air Flow – 2 pts nominal 400 cfm/ton
Water Flow – 2 pts nominal 3 gpm/ton

Flow through expansion valve is reversed
Heating Specific Model

Uses the 4 way valve template of GT Power
Switched the water flow to negative in GT Power (now parallel instead of counter flow)
Switched the air flow to negative in GT Power
Manually tuned the charge and two phase enhancements to meet the ISO conditions

Data suggests requirement of
- recreating of heat exchanger models in heating mode
- update of the TXV limitations in reverse flow
Conclusion

• Many difficulties exist in building a WSHP System Model

• Component variation may be the source of current modeling errors

• Improved round tube plate fin models for the air to refrigerant HX may assist in achieving greater simulation accuracy

The presenter would like to thank Dr. Yongfang Zhong at Gamma Technologies for her assistance in building and troubleshooting the various models.