



Energy Trust of Oregon, Inc.

BSUG – April 15, 2009

Building Simulation Users' Group

Sponsors

- **The Energy Trust - Funding**
- **NW Natural – Space & AV**
- **ODOE – Technical Input**
- **BPA – Outreach**
- **NEEA - Outreach**
- **ASHRAE - PDHs for P.E.s & CEMs**
- **Members – Substance**

Building Simulation Users' Group

Fourth Year

- **35 sessions – one weather cancellation**
- **April 2006: 38 members**
- **April 2009: 343 members**
- **April 2006: 32 Attendees**
- **April 2009: 114 attendees up as of Monday**
- **April 2009: 153 organizations**

Building Simulation Users' Group

BSUG MEMBERSHIP		
130	38%	Engineer
70	20%	Analyst
37	11%	Conservation Administrator
32	9%	Architect
29	8%	Unknown
6	2%	Contractor
9	3%	Designer
6	2%	N/A
9	3%	Student
5	1%	Management
3	1%	Programmer
3	1%	Recruiter
2	1%	Facilities Operation
2	1%	Marketing
343	100%	Active Only

Building Simulation Users' Group

Volunteers

Growth in membership has not been paralleled by number of volunteers



Building Simulation Users' Group

Today's Discussion

Variable-Refrigerant Volume/Flow (VRV/VRF) Systems

**Mark Denyer, P.E., LEED™ AP, Associate,
MFIA, Inc. Consulting Engineers**

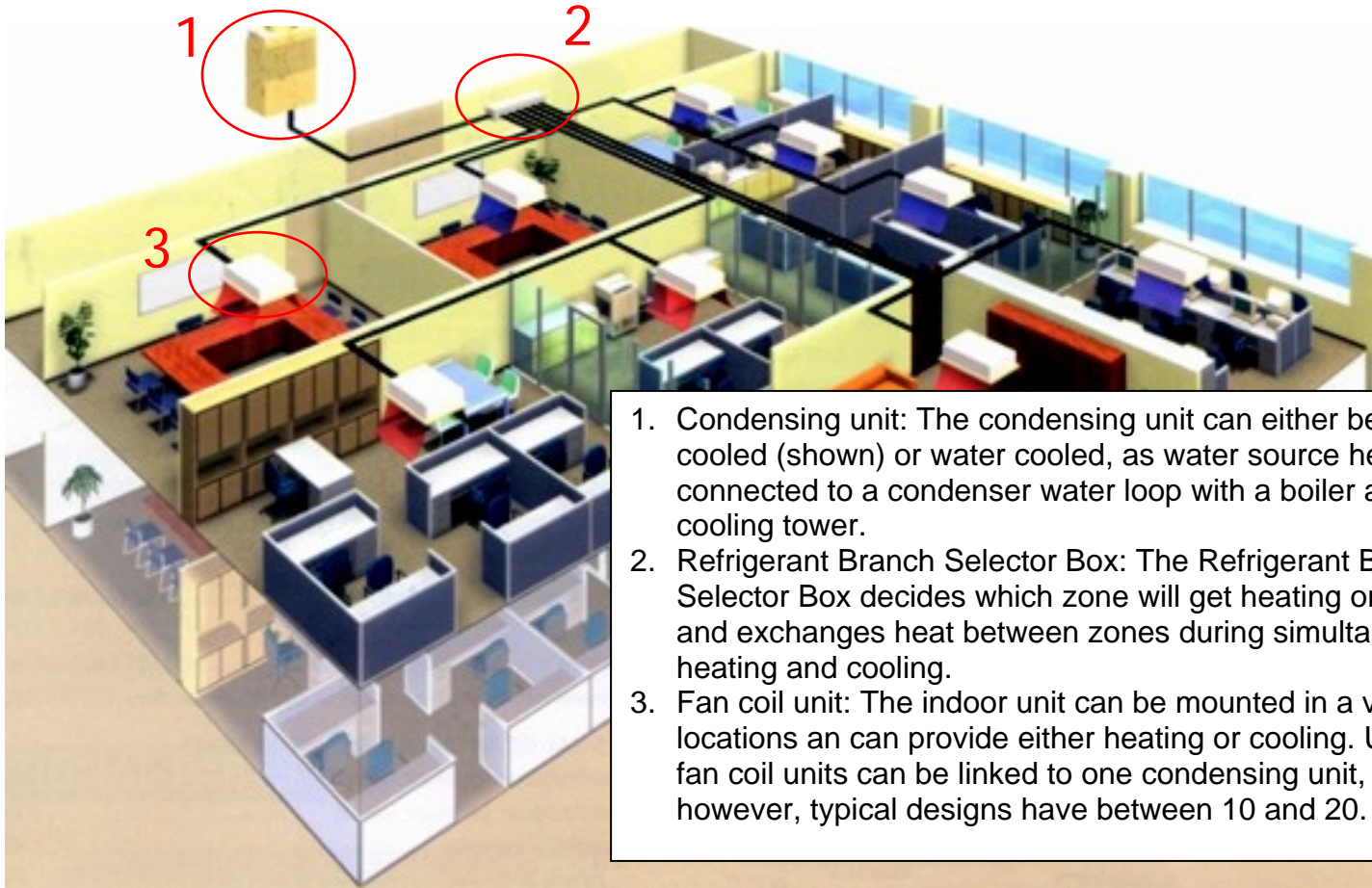
**Dana Troy, LEED™ AP, Energy Analyst,
Glumac**

Variable Refrigerant Flow Systems

What is VRF/VRV and how does it work?

- Variable refrigerant flow/volume.
- Works as a split system heat pump with local air movement.
- Multiple indoor units linked to one condenser, either air cooled or water cooled.
- The system controls the amount of refrigerant flowing to each of the indoor units.
- The Refrigerant Branch Selector Box connects all of the indoor units and allows each unit to "exchange" heat with one another. Any heat that needs to be added or rejected is then provided by the condensing unit.

Variable Refrigerant Flow Systems



1. Condensing unit: The condensing unit can either be air-cooled (shown) or water cooled, as water source heat pump connected to a condenser water loop with a boiler and cooling tower.
2. Refrigerant Branch Selector Box: The Refrigerant Branch Selector Box decides which zone will get heating or cooling and exchanges heat between zones during simultaneous heating and cooling.
3. Fan coil unit: The indoor unit can be mounted in a variety of locations and can provide either heating or cooling. Up to 50 fan coil units can be linked to one condensing unit, however, typical designs have between 10 and 20.

Picture courtesy of Mitsubishi

Variable Refrigerant Flow Systems

Effective Building Types for VRV

1. Existing Buildings
 - a. Buildings with not enough room for cooling ductwork
 - b. Option for adding cooling to a hydronic heat replacement project
2. Core and Shell Projects
 - a. Very easy system to expand or modify
 - b. Cost effective option to water source heat pumps or HW/CW Fan Coils
3. Energy Efficiency Projects
 - a. Energy efficient option to standard VAV with reheat type projects
 - No energy penalty for reheat
 - Significant reduction of fan energy
 - Better zoning options than CV systems for buildings under 75,000 sq ft

Variable Refrigerant Flow Systems

Effective Building Types for VRV (Cont)

3. Energy Efficiency Projects (Cont)

b. Energy efficient option to standard DX split systems

- Significantly higher part load performance than typical split system condensing units and heat pumps
- Higher SEER/EER ratings due to digital DC compressors and condensing fans
- Allows for smaller condensing units due to load sharing with multiple indoor units.

4. Buildings with a high level of diversity

- Mixed-use projects where certain zones require cooling year round while other zones require heating.
- Restaurants - -dining areas vs. cooking areas

Variable Refrigerant Flow Systems

System capacities and efficiencies

- Each condenser can support up to 50 indoor units; however, in common design there is typically no more than 10 to 20 indoor units connected to one condensing unit.
- Each condensing unit has a maximum capacity of approximately 20 tons.
- ILPV values have been verified as high as 16.

Variable Refrigerant Flow Systems

How does ventilation work with VRF systems

- Very similar to two and four pipe fan coils, water source heat pumps, and other zonal systems.
- 100% OA make-up air unit can provide outside air either in series or parallel.
 - Series: The outside air is ducted directly to the fan coil. The fan is always on during scheduled hours in order to keep the ventilation air moving.
 - Parallel: The outside air is ducted directly into the room, apart from the fan coil. The fan coil can then be cycled on and off when the space temperatures can be maintained with the ventilation alone.

Variable Refrigerant Flow Systems

Oregon Installations

- Esquire Apartments/Restaurant (7 story historic building)
35,000 sf mixed use (restaurant and apartments) historic building
- NuMiss office Building (3 story C&S office – under construction)
18,250 square foot 3 story core and shell office
- Oregon Air Reps Office (Daikin demonstration project)
~5,000 sf general office
- Redmond High School (Under Preliminary Design)
260,000 sq ft of all inclusive high school
- Mercy Corps (Under construction)
80,000 sf office spaces, 4 stories, half existing, half addition
- The Allison Inn (Under construction)
140,000 sf hotel, 4 stories, new construction
- UW Tacoma Joy Building (DD phase)
50,000 sf college building, 3 stories, 100% remodel
- UW Tacoma Jefferson Avenue Building (DD phase)
40,000 sf college offices and library stacks, 4 stories, new construction

Variable Refrigerant Flow Systems

Oregon VRV System Distributers

- Daikin - Oregon Air Reps 503-620-4300
- LG - Johnson Air Products 503-234-5071
- Sanyo - Airefco 503-691-4320
- Mitsubishi - FE Company - Applied Equipment Sales 503-351-1379

Variable Refrigerant Flow Systems

Comparative Costs

- VRV = \$17.75/ sq ft
- VAV w/central chiller = \$22.50/ sq ft
- VAV packaged DX units = \$18.70/sq ft
- The above values were a cost estimate for preliminary design options for a New 260,000 square foot High School in Central Oregon.

Variable Refrigerant Flow Systems

Energy Savings – Modeled Results (Using Trace 700)

- Modeled results for a well designed building with a heat recovery ventilation unit show about a 33% savings when compared to a ASHRAE baseline building (CV DX systems) These results were based on the final LEED EA-1 model for the NuMiss Office building – a 18,250 square foot 3 story core and shell office.
- Modeled results show about a 12.5% savings when comparing a VRV to Packaged DX CV systems. These results were simulated by taking the above office energy model of the proposed building and running the simulation with packaged DX in place of the VRV system that was designed.
- Modeled results have shown up to 40% to 45% savings when using a VRV with ventilation heat recovery for a remodeled mixed-use type building. These results were based on the final LEED EA-1 model for the Esquire Apartments - - a 35,000 square foot mixed use (restaurant and apartments) historic building.

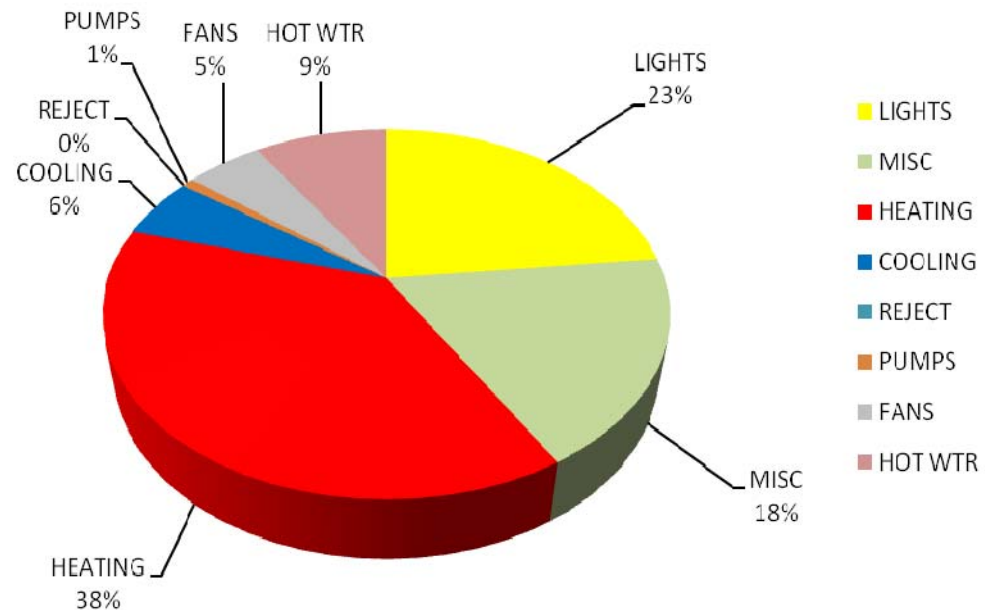
Variable Refrigerant Flow Systems

Energy Savings – Modeled Results (Using eQUEST)

Modeled results for a well designed building with a heat recovery ventilation unit show about a 10-20% total building energy savings when compared to a ASHRAE baseline HVAC system.

The total HVAC energy costs are about 50% of the total building energy use (fans, pumps, cooling, and heating). Therefore, if the HVAC savings is 100%, the total building energy savings is only 50%.

A 10-20% total building energy savings is actually a 20-40% savings in HVAC energy use.



Variable Refrigerant Flow Systems

Modeling VRV with TRACE

- Baseline Algorithms
 - TRACE can explicitly model VRV, both heat recovery and non-heat recovery options.
 - Algorithms based on Daikin empirical model
 - Baseline equipment based on first generation Daikin VRV
 - Equipment easily modified to match current generation equipment or any other manufacturer.
 - The following slide provides a description of the program's and modeler's approach to the system (from TRACE programmers).
- Modeling Inputs
 - Enter Heating and Cooling compressor COP or KW/ton
 - Enter Condensing Fan power consumption KW/ton
 - Select unloading curve, compressor power consumption curve, condensing fan curve and cycling point as appropriate.

Variable Refrigerant Flow Systems

TRACE programming information

Basis of the TRACE model: Daikin empirical model

Airside simulation:

Similar to a water source heat pump, when the room drift temperature rises above the cooling thermostat, the cooling coil is engaged at a constant cooling supply air temperature for the a percentage of the hour that it takes to bring the room temperature down to the cooling thermostat temperature. This heat is rejected to the refrigerant condenser loop. For the portion of the hour that the cooling coil is de-energized, the supply air will remain at the return/outside air dry bulb temperature (plus fan heat).

When the room drift temperature drops below the heating thermostat, the heating coil is engaged at a constant heating supply air temperature for the a percentage of the hour that it takes to bring the room temperature up to the heating thermostat temperature. The indoor unit will remove heat from the refrigerant condenser loop. For the portion of the hour that the cooling coil is de-energized, the supply air will remain at the return/outside air dry bulb temperature (plus fan heat).

Although the system default reheat minimum will be set to 10%, the user can change it on a room by room basis if they want. This minimum airflow is only used during the part of the hour in which neither heating nor cooling coils are active.

Variable Refrigerant Flow Systems

The screenshot shows the 'Cooling Equipment -- Main' configuration window in the TRANE software. The window includes a menu bar (File, View, Options, Window, Help), a toolbar with various icons, and a TRANE logo. The main configuration area contains several dropdown menus and text fields:

- Cooling category:** Air-cooled unitary
- Equipment type:** VRV III 20 ton (MFIA)
- Cooling type:** Air to air heat pump
- Comments:** Based on 20 ton Daikin-MFIA - 10% cycling

Buttons for 'Save', 'Close', 'New', and 'Curves...' are visible on the right side of the window.

Operating Mode	Capacity	Energy Rate
Cooling	tons	4.396 COP
Heat Recovery	13.5 Mbh/ton	4.946 COP
Tank Charging		
Tank Charging & heat recovery		

Pumps	Type
Primary chilled water	None
Condenser water	None
Heat recovery or aux condenser	None

The 'Unloading Curves' section includes:

- Curve type...** with radio buttons for 'Standard' (selected) and 'DOE'.
- Power consumed:** Primary (CVHE FREQ DRIVE), Secondary (CVHE FREQ DRIVE)
- Ambient modification:** Primary (VRV Cooling Amb Relief), Secondary (VRV Heating Amb Relief)
- Capacity:** Primary and Secondary dropdown menus.

At the bottom of the window, there are tabs for 'Main', 'Options', and 'Graph', and a status bar with the text 'For Help, press F1' and a 'NUM' button.

Trace Equipment Library definitions
 Note: the defined COPs, Heating Capacities and associated equipment power curves.

Variable Refrigerant Flow Systems

Library / Template Editors -

File View Options Window Help

TRANE®

Cooling Equipment -- Options

Max chilled water reset: 0 °F

Load shedding economizer: No

Fuel source: Utility

Fuel type: Electric

Evaporative precooling: No

Evap precool effectiveness: 60 %

Thermal storage type: None

Heat rejection type: VRV III 20 ton Condensing fan

Chilled water temp. Design leaving: 44 °F

Difference: 10 °F

Condenser temp. Design entering: 95 °F

Minimum operating: 0 °F

Reject condenser heat To reference type: Heating plant

At hot water temp. °F

Free Cooling

Type: None

Fluid cooler type:

Free cooling pump: None

Pump head: 0 kW

Plate and frame heat exchanger approach: 3 °F

Miscellaneous accessories	
1	Cntl panel & interlocks - 0.1 KW
2	
3	
4	
5	
6	

Main Options Graph

For Help, press F1

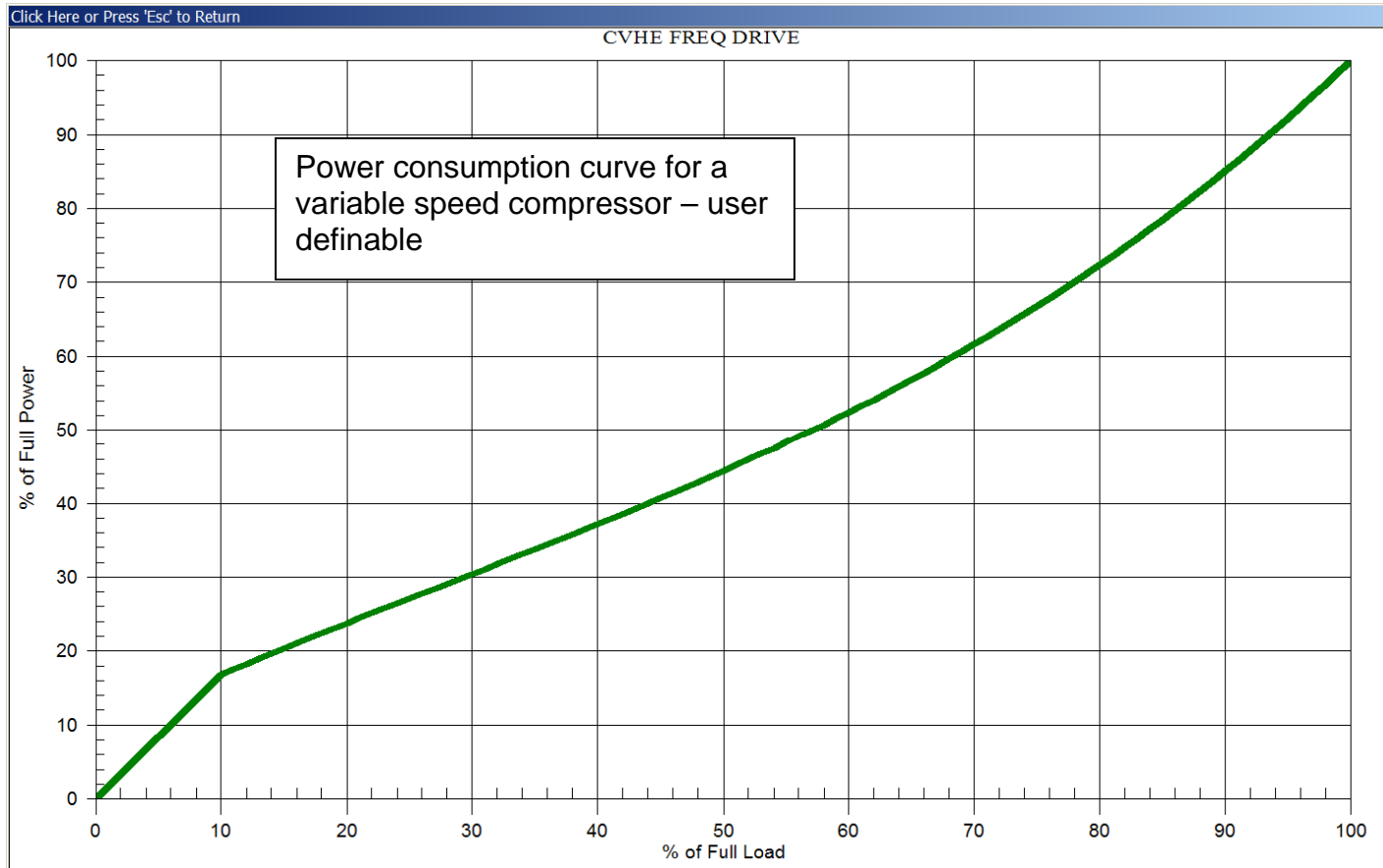
NUM

Heat pump operating temperatures

Trace definition of a heat pump

Power consuming accessories

Variable Refrigerant Flow Systems



Variable Refrigerant Flow Systems

Power consumption rate and curve for a variable speed condensing fan – user definable

The screenshot shows the TRANE Heat Rejection Library software interface. The window title is "Library / Template Editors -". The menu bar includes "File", "View", "Options", "Window", and "Help". The toolbar contains various icons for file operations and editing. The main area is titled "Heat Rejection Library" and contains several sections:

- Equipment type:** VRV III 20 ton Condensing fan
- Comments:** (empty)
- Capacity:** 100 Percent
- Energy consumption:** 0.075 kW/ton
- Fluid type:** Refrigerant (Air-cooled)
- Heat rejection type:** Air-cooled condenser
- Number of cells:** 1
- Optional Two-Speed Tower Fans:**
 - Percent airflow at low speed: 0 %
 - Low speed energy consumption: 0 kW/ton
- Design Characteristics:**
 - Temperatures: Approach 10 °F, Range 10 °F, Dry bulb 78 °F
 - Flow rates: Design water 0 gpm/ton, Makeup water 0 gal/ton-hr
 - Hourly ambient WB offset: 0 °F
- Unloading curve:** Cooling Tower with VFD
- Graph:** Cooling Tower with VFD. The graph plots "% of Full Power" (y-axis, 0 to 100) against "% of Full Load" (x-axis, 0 to 100). A green curve shows the power consumption rate, which increases from 0% at 0% load to approximately 95% at 100% load.
- Assignment of Coil Loads:**
 - Main
 - Indirect evaporative
 - Optional ventilation
 - Direct evaporative
 - Auxiliary
 - Misc. cooling load

Buttons for "Save", "Close", "New", "Copy", "Delete", and "Curves..." are located on the right side of the window. The status bar at the bottom indicates "For Help, press F1" and "NUM".

Variable Refrigerant Flow Systems

Modeling the VRF in eQUEST: PVVT Water Source Heat Pumps

- Zone the building in the same manner as the design. This is very important for the energy sharing capabilities of the VRF system.
- We do not use this method for our energy models, but it is one way of approaching the system.
- eQUEST system: PVVT, with the condenser set to water cooled to activate a condenser water loop. Create one system per zone.
- Create separate condenser water loops for each VRF condenser and zero out the pump energy.
- Manipulate the fan efficiency ratio and the electric boiler EIR to reflect the efficiencies of the VRF units.

Variable Refrigerant Flow Systems

The screenshot displays the eQUEST software interface for a project named 'MERCY CORPUS PROPOSED.pd2'. The 'Plant Equipment' tab is active, showing three distinct condenser water loops. Each loop consists of a boiler (Boiler 5, 6, and 7), a heat rejection unit (Heat Rejection 5, 6, and 7), and multiple coils. The loops are labeled '2nd Floor Addition', '3rd Floor Existing', and '1st Floor Addition'. The left-hand pane shows a hierarchical tree of the project's components, including 'Global Parameters', '1st Floor Existing', '1st Floor Addition', and 'Thermal Zone(s)'. A text box is overlaid on the screenshot, providing instructions on how to configure these loops.

Create a separate condenser water loop for each VRF condensing unit. This ensures that separate loops do not share energy with one another. Zero out the pumping energy.

Variable Refrigerant Flow Systems

The screenshot displays the eQUEST software interface for a Variable Refrigerant Flow (VRF) system. The main window shows a schematic diagram of the system, including components like the Evap. or Desic., Pre Heat, Heat Pump, Supply Fan, Return Fan, Humid. stat., System Baseboards, Heat Recovery, and Outside Air Economizer. The system is connected to various zones. On the left, a project tree lists 19 zones, including MAU, Dummy Zn, and various office and service areas across multiple floors. On the right, there are three panels: 'Zone Assignments' with a list of zones and checkboxes, 'Zone Features' showing a zone terminal, thermostat, and meters, and 'Zone Locations' showing a floor plan with a red highlighted zone.

Project: 'Mercy Corps Design'
Global Parameters
MAU
Dummy Zn
1st Floor SW Learning Ce
1st Floor Core Restrooms
1st Floor N Service/Trash
1st Floor N Stairwell Zn
1st Floor S Stairwell Zn
2nd Floor NW Private Off
2nd Floor SW Office Conc
2nd Floor Core Mech Sha
2nd Floor Core Office Zn
2nd Floor N Open Office :
3rd Floor W Private Office
3rd Floor N Open Office Z
3rd Floor S Open Office Z
3rd Floor S Stairwell Zn
3rd Floor N Stairwell Zn
4th Floor Private Office Z
4th Floor Core Office Zn
4th Floor N Open Office Z
4th Floor N Stairwell Zn
4th Floor S Open Office Z
Basement Electrical Zn
Basement Locker Rooms :
Basement Stairwell 1 Zn
Basement Storage Zn
Basement Stairwell 2 Zn
1st Floor NW Retail Zn
3rd Floor Core Office Zn

Zone Assignments
 Dummy Zn
 1st Floor SW Learning Ce
 1st Floor Core Restrooms
 1st Floor N Service/Trash
 1st Floor N Stairwell Zn
 1st Floor S Stairwell Zn
 2nd Floor NW Private Off
 2nd Floor SW Office Conc
 2nd Floor Core Mech Sha
 2nd Floor Core Office Zn
 2nd Floor N Open Office :
 3rd Floor W Private Office
 3rd Floor N Open Office Z
 3rd Floor S Open Office Z
 3rd Floor S Stairwell Zn
 3rd Floor N Stairwell Zn

Zone Features
Zone Terminal
Thermostat
Meters
Zone Baseboards

Zone Locations

Create a PVVT systems for each conditioned zone.

Variable Refrigerant Flow Systems

Air-Side HVAC System Parameters [?] [X]

Currently Active System: **1** System Type: Pkgd Var Vol Var Temp

Basics | Fans | Outdoor Air | Cooling | Heating | Preconditioner | Meters | Refrigeration

Coil Cap / Control | Unitary Power | Preht / Basebrd | Supp Heat/Defrost | Cap Curves/Waste Ht | Stages

Heating Capacity Heating Control and Reset

Heat Source: **Heat Pump** **Change the heat source to heat pump, and...**

Zone Heat Source: **Not Installed**

Heating Capacity: [] Btu/h

Heat Sizing Ratio: **1.00** ratio

Min Cycling Part Load Ratio: **0.80** ratio

Hot Water Coil Head: [n/a] ft

Hot Water Coil Delta T: [n/a] °F

HW Valve Type: [n/a]

HW Loop: [n/a]

DHW Loop: [n/a]

Zone HW Loop: [n/a]

Hot Deck Max Leaving Temp: [] °F

Reheat Delta T: [n/a] °F

RPM Limits: Maximum: [n/a] rpm
Minimum: [n/a] rpm

Hot Deck Sched: [n/a]

Availability Sch: [- undefined -]

Heat Control: [n/a]

Heat Reset Sch: [n/a]

Minimum Heating Reset Temp: [n/a] °F

Heating Coil Wipe = f(cooling flow): [n/a]

Done

Variable Refrigerant Flow Systems

Air-Side HVAC System Parameters [?] [X]

Currently Active System: **1** System Type: Pkgd Var Vol Var Temp

Basics | Fans | Outdoor Air | **Cooling** | Heating | Preconditioner | Meters | Refrigeration

Coil Cap / Control | Unitary Power | **Condenser** | Cap Curves | Evap Cooling | Economizer | Stages

Air-Cooled Condenser & Outdoor Fan

Condenser Type: **Water Cooled**

Outside Fan Mode: **Intermittent**

Outside Fan Temperature: **45.0** °F

Evaporative Precooler

Evap Condenser Effectiveness: **n/a** Btu/Btu

Evap Cond Sched: **n/a**

Evap Condenser Electric: **n/a** W/Btu

Water-Cooled Condenser

Condenser Water Coil Head: **20.0** ft

Condenser Water Coil Delta T: **10.0** °F

Isolation Valve? **No**

CW Loop: **1st Floor Existing**

Done

...change the condenser type to Water Cooled and assign the CW loop the zones corresponding condenser loop. This will turn the PVVT system into a WSHP system. Be sure to label your zones in a way that identifies them with their condenser or Refrigerant Branch Selector Box. For example, on the drawings, the equipment will have names such as BC-1, BC-2, or CU-1, CU-2, etc. Give you systems a prefix that matches the CU. For example, if you have north office zone served by CU-1, call it 1 North Office, and give all other zones under that CU the same "1-" prefix. This will save you a lot of time later on for the hourly calculations.

Variable Refrigerant Flow Systems

Air-Side HVAC System Parameters

Currently Active System: 1 System Type: Pkgd Var Vol Var Temp

Basics | Fans | Outdoor Air | Cooling | Heating | Preconditioner | Meters | Refrigeration

Coil Cap / Control | Unitary Power | Condenser | Cap Curves | Evap Cooling | Economizer | Stages

Cooling Power

Cooling Electric Input Ratio: 0.2000 Btu/Btu

Cooling Compressor

Compressor Type: Single Speed

Minimum Unload Ratio: 0.10 ratio

Min Hot Gas Bypass Ratio: 0.10 ratio

Crankcase Power

Crankcase Heat: n/a kW

Crankcase Max Temperature: n/a °F

Cooling Electric Input Ratio Curves

f(t entering wetbulb, ...)

f(part l ...)

f(RPM) ...

Low Speed ...

f(t ente ...)

t out ...

Gas Heat Pump Auxiliary Electric

Gas HP Pump kW: n/a W/Btu

Gas HP Aux kW: n/a kW

Done

One of the benefits of the PVVT system is that you can set it to a variable speed compressor. Unfortunately, you cannot set it to variable speed if you have the system running as a WSHP.

Variable Refrigerant Flow Systems

Modeling the VRF in eQUEST: PVVT air cooled heat pumps

- eQUEST system: PVVT, modeled as air cooled heat pumps. Create one system per zone.
- Change the compressor speed to variable.
- Be sure to label each system and zone so you can identify which condenser each zone is connected to.
- Create hourly reports for the total energy uses for heating and cooling for each system. Use the spreadsheet to find the simultaneous heating and cooling performed for each system and sum the savings.

Variable Refrigerant Flow Systems

MERCY CORPS PROPOSED.pd2 - eQUEST Quick Energy Simulation Tool

File Edit View Mode Tools Help

Plant Equipment Spreadsheet Summary

Projects: 'Mercy Corps Design'

- Global Parameters
- Domestic Hot Water Loop
 - Domestic Water Heater
- Air-Side System(s)
- Thermal Zone(s)
- Performance Curves
 - DX-Cool-Cap-FRPM
 - DW-Elec-EIR-FPLR
 - HP-Heat-EIR-FPLR
 - Variable Speed Drive FPLR
 - PWVT-Cool-EIR-FEWB&OA
 - PWVT-Heat-EIR-FEDB&OA
 - PWVT-Cool-EIR-FPLR
 - DX-Cool-Cap-FEWB&OAT
 - DX-Cool-EIR-FEWB&OAT
 - DX-Cool-EIR-FPLR
 - DX-Sens-Cap-FEWB&OAT
 - DX-Bypass-Factor-fAirFlo
 - DX-Bypass-Factor-FEWB&OAT
 - Furnace-HIR-FPLR
 - DX-Bypass-Factor-FPLR
 - DX-Cool-CycleLoss-FPLR
 - HeatWheel-EIR-fSpeed
 - DX-Heat-EIR-FPLR
 - PWVT-Cool-Cap-FEWB&OAT
 - PWVT-Sens-Cap-FEWB&OAT
 - PWVT-Bypass-Factor-fAirFlo
 - PWVT-Bypass-Factor-FEWB&OAT
 - Defrost-ResisTime-Frac-f
 - DX-Cool-CondFan-FPLR&C
 - DX-Heat-EIR-FRPM&OAT
 - DX-Heat-CondFan-FPLR&C
 - DX-Heat-CycleLoss-FPLR
 - DX-Cool-Cap-FRPM&OAT
 - DX-Heat-Cap-FRPM&OAT
- Electric Meters
 - EM1
- Fuel Meters
 - FM1
- Steam Meters
- CHW Meters
- Electric Generators
- Heat Exchangers
- Equipment Controls
- Load Management
- Air-Side System(s)
 - MAU
 - 2 - 1
 - 2 - 2
 - 2 - 3

Ready

NUM

No more condensing water loops!

Domestic Water Heater

Domestic Hot Water Loop

Variable Refrigerant Flow Systems

Air-Side HVAC System Parameters

Currently Active System: **2 - 1** System Type: Pkgd Var Vol Var Temp

Basics | Fans | Outdoor Air | Cooling | Heating | Preconditioner | Meters | Refrigeration

System Name: **2 - 1**
System Type: **Pkgd Var Vol Var Temp**

General Parameters

Return Air Path: **Direct**
Control Zone: **1st Floor SW Learning C**
System Reports: **Yes**
Dual Duct Type: **n/a**
WL/GS Ht Pump: **No**

System Sizing

Sizing Ratio: **1.00** ratio
Sizing Option: **Non Coincident**

Duct Losses

Duct Air Loss: ratio
Duct Air Loss OA: **n/a** ratio
Duct Zone: **n/a**

Hot Duct UA: **n/a** Btu/h-°F
Hot Duct DT: **n/a** °F

Humidity Control

Maximum Humidity: **100.0** %
Minimum Humidity: **0.0** %
Humidifier Type: **n/a**
Humidifier Location: **n/a**

Done

Again, use the PVVT system and create one system per conditioned zone.

Variable Refrigerant Flow Systems

Air-Side HVAC System Parameters

Currently Active System: 2 - 1 System Type: Pkgd Var Vol Var Temp

Basics Fans Outdoor Air Cooling Heating Preconditioner Meters Refrigeration

Coil Cap / Control Unitary Power Condenser Cap Curves Evap Cooling Economizer Stages

Cooling Power _____

Cooling Electric Input Ratio: 0.3150 Btu/Btu

Cooling Compressor _____

Compressor Type: Variable Speed

Minimum Unload Ratio: 0.15 ratio

Min Hot Gas Bypass Ratio: 0.15 ratio

Crankcase Power _____

Crankcase Heat: 0.050 kW

Crankcase Max Temperature: 50.0 °F

Gas Heat Pump Auxiliary Electric _____

Gas HP Pump kW: n/a W/Btu

Gas HP Aux kW: n/a kW

Done

You can now change the compressor type to Variable Speed since it is an air cooled condenser. Essentially, we are modeling each zone as having its own split system air cooled heat pump. The main difference between the VRF is that 10 to 20 zones are served one condenser instead of just one.

Variable Refrigerant Flow Systems

Air-Side HVAC System Parameters

Currently Active System: 2 - 1 System Type: Pkgd Var Vol Var Temp

Basics Fans Outdoor Air Cooling Heating Preconditioner Meters Refrigeration

Coil Cap / Control Unitary Power Condenser Cap Curves Evap Cooling Economizer Stages

Air-Cooled Condenser & Outdoor Fan

Condenser Type: Air Cooled

Outside Fan Mode: Intermittent

Outside Fan Temperature: 45.0 °F

Outside Fan Electric: W/Btu

Outdoor Fan Pwr = f(cool PLR, osa db): DX-Cool-CondFan-fPL

Outdoor Fan Pwr = f(heat PLR, osa db): DX-Heat-CondFan-fPL

Evaporative Processor

Evap Cond Sched: n/a

Evap Condenser Electric: n/a W/Btu

Water-Cooled Condenser

Condenser Water Coil Head: n/a ft

Condenser Water Coil Delta T: n/a °F

Isolation Valve? Yes

CW Loop: n/a

Done

The condenser type is set at Air Cooled.

Variable Refrigerant Flow Systems

Air-Side HVAC System Parameters [?] [X]

Currently Active System: **2 - 1** System Type: Pkgd Var Vol Var Temp

Basics | Fans | **Outdoor Air** | Cooling | Heating | Preconditioner | Meters | Refrigeration

Outside Air and Economizer | Heat Recovery 1 | Heat Recovery 2 | Natural Ventilation

Outdoor Ventilation Air

Minimum Outside Air: ratio

Minimum OA Control Method: **Fraction of Design Flow**

Minimum OA Sizing Method: **Sum of Zone OA**

Minimum Air Schedule: **- undefined -**

Outside Air from System: **MAU**

Air-Side Economizer Cycle

Outside Air Control: **OA Temperature** Lockout Compressor: **No**

Drybulb High Limit: **65.0** °F Economizer Low Limit: °F

Enthalpy High Limit: Btu Maximum OA Fraction: **1.00** ratio

Done

Note: A red circle highlights the 'Minimum OA Control Method', 'Minimum OA Sizing Method', and 'Outside Air from System' fields.

Depending on the design, you can set the OA supply to "Outside Air from System". If untempered air is ducted directly to the fan coils, you can just assign the OA the standard way.

Variable Refrigerant Flow Systems

Schedule Properties

Annual Schedules | Week Schedules | Day Schedules

Currently Active Day Schedule: Office Fan Day Type: On/Off Flag

Day Schedule Name: Office Fan Day Type: On/Off Flag

Hourly Values

Mdnt - 1:	0	8-9 am:	0	4-5
1-2 am:	0	9-10 am:	0	5-6
2-3 am:	0	10-11 am:	0	6-7
3-4 am:	0	11-noon:	0	7-8
4-5 am:	0	noon-1:	0	8-9
5-6 am:	0	1-2 pm:	0	9-10
6-7 am:	0	2-3 pm:	0	10-11
7-8 am:	0	3-4 pm:	0	11-M

Air-Side HVAC System Parameters

Currently Active System: 2 - 1 System Type: Pkgd Var Vol Var Temp

Basics | Fans | Outdoor Air | Cooling | Heating | Preconditioner | Meters | Refrigeration

Fan Power and Control | Flow Parameters | Night Cycle Control

Night Venting

Night Vent Control: Not Available

Night Vent Schedule: n/a

Vent Temperature Sch: n/a

Night Vent Delta T: n/a °F

Night Vent Ratios

Supply CFM:	n/a	Return CFM:	n/a
Supply kW:	n/a	Return kW:	n/a
Supply dT:	n/a	Return dT:	n/a

Night Cycle Fan Control

Night Cycle Control: Cycle On Any

Night Cycle Fans: n/a

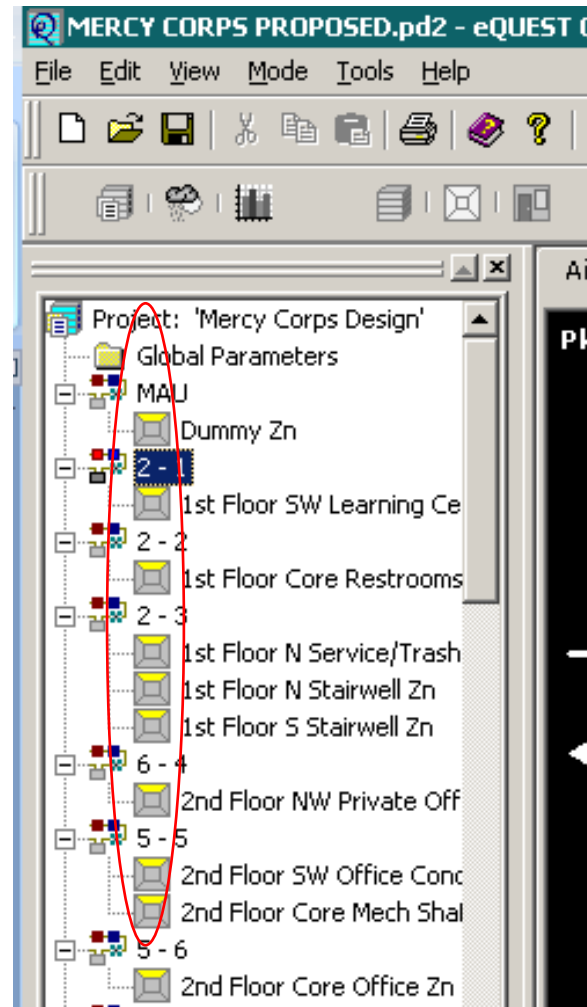
Done

This model has OA running in Parallel, so we set the fan control to be "off" for all hours of the day, but changed the Night Cycle Control to "Cycle On Any", which turns the fans on and off to meet set points. The design must include these controls to incorporate these changes in the model.

Variable Refrigerant Flow Systems

Here is a closer look at the naming of the systems. We named each system 1, 2, 3, etc and put the CU prefix before it. Most of these systems are linked to one another, so we created each system in the INP file, saving a couple of hours.

Note that the MAU has to be before any of the systems that reference it. DOE-2 is a top-down type code.



Variable Refrigerant Flow Systems

Create an hourly report. Note that each hourly report can only hold a finite amount of hourly outputs. We had to create two hourly reports to get all of the data we needed.

Create a separate block for each of the VRF (PVVT) systems you have defined in eQUEST and give them the same name, but slightly difference in case eQUEST gets confused with the naming.

Each block should have two series, Elec input to heat (kW and Elec input to cool (kW). Each data output cell will be in kWh.

Hourly Results Selection

Select Report or Block to View/Edit:

- HR1
 - 2-1**
 - 2-2
 - 2-3
 - 8-18
 - 3-17
 - 11-16
 - 11-15
 - 10-14
 - 10-13
 - 10-12
 - 10-11
 - 8-10
 - 8-9
 - 8-8
 - 5-7
 - 5-6
 - 5-5
 - 6-4
 - 1-20
- HR2
 - 9-28
 - 9-29

Report Block Name: 2-1

Variable Type: HVAC System

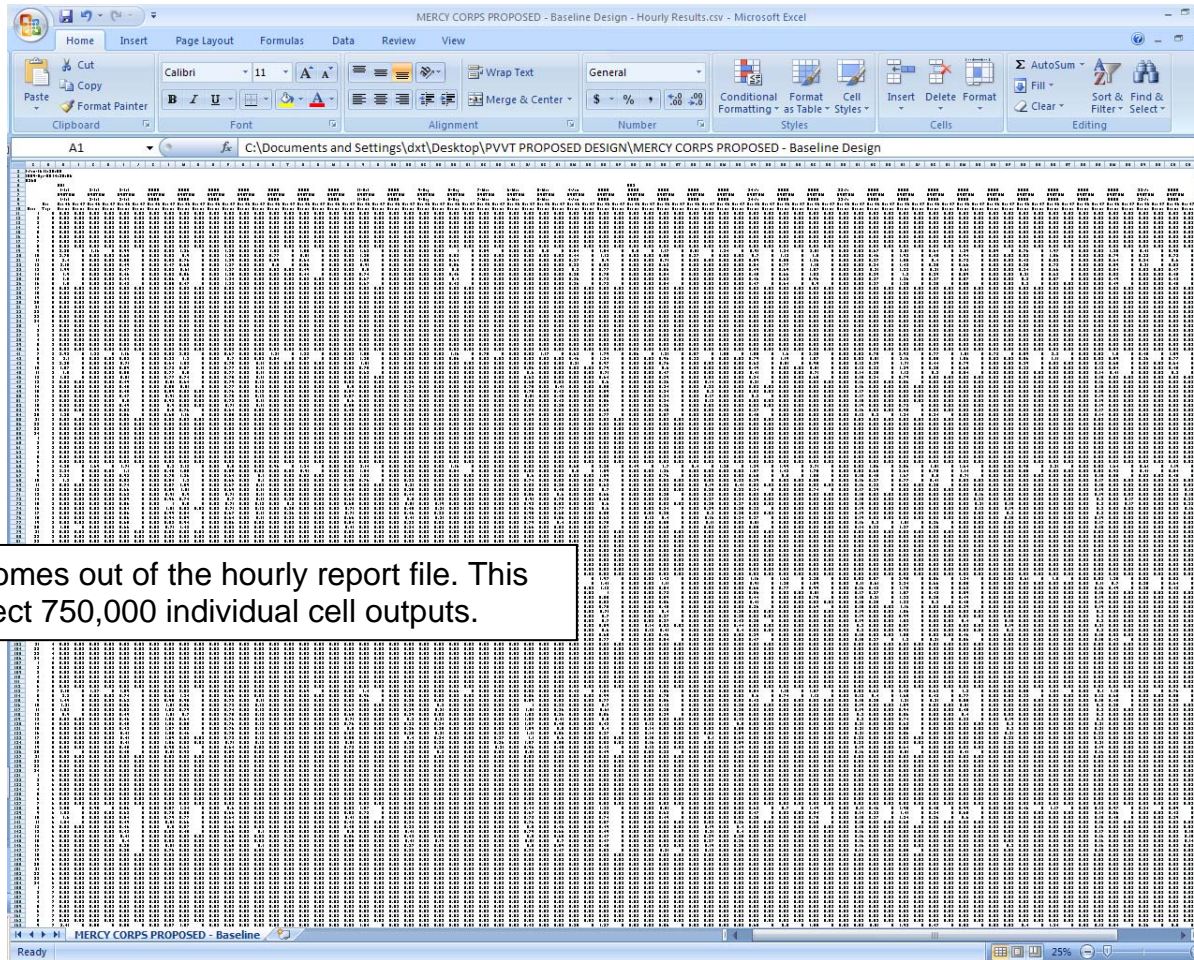
Building Component: 2 - 1

Selected Hourly Results Series:

- Elec input to heat (kW)
- Elec input to cool (kW)
-
- Temp of air leaving heat coil - hot deck temp (deg
- Temp of air leaving cool coil - cold deck temp (deg
- Temp of air entering coil (deg F)
- Return air temp on downstream side of ret fan and
- Total central heat coil output (Btu/hr)
- Total central cool coil output (Btu/hr)
- Total zone heat coil output (Btu/hr)
- Total zone cool coil output (Btu/hr)
- Total baseboard heat coil output (Btu/hr)
- Total preheat coil output (Btu/hr)
- Humidification heat output (Btu/hr)
- Dehumidification reheat heat output (Btu/hr)
- Minimum temp air handler could supply (deg F)
- Maximum temp air handler could supply (deg F)
- Total SPACE latent heat load from LOADS (Btu/hr)
- Total SPACE light heat to return (Btu/hr)

New Report New Block Del Block Done

Variable Refrigerant Flow Systems



A lot of data comes out of the hourly report file. This particular project 750,000 individual cell outputs.

Variable Refrigerant Flow Systems

The screenshot shows an Excel spreadsheet with the following data structure:

	A	B	C	L	M	N	O	P	Q	R	S	T	U	V	W	X	Y	Z	AA
1				1	1	1	1	1				2	2	2	2	2	2		
2	1	1	1	0.025	0.025	0.025	0.025	0.15	0.15	0.15		0.025	0.025	0.025	0.025	0.025	0.025	0.075	0.075
3	1	1	2	0.025	0.025	0.025	0.025	0.15	0.15	0.15		0.025	0.025	0.025	0.025	0.025	0.025	0.075	0.075
4	1	1	3	0.025	0.025	0.025	0.025	0.15	0.15	0.15		0.025	0.025	0.025	0.025	0.025	0.025	0.075	0.075
5	1	1	4	0.025	0.025	0.025	0.025	0.15	0.15	0.15		0.025	0.025	0.025	0.025	0.025	0.025	0.075	0.075
6	1	1	5	0.025	0.025	0.025	0.025	0.15	0.15	0.15		0.025	0.025	0.025	0.025	0.025	0.025	0.075	0.075
7	1	1	6	0.025	0.025	0.025	0.025	0.15	0.15	0.15		0.025	0.025	0.025	0.025	0.025	0.025	0.075	0.075
8	1	1	7	0.025	0.025	0.025	0.025	0.15	0.15	0.15		0.025	0.025	0.025	0.025	0.025	0.025	0.075	0.075
9	1	1	8	0.025	0.025	0.025	0.025	0.15	0.15	0.15		0.025	0.025	0.025	0.025	0.025	0.025	0.075	0.075
10	1	1	9	1.497	0	1.054	0	8.241	0	0		2.437	0	0.889	0	0.854	0	4.18	0
11	1	1	10	0.831	0	0.656	0	6.145	0	0		2.353	0	0.025	0.025	0.597	0	2.975	0.025
12	1	1	11	0.655	0	0.525	0	4.842	0	0		1.912	0	0.025	0.025	0.462	0	2.399	0.025
13	1	1	12	0.586	0	0.464	0	4.341	0	0		1.734	0	0.025	0.025	0.408	0	2.167	0.025
14	1	1	13	0.536	0	0.415	0	3.967	0	0		1.578	0	0.025	0.025	0.374	0	1.977	0.025
15	1	1	14	0.499	0	0.396	0	3.806	0	0		1.51	0	0.025	0.025	0.358	0	1.893	0.025
16	1	1	15	0.463	0	0.374	0	3.615	0	0		1.429	0	0.025	0.025	0.337	0	1.791	0.025
17	1	1	16	0.025	0.025	0.374	0	3.15	0.025	0.025		1.433	0	0.025	0.025	0.325	0	1.783	0.025
18	1	1	17	0.025	0.025	0.025	0.025	0.15	0.15	0.15		0.025	0.025	0.025	0.025	0.025	0.025	0.075	0.075
19	1	1	18	0.025	0.025	0.025	0.025	0.15	0.15	0.15		0.025	0.025	0.025	0.025	0.025	0.025	0.075	0.075
20	1	1	19	0.025	0.025	0.025	0.025	0.15	0.15	0.15		0.025	0.025	0.025	0.025	0.025	0.025	0.075	0.075

Group the datasets by condenser number. Create a formula that takes the difference between the amount of energy used for heating and cooling for each hour for each condenser. When there is both heating and cooling for a particular hour, the smaller value of the two is the energy recovered by the Refrigerant Branch Selector Box.

The amount of energy saved will be implemented as an Exceptional Calculation for EAc1.

Variable Refrigerant Flow Systems

DOE-2 Accuracy

- The eQUEST methodology is not perfect, but it is felt to be a conservative approach to modeling the system.
- The methodology has been accepted by the USGBC (to date).
- DOE-2 VRF system curves: any volunteers to create these?

Variable Refrigerant Flow Systems

Questions