APPLICATION NOTES

Application Note 2023:
Variable Refrigerant Flow Modeling Using eQUEST

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Reference Documents
Engineering Manual | PLFY
Engineering Manual | PEFY
Engineering Manual | PKFY
Engineering Manual | PUHY-K/L
Engineering Manual | PURY-K/L

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Introduction

Mitsubishi Electric Cooling & Heating has explored the modeling capabilities of several software programs as they relate to modeling energy performance and relative energy savings between variable refrigerant flow (VRF) systems and other standard systems. Mitsubishi Electric has provided input and collaboration with EnergySoft in developing accurate algorithms and proper inclusion of equipment unloading curve information relating to Mitsubishi Electric Variable Refrigerant Flow (VRF) equipment for use in EnergyPro.

Mitsubishi Electric recognizes the desire in the industry among design professionals to utilize software they are trained on, are accustomed to using, and have invested money in. For this reason it is Mitsubishi Electric's intent to try and provide information as accurate as possible for use in eQUEST as it pertains to our VRF equipment.

Mitsubishi Electric, however, does not have access to, nor is part of the background programming or algorithms inside the DOE2.2 computational engine. Mitsubishi Electric has provided a method to approximate the energy consumption of VRF using the available modeling capabilities in eQUEST.

This application notes summarizes the known limitations, as well as provides guidance for the designer on how to, within the capabilities of the eQUEST software, utilize our equipment library information. A sample .INP file can be made available to more easily import custom curve data into the project.

Important note

It is the designer's responsibility to assess all information contained in any equipment library file and to apply sound engineering judgment and evaluation when performing any energy model. Mitsubishi Electric US, Inc. has no responsibility for the accuracy of this information used within the context of the eQUEST software, nor for the misuse or extrapolation of data taken from this document or accompanying .INP file.

Mitsubishi Electric US, Inc. makes no warranties or financial guarantees based on any information stated in this report or data contained within the accompanying .INP file. These guidelines are for special applications and are not supported by Diamond System Builder. Always consult a Mitsubishi Electric Mechanical Engineer for additional support on how to utilize these guidelines.

Known Limitations & Clarifications

1. The actual heating ambient unloading curves within eQUEST can only be defined for a single temperature range. Mitsubishi Electric's VRF equipment heating ambient curves are different for different ambient temperature ranges. Trying to define a single bi-quadratic curve for all ambient conditions introduces significant error along the curve fit compared to actual tested conditions.

2. All the Mitsubishi Electric nominal capacity, peak power, and modification curves are for the outdoor compressor unit as a whole. The eQUEST library files for air to air heat pumps have the option for condenser fan power to be defined separately. This value in

the Mitsubishi Electric library files has been zeroed out since condenser fan energy is already included in peak power values and part load custom curves.

3. No Mitsubishi Electric water source VRF equipment curves have been provided in the accompanying .INP file. While similar approximations to those described in this paper can be made for the water source equipment, there will still be limitations within the capabilities of eQUEST.

4. eQUEST doesn't have the capability to directly model the heat recovery operation of VRF equipment. This special application notes will describe some methods for performing additional calculations using the results and outputs from eQUEST to make an approximation of the heat recovery savings.

eQUEST Modeling Notes

There are several different system choices that have been suggested for modeling VRF in eQUEST. While all of these systems are and acceptable choice, there are certain systems that can better utilize the curves that can be provided by VRF manufacturers.

Several suggestions have been made to model VRF systems as Packaged Variable-Volume/Variable Temperature (PVVT) systems, which will allow variable speed compressors to be used. It is not absolutely necessary to use a variable speed compressor to approximate VRF systems in eQUEST. Selecting a variable speed compressor will require that an additional low speed curve be used based on compressor rotations per minute (RPM). This makes it more difficult to directly use the curves that can be provided by VRF manufacturers.

The Part Load Ratio (PLR) curves, Energy Input Ratio (EIR) curves, and capacity curves provided by the manufacturer should address the variable operation of VRF systems. It is because of this that Packaged Single Zone (PSZ) is used for modeling described in this paper. When modeling VRF systems, it is generally best to break up each individual indoor unit as its' own mechanical system. This will help to better approximate the variable nature of VRF and better mimic the real world operation of a VRF system.

Although this special application uses PSZ systems to model VRF, Packaged Terminal Air Conditioner (PTAC) systems can also be used to model VRF systems. Depending on the baseline system this approach may be easier, but keep in mind that the PSZ system may make it easier to add Energy Recovery Ventilation in conjunction with the VRF system. Similar methods to those described can also be applied to PVVT systems.

Many of the modifications shown on the following pages can also be done in the spreadsheet view to save time.

eQUEST Modeling : Importing Curves

Start out by modeling the building and zoning the building as you normally would in eQUEST. If using the wizard to create the shell and zone the building, it will be easier if PSZ is selected as the HVAC system in the wizard. This will create the building so that each individual zone gets assigned to a thermal zone and an individual PSZ system.

Once the building construction has been created and zoned, switch from the wizard input mode to the detailed input mode. The file can now be saved and temporarily closed to copy the custom curves into the project .INP file.

Save and close the project, then locate the project .INP file. The project .INP file can be found in the folder where the project has been created. The .INP file can be opened using notepad. Once opened, search for the term “performance” using CTRL+F. Copy and Paste the custom curves from the provided .INP as shown below:

Curves shown are based on those created for use in Trane Trace and data from the Engineering Manual

Table 1 Standard and extended furthest vertical distances between outdoor and indoor units

Equest Paper Sample Project VRF.inp - Notepad

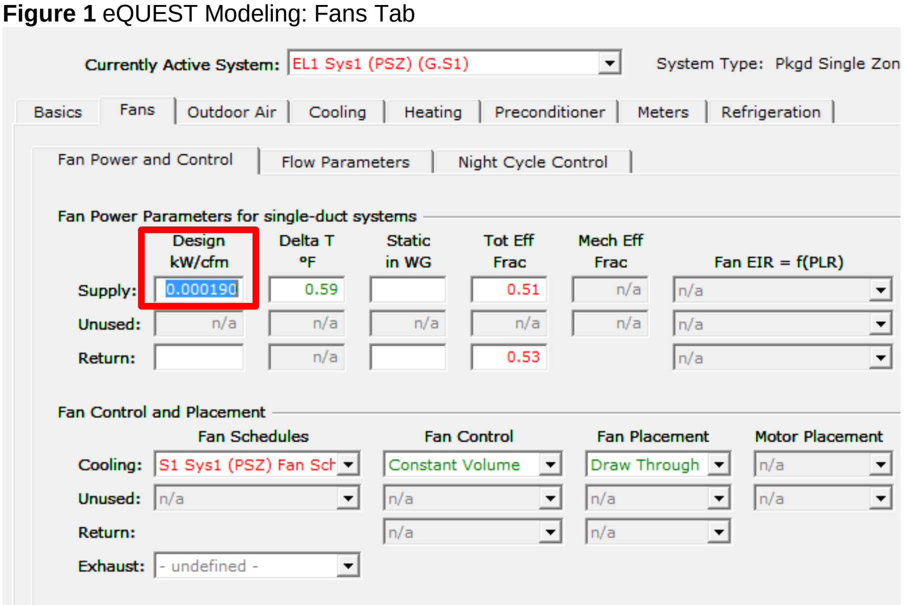
File Edit Format View Help

```
$ **************************************************************
$ **                                                          **
$ **                  Performance Curves                      **
$ **                                                          **
$ **************************************************************

"VRF Cooling Capacity" = CURVE-FIT
   TYPE              = BI-QUADRATIC-T
   INPUT-TYPE        = COEFFICIENTS
   COEFFICIENTS      = ( 3.45972, -0.09322, 0.00086, 0.00948, -5e-005, -8e-005 )
   ..
"VRF Cooling EIR F EWB / ODB" = CURVE-FIT
   TYPE              = BI-QUADRATIC-T
   INPUT-TYPE        = COEFFICIENTS
   COEFFICIENTS      = ( 1.56571, -0.02679, 0.00021, -0.00566, 7e-005, 3e-005 )
   ..
"VRF Heating Capacity Curve" = CURVE-FIT
   TYPE              = BI-QUADRATIC-T
   INPUT-TYPE        = COEFFICIENTS
   COEFFICIENTS      = ( -3.43603, 0.12032, -0.00088, 0.03598, -5e-005,
         -0.00038 )
   ..
"VRF Heating Eir F EWB / ODB" = CURVE-FIT
   TYPE              = BI-QUADRATIC-T
   INPUT-TYPE        = COEFFICIENTS
   COEFFICIENTS      = ( -3.62297, 0.12715, -0.00083, 0.05509, -0.00018,
         -0.00074 )
   ..
"VRF Cooling PLR" = CURVE-FIT
   TYPE              = QUADRATIC
   INPUT-TYPE        = COEFFICIENTS
   COEFFICIENTS      = ( 0.1181, 0.3937, 0.4731 )
   ..
"VRF Heating PLR" = CURVE-FIT
   TYPE              = QUADRATIC
   INPUT-TYPE        = COEFFICIENTS
   COEFFICIENTS      = ( 0.0575, 0.9193, 0.0183 )
   ..

$ **************************************************************
$ **                                                          **
$ **               Electric & Fuel Meters                     **
```

eQUEST Modeling : Fan Power

Once the curves have been inserted into the .INP file, save and close the file then reopen the project. Go to the Air-Side HVAC system tab and begin to modify the PSZ system. Start by modifying the fan power by going to the Fans – Fan Power and Control tab.

Figure 1 eQUEST Modeling: Fans Tab



Ensure that the fan control is defined as constant volume, and modify the Design kW/CFM. Information to calculate the kW/CFM can be found on the indoor unit submittal. See Table 2 below for more details.

Table 2 CITY MULTI® Indoor Unit Power in kW/CFM

Model	CFM	Input power (kW)	kW/CFM
PEFY-P24NMAU-E2	883	0.17	0.000193
PLFY-EP24NEMU-E	812	0.04	0.000049
PKFY-P18NHMU-E2	425	0.03	0.000071

eQUEST Modeling : Cooling and Heating EIR

The next step is to define the cooling and heating EIR. This will define the efficiency of the outdoor unit. This can again be calculated using the information provided on the outdoor unit submittal, see Table 3 below:

Table 3 CITY MULTI® Outdoor Unit Cooling and Heating EIR values

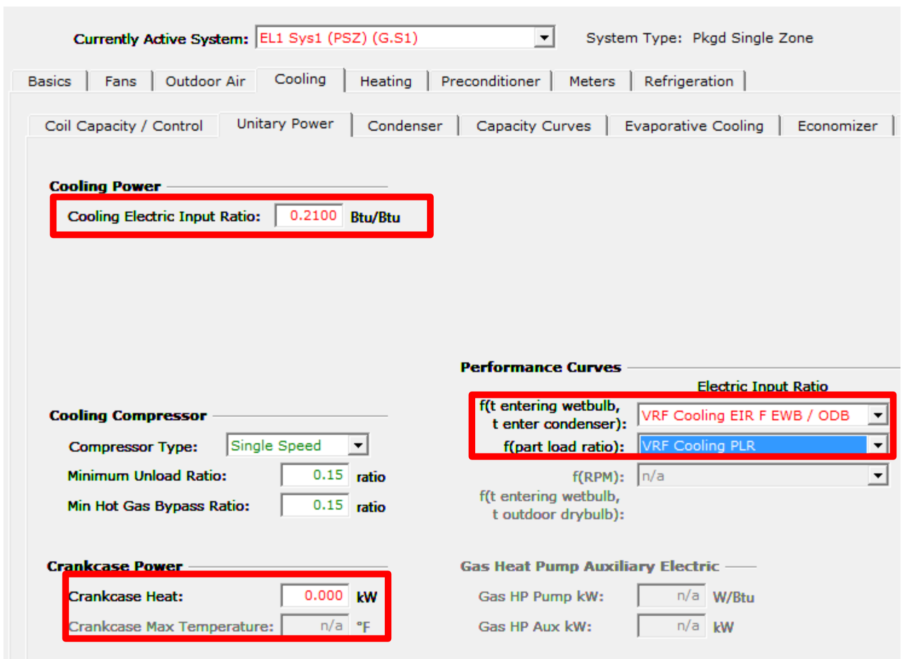
Model	Cooling Capacity (Btu/h)	Cooling Power Input (kW)	Cooling EIR (Btu/Btu)	Heating Capacity (Btu/h)	Heating Power Input (kW)	Heating EIR (Btu/Btu)
PURY-P72T(Y)KMU	72000	4.4	0.209	80000	5.92	0.253
PURY-P96T(Y)KMU	96000	7.05	0.251	108000	8.28	0.262
PURY-P120T(Y)KMU	120000	9.44	0.268	135000	10.86	0.275
PURY-P144T(Y)KMU	144000	11.2	0.265	160000	13.54	0.289
PURY-P144YSKMU	144000	10.31	0.244	160000	12.54	0.267
PURY-P168T(Y)SKMU	168000	12.8	0.260	188000	14.91	0.271
PURY-P192T(Y)SKMU	192000	15.61	0.277	215000	17.2	0.273
PURY-P216T(Y)SKMU	216000	18.22	0.288	243000	19.89	0.279
PURY-P240T(Y)SKMU	240000	21.11	0.300	270000	22.73	0.287
PURY-P264T(Y)SKMU	264000	23.05	0.298	295000	25.37	0.294
PURY-P288T(Y)SKMU	288000	24.57	0.291	320000	27.62	0.295
PUHY-P72T(Y)KMU	72000	5.06	0.240	80000	5.62	0.240
PUHY-P96T(Y)KMU	96000	7	0.249	108000	7.47	0.236
PUHY-P120T(Y)KMU	120000	9.09	0.259	135000	10.28	0.260
PUHY-P144T(Y)KMU	144000	11.84	0.281	160000	12.47	0.266
PUHY-P144YSKMU	144000	10.57	0.251	160000	11.68	0.249
PUHY-P168T(Y)SKMU	168000	12.71	0.258	188000	14.02	0.255
PUHY-P192T(Y)SKMU	192000	14.81	0.263	215000	16.91	0.268
PUHY-P216T(Y)SKMU	216000	16.9	0.267	243000	19.26	0.271
PUHY-P240T(Y)SKMU	240000	19.12	0.272	270000	21.86	0.276
PUHY-P264T(Y)SKMU	264000	20.35	0.263	295000	23.11	0.267
PUHY-P288T(Y)SKMU	288000	22.39	0.265	320000	25.36	0.270
PUHY-P312T(Y)SKMU	312000	24.87	0.272	350000	28.71	0.280
PUHY-P336T(Y)SKMU	336000	27.21	0.276	378000	31.73	0.286
PUHY-P360T(Y)SKMU	360000	29.65	0.281	405000	35.39	0.298

Model	Cooling Capacity (Btu/h)	Cooling Power Input (kW)	Cooling EIR (Btu/Btu)	Heating Capacity (Btu/h)	Heating Power Input (kW)	Heating EIR (Btu/Btu)
PURY-P72T(Y)LMU	72000	4.57	0.217	80000	5.63	0.240
PURY-P96T(Y)LMU	96000	6.92	0.251	108000	8.11	0.262
PURY-P120T(Y)LMU	120000	8.08	0.229	135000	10.21	0.258
PURY-P144T(Y)LMU	144000	10.22	0.242	160000	12.73	0.272
PURY-P144T(Y)SLMU	144000	10.09	0.239	160000	11.78	0.251
PURY-P168T(Y)LMU	168000	14.74	0.299	188000	15.92	0.289
PURY-P168T(Y)SLMU	168000	13.60	0.276	188000	14.94	0.271
PURY-P192T(Y)SLMU	192000	15.56	0.277	215000	17.18	0.273
PURY-P216T(Y)SLMU	216000	17.03	0.269	243000	19.47	0.273
PURY-P240T(Y)SLMU	240000	18.44	0.262	270000	21.76	0.275
PURY-P264T(Y)SLMU	264000	20.98	0.271	295000	24.54	0.284
PURY-P288T(Y)SLMU	288000	23.42	0.277	323000	27.35	0.289
PURY-P312T(Y)SLMU	312000	27.83	0.304	350000	30.78	0.300
PURY-P336T(Y)SLMU	336000	33.20	0.337	378000	33.89	0.306
PUHY-P72T(Y)LMU	72000	4.55	0.216	80000	5.48	0.234
PUHY-P96T(Y)LMU	96000	6.39	0.227	108000	7.65	0.242
PUHY-P120T(Y)LMU	120000	8.07	0.229	135000	9.84	0.249
PUHY-P144T(Y)LMU	144000	10.38	0.246	160000	12.30	0.262
PUHY-P144T(Y)SLMU	144000	10.09	0.239	160000	11.68	0.249
PUHY-P168T(Y)LMU	168000	13.52	0.275	188000	14.91	0.271
PUHY-P168T(Y)SLMU	168000	12.56	0.255	188000	14.60	0.265
PUHY-P192T(Y)SLMU	192000	14.23	0.253	215000	16.97	0.269
PUHY-P216T(Y)SLMU	216000	16.43	0.260	243000	19.46	0.273
PUHY-P240T(Y)SLMU	240000	18.36	0.261	270000	21.69	0.274
PUHY-P264T(Y)SLMU	264000	19.61	0.253	295000	23.07	0.267
PUHY-P288T(Y)SLMU	288000	21.83	0.259	323000	25.82	0.273
PUHY-P312T(Y)SLMU	312000	23.73	0.260	350000	28.41	0.277
PUHY-P336T(Y)SLMU	336000	26.07	0.265	378000	31.42	0.284
PUHY-P360T(Y)SLMU	360000	27.94	0.265	405000	33.83	0.285

eQUEST Modeling Cooling Modifications

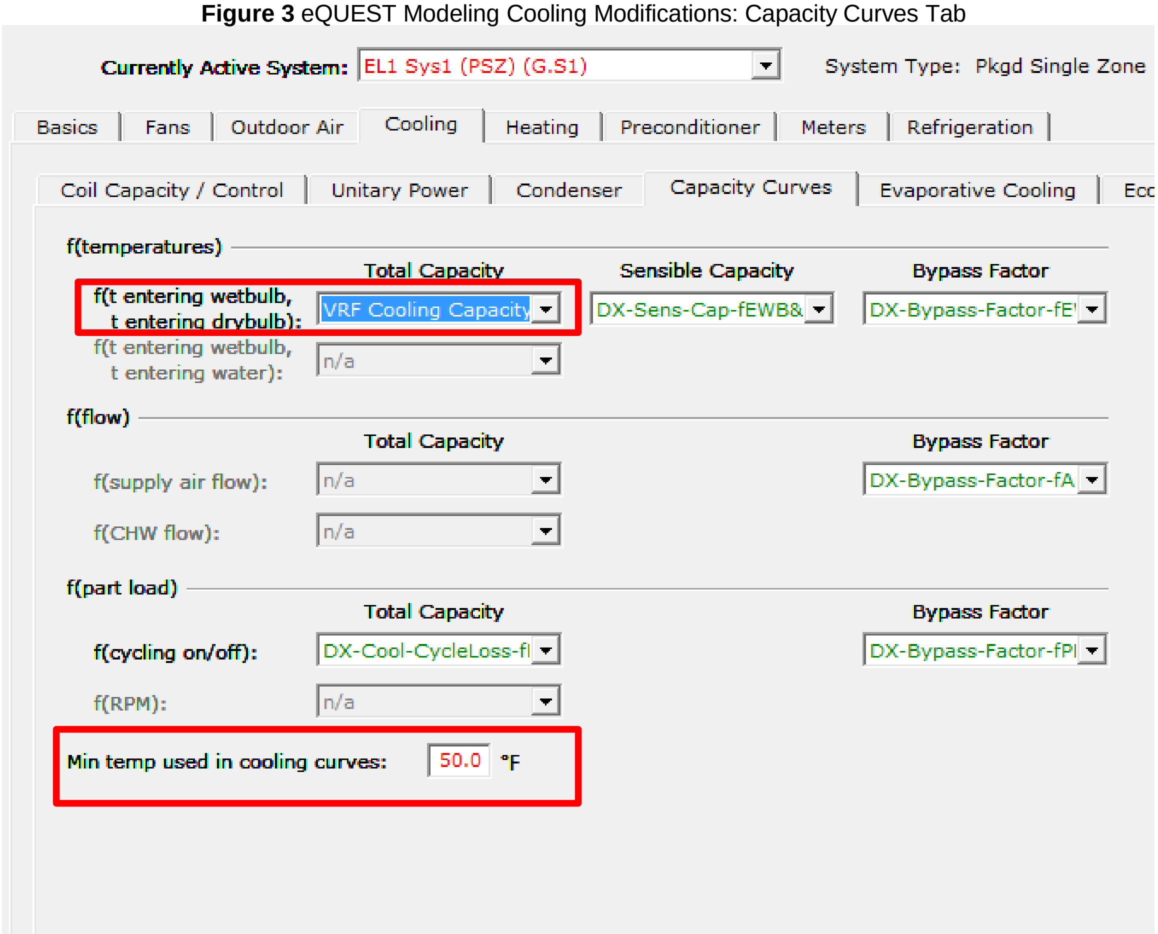
On the Unitary Power tab, the cooling EIR should be entered from the table above. The performance curves for VRF should be selected and the crankcase heat should be set to 0. The crankcase power is included in the EIR value.

Figure 2 eQUEST Modeling Cooling Modifications: Unitary Power Tab



On the Capacity curves tab, the VRF capacity curve will need to be selected and the minimum temp used in cooling curves should be set to 50° F

Figure 3 eQUEST Modeling Cooling Modifications: Capacity Curves Tab



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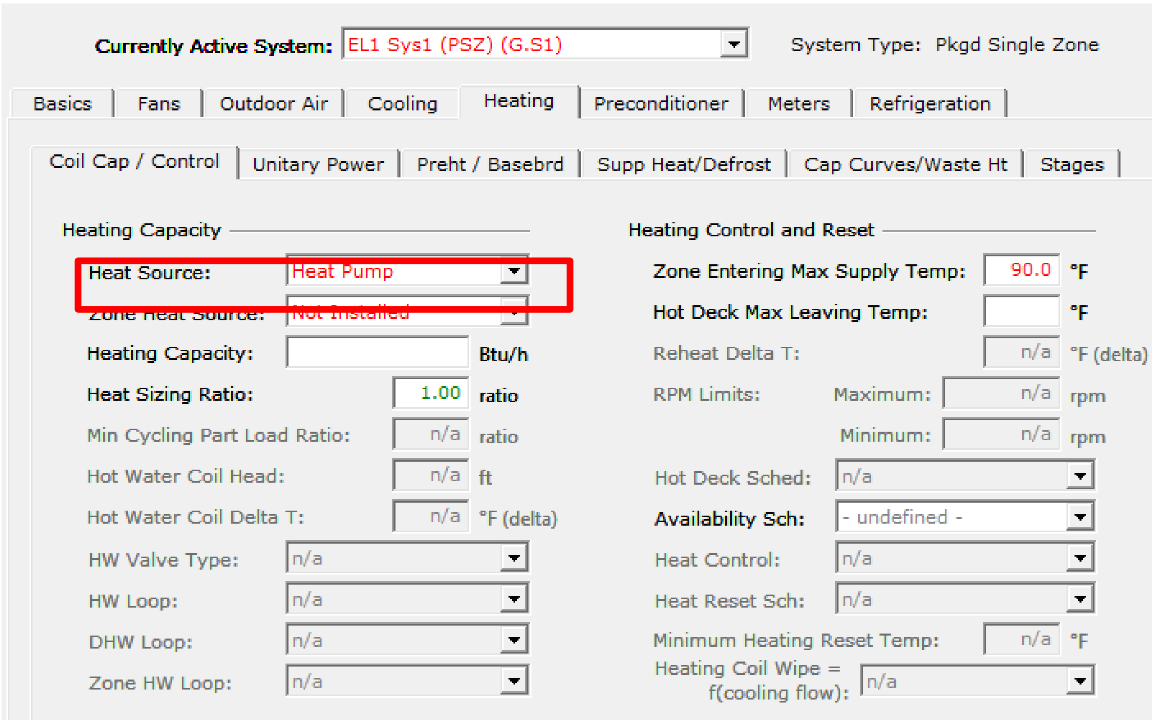
eQUEST Modeling Heating Modifications

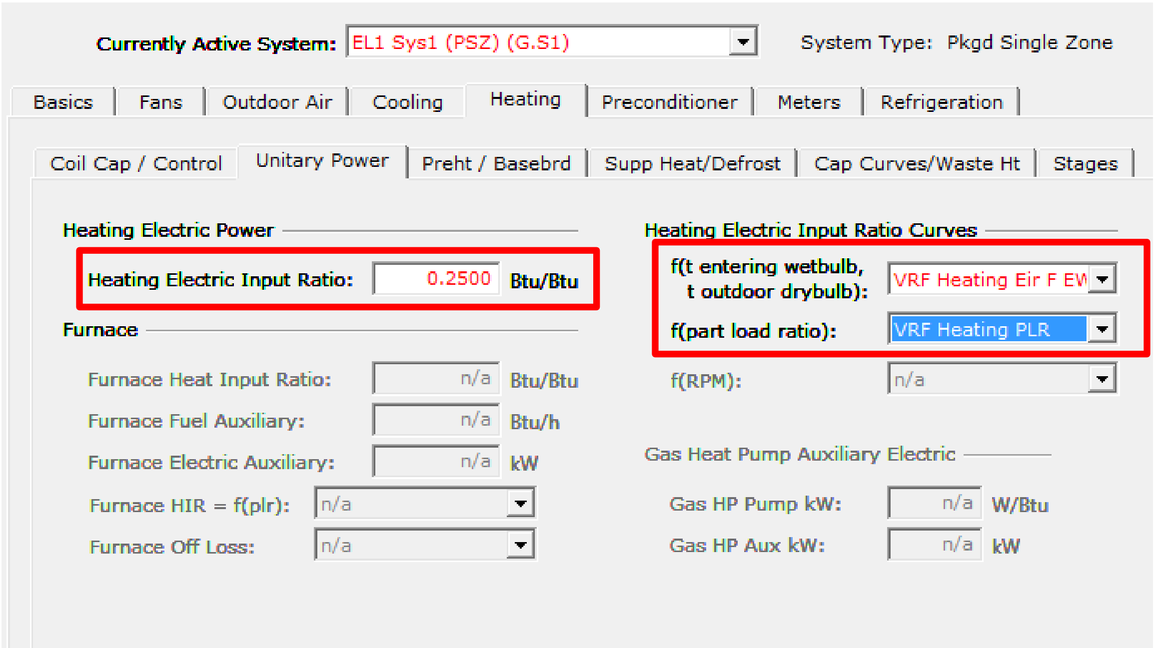
On the heating coil cap / control tab, ensure that there is no zone heat source installed.

Figure 4 eQUEST Modeling Heating Modifications: Heating Coil Cap / Control Tab



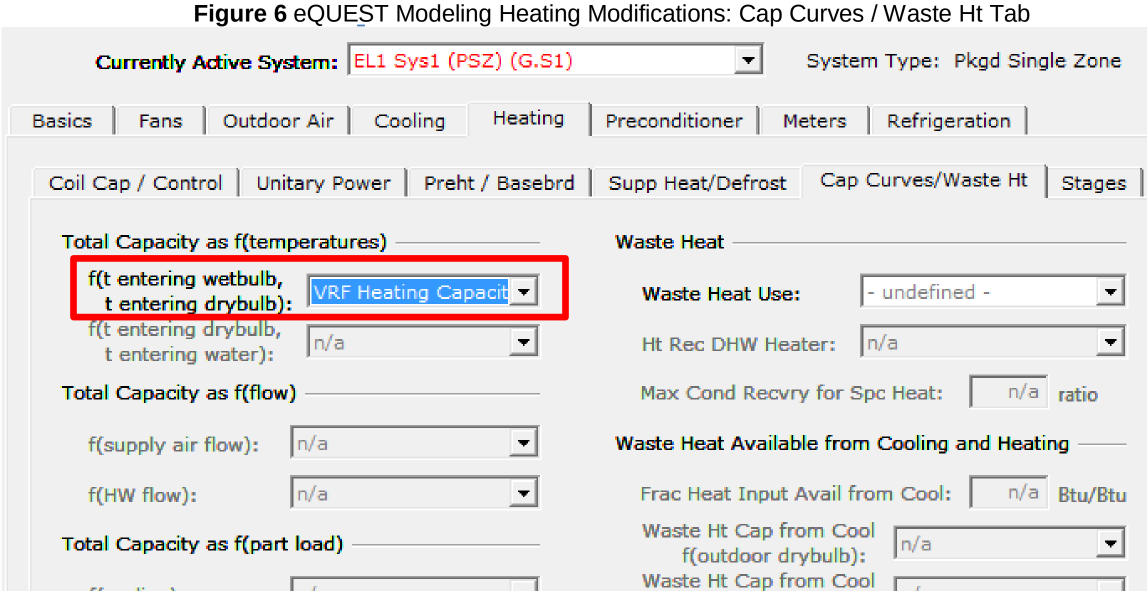
On the heating unitary power tab, the heating EIR can be entered from the table above and the VRF heating power curves can be selected.

Figure 5 eQUEST Modeling Heating Modifications: Unitary Power Tab



On the heating capacity curves / waste heat tab, "VRF heating capacity curve" should be selected.

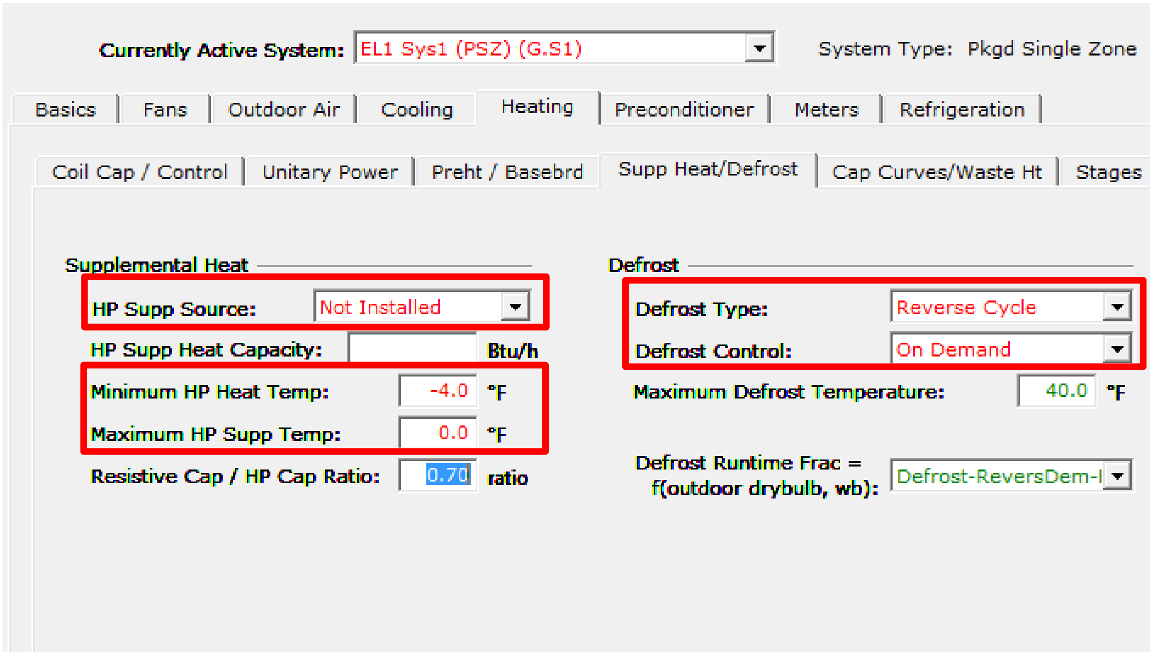
Figure 6 eQUEST Modeling Heating Modifications: Cap Curves / Waste Ht Tab



On the heating supplemental heat tab, this tab will need to be modified based on the project design. Many VRF systems are designed will no supplemental heat and as such the supplemental heat should be set to "Not installed". If supplemental heat is installed, the Minimun HP heat Temp and Maximum HP Supp Temp should be adjusted to meet the project design.

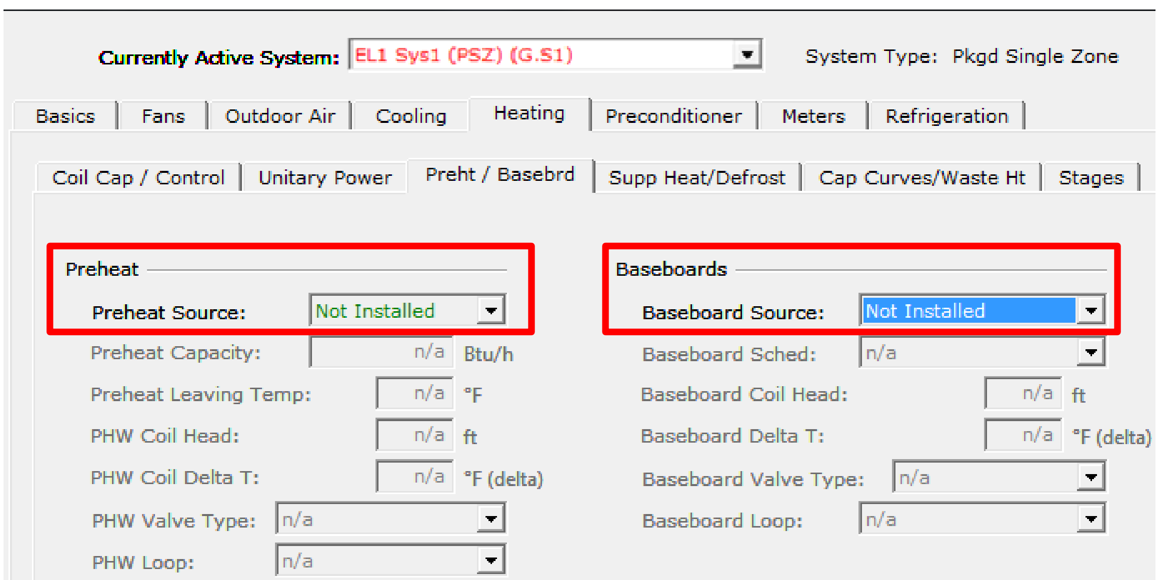
The Defrost should be adjusted to "Reverse Cycle" and "On Demand" to match the way that VRF systems defrost.

Figure 7 eQUEST Modeling Heating Modifications: Heating Supplemental Heat Tab



On the preheat / baseboard tab, both values should be set to "Not Installed" unless VRF is being used as a second stage of heating.

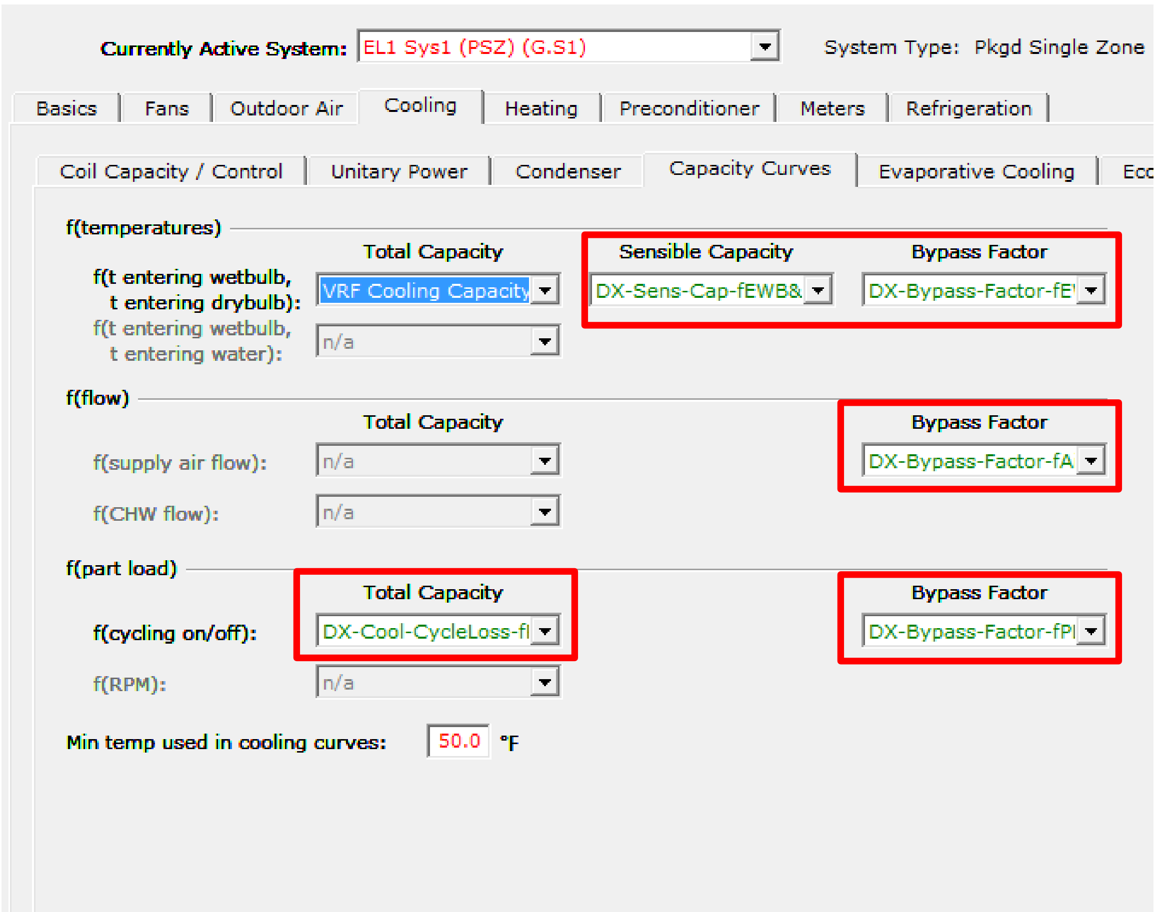
Figure 8 eQUEST Modeling Heating Modifications: Preheat / Baseboard Heat Tab



eQUEST Modeling Clarifications

After completing the aforementioned steps, several fields in the fan, cooling, and heating input screens will still reference the eQUEST default curves (text in green); the cooling input screen is shown below for example purposes. These fields are intentionally left at the eQUEST default as they have comparatively little impact on the resulting energy calculation and therefore do not require modification in order to approximate VRF operation. As mentioned in the forward, eQUEST does not explicitly support the modeling of VRF systems and this is one such instance where an approximation of VRF system operation is made.

Figure 9 eQUEST Modeling Clarifications: Capacity Curves Tab



eQUEST Modeling Heating Recovery Approximation

eQUEST does not have the capability to model the heat recovery feature of VRF systems. That being stated, there are methods to approximate the savings seen through heat recovery, by using hourly outputs and reports. Each VRF outdoor system can be set on an individual electric meter, and then define an hourly report for each meter to report the cooling and heating end use. Export the hourly reports to a CSV file so that they can be viewed and manipulated in excel. Analyze the excel data to delete the cooling energy consumption when the heating energy consumption is larger for a given hour on a single outdoor system. When the cooling energy is larger than the heating energy, the heating energy can be cut in half. This method is not perfect or completely accurate, but it is the best way to approximate the heat recovery savings using eQUEST

Conclusion

The eQUEST software is a robust and complex modeling software program; however, Mitsubishi Electric has neither affiliation nor input into its' computational engine.

Mitsubishi Electric is focused, however, on providing support to engineers and designers to the extent possible to allow them to model VRF systems with software they are trained on and accustomed to using.

Again, it is intended that this information be used as a general guide offering some additional accuracy when modeling Mitsubishi Electric equipment for air cooled systems in the eQUEST software.

However, it is ultimately the designer / engineer of record's responsibility to access all information provided.