Application Note 2017: Water-Source VRF Application Guide

Reference Documents 2015 Engineering Manual – WY & WR2 – Section & Design (**L Generation Only**)

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Introduction

This document is a general application guide for the Mitsubishi Electric CITY MULTI® water-source VRF equipment. This document is to serve as a supplement to the technical data already contained within the Mitsubishi Electric CITY MULTI® engineering manuals, submittal sheets, and other service, operation and installation manuals.

This document will cover the general application of the following products:

WR2-Series: PQRY-P72T/YLMU-A through PQRY-P336T/Y(S)LMU-A
WY-Series: PQHY-P72T/YLMU-A through PQHY-P360T/Y(S)LMU-A

Please Note: *Certain portions of this document are NOT applicable to the prior H-generation (HMU) water source VRF equipment. The prior H-generation (HMU) water source application guide can be made available upon request.*

WHAT IS WATER SOURCE VRF?

Water-source VRF is similar to air-source VRF on the refrigeration side. Multiple indoor units can be connected to a compressor module where each module houses a single inverter driven compressor.
The primary difference is the fact that the compressor module absorbs and rejects heat from or to a
water-source heat sink instead of an air-source heat sink.

Two distinct types of water-source VRF systems are offered. The WR2-Series allows simultaneous heating and cooling between fan coil units attached to each individual system (**Figure 1**).

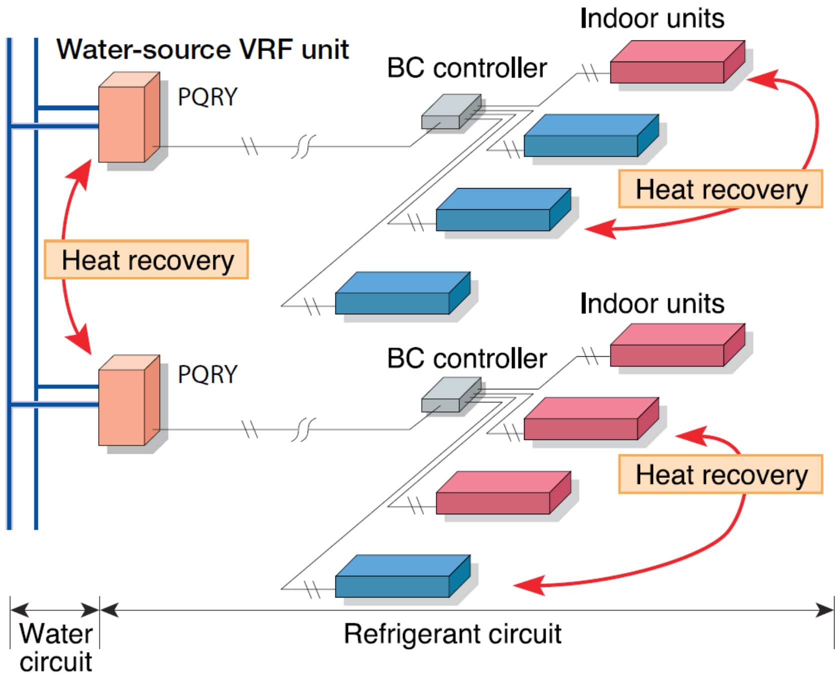


Figure 1. Water-Source VRF General Schematic. WR2-Series Shown. The WY-series requires that all the fan coil units attached to a system be in the same mode, either heating or cooling (**Figure 2**).

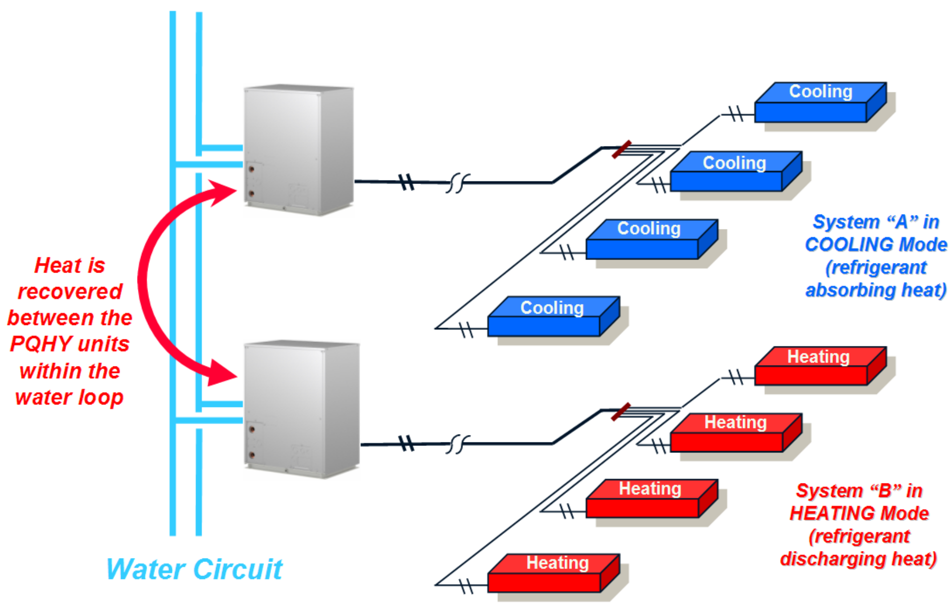


Figure 2. Water-Source VRF General Schematic. WY-Series Shown

Both the WR2 and WY-Series systems will provide heat recovery between modules connected to a common hydronic loop. However, only the WR2 can preferentially provide heat recovery on the refrigeration side first. The WR2 will then absorb or reject heat, from or to the building hydronic loop. The WY-Series is not capable of heat recovery on the refrigeration side.

SYSTEM APPLICATION & ADVANTAGES

General Application Considerations

Similar to air-source VRF systems, consideration of load profile and zoning is important depending on the series of water-source VRF being applied.

For the WY-Series, zones should be grouped with similar load profiles with similar exposures, occupancy schedules, and other internal load schedules. WY-Series VRF is also well suited to large open area applications.

With the WR2-Series, providing a good mixture or balance of external and internal spaces with varying or opposite load profiles is advantageous to maximize heat recovery potential.

Both water-source units are able to take advantage of building load diversity. The maximum allowable connected nominal capacity of fan coils is 130% for the WY-Series and up to 150% for the WR2-Series.

In terms of heat recovery potential, the WR2-Series offers greater advantage compared to the WY-series. Both recover heat via the condenser water loop in the building, but the WR2 system recovers heat more efficiently.

Advantages of VRF versus Traditional WSHP Systems

A simultaneous heating and cooling VRF system (WR2-Series) strives to meet the larger of the loads connected at any given hour. The lesser load is in the form of recovered energy via the refrigeration circuit. For example, if a majority of the building requires heating, recovered energy from the heating operation will be used for any spaces that demand cooling.

Because of this, the compressor operating power in a VRF system will be reduced during heat recovery periods compared to that of an equivalently zoned traditional Water Source Heat Pump (WSHP) system. The traditional WSHP system will still require compressor operation in each zone, even during balanced (50/50 – heating/cooling) operation in the building.

The serviceability of water-source VRF systems offers a major advantage over traditional WSHP systems as well. With traditional WSHP installations, the units are installed in the ceiling space. Since each unit contains a compressor (cyclically loaded compressors) the need for future maintenance and replacement of compressors is inevitable.

Water-source VRF however will provide more centralized placement of compressors with reduced quantity. Instead of multiple compressors present in each zone unit, a single inverter driven compressor will exist in each water-source module. Each water-source module is capable of serving multiple zones and would be serviceable, for example, from a utility closet that houses the water-source VRF module at floor level for improved access and minimal disruption to occupied spaces.

Advantages of Water-Source VRF versus Air-Source VRF

Probably the largest advantage water-source VRF offers in comparison to air-source VRF is heating de-rates for ambient temperature and defrosts in cold climates. Due to heating de-rates for air-source VRF, equipment must often be upsized to handle the peak heating demand or auxiliary heat installed throughout the building to cover colder periods.

With water-source VRF equipment, there is an opportunity to centralize the heat source with a boiler without installing auxiliary heat at the zone level. This will also remove the natural hysteresis that will exist at the zone level with air source VRF as a differential of over 2 degrees must always exist to activate axillary backup heat at VRF indoor units.

Typically air-source VRF equipment is a good choice for energy savings opportunities because of its ability to source heat from ambient with a far greater extended heat pump operating range compared to traditional air-source heat pumps. However, water-source may offer an advantage in areas where the local utilities have higher electric rates, thus offering a greater value to heating with gas.

Consider Figure 3 below. In this example, the electric blended rate, even with air source VRF heat pump capabilities, is at a disadvantage compared to WS VRF with condensing gas boiler for injection into condenser water loop for heating. For much of the heating season at these rates shown, with ambient conditions below 35F, using natural gas with water-source VRF has a higher BTU/$ than air-source VRF. For this reason, water-source VRF, especially with improved efficiency in cooling, may be better suited in these situations.

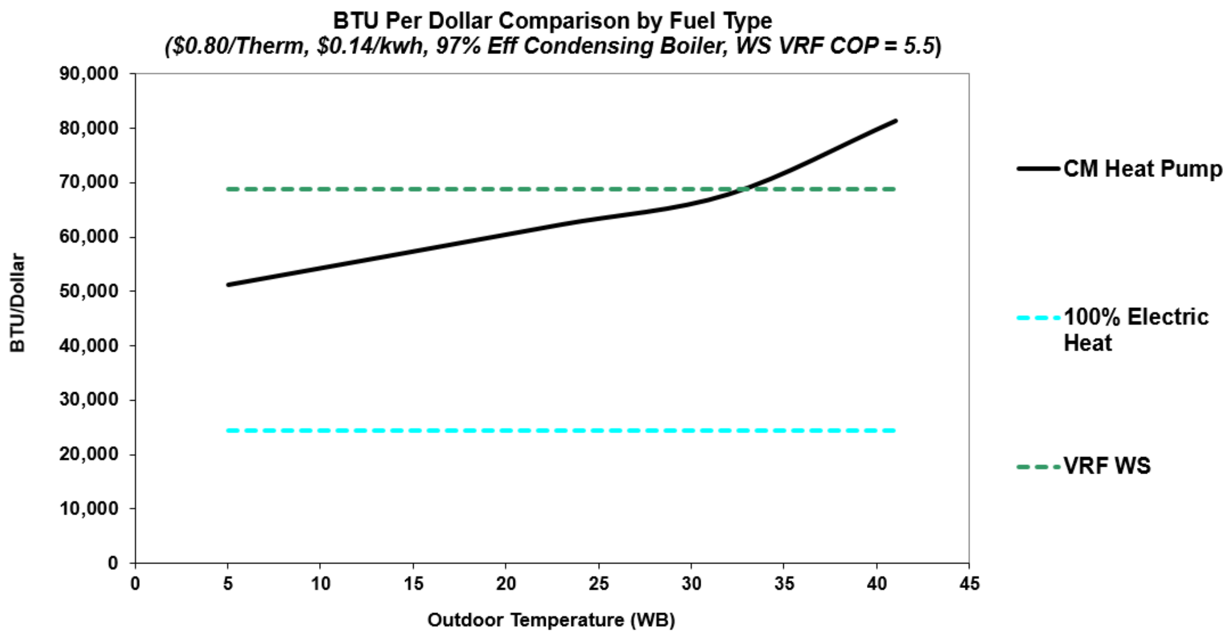


Figure 3. Btu per Dollar Comparison by Fuel Type

Advantages to Geothermal Water-Source VRF versus Other Systems

The Mitsubishi Electric water-source equipment is also capable of operating in a closed loop ground source / geothermal heat sink application. Project site conditions and available funding along with local, state, and federal subsidy/rebate programs will always be key factors in assessing the viability of this application.

In terms of year round energy savings potential, this application offers significant advantages. In many cases this application will yield improved cooling efficiency due to lower average loop water temperatures. This application also offers the ability to source heat from the geothermal heat sink at higher COP's on average compared to air-source heat pump.

In many cases the efficiency of these systems will exceed that of standard air-source VRF systems for the above reasons. In addition, ground source VRF will often exceed the efficiency of traditional geothermal WSHP systems due to the aforementioned ability to recover energy more efficiently on the refrigeration side first compared to multiple distributed traditional geothermal WSHPs.

Again, providing a well field, as well as having land available for such installations, may be cost-prohibitive in many cases; careful analysis is always recommended.

Sample system design schematics at the end of this application guide illustrate the major system components that may be required with traditional boiler tower water-source VRF and geothermal water-source VRF with optional hybrid applications.

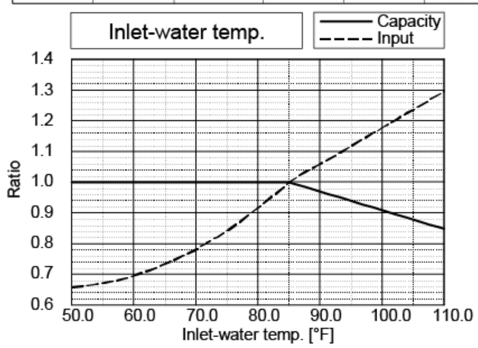
DESIGN CONSIDERATIONS

System Operating Temperatures

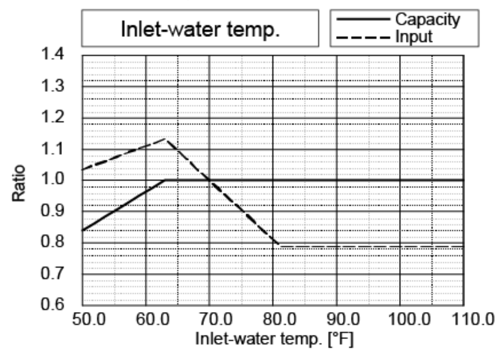
Water-source VRF equipment is capable of operating in a wide range of water temperatures. Capacity and power consumption is affected by the inlet water temperature. The engineering manual provides capacity correction factor charts for inlet water temperature. This is in addition to other applicable correction factors for piping, connection ratio, defrost, etc. Diamond System Builder should always be used to accurately account for all de-rates.

Chart 1. Sample Capacity Correction Charts from Engineering Manual

PQRY-	P72TLMU/YLMU				
Nominal Cooling Capacity	kW	21.1	Rated Cooling Capacity	kW	20.2
	BTU/h	72,000		BTU/h	69,000
Input	kW	3.23	Input	kW	(Non-Ducted) 2.96 (Ducted) 3.12



PQRY-	P72TLMU/YLMU				
Nominal Heating Capacity	kW	23.4	Rated Heating Capacity	kW	22.3
	BTU/h	80,000		BTU/h	76,000
Input	kW	3.63	Input	kW	(Non-Ducted) 3.34 (Ducted) 3.36



<u>Please Note:</u> Operation below 50° F down to 23° F inlet water temperature requires glycol for 5° F freeze protection. Additional capacity correction applies below 50° F – consult a Mitsubishi representative.

Clearance Considerations & Maximizing Utility Space

Consideration of clearance requirements is important for proper space planning for the water-source modules. Unlike traditional water-source heat pumps which are ceiling mounted, VRF water-source modules can be installed at floor level for ease of access.

One advantage the CITY MULTI® water-source VRF modules have is their ability to be installed in relatively small utility closets with little-to-no access on either side of the module. Service clearance can be achieved by simply opening the utility closet door where the unit is housed to reveal the front of the unit. The service clearance drawing from the Engineering Manual

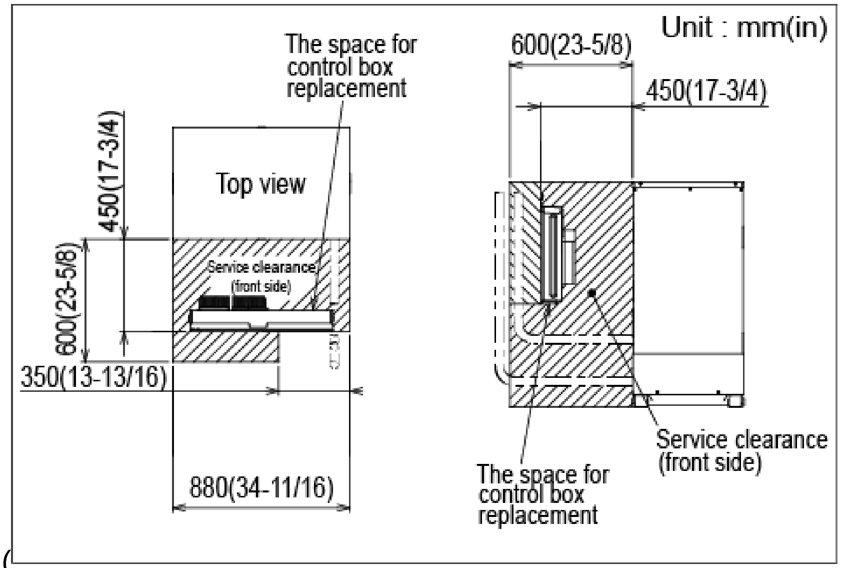


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Figure **4**) reflects these requirements.

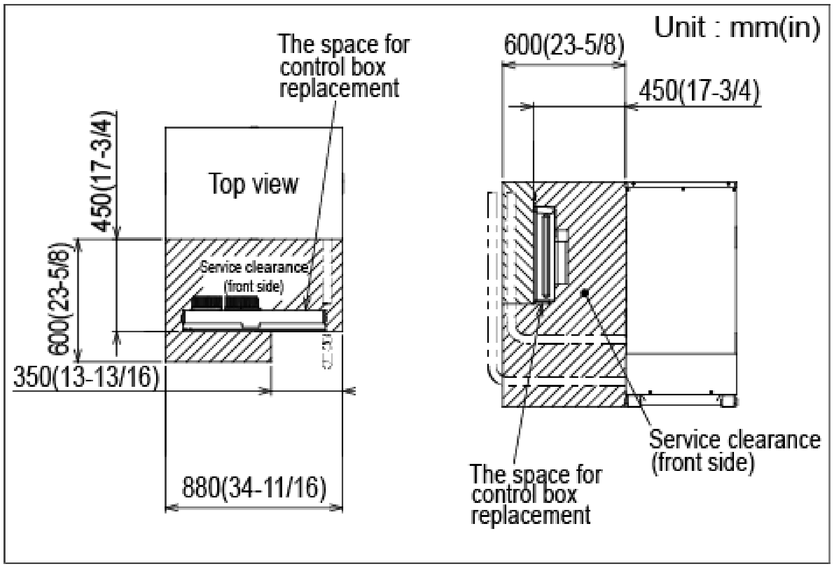


Figure 4. Service clearance drawing from the Engineering Manual

Units that are twinned should always be installed at the same level. However, sets of twinned systems can be stacked in utility closets to maximize space in buildings. The below schematic illustrates the stacking of independent systems. Consult the Engineering Manual for further guidance on piping requirements when twinning modules.

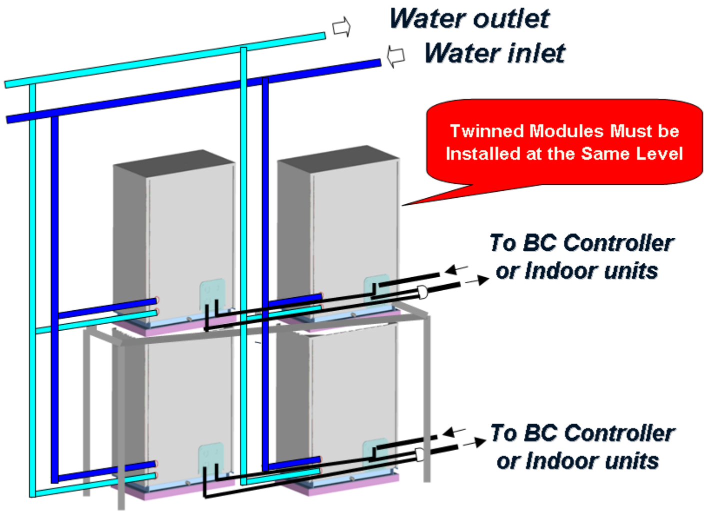


Figure 5. General diagram of stacked twinned units

Heat Rejection Requirements

When applying water-source VRF with a traditional boiler and tower, the capacity of the heat rejection device (e.g., evaporative tower, dry cooler, closed circuit cooling tower), becomes critical. At a minimum this device should be sized to dissipate the entire building cooling load, plus the VRF heat pump module compressor energy input, plus any pumping energy imparted on the circulating water loop. Equation 1 illustrates the required parameters to properly size the primary heat rejection device.

Equation 1. Cooling Tower Capacity Formula

$$Cooling\ Tower\ Capacity = \frac{Q_c + 3{,}412\ \times (\sum Q_w + P_w)}{15{,}500}\ [Refrigeration\ Ton]$$

Q_c: Actual Peak Cooling Load [BTU/h]
Q_w: Total input of water-source units at simultaneous peak operation [kW]
P_w: Power of circulation pumps [kW]

If using a dry cooler, ensure:

1- The approach temperature used for sizing and selecting the dry cooler is based on the design ambient dry bulb condition for the climate you are designing for and,
2- The upper thresholds for the water-source VRF module inlet water temperature are not exceeded. One way to check this is by using the ASHRAE "Extreme Annual DB" Mean-Max condition.

Table 2. Sample weather data from ASHRAE Fundamentals (Cincinnati, OH shown)

Extreme Annual Design Conditions

Extreme Annual WS			Extreme Max WB	Extreme Annual DB				n-Year Return Period Values of Extreme DB							
				Mean		Standard deviation		n=5 years		n=10 years		n=20 years		n=50 years	
1%	2.5%	5%	WB	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max
20.2	18.3	16.6	84.2	-1.8	96.2	9.1	3.2	-8.4	98.5	-13.7	100.4	-18.8	102.2	-25.4	104.5

Closed Hydronic Loop Requirements

All CITY MULTI® water-source VRF units are designed for closed loop heat exchange applications. Connections to any other open loop systems should be handled via a secondary heat exchanger.

The closed loop system serving water-source VRF units should be chemically treated with corrosion and/or rust inhibitors, have balanced PH, and include air separation and water expansion devices. These measures are to ensure the integrity and performance of the refrigerant to water heat exchangers. Reference the sample schematic drawings at end of this guide for illustration of major hydronic components required.

For geothermal applications with freezing winter loop temperatures expected, glycol must be provided in the heat exchange loop to provide freeze protection to at least 5° F.

Since these units are intended for closed loop applications, circulation pumps must be used to circulate the heat exchange fluid through the unit. Pressure drop, flow ranges, and other piping losses must be considered to properly size the pump.

Below is a sample pressure drop chart – consult the Mitsubishi Electric Engineering Manual for additional charts pertaining to pressure drop and other de-rates.

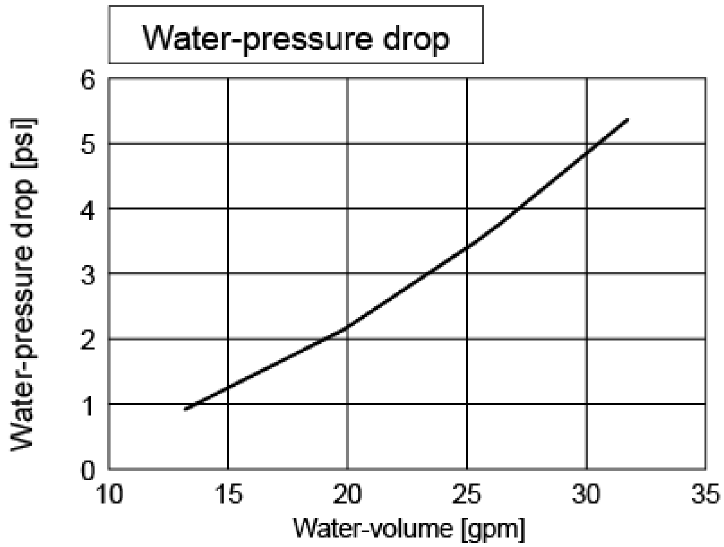


Figure 6 Water-Pressure Drop Chart (PQRY-P72 Shown)

General Piping Accessory Provisions at Water Source Unit

The units are equipped with brazed plate heat exchangers. These heat exchangers have multiple plates with small passages and as such are prone to partial clogging of debris/contaminants in system during initial flushing and debris arising over long term deterioration of piping systems in buildings.

As such, a greater than 50 mesh strainer is required immediately at inlet connections of the water source modules. Failure to follow this may result in reduced flow, heat transfer, higher operating head pressure on refrigerant circuit, and resulting compressor power / energy use penalties.

The below diagram illustrates some of the basic provisions that should be provided at each water source module:

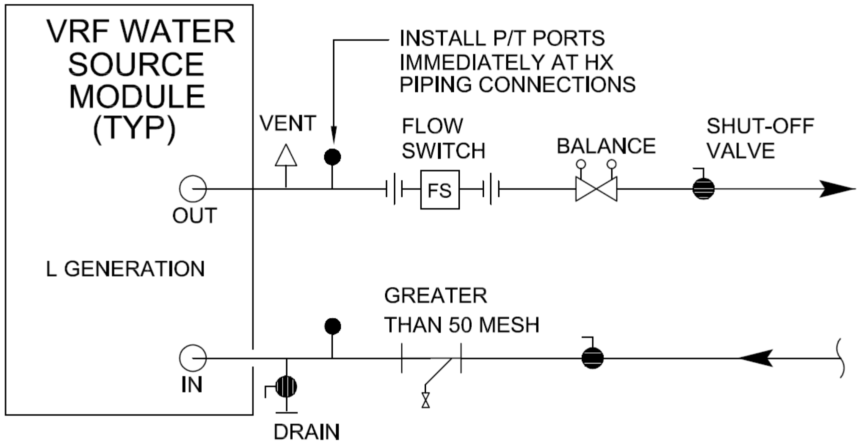


Figure 7. Minimum Piping Provisions at Each Water Source Module (L-Generation)

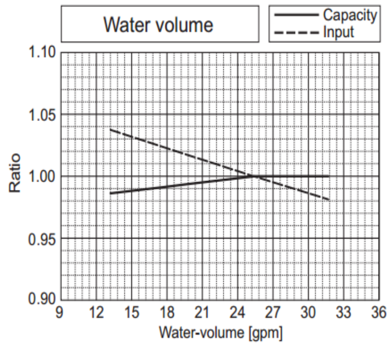
Condenser Water Flowrates & Pumping with Water-source VRF

The Mitsubishi L Generation water source modules are capable of operating under a wide water flow range for full and part load operation. In addition provisions exist to incorporate a two position motorized valves or pumps on each module to allow for full condenser water flow shut-off when systems are OFF.

The engineering manuals provide capacity correction tables for the entire flow range available – below is one such example (left). The table below (right) provides guidance on allowable minimum full load design flow rates for each module size and recommended flow switch selection point. This incorporates a 15% safety factor on guaranteed minimum flow to allow for future inlet strainer loading.

This strategy will allow for reduced pumping cost with a lower designed GPM/Ton than conventional water source heat pump systems, while encouraging higher Delta T on the condenser water loop to promote more efficient heat rejection. ***An auto flow limiting balance valve on each water source module is highly recommended, Griswold or equal, for proper balancing when designing around these minimum flow rates, especially for designs with two position valves and variable central station condenser water pumping.***

PQRY-		P120TLMU/YLMU			
Nominal Cooling Capacity	kW	35.2	Rated Cooling Capacity	kW	33.4
	BTU/h	120,000		BTU/h	114,000
Input	kW	7.24	Input	kW	(Non-Ducted) 6.66 (Ducted) 7.35



Full Load Design Minimum Recommended Flow Rates					
Module Model Size (Single Module)		Water Connection Size (in)	GPM	GPM/Ton	Recommended Flow Switch Break Point
P	72	1-1/2"	16	2.7	11
P	96	1-1/2"	16	2.0	11
P	120	1-1/2"	20	2.0	15
P	144	1-1/2"	23	1.9	18
P	168	1-1/2"	27	1.9	22
P	192	1-1/2"	30	1.9	25
P	216	1-1/2"	32	1.8	27
P	240	1-1/2"	36	1.8	31

Please Note:

1. **When designing at lower flow rates, the inlet strainer and piping to the water source module should not be reduced below nominal pipe size connection of the unit.**

2. **The above minimum flows are suitable for cooling design entering water temperatures at or below 100 deg F. For entering water temperatures above 100 deg F up to 113 deg F maximum, it is recommended that the flow rates be increased per the below table:**

Module Minimum Full Load Design Flow vs. EWT						
Module Size	50 Deg F EWT Min Flow (gpm)	100 Deg F EWT Min Flow (gpm)	105 Deg F EWT Min Flow (gpm)	107.5 Deg F EWT Min Flow (gpm)	110 Deg F EWT Min Flow (gpm)	113 Deg F EWT Min Flow (gpm)
P72	16	16	16	18	25.5	25.5
P96	16	16	16	20	25.5	25.5
P120	20	20	20	20	25.5	25.5
P144	23	23	23	26	32	32
P168	27	27	27	27	32	32
P192	30	30	30	27	32	32
P216	32	32	34	40	50	50
P240	36	36	36	41	50	50

Full Condenser Water Flow Shutoff via Terminal Block 8 (TB8)

Water-source modules contain a terminal block with dry contacts for proof of flow status via a field provided flow switch, as well as a dry contact to energize the control circuit for an auxiliary dedicated pump or motorized isolation valve.

Variable flow pumping can be achieved to some extent during scheduled night set back periods when all indoor units on a water source system are OFF, by installing motorized two position valves on each of the water source modules tied to the appropriate terminal block.

Systems comprised of twinned modules will not de-energize the field provided two position valves on any of the modules, until all the modules become thermally inactive AND all connected indoor units are OFF.

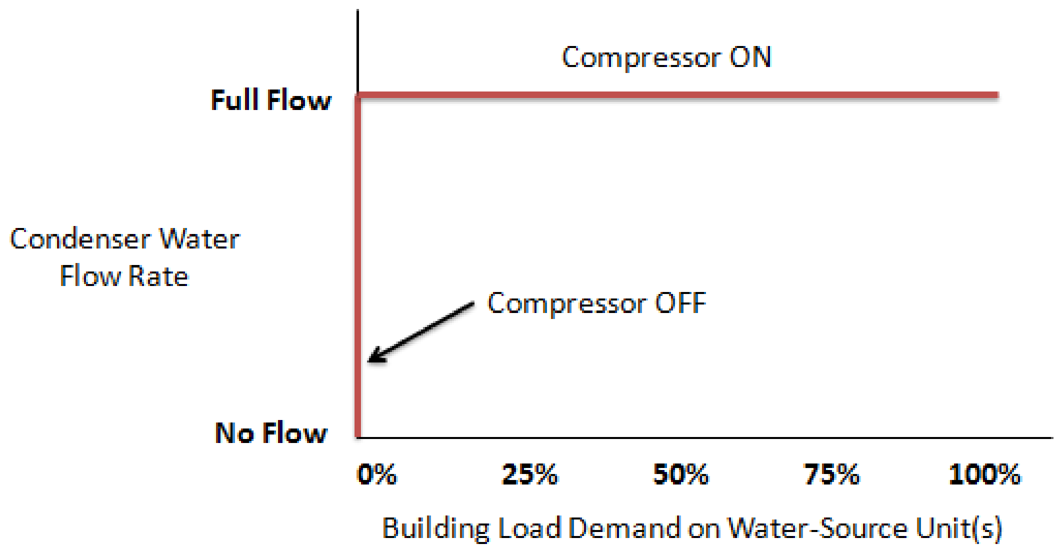


Figure 8. Diagram showing Full Condenser Water Flow Shutoff

Figure 9 below depicts the interface of terminal block (TB8) on the water-source modules to this auxiliary pump / motorized isolation valve.

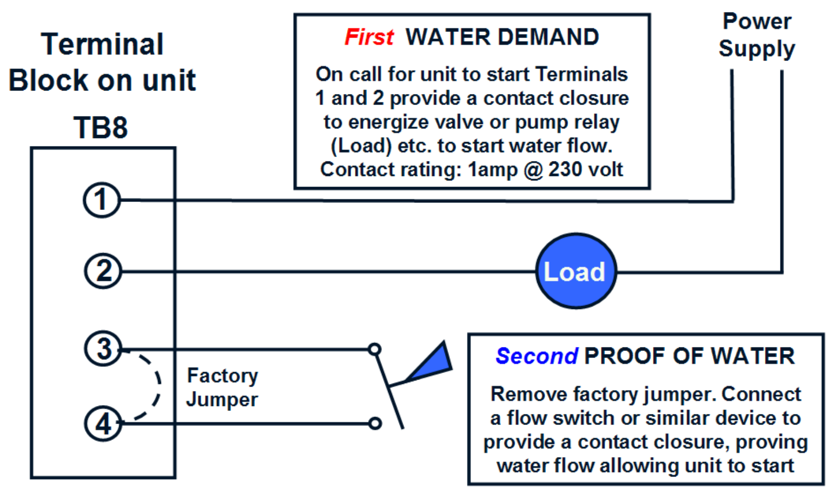


Figure 9. WR2 / WY Water-Source Unit Start Sequence

<u>Please Note:</u>

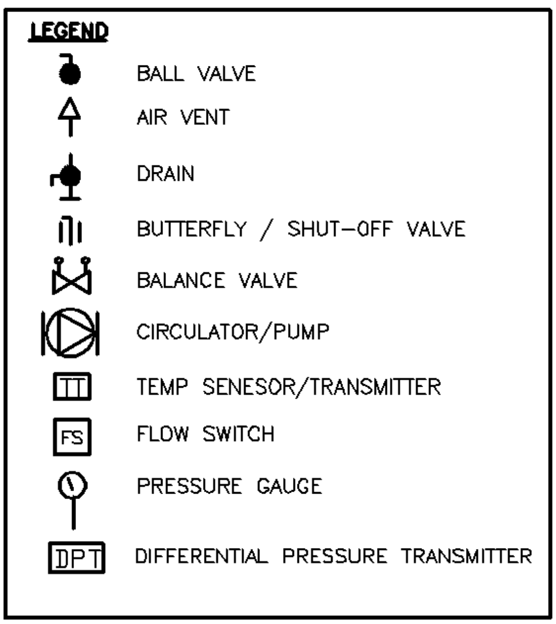
- **Valve Or Pump Will NOT be de-energized until ALL indoor units are OFF on the associated system.**
- Function 917 ON (same as SW2-7, H Gen) is required to get TB8(1-2) to close when the unit is ON and ANY indoor unit is ON. TB8(1-2) remains closed during the preliminary 10 minute restart delay and the unit starts if TB8(3-4) closes in this delay period, Function 919 should remain OFF (similar to SW2-8, H Gen)

Full Variable Flow Control at Water Source Modules

The L generation water source modules also contain the functionality to completely vary water source flow per module in lieu of a simple two position on/off valve method indicated above. Details of this method is not covered in the scope of this application note – please reference ***"Application Note 2031: Variable Condenser Water Flow Control on L Generation Water Source VRF"*** for proper application of this feature and additional requirements and accessories required.

APPENDIX

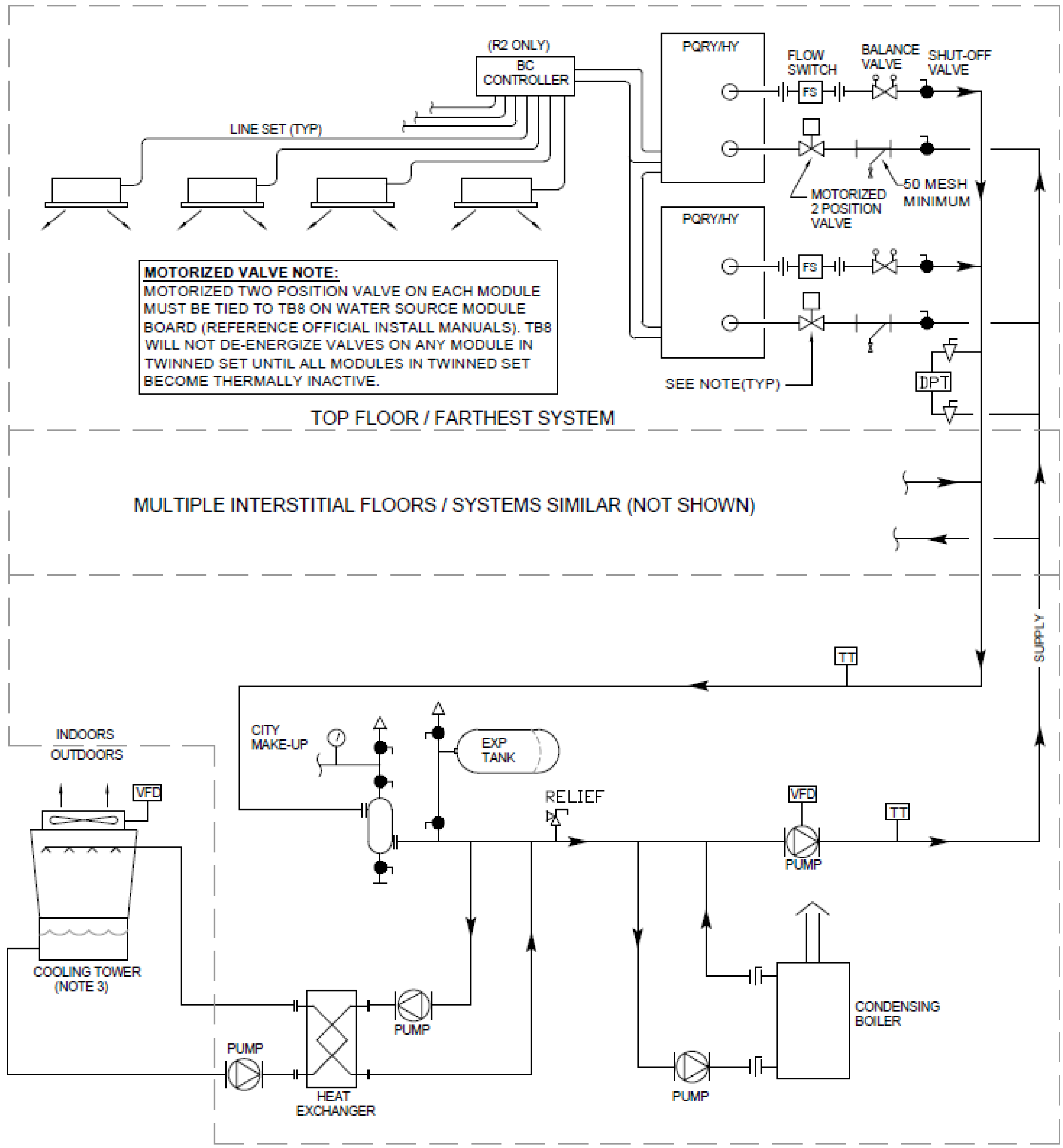
Schematic Piping Diagram Legend



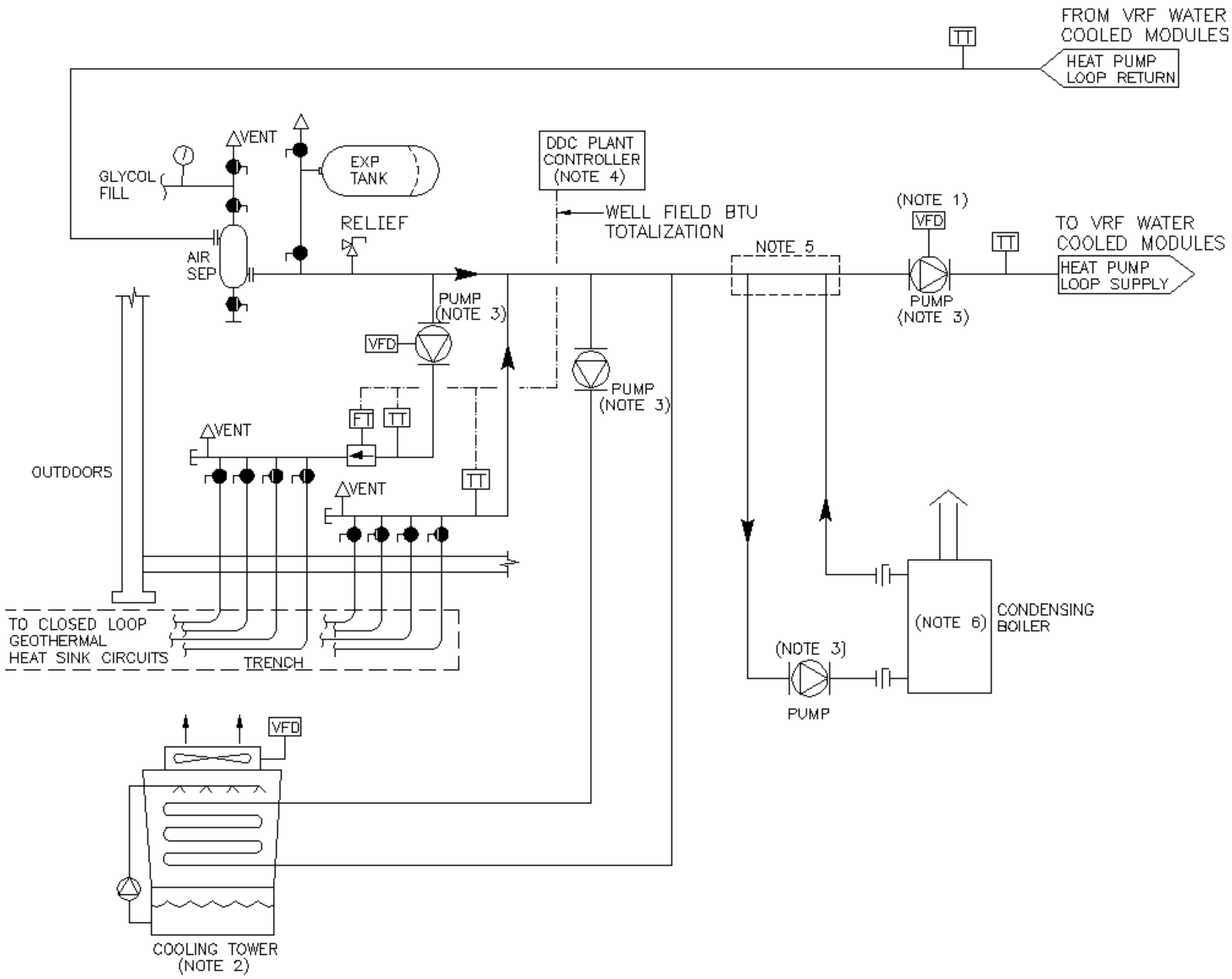
GENERAL NOTE / DISCLAIMER:

THE SCHEMATIC DRAWINGS IN THIS DOCUMENT TO WHICH THIS LEGEND REFERS ARE GENERAL IN NATURE TO ILLUSTRATE BASIC ARRANGEMENT AND MAJOR SYSTEM COMPONENTS. NOT ALL REQUIRED SPECIALTIES AND DEVICES SHOWN. FINAL DESIGN SHOULD BE BY A QUALIFIED LICENSED ENGINEER IN COMPLIANCE WITH LOCAL SPECIFIC CODE REQUIREMENTS.

APPENDIX 1 – Traditional Boiler Tower Water Source VRF Diagram



APPENDIX 2 – Geothermal Water Source VRF Plant with Optional Hybrid Schematic



NOTES:

1. CONTROLLED BY REMOTE DIFFERENTIAL PRESSURE TRANSMITTER NEAR FARTHEST PIPING RUN.
2. CLOSE CIRCUIT EVAPORATIVE COOLING TOWER FOR HYBRID GEOTHERMAL APPLICATIONS WITH COOLING DOMINANT BUILDING LOAD PROFILES FOR SUPPLEMENTAL HEAT REJECTION.
3. NOT SHOWN FOR CLARITY – STRAINER, ISOLATION VALVES, CHECK VALVE, BALANCE VALVE, PRESSURE GAUGES, STATUS SENSOR/SWITCH, ETC...
4. DDC PLANT CONTROLLER BY OTHERS REQUIRED TO PROPERLY CONTROL STAGING AND MODULATION OF PUMPS, COOLING TOWER FAN, BOILER, AND ALL ANCILLARY DEVICES AND EQUIPMENT OTHER THAN THE MITSUBISHI WATER SOURCE MODULES.
5. ISOLATION HEAT EXCHANGER MAY BE REQUIRED DUE TO FILL PRESSURE ON HIGH RISE APPLICATIONS TO PROTECT BOILER OR TO MEET SPECIFIC BOILER MANUFACTURER REQUIREMENTS FOR INLET WATER TEMP, FLOW, AND CHEMICAL TREATMENT SPECIFICATIONS.
6. BOILER FOR HYBRID GEOTHERMAL APPLICATIONS WITH HEATING DOMINANT LOAD PROFILE TO SUPPLEMENT HEATING ONCE TOTAL HEAT ABSORPTION FROM WELL FILED EXCEEDS PRIOR COOLING SEASON HEAT REJECTION – COMPUTED VIA FLOW TRANSMITTER AND TEMPERATURE TRANSMITTERS IN MAIN WELL FIELD SUPPLY AND RETURN PIPING.