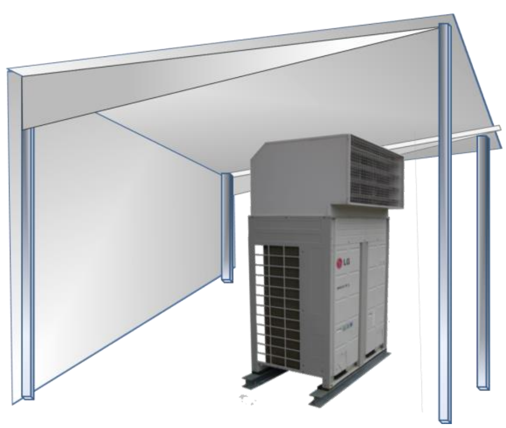
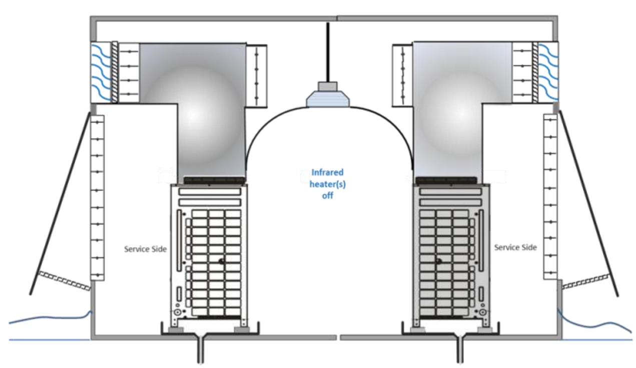
Air-Source VRF Mechanical Room Design Considerations for Outdoor Unit Placement in Enclosures





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WP-VRF_Mechanical_Room_Design_ODU_Placement-12-14

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Executive Summary

In extremely cold environments, where there is a significant amount of run-time at temperatures well below freezing, it may be more economical and prudent to place the outdoor units in a partial or fully enclosed equipment room. In situations where operation is anticipated at temperatures of -13F and lower, provision of ancillary heat should be provided for the outdoor unit to assure continuous compressor operation and heating.

Introduction

Overview

The purpose of this publication is to provide VRF system designers with ideas and concepts that can be utilized to maximize VRF system performance in inclement weather prone environments.

Design considerations include:

- Assuring continuous compressor operation (i.e., continuous heating) at low ambient temperatures
- Types of enclosures
- Design of enclosure elements such as:
    - Louvers
    - Rain hoods
    - Dampers and controls
    - Heating methods
    - Sizing of heating devices
- Heating strategies
- Duct design
- Handling condensate

Many benefits can be had installing the outdoor units (ODU) in a manner that shelters them from direct exposure to adverse weather and environmental conditions. The enclosure could be a former chiller, boiler, or air handler mechanical area or penthouse.

When mounting on the roof is not an option due to a lack of roof space or the roof warranty will be voided if mechanical equipment is placed on the membrane, move the outdoor units indoors.

On retrofit projects, often a former chiller/boiler equipment room is a perfect location to mount outdoor units since it is an enclosed fully protected room. On projects that have vertical, self-contained VAV air handlers on each floor, in lieu of a centralized mechanical room, they make great locations to mount LG VRF outdoor units.

When mounted in a fully enclosed space, additional capital saving benefits may be possible. Limiting the ambient air temperature in the ODU space may allow the Multi V system designer to eliminate oversizing the outdoor unit to compensate for loss of capacity at low ambient temperatures. This move will also curtail the potential need to provide inefficient redundant zone heating devices, such as wall-fin radiators, or duct heaters.

Q: Is it an acceptable risk to have intermittent heating available on extremely cold winter days?

In most cases it is not. Verify your design is not based on manufacturer's reference data.

VRF system manufacturers sometimes publish "reference data" in lieu of performance data. "Reference data" provides capacity information for a VRF system when the compressor is running. It does not guarantee the compressors will be operating at the "reference data" temperature condition. Reference data can be found in the same data tables that present the manufacturer's guaranteed continuous compressor operation data and is usually delineated using a shaded background and footnoted.

Never design a VRF system based on manufacturer's "Reference Data"!

Multi V IV System Heating Performance Guarantee

With all heating/cooling direct-expansion type equipment there is a risk of intermittent compressor operation at low ambient temperatures. LG guarantees continuous compressor operation at this low temperature. The advanced technology of the LG Multi V IV air source VRF heat recovery and heat pump systems is designed to provide heat at outdoor ambient conditions as low as -13F. Furthermore, LG only publishes performance data for conditions at which continuous compressor operation can be guaranteed.

Enclosures

Various factors unique to the project at hand will be used to determine what low ambient heating solution is best. In all cases, the best solution will be a balance between acceptable heating performance considering local weather conditions, capital cost, life cycle energy consumption, and limitations set forth by local building codes.

Outdoor units are engineered to be mounted outdoors and have technology designed to minimize the negative effects of winter weather's freezing rain, sleet, and snow. However, depending on the severity and frequency of precipitation, it may be prudent to consider protecting the outdoor unit(s) from direct contact with prevailing winds and winter precipitation.

Prevailing winds against the outdoor unit coil conduct heat transfer. When severe winds are cold and blowing for an extended period of time, they will lower the outdoor unit capacity. Depending on the system's combination ratio, this may impact the ability to effectively heat the building.

Keeping snow and freezing rain away from LG outdoor units provides peace of mind knowing the equipment is protected from ice build-up that could hinder unit operation. Protecting the outdoor unit from freezing precipitation also has other potential benefits such as maintaining coil heat transfer efficiency; reducing the number of and shortening the cycle time for defrost operation. Maintenance personnel will also appreciate the enclosure while servicing during inclement weather conditions.

To protect outdoor equipment from prevailing winds a fully enclosed room may not be necessary. When capital dollars are at a premium, a roof over the outdoor units in combination with a wind break may be all that is necessary.

Spot Heating

If equipment is mounted under a protective roof with a wind break wall, localized spot heating may be an economical way to maintain a minimum entering air temperature at the outdoor unit coil. This method also reduces the amount of time the system operates in defrost mode and maintains outdoor unit capacity at extremely low ambient conditions. Maintaining the temperature above -13F will also assure continuous compressor operation (continuous heating). Pre-heating can be accomplished using localized directional infrared heaters (see, Figure 1) or using ducted warm air from a gas-fired or electric make-up air unit, duct furnace, or blower coil (see, Figure 2).

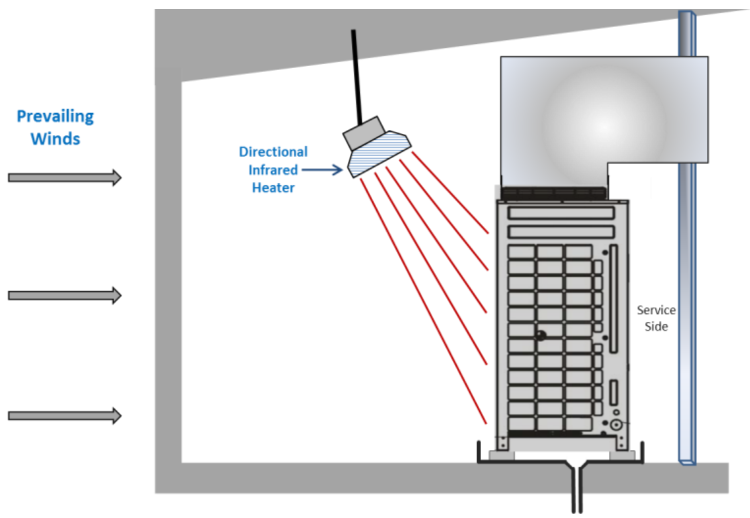

Figure 1. Infrared Spot Heat in an Open Enclosure

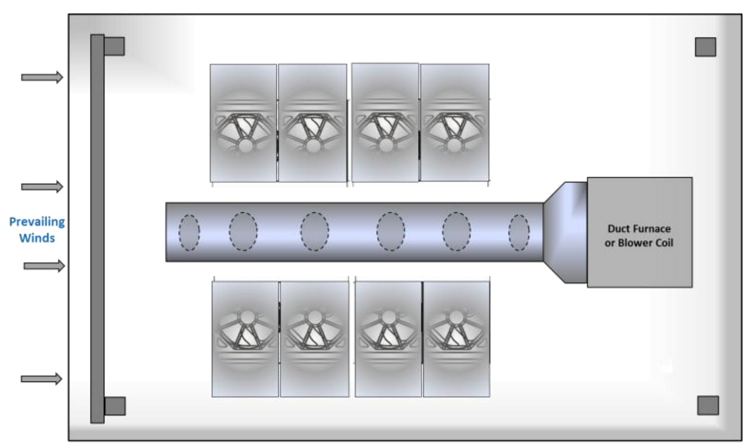

Figure 2. Overhead Duct Furnace or Blower Coil with Duct

Ventilation Openings

Roof top openings and/or architectural louver design, duct configuration and choice of insulation material may have a significant impact on the potential for microbial growth in the ventilation system airstream. ASHRAE 62.1 addresses best practices to avoid microbial growth.

Water Entrainment

Discharge and supply ductwork should be designed to avoid weather related long periods of water entrainment and the potential for microbial growth. Use good quality louvers (see, Figure 3), or a rain hood over the ventilation air inlet (see, Figure 4). If the possibility of rainwater infiltration is present, install a drain pan next to the interior side of the louver (see, Figure 3) to collect any rain water that passes through the louver. For more information refer to the guidelines in ASHRAE 62.1-2010 section 5.5.2 and 5.5.3.

Insect Control

Discharge and supply louvers should be equipped with insect screens to prevent bird and insect infiltration (see, Figure 3 and Figure 4). For more information refer to the guidelines in ASHRAE 62.1-2010 section 5.5.

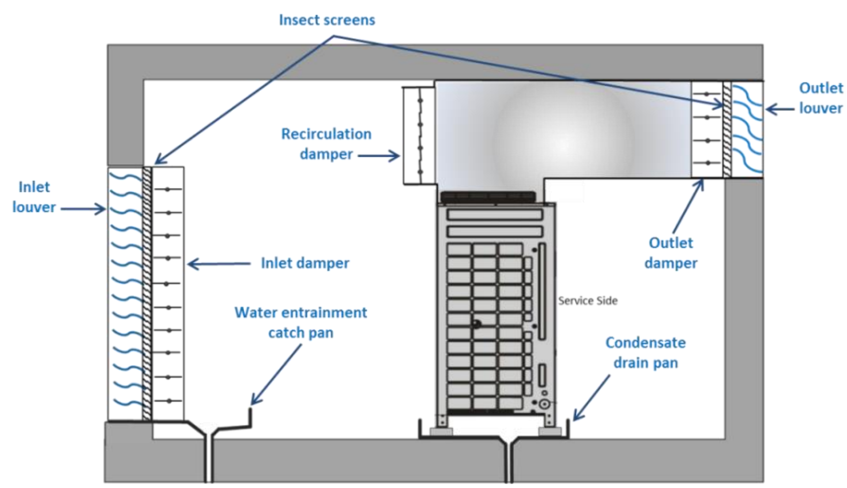

Figure 3. Wall Louver Option

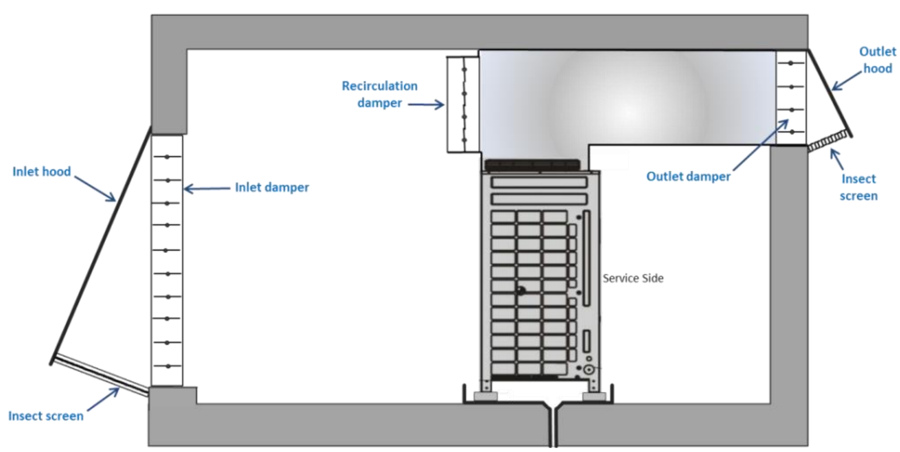

Figure 4. Rain Hood Option

Avoiding Snow Blockage

Consider the potential for snow accumulation near louvers/roof openings. Openings should be located and designed to minimize the potential of increased static pressure or blockage resulting from snow accumulation near the openings.

Roof top ventilation ducts should be engineered so the duct inlet clears the anticipated snow accumulation level by at least one foot as depicted in Figure 6. The bottom edge of architectural wall louvers or ventilation opening rain hoods should be mounted a minimum of one foot above the anticipated snow accumulation level as shown in Figure 5. For more information refer to guidelines in ASHRAE 62.1-2010 section 5.5.4.

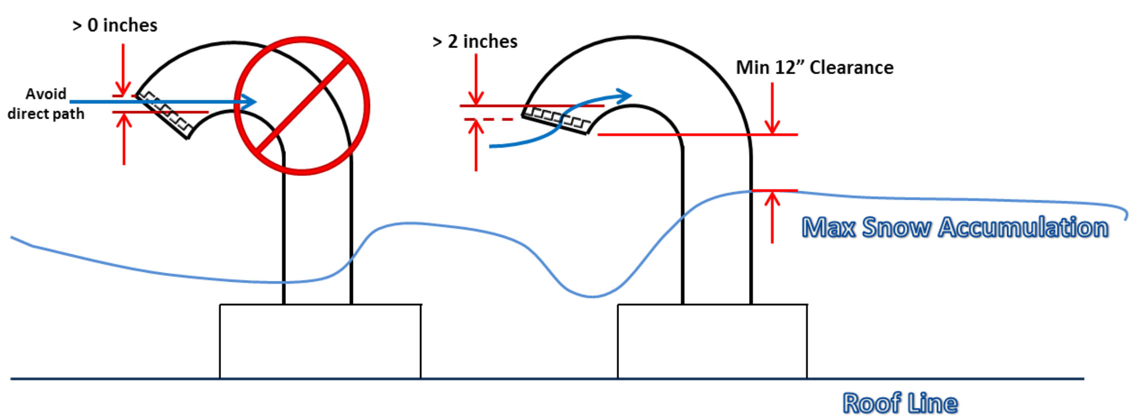

Figure 5. Roof-mounted Ventilation Opening Design

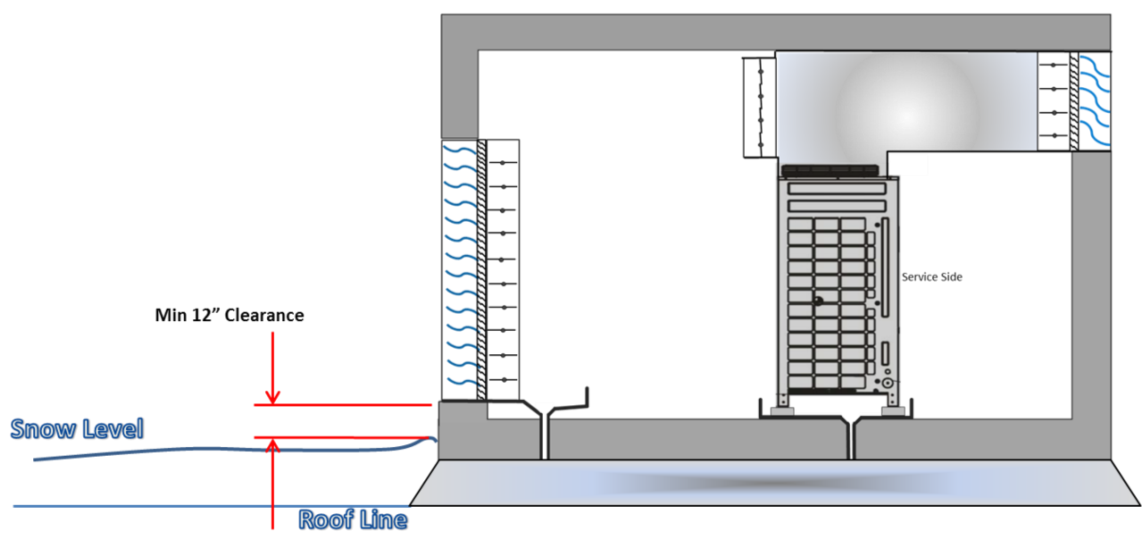

Figure 6. Wall Louver Minimum Mounting Height

Avoiding Short Circuiting

Follow the design guidelines of ASHRAE 62.1-2010 section 5.5 and Table 5-1.

Short circuiting is defined as air discharged from the outdoor unit fan and drawn back into the outdoor unit coil. In the cooling season, discharge air is heated; in the heating season discharge air is cooled. If discharge air is allowed to recirculate, the entering air temperature will continually rise above ambient conditions in the summer and continue to fall below the ambient air temperature in the winter. Both scenarios will have a negative impact on the VRF system operating efficiency. In extreme climatic conditions, short circuiting could lead to unit malfunction.

To prevent short circuiting inside the enclosure install field provided ductwork between the top of the outdoor unit and the exterior grille on the building. Avoid using a single duct on multi-fan units to prevent recirculating air between frames when a single fan is operating. The most economical installation to prevent recirculation between fans is to provide a dedicated duct for each ODU fan discharge (see, Figure 7)

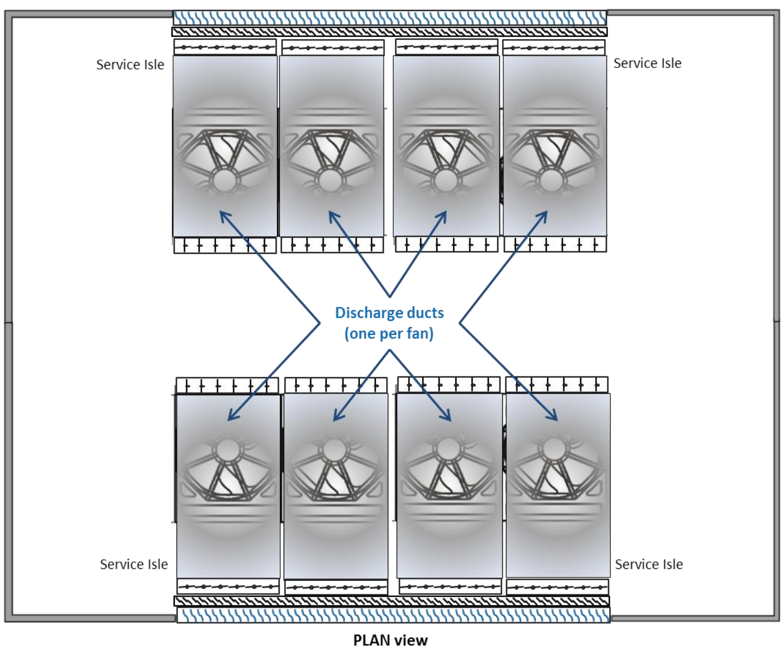

Figure 7. Individual Discharge Ducts

To prevent short circuiting outlet and inlet opening of the enclosure, first consider the direction of prevailing winds and then opening placement. Locate inlet openings upwind of discharge openings and other exhaust outlets.

When inlet and outlet openings are placed on the same wall, it is suggested that a minimum distance between the two openings be approximately three feet.*

If roof-mounted ventilation openings are utilized, strategically locate the inlet ventilation opening(s) upwind of the outlet opening(s).

* Minimum distance varies significantly with variations in outlet opening face velocity.

Avoid Frozen Condensate

In the heating mode, Multi V IV outdoor unit coils will operate with a surface temperature below the ambient air dew point at some time. When this occurs frost will build on the coil surface. In addition, if the outdoor unit is not protected from contact with precipitation, frozen rain and snow will also accumulate on the cold coil surface. The Multi V equipment is equipped with a defrost cycle that will remove the frost and frozen precipitation from the coil surface by heating it. During this process liquid condensate will roll off the coil and eventually reach the floor of the equipment room, roof, or mounting pad around the unit. If the ambient air temperature is below 32F, the condensate will refreeze and if not properly collected creates a hazardous condition when accessing the outdoor units. To avoid this hazard, control the run-off by installing a field provided drain pan under the outdoor units and provide a path to a nearby floor drain. If the ambient air temperature is expected to drop below 32F, make arrangements to heat the bottom surface of the pan, drain line, and floor drain to assure the condensate does not freeze before reaching the drain.

Sizing Wall Louvers/Openings

Select the size, type and orientation of architectural louvers with adequate "net free area" that ensures the total external static pressure seen by the outdoor unit fan does not exceed design limitations. Free area is provided by the louver manufacturer and is specific to each model louver. It is defined as the wall opening area (rough-in dimensions) less the cross sectional surface area populated by the louver frame and blades.

Louver Height (Inches) \ Louver Width (Inches)	12	24	36	48	60	72	84	96
12	0.33	0.72	1.10	1.48	1.86	2.20	2.58	2.96
24	0.81	1.73	2.66	3.59	4.51	5.32	6.25	7.17
36	1.28	2.75	4.22	5.69	7.16	8.44	9.91	11.38
48	1.76	3.77	5.78	**7.79**	9.81	11.56	13.58	15.59
60	2.23	4.79	7.34	9.90	12.45	14.69	17.24	19.80
72	2.71	5.81	8.90	12.00	15.10	17.81	20.91	24.00
84	3.19	6.83	10.47	14.11	17.75	20.93	24.57	28.21
96	3.66	7.84	12.03	16.21	20.39	24.05	28.24	32.42

Table 1. Sample louver* -- net free-area technical data

** Data provided by Architectural Louvers Inc. Cincinnati, OH. Model E2JS. Data provided for technical data sample purposes only. LG Electronics U.S.A., Inc. does not endorse or provide any warranties, express, implied or otherwise for any product manufactured and/or branded by any third party for any reason whatsoever including all implied warranties of merchantability and fitness for a particular use or purpose.*

Typically louvers have a net free area opening between 35% and 70% without insect screens. Models with insect screens range between 40% and 60%. Louvers with a higher percentage free area tend to have a lower first cost because the overall louver size can be reduced without increasing air pressure drop loss.

The outlet louver(s) (see, Figure 3) should have a net free area and be designed to provide directional throw to expel air away from the building. No obstructions should be placed in front of the louver that could hamper the free flow (throw) of air away from the building.

Outlet louvers typically have an air velocity across the face of somewhere between 900 and 1200 feet per minute with the ODU fan operating at maximum design speed. The direction of the outlet air stream should be set to direct discharge air away from the ventilation air intake. When possible, it is best to use a rain hood similar to that shown in Figure 4 to avoid short circuiting and mixing of the inlet and outlet airstreams. Inlet louver(s) should be large enough to minimize the entrainment of undesirables such as rain water and insects. Inlet louver free area face velocity should not exceed 350 fpm. In cases where water entrainment is a major concern, select a louver from a manufacturer that provides water entrainment vs free area velocity engineering data that has been certified by the Air Movement and Control Association International, Inc. (see, Figure 8).

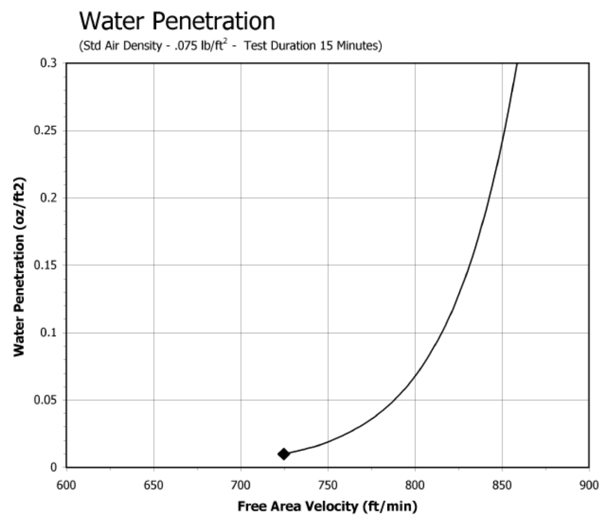

Figure 8. Sample Louver Performance * - Water Entrainment vs Free area Velocity

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Duct Design - Fan Static Limitations

Multi V IV air source outdoor unit fans are capable of moving ODU design airflow volume at a maximum fan external static pressure of 0.32 in-wg. When designing ductwork, verify that the total resistance to airflow does not exceed this limitation. Resistance to airflow includes the static pressure drop through the inlet and outlet louvers, dampers, bird screens, and ductwork fittings. Air pressure drop data is provided by louver manufacturers (see, Figure 9). Duct losses may be calculated using conventional means.

Total Fan External Static Pressure (ESP) ≤ 0.32 in-wg = Inlet Louver + Inlet insect screen + inlet damper + discharge duct losses + outlet damper + outlet insect screens + outlet louver static pressure drop.

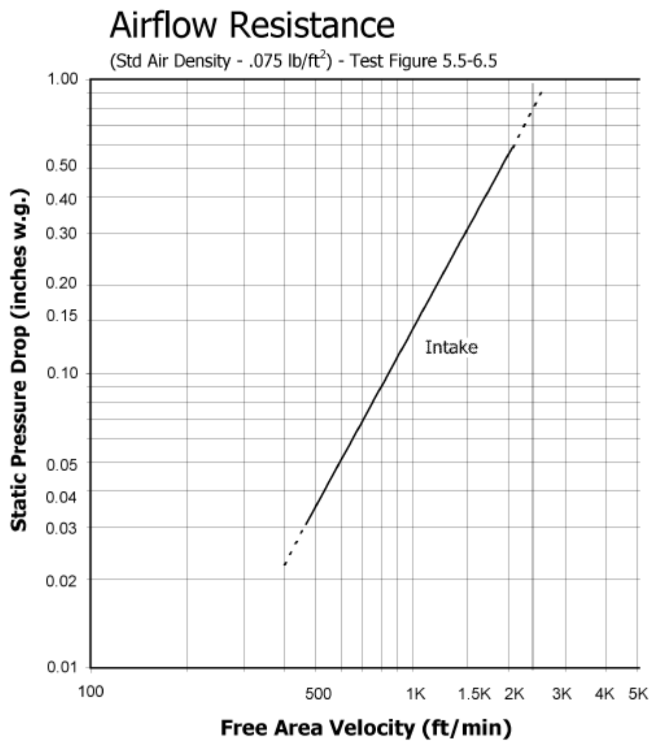

Figure 9. Sample Louver Air Pressure Drop data*

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Available wall space - locating the inlet and discharge louvers

Q: Should I pre-heat enclosure air?

The answer should be based on economics. Will the total cost of building ownership considering the project's initial capital cost be better/worse if a pre-heat system is utilized?

There is much discussion about ancillary heating to control the minimum air temperature at the ODU. For example, what target temperature should be maintained? For LG Multi V IV air source systems, in extreme climates, it may be wise to install a small pre-heat system to assure that the entering air temperature is never lower than -13F. This provides peace of mind for the designer and the building engineer knowing that their LG Multi V IV system's compressor(s) will be running continuously.

Depending on the annual heating season run-hours, the total cost to own the building may be lower and the return on initial investment may increase when air is pre-heated before it enters the ODU coil.

Designing for operation in low ambient conditions may require oversizing of the outdoor unit to generate the required system heating capacity if the local winter design condition is below 15ºF. In addition, the VRF system's Coefficient of Performance (COP) may decrease with a drop in the air temperature entering the ODU heat exchanger. For these two reasons, it may be more economical to provide and operate a booster heater at extremely low ambient temperatures.

Sources of Ancillary Heat

The type of heater selected will depend on local utility rates, enclosure type, physical constraints within the enclosure, and the desired location of the heater. On retrofit projects, consider existing sources of heat such as steam or hot water if available. On existing facilities consider reclaiming heat from existing sources. If natural gas is available, it will probably be the most economical pre-heating fuel source.

Heating enclosures

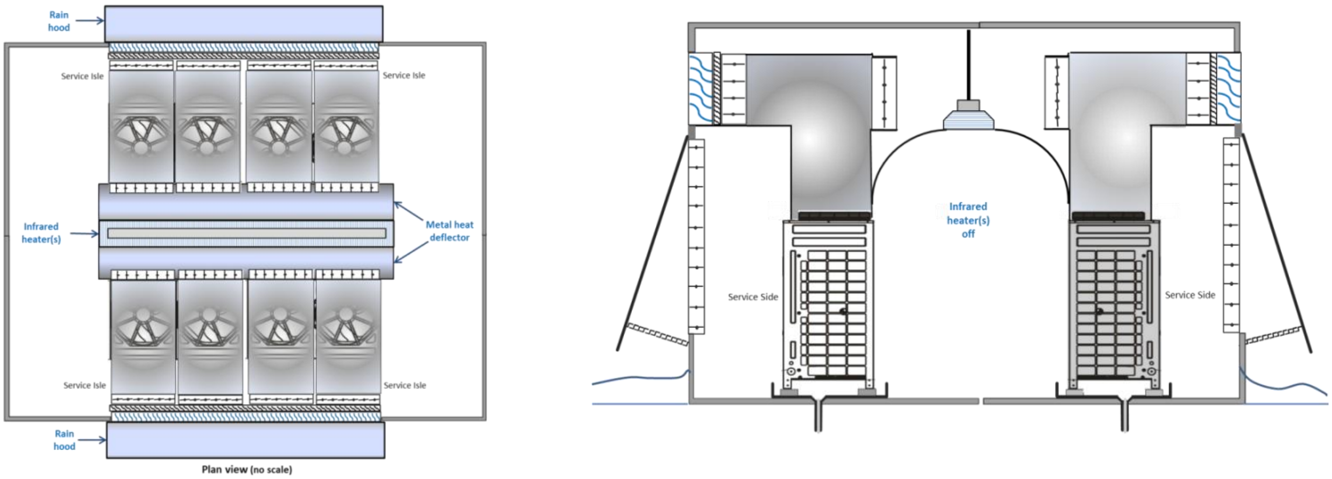

Figure 10. Heated Enclosure - Infrared Heat Source (Normal Ambient Operation Shown)

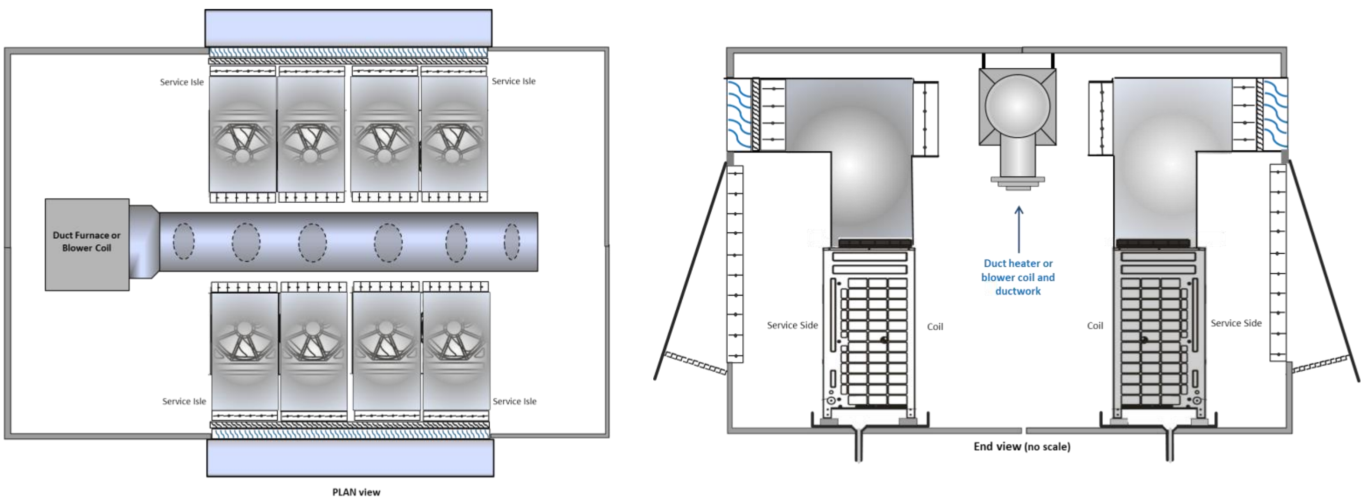

Figure 11. Heated Enclosure - Duct Furnace or Blower Coil Heating Source (Normal Ambient Operation Shown)

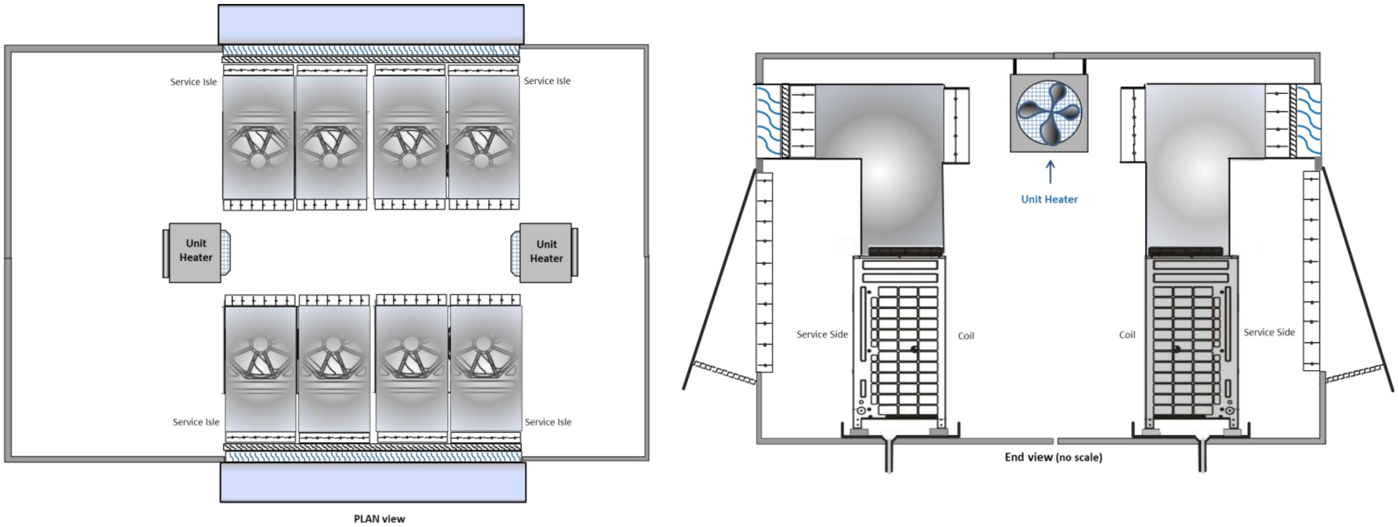

Figure 12. Heated Enclosure - Unit Heater (Normal Ambient Operation Shown)

Selecting a Pre-heat Temperature Set-point

For the most economical set-point temperature, the designer will need to consider local weather conditions, the VRF systems capacity loss and machine efficiency characteristics during low ambient operations, along with the desired indoor unit operating mode at low ambient conditions.

If night setback strategies are used in the building, then the designer will want to consider varying the temperature in the enclosure based on time of day. For example, it may be prudent to raise the temperature in the enclosure during the morning warm-up period to abbreviate the time it will take to bring the building to occupancy temperature. This method can also be used to improve the heating capacity during high heating demand periods.

If a Multi V IV heat recovery system is installed, and the designer wants to be assured of year round full cooling capacity, the enclosure temperature will need to be maintained at 14F which the minimum temperature for synchronous heating/cooling operation. If the enclosure temperature is not maintained at 14F, system cooling capacity becomes dependent on the amount of heating that occurs at any given time.

If a Multi V IV heat pump system is installed and low ambient cooling operation is desired, an enclosure solution with a minimum enclosure temperature of 14F may be used in lieu of installing low ambient dampers and controls on each unit.

To estimate the operating cost of the VRF system at different ambient temperatures, first estimate the number of run-hours the VRF system will operate below the desired enclosure temperature. Next, estimate the differential in the power consumed by the VRF system ODU for the period along with the enclosure temperature at the selected minimum ambient set-point and subtract this from the power consumed for the period while operating the ODU at nominal ambient conditions. Calculate the energy consumed by the ancillary heater(s) for the estimated run hours and convert to kW. Annualize the power consumed in each scenario. If the amount of energy consumed while preheating is less than the amount saved, then preheating will pay for itself.

Sizing Heaters

Sizing the ancillary heating devices is critical to the desired outcome. After the enclosure minimum design temperature has been defined, calculate the heat loss through the enclosure walls. Next calculate the Multi V compressors heat of compression at full load while in heating mode. Lookup the power consumption of the ODU at the minimum enclosure design temperature.

For example, typically a Multi V IV system will maintain full heating capacity with a minimal rise in power consumption down to 15F. Therefore, 15F would be the optimum minimum enclosure temperature to maintain to minimize the project capital investment and the building's total cost of ownership (assuming the utility cost $/BtuH is the same for electricity and any alternative fuel source).

The Multi V IV outdoor unit's heating capacity is the combination of the heat of compression and heat of absorption. The ancillary heaters must be sized to provide the Multi V IV with the heat of absorption plus the heat loss through the enclosure envelope.

Calculate the heat of absorption by subtracting the heat of compression from the heating capacity of the outdoor unit. The heat of compression is calculated using the outdoor unit power consumption at design conditions.

Combination (%)	Outdoor air temp.		Indoor Air Temp. °F DB/°F WB									
			59		61		64		67		70	
	°F DB	°F WB	TC MBh	PI kW	TC MBh	PI kW	TC MBh	PI kW	TC MBh	PI kW	TC MBh	PI kW
100	-12.6	-13.0	150.9	11.96	150.9	12.96	150.9	14.46	150.4	14.92	149.9	15.37
	-7.0	-7.6	163.3	12.92	163.3	13.93	163.3	15.43	162.8	15.88	162.3	16.33
	-4.0	-4.4	170.7	13.50	170.7	14.50	170.7	16.00	170.2	16.46	169.6	16.91
	0.0	-0.4	179.7	14.22	179.3	15.23	178.8	16.72	178.5	17.17	178.2	17.62
	5.0	4.5	190.8	15.11	190.8	16.11	190.8	17.62	190.3	18.06	189.8	18.52
	10.0	9.0	203.3	16.00	202.7	17.00	201.9	18.50	201.7	18.96	201.7	19.41
	15.0	14.0	213.9	16.88	213.9	17.88	213.9	19.38	213.4	19.44	212.8	19.50
	20.0	19.0	230.6	17.98	229.7	18.79	228.5	20.00	222.2	19.33	216.0	18.64
	25.0	23.0	245.3	19.17	241.8	19.02	236.6	18.79	226.3	18.30	216.0	17.82
	30.0	28.0	257.0	18.44	249.1	18.24	237.4	17.94	226.7	17.46	216.0	16.98
	35.0	32.0	261.3	17.71	251.7	17.46	237.4	17.09	226.7	16.62	216.0	16.15
	40.0	36.0	261.3	16.98	251.7	16.69	237.4	16.25	226.7	15.78	216.0	15.31
	45.0	41.0	261.3	16.25	251.7	15.91	237.4	15.42	226.7	14.95	216.0	14.50
	47.0	43.0	261.3	15.96	251.7	15.62	237.4	15.14	226.7	14.68	**216.0**	**14.23**
	50.0	46.0	261.3	15.58	251.7	15.26	237.4	14.78	226.7	14.34	216.0	13.89
	55.0	51.0	261.3	15.00	251.7	14.69	237.4	14.24	226.7	13.80	216.0	13.38
	60.0	56.0	261.3	14.38	251.7	14.08	237.4	13.64	226.7	13.23	216.0	12.82
	-12.6	-13.0	150.2	13.09	150.2	13.42	150.2	13.90	149.8	14.43	149.3	14.96

Table 2. Multi V IV ARUN192 heating capacity at 100% combination ratio

Selecting a pre-heat temperature set-point example:

Given:

2 - 16 ton Multi V IV heat recovery VRF systems.

Model: ARUN 192BTE4

Heat loss through enclosure at 14F = 32,500 BtuH

Ancillary heater efficiency = 80%

Safety factor = 10%

Solution:

From Table 2, the heating capacity of the ARUN192BTE4 is 212,800 BtuH.

Power consumed is 19.50 kW.

Heat of compression (BtuH) = 19.50 kW * 3414 BtuH = 66,573 BtuH.

Heat of absorption (BtuH) = 212,800 BtuH - 66,573 BtuH = 146,227 BtuH.

Required ancillary heater capacity = qty of units * Heat of compression (BtuH)/unit + enclosure heat loss (BtuH)

= (2 * 146,227 BtuH)+ 32,500 BtuH

Required ancillary heating capacity = 259,954 BtuH.

Safety factor 259,954 BtuH * 10% = 25,995 BtuH

Ancillary heating device NET capacity required = 285,949 BtuH

Required gross heating capacity = 285,949 ÷ 80% = 357,437 BtuH

Dampers and Controls

Inlet and outlet dampers are to be open and the bypass damper closed when the outdoor ambient temperature is above the Pre-heat Temperature Setpoint. When outdoor ambient temperature is below the Setpoint, inlet and outlet dampers are to be closed, the bypass damper opens, and the heating device is operational.

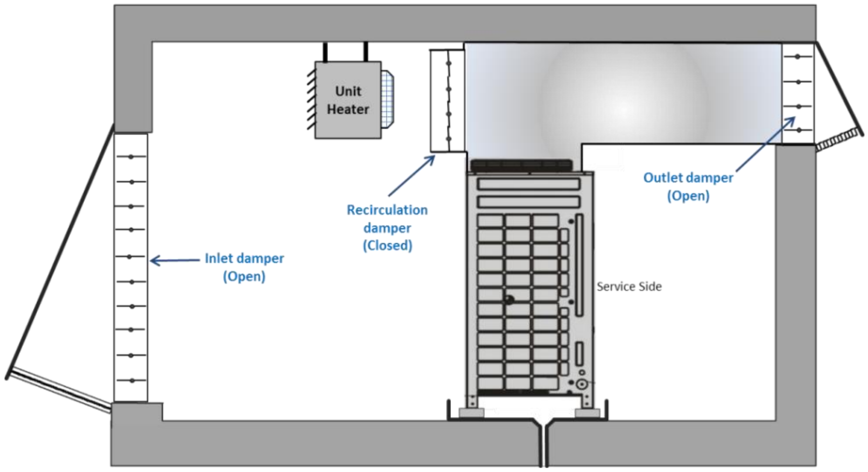

Figure 13. Heated Enclosure Damper Positions - Normal Ambient Conditions

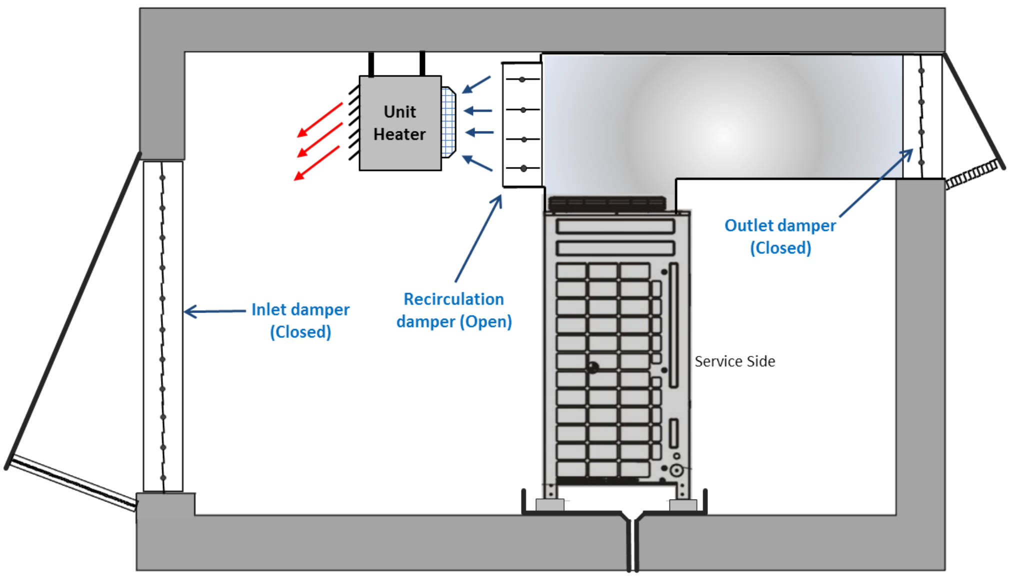

Figure 14. Heated Enclosure Damper Positions - Low Ambient Conditions with Heater Operational

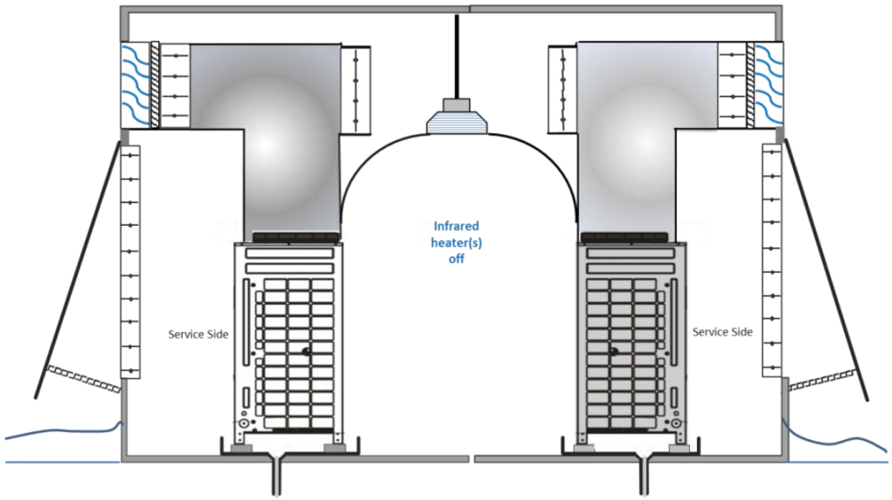

Figure 15. Heated Enclosure Damper Positions - Normal Ambient Operation Heater Idle

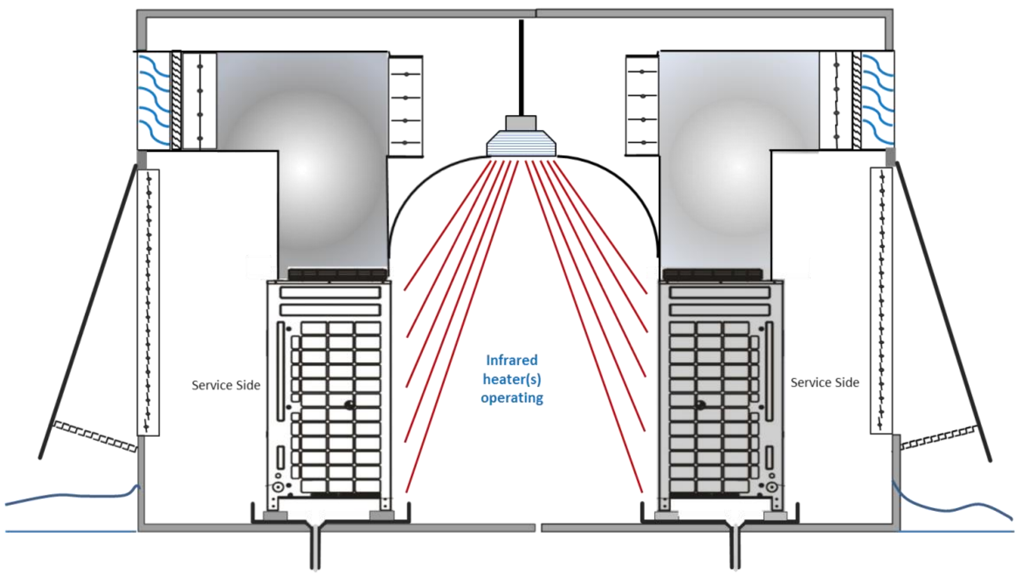

Figure 16. Heated Enclosure Damper Positions - Low Ambient Operation with Heater Operational

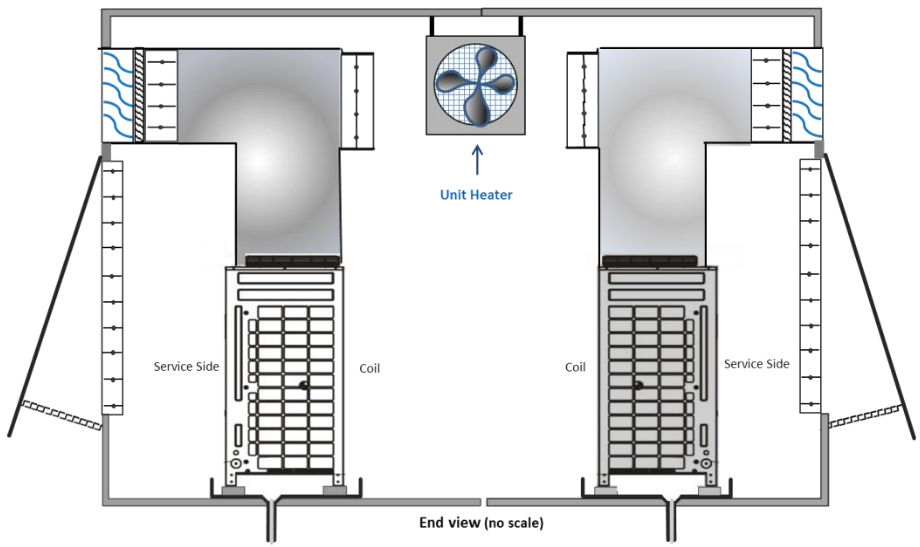

Figure 17. Heated Enclosure Damper Positions - Normal Ambient Operation Heater Idle

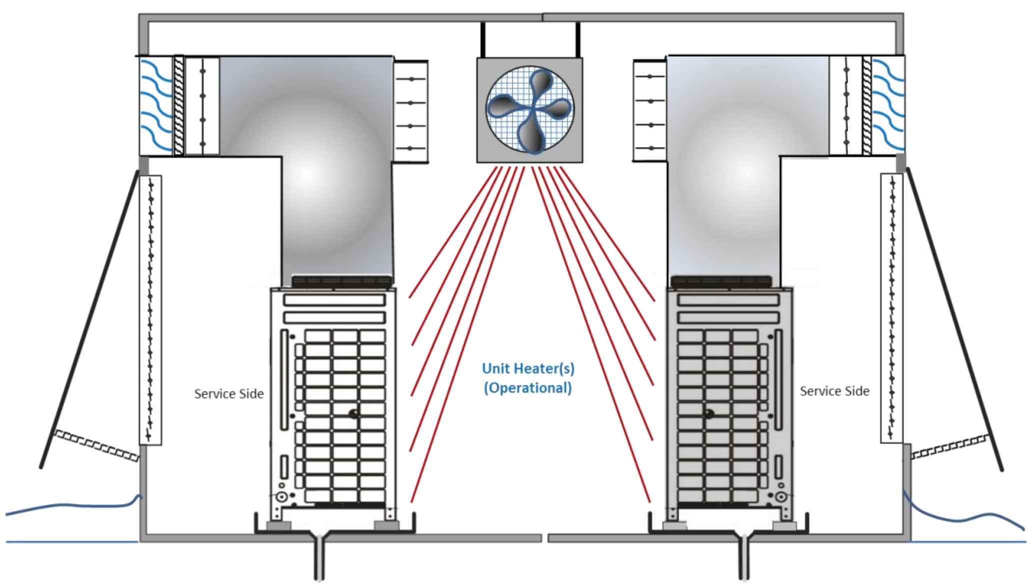

Figure 18. Heated Enclosure Damper Positions - Low Ambient Operation with Heater Operational