Network Zone Systems Thermal Management

Network enclosures are widely used both indoors and outdoors to secure a wide range of electronic equipment such as: switches, routers, gateways, power supplies, etc. These enclosures are used in a wide range of markets including hospitals, manufacturing plants, refineries, stadiums, etc. Therefore, these enclosures are exposed to a wide variety of ambient conditions.

Such enclosures (Figure 1) can have strict ingress ratings such as NEMA 4/4X, IP54/55, etc. These ratings, while protecting the equipment from some environmental conditions (dust, water spray, etc.), also effectively trap the heat dissipated by the active equipment inside the enclosure. This air, that has increased in temperature, must still provide adequate cooling for the components mounted inside the enclosure.

This application guide gives an overview of key design considerations for thermal management solutions to mitigate these thermal factors for Panduit's zone enclosures. The capabilities of the various thermal management solutions are discussed and guidelines for recommended solutions are provided.

Figure 1: Z23U-S24 Enclosure

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Introduction

Most of the power consumed by electronic endpoint devices is dissipated as heat, this is especially true of IT equipment (switches, servers, routers, etc.). To avoid equipment overheating or even failure the cooling of this equipment should be considered as part of the deployment plan. When an enclosure is placed in a high ambient temperature environment this choice further increases the need to consider cooling options for any enclosure. Given the stringent sealing requirements for NEMA 4 enclosures, the air inside is completely enclosed severely limiting the options for cooling the air. Some of the current cooling solutions in the market use fans and vents, small enclosure mounted air conditioners, liquid cooled heat exchangers, compressed air vortex tubes, etc. In the solutions section of this document some of the more practical thermal management solutions will be considered for Panduit Zone Enclosures.

Solutions

The air temperature surrounding the active equipment is affected not only by the heat load (power used) of the active equipment, but the size of the enclosure, the thermal resistance between the chassis of the active equipment and the air, the construction material of the enclosure and the air temperature surrounding the outside of the enclosure. Several cooling techniques are discussed from the simplest to the more complex. Depending on the cooling option selected (Passive Cooling Solution, Fan Assisted Cooling Solution or AC Unit Cooling Solution) additional penetrations to the enclosure and power sources for the cooling unit may be required.

Information Gathering

To properly select any thermal solution some basic information about system (enclosure and the equipment it will house) must be collected. Most of this information is available from the equipment vendor in the form of data sheets, specifications, instruction manuals, deployment guides etc. Below is a list of the information required to apply ***any*** of the cooling solutions.

1. Maximum Ambient Air Temperature.
   This is air temperature that will surround the exterior of the enclosure.
2. The Internal Heat-load.
   This is the sum of the power consumed by the equipment mounted inside the enclosure. When calculating heat created by POE devices outside the enclosure, include 15% of the total POE power provided by the switches. If the POE device is inside the enclosure, 100% of the total POE power stays inside the enclosure.
3. Maximum Desired Internal Enclosure Temperature.
   The equipment with the lowest maximum temperature limit will dictate the maximum allowable internal temperature for the enclosure. Likewise, the highest minimum temperature limit will dictate the minimum allowable internal temperature for the enclosure.
4. Two of the first three data points must be known to allow the third data point to be determined from the charts in the cooling solutions.
5. Enclosure dimensions.
   The height, width, and depth of the nearest inch.
   Z22x: 24” x 24” x 12”
   Z23x: 36” x 24” x 12”
6. Enclosure Material.
   The solutions below are for enclosures constructed from steel (the type of steel e.g., stainless, or mild will have a minimum impact on these calculations).
7. Indoor or Outdoor.
   The charts found later in this guide apply only to an enclosure not exposed to direct sunlight.

Passive Natural Convection Cooling (Sealed Enclosure) Fundamentals

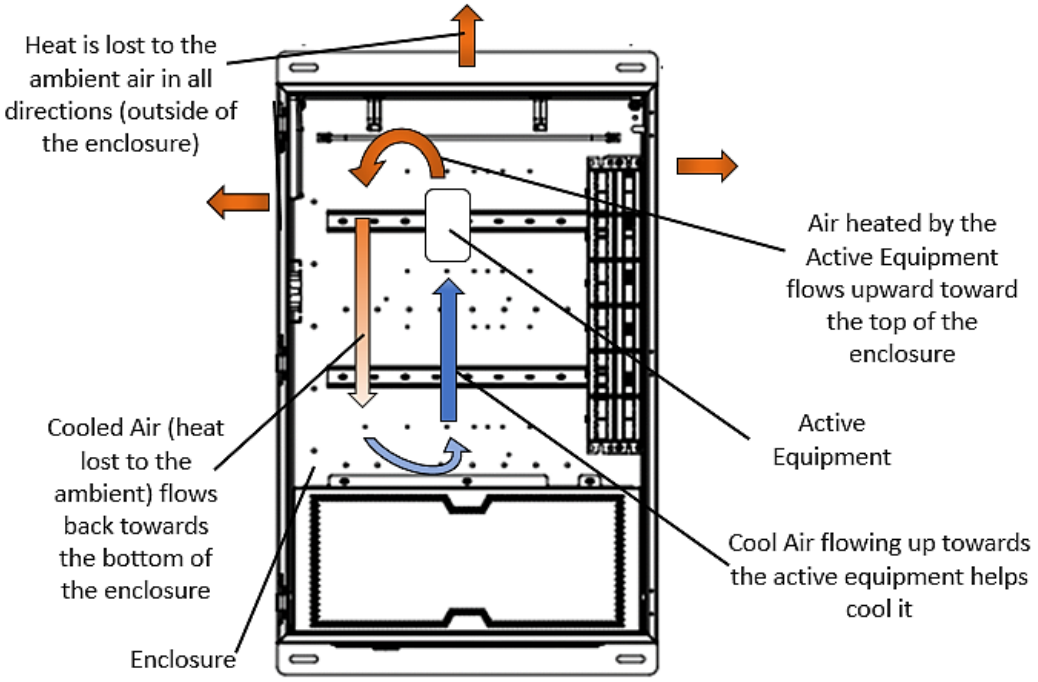


Figure 2: Idealized Thermal (aka Natural) Convection Cooling. Enclosure is 12" deep. The door has been removed to see inside the enclosure.

During normal operation, the active equipment dissipates heat to the air inside the enclosure which in turn increases the air temperature inside the enclosure. The air then transfers this heat to the exterior of the enclosure through convection, conduction, and radiation (Figure 2). A minor amount of the heat is transferred directly to the enclosure from the active device through conduction since the equipment is in contact with the mounting (DIN) rail. Heat flows from high temperature to low temperatures. So, the air temperature inside the enclosure will increase until it exceeds the temperature outside of the enclosure. After a period (typical < 48 hours under continuous operation) a steady state temperature is reached inside the enclosure. This internal air temperature must be at or below the operating temperature specified for the components installed inside the enclosure. Since hot air is more buoyant it will rise towards the top of the enclosure this creates a temperature gradient inside the enclosure. The bottom area of the enclosure will be near the outside ambient temperature and the top area can be 10°C to 20°C higher than the bottom of the enclosure.

POE Considerations

If devices inside the enclosure will be providing POE power, it is important to account for the additional heat and power that will be generated. POE switches will require higher voltages (48-54 VDC) to compared to a typical switch that runs off 24 VDC power. When the device(s) drawing POE load are located outside the enclosure, 15% of the heat generated will stay inside the enclosure (at the switch providing power). We recommend biasing POE load to the lower switch for enclosures with two switches as this provides a slight improvement (3.7%) on the upper switch temperature.

Z23x Thermal Charts and Cooling Options

Sealed Z23x System Recommendations

1. Follow vendor recommendations for minimum clearances around active equipment (e.g., typically 2" for convection cooled switches).
2. Mount equipment with lower recommended operating temperatures on the lower DIN rails.
3. If using multiple switches, when possible, stagger switches to avoid placing a switch directly below another switch as the lower switch can increase the air temperature significantly for the upper switch.
4. For sealed enclosures, its recommended to stay below 400W of total power (including power drawn by switches, switch expansions, and any POE devices located outside of the enclosure).
5. Figure 3 provides a guide for a sealed Panduit Z23 enclosure heat dissipation for various external ambient temperatures.
6. For outdoor deployments a 150-watt heater will increase the internal temperature of a sealed Panduit Z23 enclosure by 15 °C above the external ambient temperature.

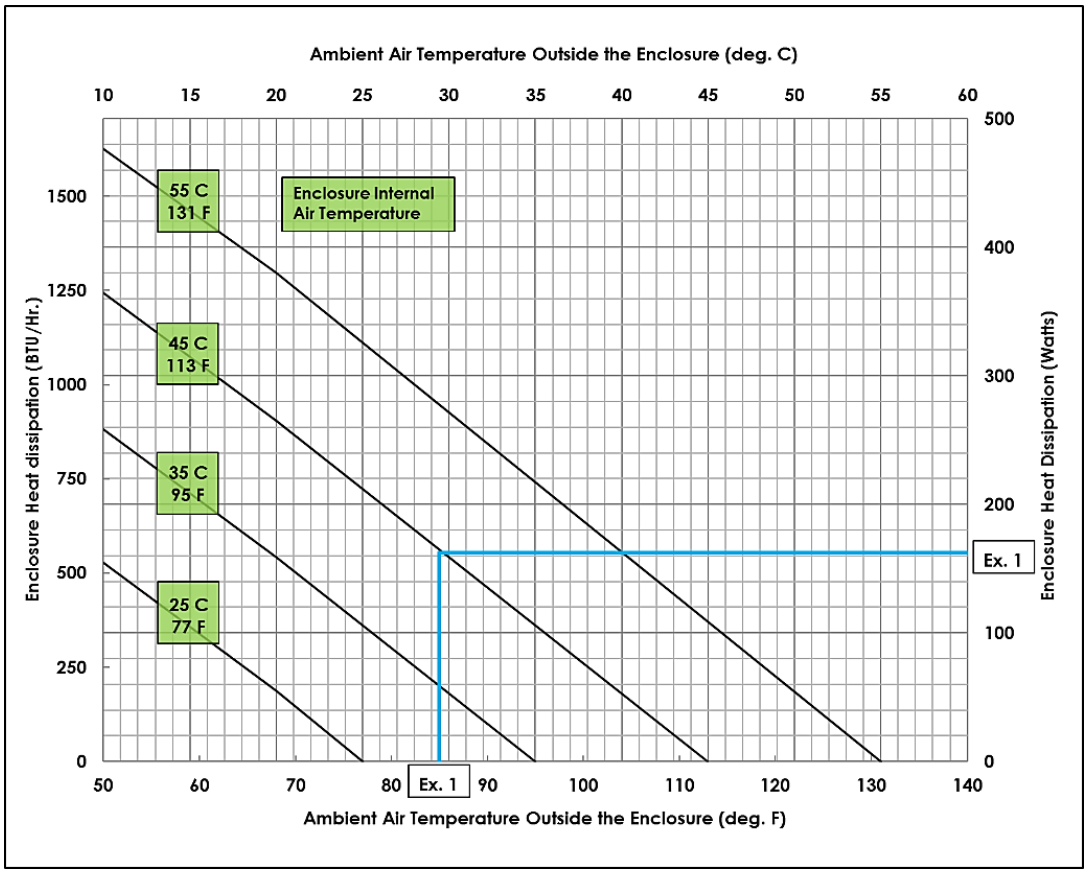


Figure 3: Z23 Enclosure Thermal Guideline – Sealed
See next page for example situations and guidance for reading this chart

Example 1: *Determine the heat load allowable for an 85 F ambient temperature and an internal enclosure temperature of 113 F.*

Answer: The maximum allowable power draw for the equipment inside the enclosure is 162 watts.

How to: Find the 85 F point on the bottom horizontal axis. From that point draw a vertical line to the sloped 113 F internal air temperature line. Then draw a horizontal line to the right-hand vertical axis.

Example 2: *Determine the size of a heater required to maintain an internal temperature of 15 °C when the enclosure is exposed to a -15 °C outside ambient temperature and the power draw of the active equipment inside the enclosure is 150 watts. The enclosure is not exposed to direct sunlight.*

Answer: A single 150-watt heater is needed to maintain the internal temperature at 15 °C.

How to: Apply recommendation #5 to the problem. The Z23 enclosure internal temperature will be 15 °C greater than the ambient temperature for every 150-watts of heat dissipation. The power draw of the active equipment plus the heater 150 w + 150 w = 300 w = a 30 °C temperature increase so -15 °C (ambient) + 30 °C (from the total heat load) = 15 °C inside the enclosure.

Fresh Air/Vented Cooling Z23x System

Introduction

As can be seen in the examples above exceeding the capability of natural convection cooling is quite possible especially in increased ambient temperature environments. A possible next step in cooling management is to provide ventilation to the zone enclosure with the addition of fans and vents. Fans will still result in a higher internal temperature than the ambient air temperature outside the enclosure, however, the difference in temperature between the external ambient temperature and the internal temperature is reduced. But the addition of outside ventilation will reduce the enclosure ingress rating to IP54. Some of the recommendations will be like the sealed enclosure but to stress their importance they will be repeated as appropriate.

The cooler air brought into the enclosure by the fan allows the hot air to exhaust from the enclosure. Without the vent the fan would stall, and no air would be brought into the enclosure. Therefore, two openings need to be created on the enclosure, one for the fan and one for the exhaust vent. The fan should be mounted low on the non-hinge side of the Z23 enclosure. If the system is going to have a lot of copper coming into the enclosure, the fan can be mounted on the hinge side with minimal impact to performance, but the power system might need to be shifted toward the middle to make room for the fan. The vent should be mounted high on the door of the enclosure. Figure 6 (fan HF05) and Figure 10 (fan HF09) show the location for a fan and a vent.

Two different fan sizes are available for the enclosure. The smaller HF05 fan provides 24 CFM of airflow to cool the equipment inside the enclosure. The larger HF09 fan is for deployments WITHOUT AN ELECTRONICS COVER and provides 42 CFM of airflow to cool the equipment inside the enclosure. Figures 5 (HF05) and 8 & 9 (HF09) provide the fan dimensions and enclosure cutout dimensions for each respective fan.

Active cooling with POE

To better understand how impactful active cooling can be, let's look at the following test system. For this example, a Z23x enclosure is installed on a wall. This wall is inside a room with an external ambient temperature of 40°C. Inside the enclosure are two switches, two expansions (one per switch), and up to 32 Ethernet ports that are operating at full network traffic and going to POE devices outside the enclosure. This enclosure has a HF09 fan/exhaust system installed per the guidance in this document.

When running 10 POE+ ports (5 per switch), we see reduced ambient temperatures inside the enclosure (up to 18.5%) compared to a sealed version of the same test system. This correlates to a 16.2% temperature drop on the upper switch internal temperatures and a 28.6% temperature drop on the lower switch internal temperature. These thermal improvements can be used as margin to extend the life of the electronics, to use more devices inside the enclosure, or to allow the enclosure to be installed in locations with even higher ambient temperatures than would've been possible with a sealed system.

This same test system running 32 POE+ ports can operate safely as well, with the internal ambient temperature of the enclosure only rising 7.8% compared to our 10 POE+ port systems internal temperature. The biggest limiting factor to POE load capabilities when using a fan will be the power supplies; a system with 32 POE+ ports require over 1,000 W of power as measured from the AC wiring going into the enclosure.

While the thermal improvements from a fan & exhaust system are significant, there is an impact to the overall power; an enclosure using a HF09 fan will draw 10% more power compared to a sealed enclosure with no other changes made. This power increase comes from both the fan and the additional AC/DC conversion losses in the power supplies.

Fan-Assisted Z23x System Recommendations

1. Follow vendor recommendations for minimum clearances around active equipment (e.g., 2” for convection cooled switches) mounted in the enclosure.
2. Read the instruction manual available from the vendor for the fan. A hyperlink to the manual is provided at the end of this document.
3. Follow vendor recommendations for minimum clearances around fans and filters (e.g., 7” for HF09 fan on the outside of the enclosure).
4. Mount equipment with lower operating temperatures on the lower DIN rails.
    a. As with sealed systems, bias any POE loads to the lower switch, if possible.
5. On the lowest din rail, space needs to be left for the fan on the non-hinge side (see Figure 6 below).
6. On the highest din rail, space needs to be left for the vent mounted on the door to when installing equipment. (e.g., Switch patch cords extend beyond the face of the switch towards the door of the enclosure and could affect a potential vent location).
7. Figure 4 provides the heat dissipation guide for a Panduit Z23 enclosure heat dissipation with a HF05 fan for various external ambient temperatures with the IP54 filter kit.
8. Figure 7 provides the heat dissipation guide for a Panduit Z23 enclosure with a power shield and an HF09 fan with the IP54 filter kit.

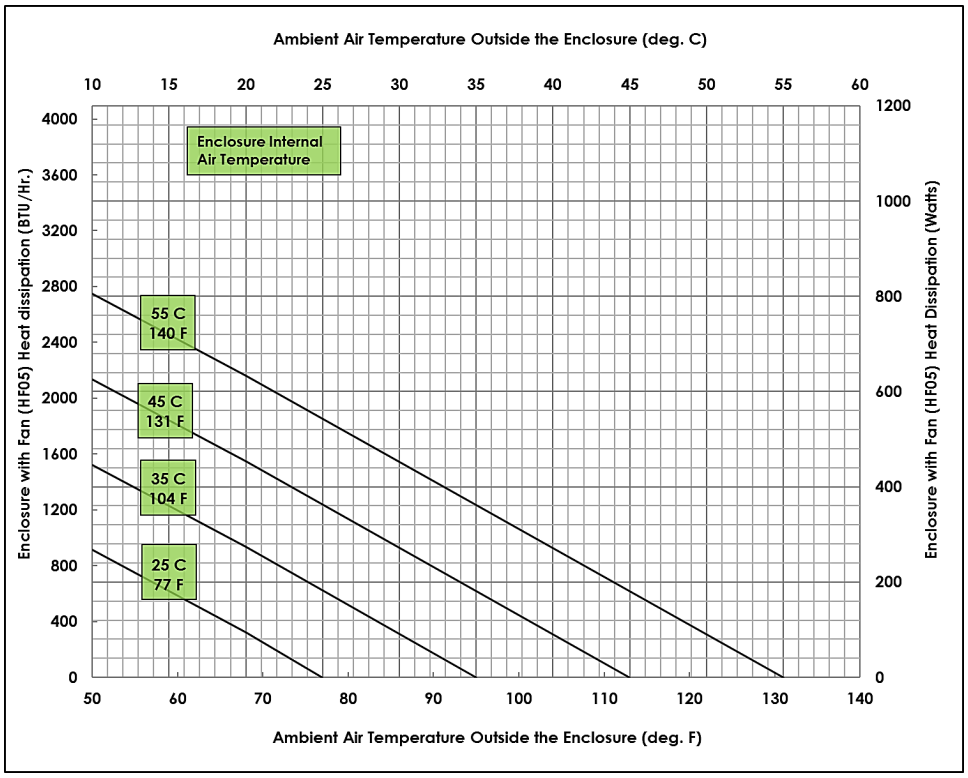
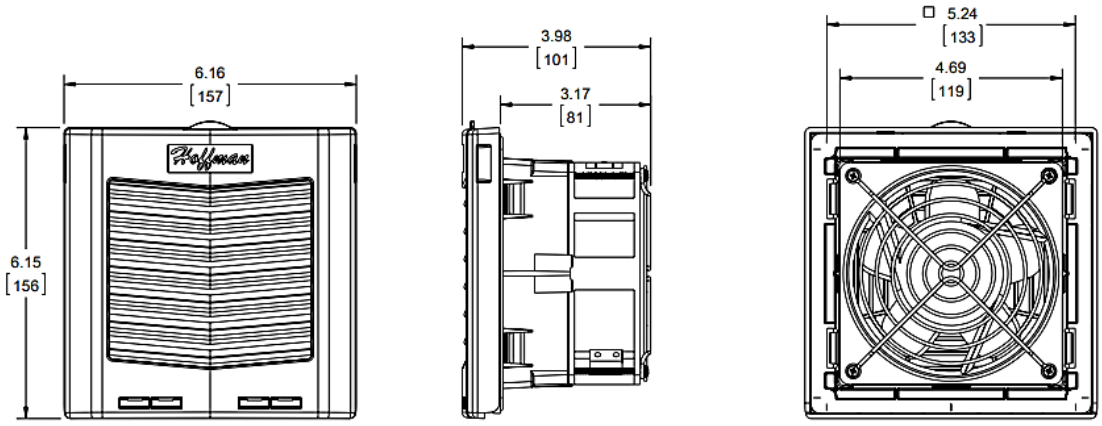
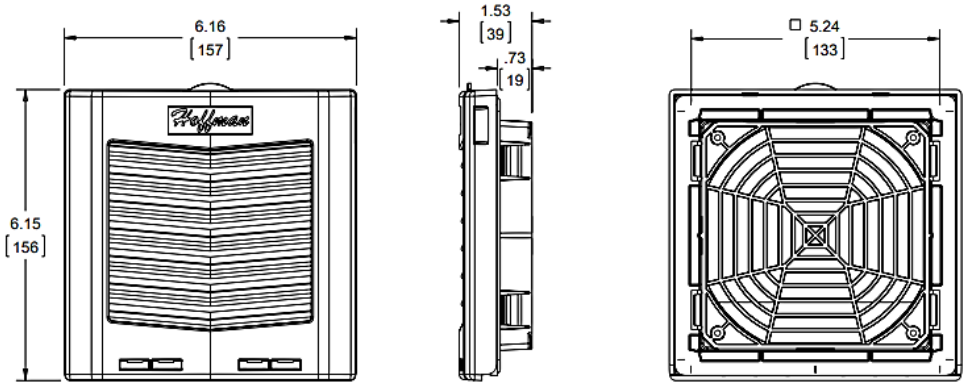


Figure 4: Z23 Enclosure Thermal Guideline – HF05 Fan Assisted. The HF05 Fan is available separately from Pentair.

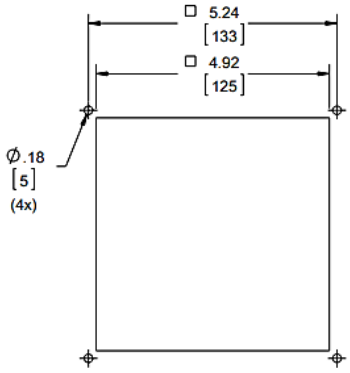
HF05 35 CFM (59 m³/hr.) Side-Mount Filter Fans



Exhaust Grille



Order exhaust grille kits separately.



Cutout Dimensions

Figure 5: Dimensions of a HF05 exhaust fan and exhaust vent and cutout dimension.

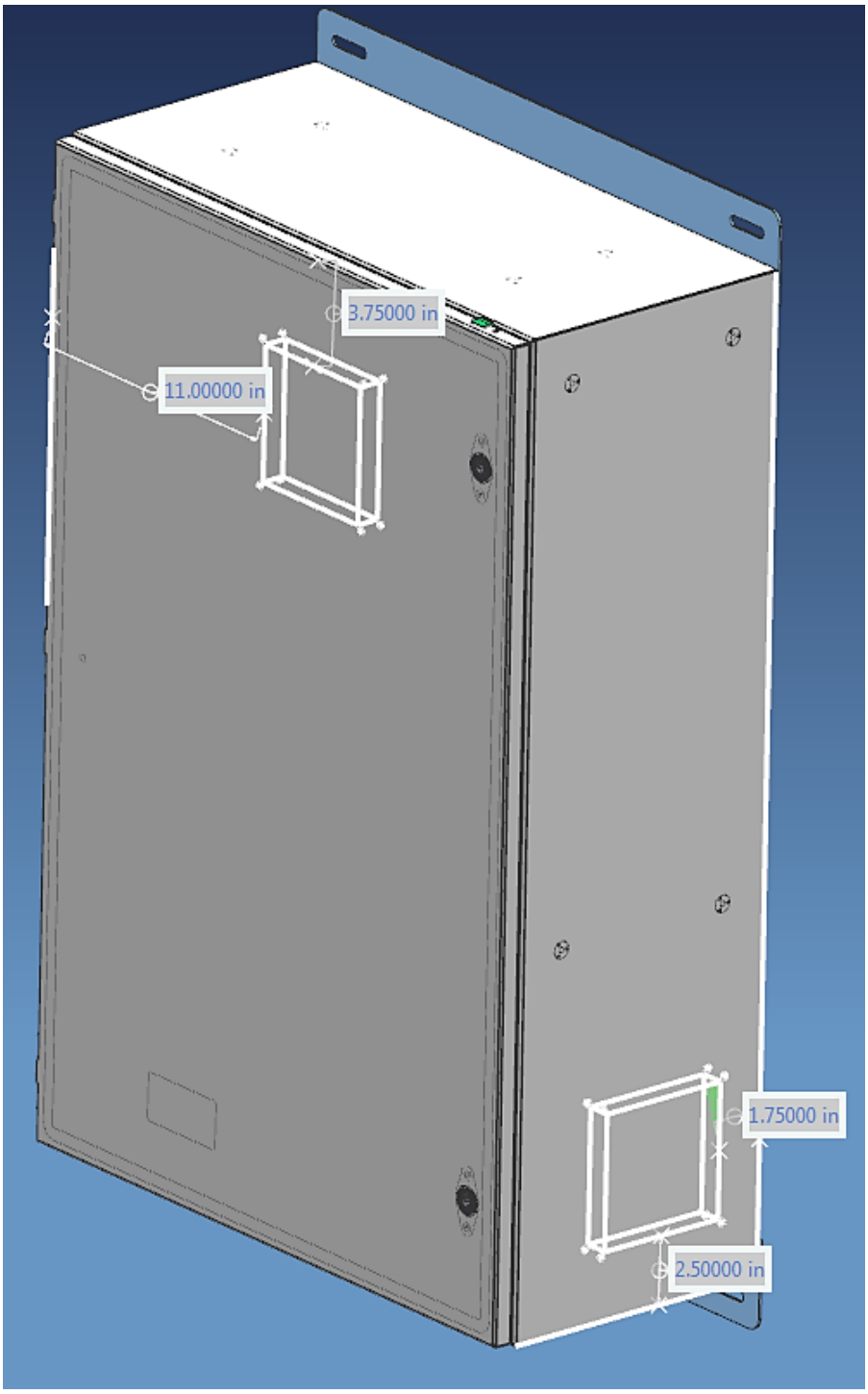


Figure 6: Approximate location for the HF05 fan and vent cutouts. The white lines give a relative indication of the location for the fan and the dimensions show the location for the cutouts to install the fan and vent. If desired, the fan can be installed on the opposite side of the enclosure, using the same positioning dimensions from the bottom & rear edges.

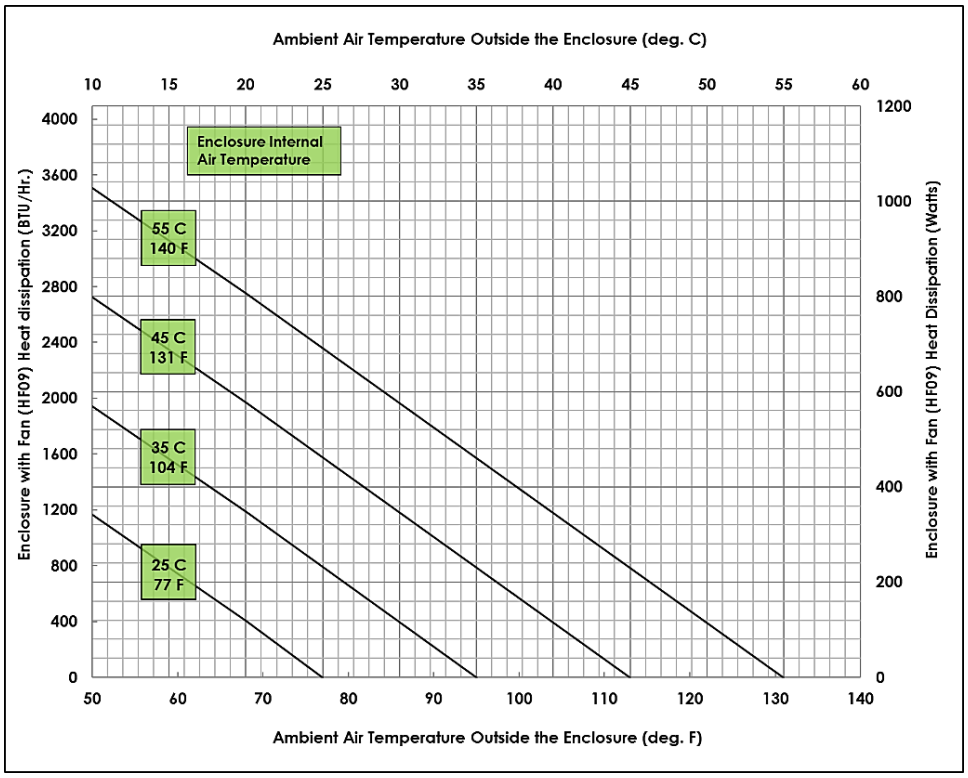


Figure 7: Z23 Enclosure Thermal Guideline – HF09 Fan Assisted. The HF09 Fan is available separately from Pentair.

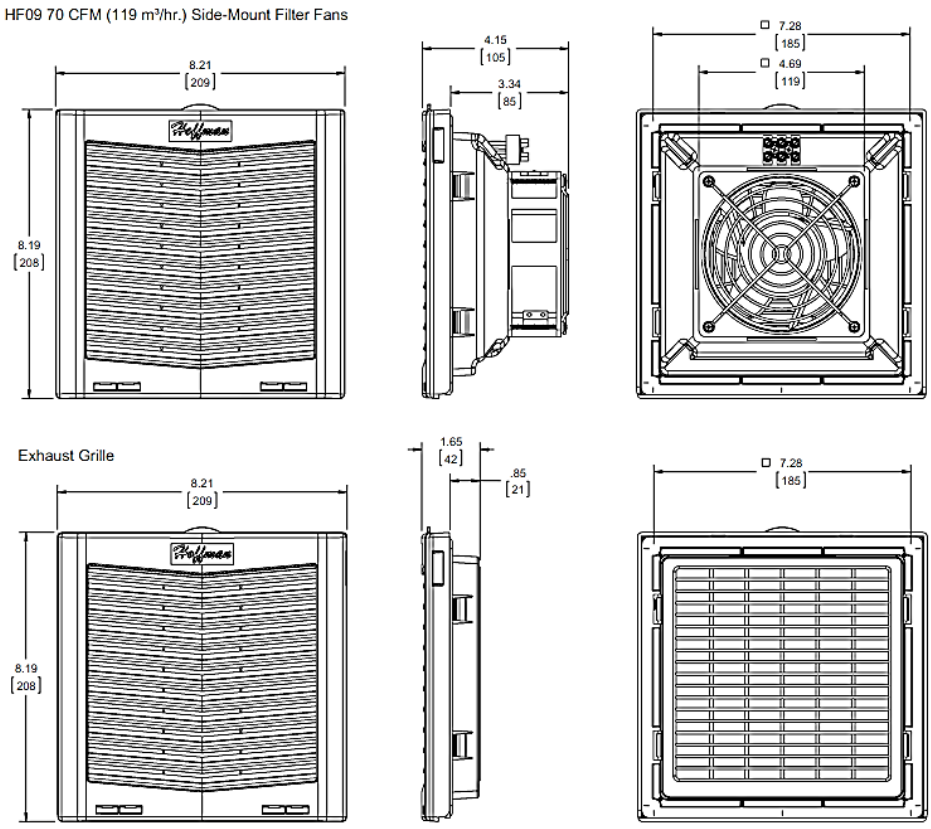


Figure 8: Dimensions of a HF09 exhaust fan and exhaust vent.

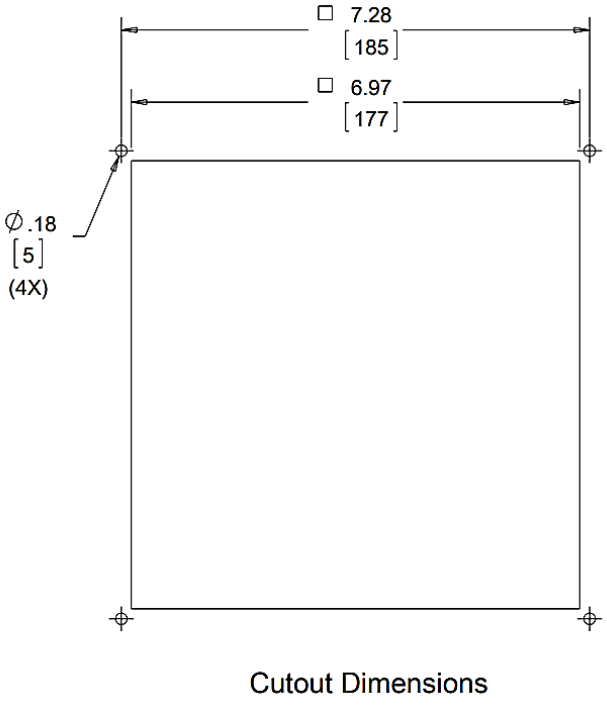


Figure 9: Cutout Dimensions for HF09 fan.

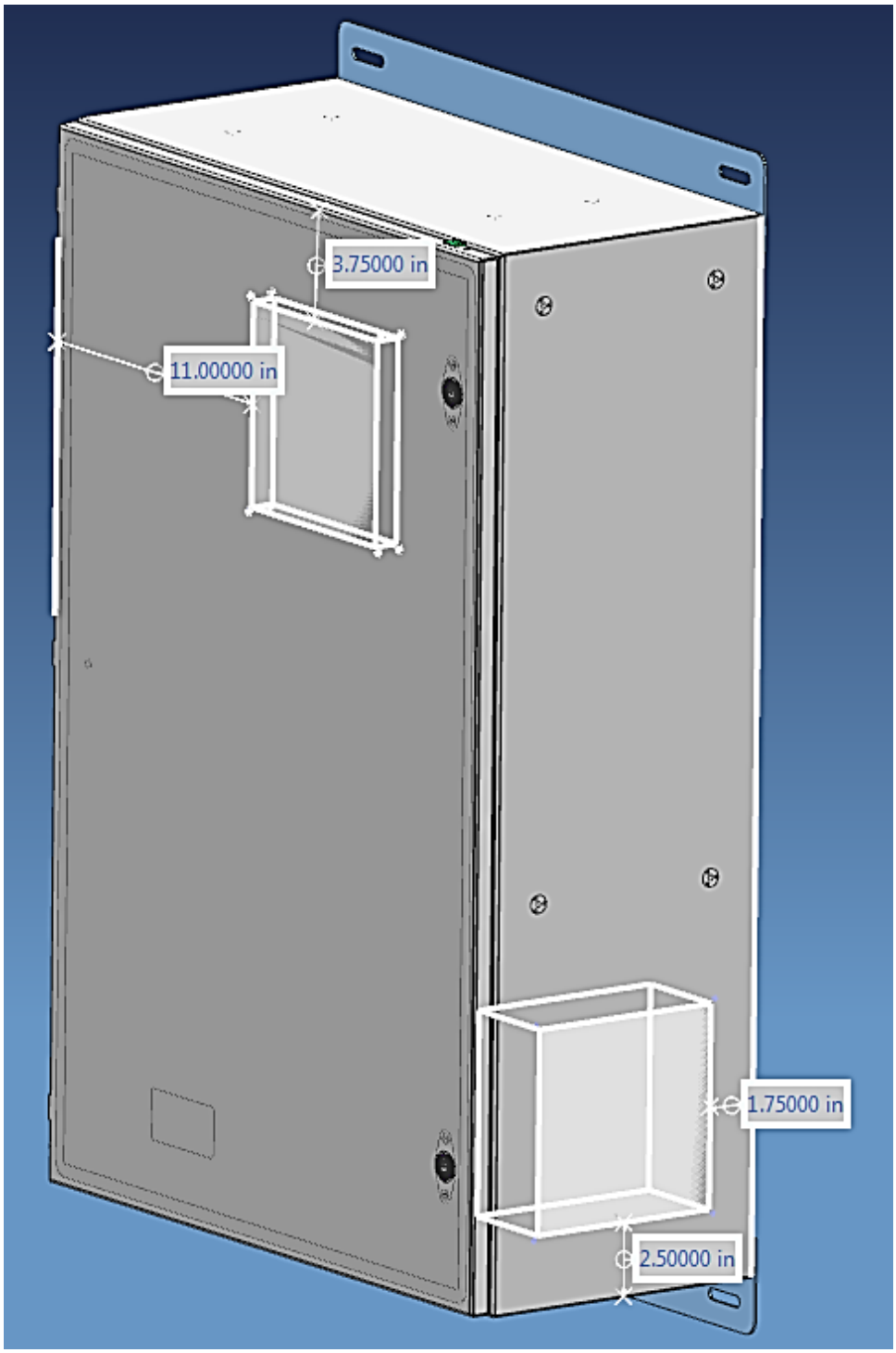


Figure 10: Approximate location for the HF09 fan and vent cutouts. The white lines give a relative indication of the space required for the fan and the dimensions show the location for the cutouts to install the fan and vent. The starting location is the same as the HF05 fan only the hole dimensions are larger. If desired, the fan can be installed on the opposite side of the enclosure, using the same positioning dimensions from the bottom & rear edges.

Closed Loop Cooling System (AC Unit) on Z23x enclosures

Introduction

When it becomes necessary to have a lower internal temperature than the external ambient temperature around the enclosure then an air conditioner (AC unit) is required. The AC unit will result in an increase in the average heat dissipation of a Z23 enclosure and therefore it may allow more equipment to be deployed. The T15 AC unit can be used with or without a power shield and provides 30 CFM of 75 °F air to cool the equipment inside the enclosure. Figure 12 provides the T15 cutout dimensions required to externally mount it on a Z23 enclosure. The unit should be mounted on the left (hinge) side of the enclosure as shown in Figure 13. Figures 14 & 15 provide additional aids in locating the cutouts on the side of the Z23 enclosure.

Recommendations for Closed Loop (with AC Units) Z23x

1. Remove the electronics cover. Three screws mount the cover to the back panel.
2. Remove the left side panel from the hinge side of the Z23 enclosure.
3. Follow vendor recommendations for minimum clearances around active equipment (e.g., 2” for convection cooled switches).
4. Read the instruction manual available from the vendor for the T15 AC Unit. A hyperlink to the manual is provided at the end of this document.
5. Follow vendor recommendations for minimum clearances around the exterior of the AC unit.
6. Mount equipment with lower operating temperatures on the lower DIN rails.
7. Stagger switches to avoid placing a switch directly below another switch as the lower switch can increase the air temperature significantly for the upper switch.
    a. Bias any POE loads to the lower switch, if possible.
8. The graph below (Figure 11) provides a heat dissipation guide for a Panduit Z23 enclosure with a T15 air conditioner.
9. For outdoor deployments a 150-watt heater will increase the internal temperature of a Panduit Z23 enclosure by 15 °C above the external ambient temperature. Depending on ambient conditions and equipment specifications an additional heater may be required. Outdoor models of the T15 unit include a 150-watt heater.
10. Reinstall the left side panel after the air conditioner is installed.
11. Reinstall the electronics cover.

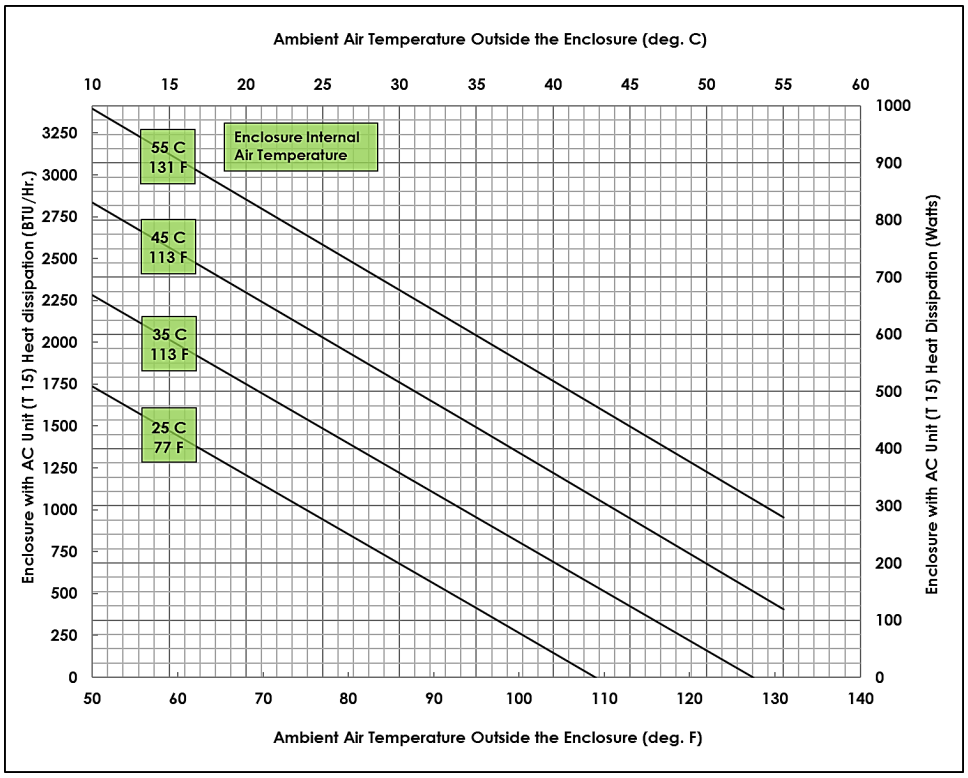


Figure 11: Z23 Enclosure Thermal Guideline – T15 Air Conditioner is available separately from Pentair. The outdoor model is equipped with a 150-watt heater. The maximum ambient operating temperature for the T15 is 55 °C. Therefore, the upper curves truncate at 55 °C outside ambient temperature.

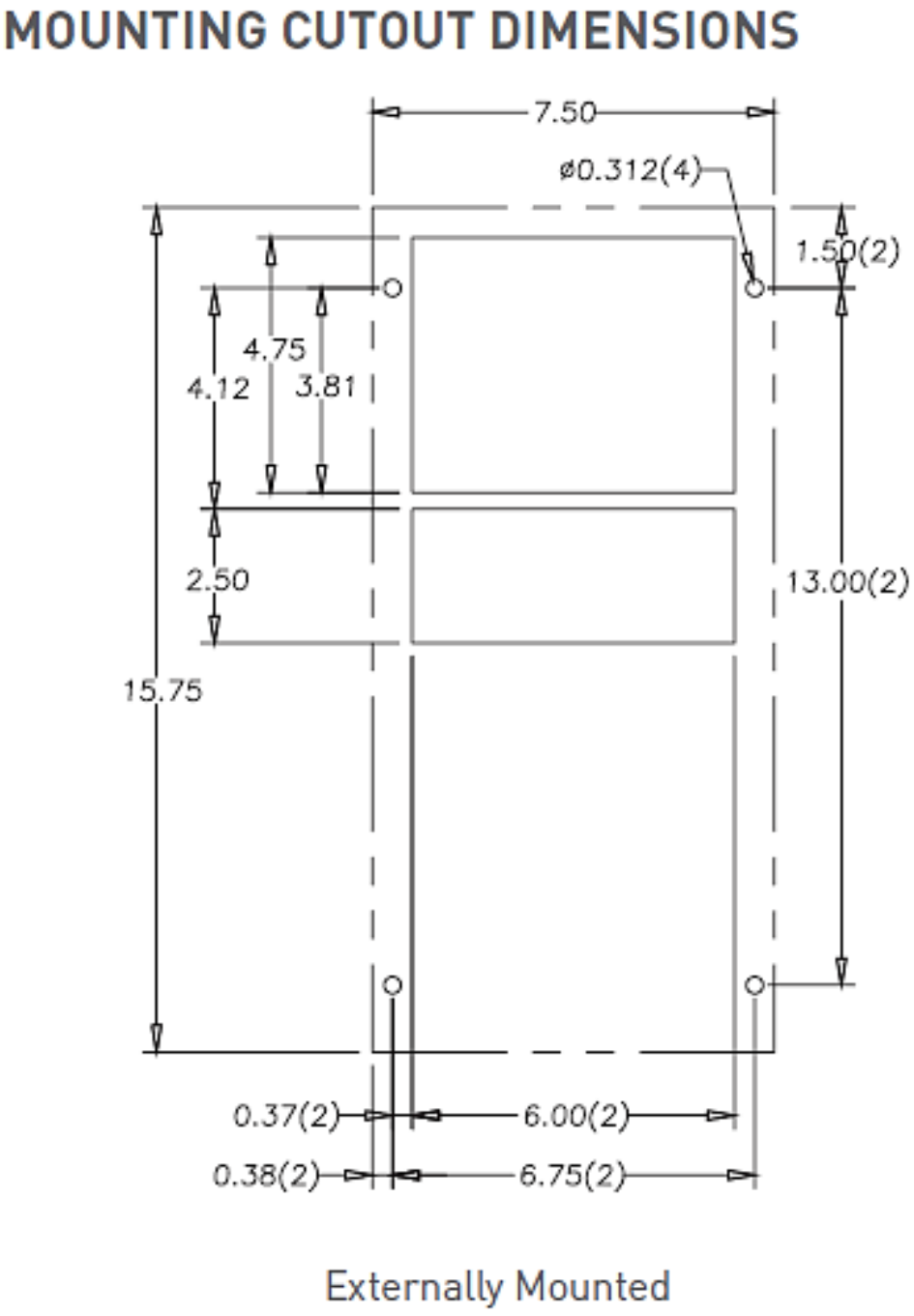


Figure 12: Cutout dimensions for the T15 AC unit as viewed from the outside of the enclosure.

Note: *Phantom lines represent air conditioner. The small web between the cutouts can be eliminated for convenience as the discharge of the T15 is ducted away from the intake.*

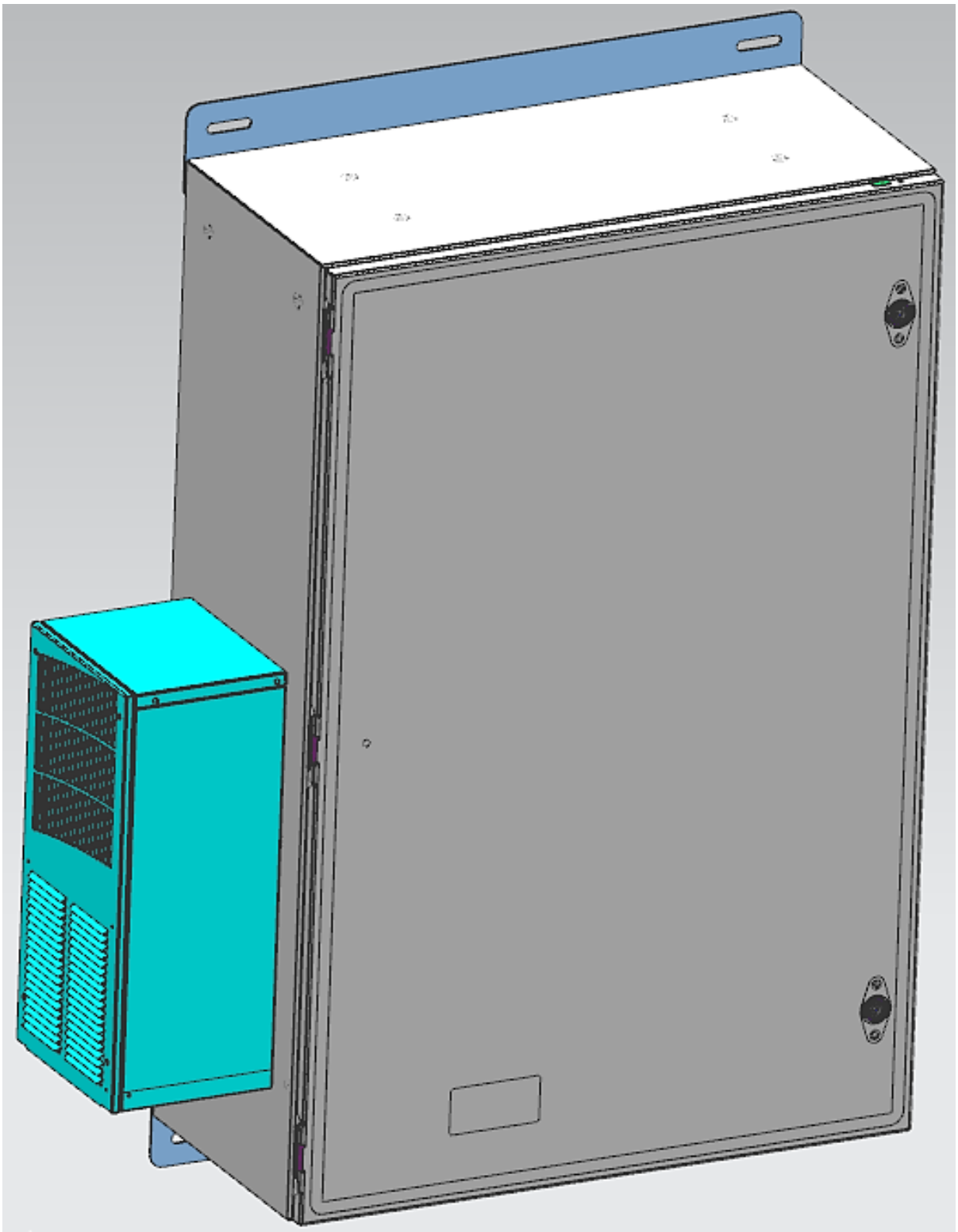


Figure 13: Z23 shown with T15 AC unit.

Note the recommended mounting location low, on the hinge side.

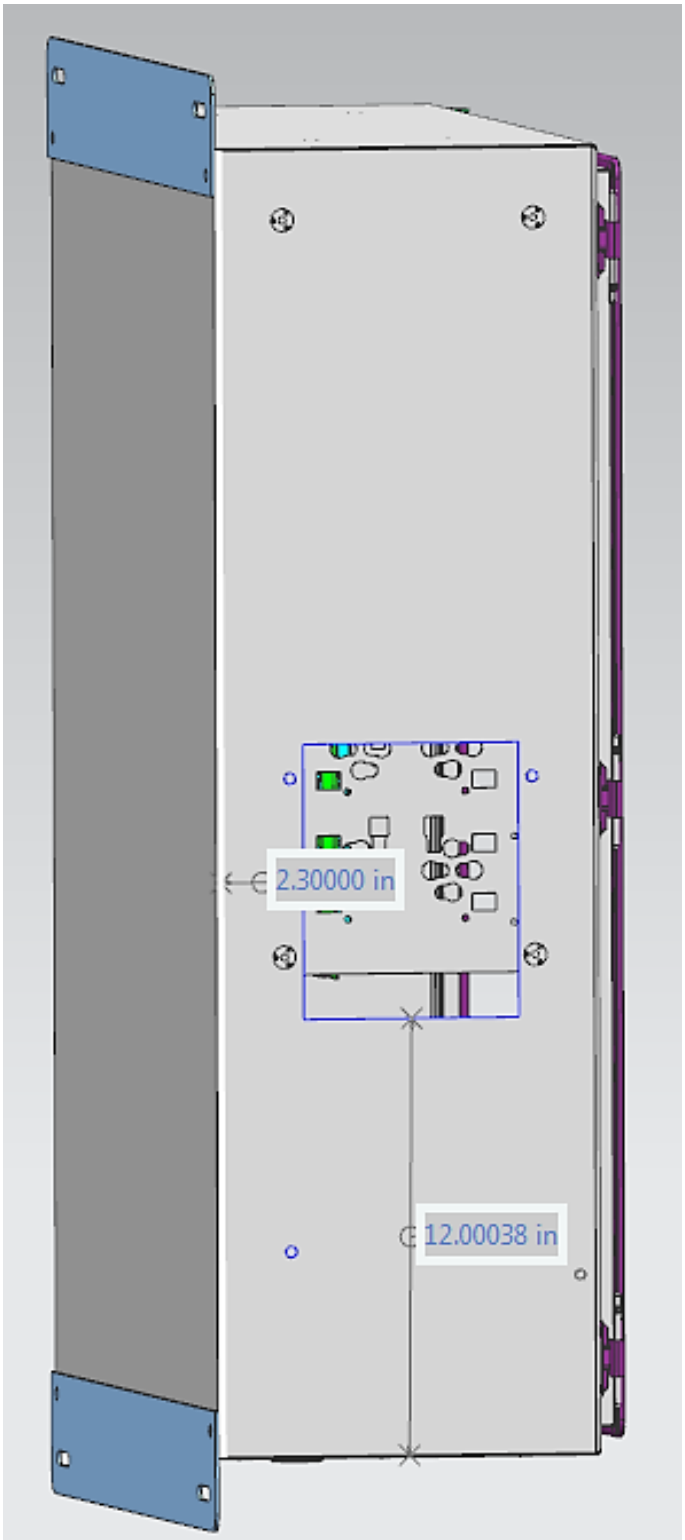


Figure 14: Shows the location of the cutout for the T15 AC unit on the Z23 enclosure. The cutout starts approximately 12 inches from the bottom of the enclosure to allow the discharge duct to just clear the accessory bracket above it and the power shield below (not shown). This location will allow the power shield to be removed from the enclosure with the T15 unit installed.

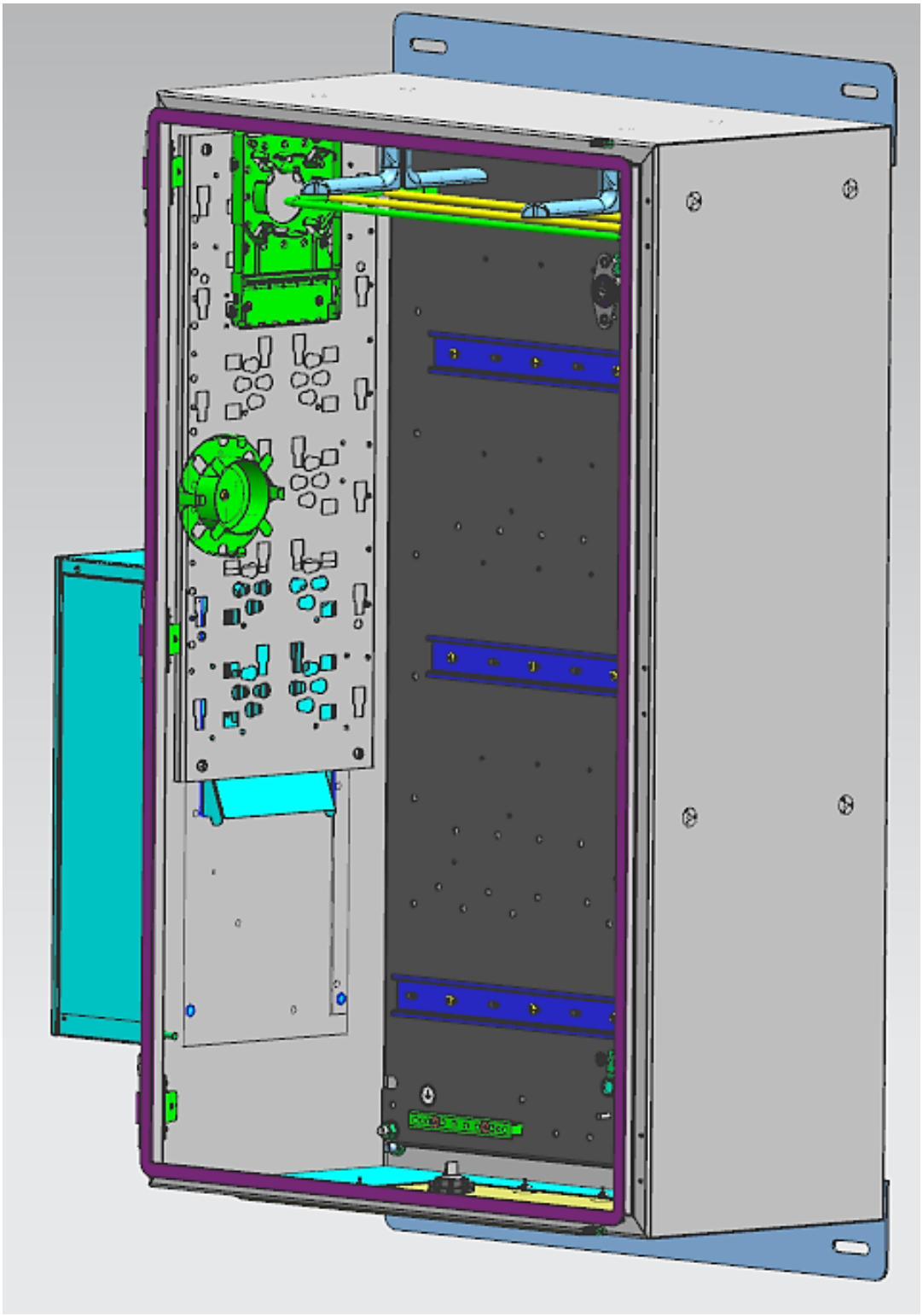


Figure 15: Interior view showing the location of the T15 discharge with the mounting bracket on the interior of the Z23 enclosure. The bracket needs to be removed to access the upper mounting holes for the T15. The discharge duct sits above the power shield (not shown).

Z22x Thermal Charts and Cooling Options

Introduction

The Z22 enclosure's compact size limits the amount of networking equipment that can be deployed inside it. This reduced size can also create a challenge when trying to cool the devices inside the enclosure based on the ambient environment the system is deployed in. If active cooling is required, these physical space constraints will also require one of the enclosure side panels to be removed to allow space for a fan or air conditioning unit to be installed

Figure 16: Z22U Enclosure.

Sealed Z22x System Recommendataions

1. Follow vendor recommendations for minimum clearances around active equipment (e.g., typically 2" for convection cooled switches).
2. Figure 17 provides a guide for a sealed Panduit Z22x enclosure heat dissipation for various external ambient temperatures.
3. For outdoor deployments a 150-watt heater will increase the internal temperature of a sealed Panduit Z22 enclosure by 15 °C above the external ambient temperature.

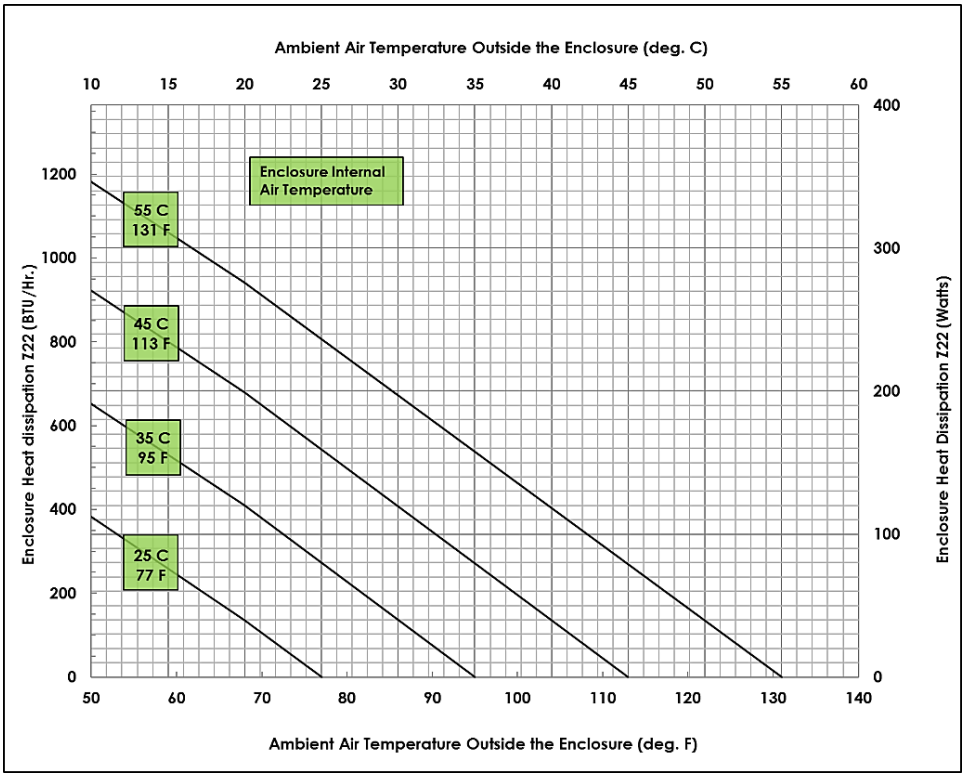


Figure 17: Z22 Enclosure Thermal Guideline – Sealed

Fresh Air/Vented Cooling Z22x System

Introduction

The cooler air brought into the enclosure by the fan allows the hot air to exhaust from the enclosure. Without the vent the fan would stall, and no air would be brought into the enclosure. Therefore, two openings need to be created on the enclosure, one for the fan and one for the exhaust vent. The fan should be mounted low on the Z22 enclosure. The vent should be mounted high on the door of the enclosure. There are two installation options for the fan depending on the amount of copper required to pass through the power cage cable entry area. The HF05 fan provides 24 CFM of airflow to cool the equipment inside the enclosure. Figure 5 shows dimensional information for the HF05 fan and opening size.

Fan-Assisted Z22x System Recommendations

1. Follow vendor recommendations for minimum clearances around active equipment (e.g., 2” for convection cooled switches) mounted in the enclosure.
2. Read the instruction manual available from the vendor for the fan. A hyperlink to the manual is provided at the end of this document.
3. Follow vendor recommendations for minimum clearances around fans and filters (e.g., 7” for HF05 fan on the outside of the enclosure).
4. On the highest din rail, space needs to be left for the vent mounted on the door to when installing equipment. (e.g., Switch patch cords extend beyond the face of the switch towards the door of the enclosure and could affect a potential vent location).
5. Figure 18 provides the heat dissipation guide for a Panduit Z22 enclosure with an electronics cover and an HF05 fan with the IP54 filter kit.

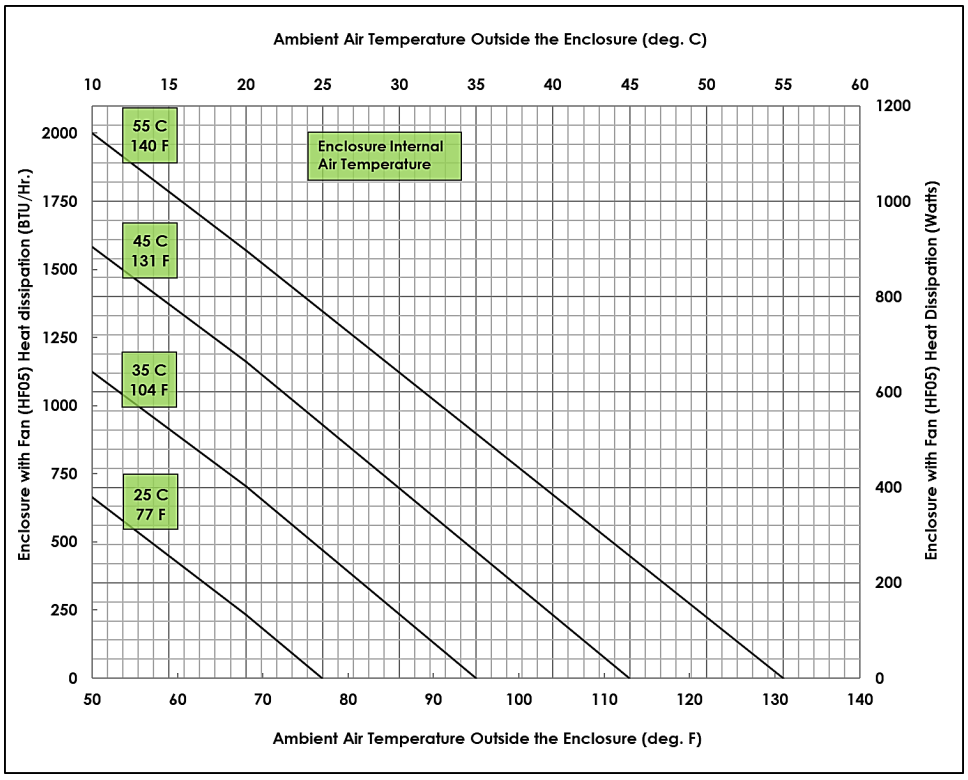


Figure 18: Z22 Enclosure Thermal Guideline – HF05 Fan Assisted. The HF05 Fan is available separately from Pentair.

Fan-Assisted Z22x Exhaust Location

The HG05 exhaust should always be mounted 11” from the left (hinge) side of the enclosure and 3.75” from the top of the enclosure as shown in Figure 19. Reference Figure 5 or the links at the end of this document for details about the exhaust opening size.

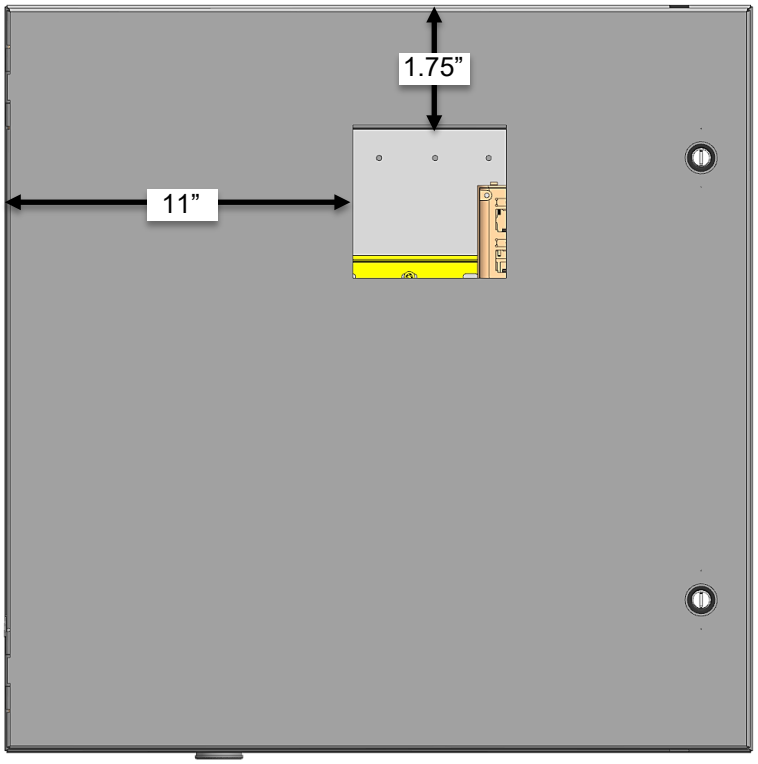


Figure 19: Z22 Enclosure HG05 Exhaust Opening Location. The HG05 Exhaust is available separately from Pentair.

Fan-Assisted Z22x Installation Option 1 (Right [non-Hinge] Side)

If your application has less than eight copper patch cords passing through the electronics cover, a fan can be installed on the right (non-hinge) side at the base of the enclosure. See Figures 20 & 21 for views showing the fan location and Figure 22 showing the reduced area for copper patch cords.

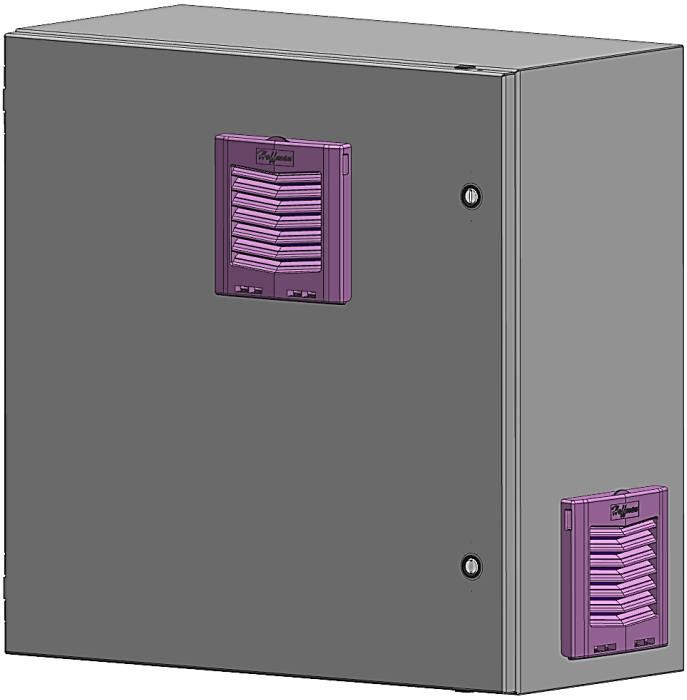


Figure 20: Z22 Enclosure with HF05 Fan and HG05 Exhaust. The HF05 Fan is available separately from Pentair.

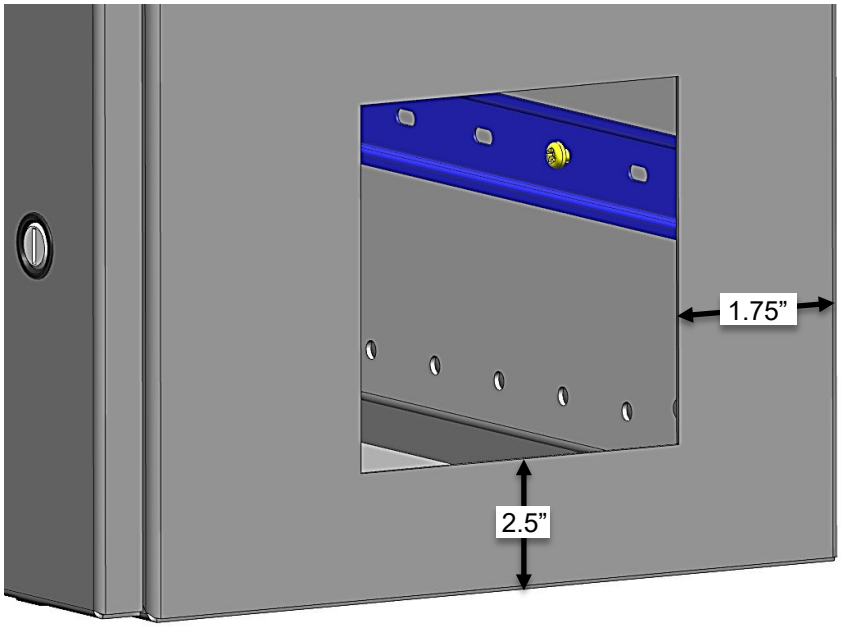


Figure 21: Z22 Enclosure showing HF05 Fan Option 1 placement. The HF05 Fan is available separately from Pentair.

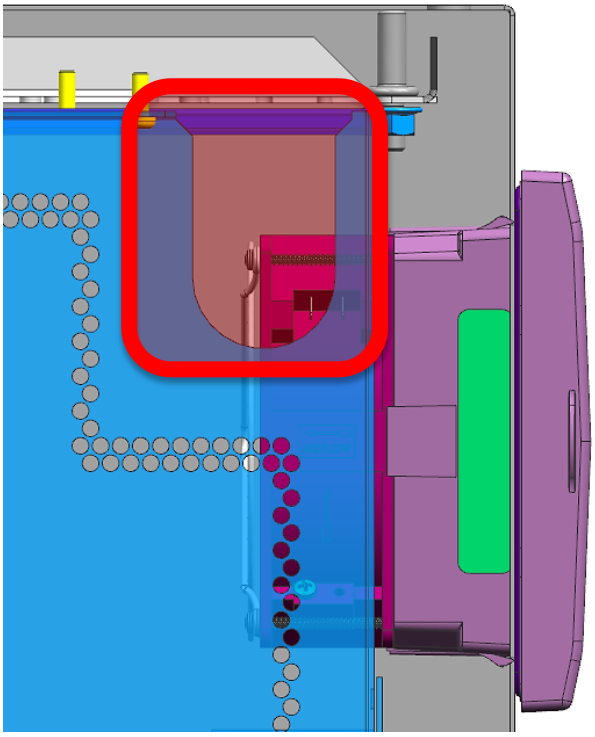


Figure 22: Z22 Enclosure with HF05 Fan installed on right (non-hinge) side. The area in red shows the reduced area for copper cable passing through the electronics cover with the fan mounted at this location.

Fan-Assisted Z22x Installation Option 2 (Left [Hinge] Side)

If your application has more than roughly eight copper patch cords passing through the power cage, a fan can be installed on the left (hinge) side at the base of the enclosure. To accommodate the fan, the power system will need to be moved over at least 0.75” to the right (non-hinge) side by cutting the cable ties holding the power cables between the switch and the power supplies to loosen 0.75” of low voltage cable. Loosen terminal block end caps, power supplies, and UPS (if installed) and shift those devices 0.75” to the right (away from the fan opening). Figure 25 shows the items that interfere with the fan and what cable ties will need to be cut.

The fan cutout should be created 2.5” from the rear of the enclosure and 1.75” from the bottom of the enclosure as shown in Figure 24. See Figures 23 & 24 for views showing the fan location.

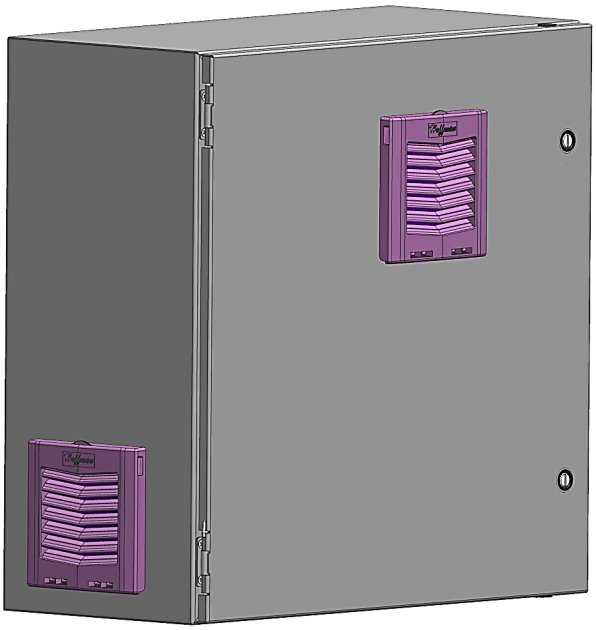


Figure 23: Z22 Enclosure with HF05 Fan and HG05 Exhaust. The HF05 Fan is available separately from Pentair.

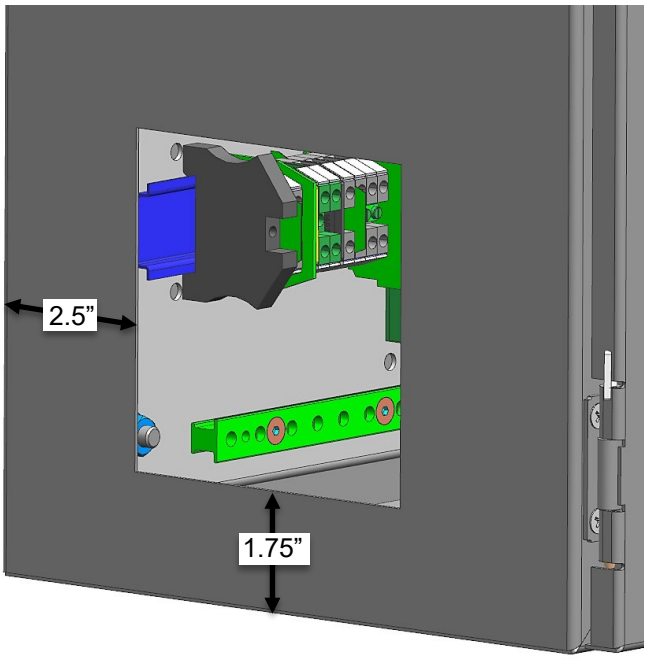


Figure 24: Z22 Enclosure showing HF05 Fan Option 2 placement. The HF05 Fan is available separately from Pentair.

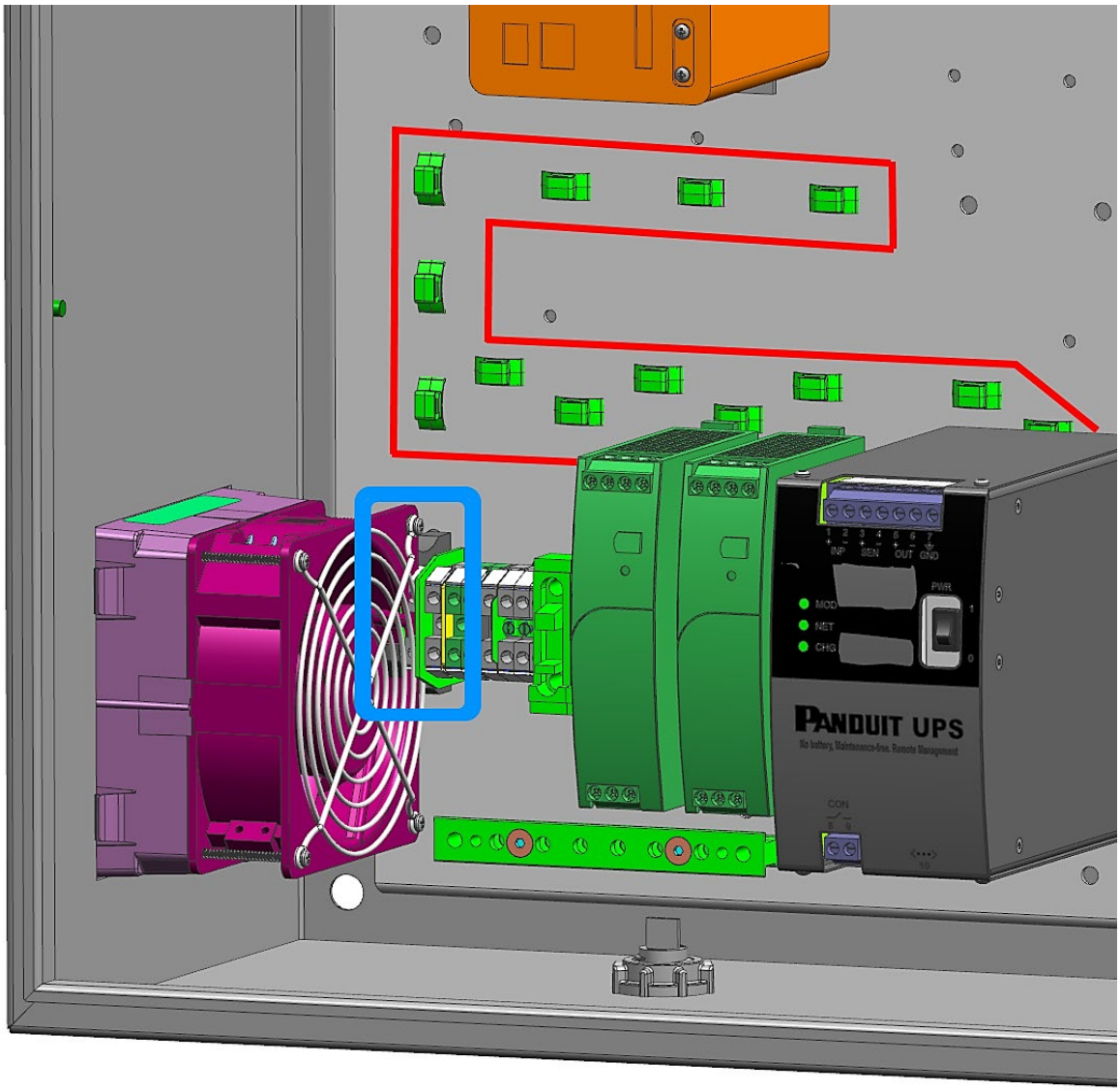


Figure 25: Z22 Enclosure with HF05 Fan installed on left (hinge) side. The area outlined in red shows where cable ties will need to be cut to make cable slack to slide the power supplies over. The area outlined in blue shows the terminal blocks that would interfere with the fan if not moved.

Closed Loop Cooling System (AC Unit) Z22x enclosures

Introduction

When it becomes necessary to have a lower internal temperature than the external ambient temperature around the enclosure then an air conditioner (AC unit) is required. The AC unit will result in an increase in the average heat dissipation of a Z22 enclosure and therefore it may allow more equipment to be deployed or a higher ambient temperature. The T15 AC unit can be used with or without a power shield and provides 30 CFM of 75 °F air to cool the equipment inside the enclosure. Figure 12 provides the T15 cutout dimensions required to externally mount it on a Z22 enclosure. The unit should be mounted on the hinge side of the enclosure as seen in Figure 28. Figures 29 provides additional aid in locating the cutouts on a Z22 enclosure.

It is required to remove the left side panel to install the AC unit. Removing the side panel also removes the fiber surface mount patch box and spool. DIN Rail mounted patch panels are available from Panduit. These can be mounted to the right side of the upper DIN Rail. The patch panels are illustrated in Figure 27.

- FDPPSIG IndustrialNet™ DIN Rail Fiber Optic Enclosure, Standard Depth
- FDPPEIG IndustrialNet™ DIN Rail Fiber Optic Enclosure, Extended Depth
- CDPP8RG IndustrialNet™ 8-port DIN Rail Mount Copper Patch Panel
- CDPP8RG-S IndustrialNet™ 8-port Shielded DIN Rail Mount Copper Patch Panel

Recommendations for Closed Loop (with AC Units) Z22x

1. Remove the electronics cover. Three screws mount the cover to the back panel.
2. Remove the left side panel from the hinge side of the Z22 enclosure.
3. Follow vendor recommendations for minimum clearances around active equipment (e.g. 2” for convection cooled switches).
4. Read the instruction manual available from the vendor for the T15 AC Unit. A hyperlink to the manual is provided at the end of this document.
5. Follow vendor recommendations for minimum clearances around the exterior of the AC unit.
6. Mount equipment with lower operating temperatures on the lower DIN rails if possible.
7. Figure 26 provides a guide for a Panduit Z22x enclosure heat dissipation for various external ambient temperatures.
8. For outdoor deployments a 150-watt heater will increase the internal temperature of a Panduit Z22 enclosure by 15 °C above the external ambient temperature. Depending on ambient conditions and equipment specifications an additional heater may be required. Outdoor models of the T15 unit include a 150-watt heater.
9. Reinstall the electronics cover after the air conditioner is installed.

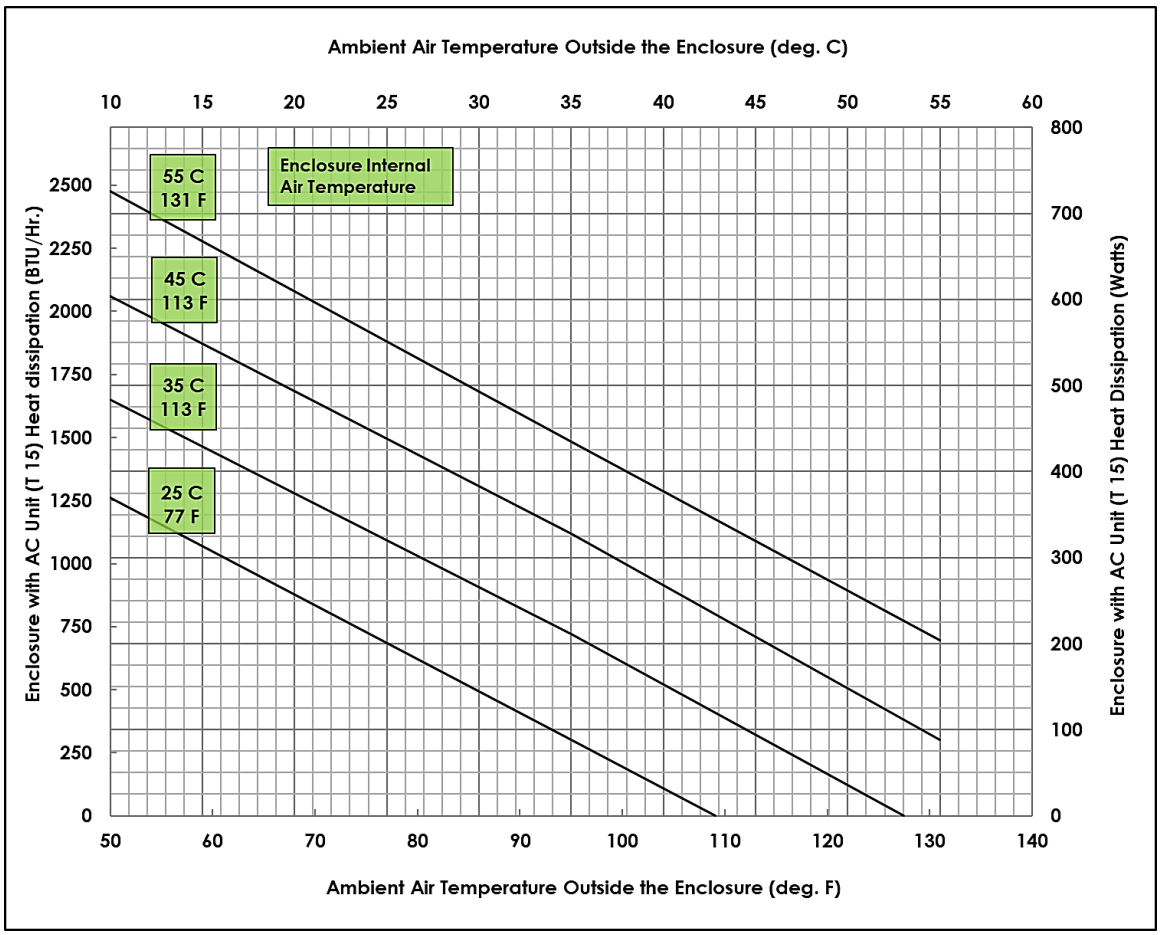


Figure 26: Z22 Enclosure Thermal Guideline – T15 Air Conditioner is available separately from Pentair. The outdoor model is equipped with a 150-watt heater. The maximum ambient operating temperature for the T15 is 55 °C. Therefore, the upper curves truncate at 55 °C outside ambient temperature.

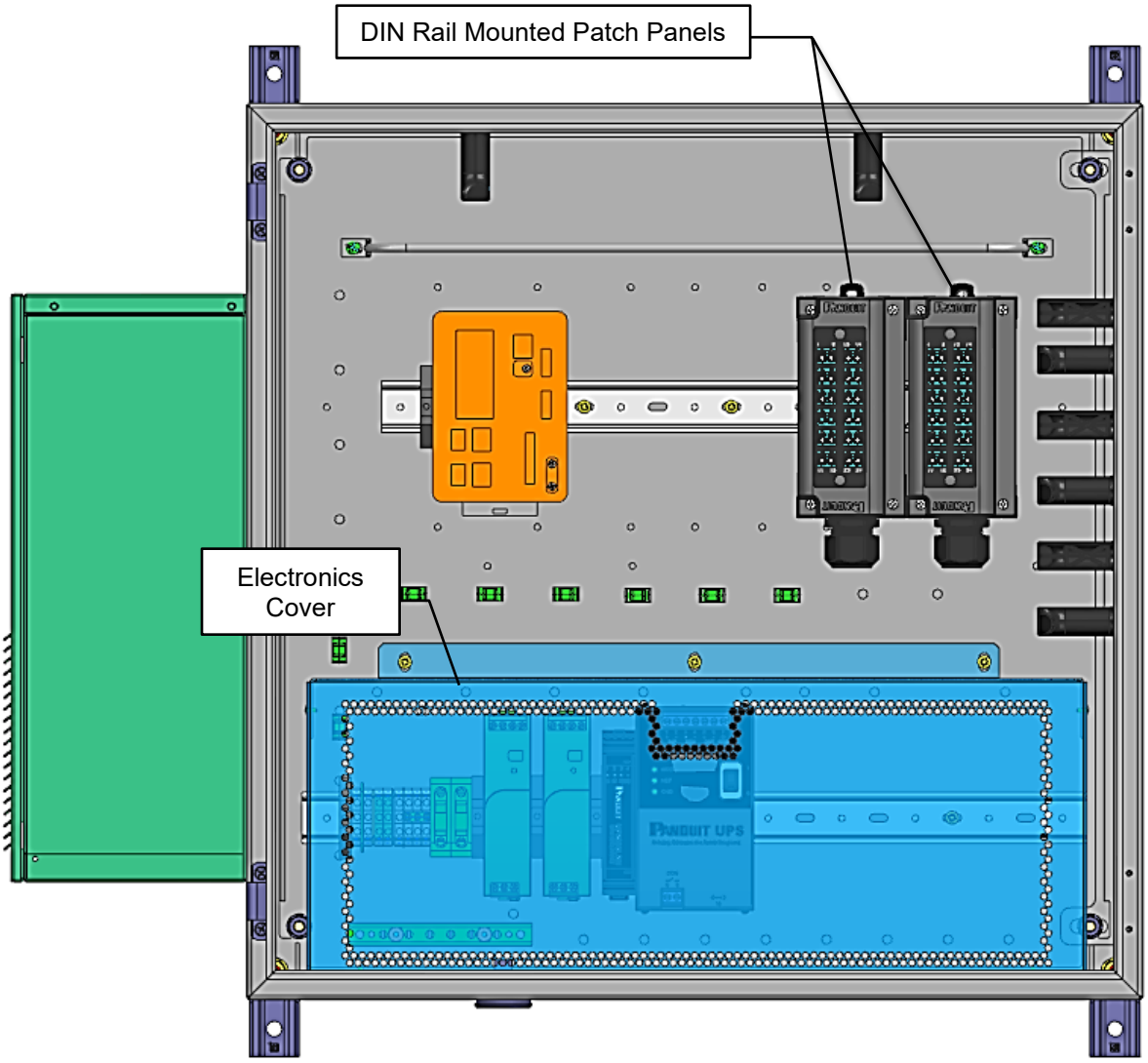


Figure 27: Front view of the Z22 Enclosure (front door removed for clarity).

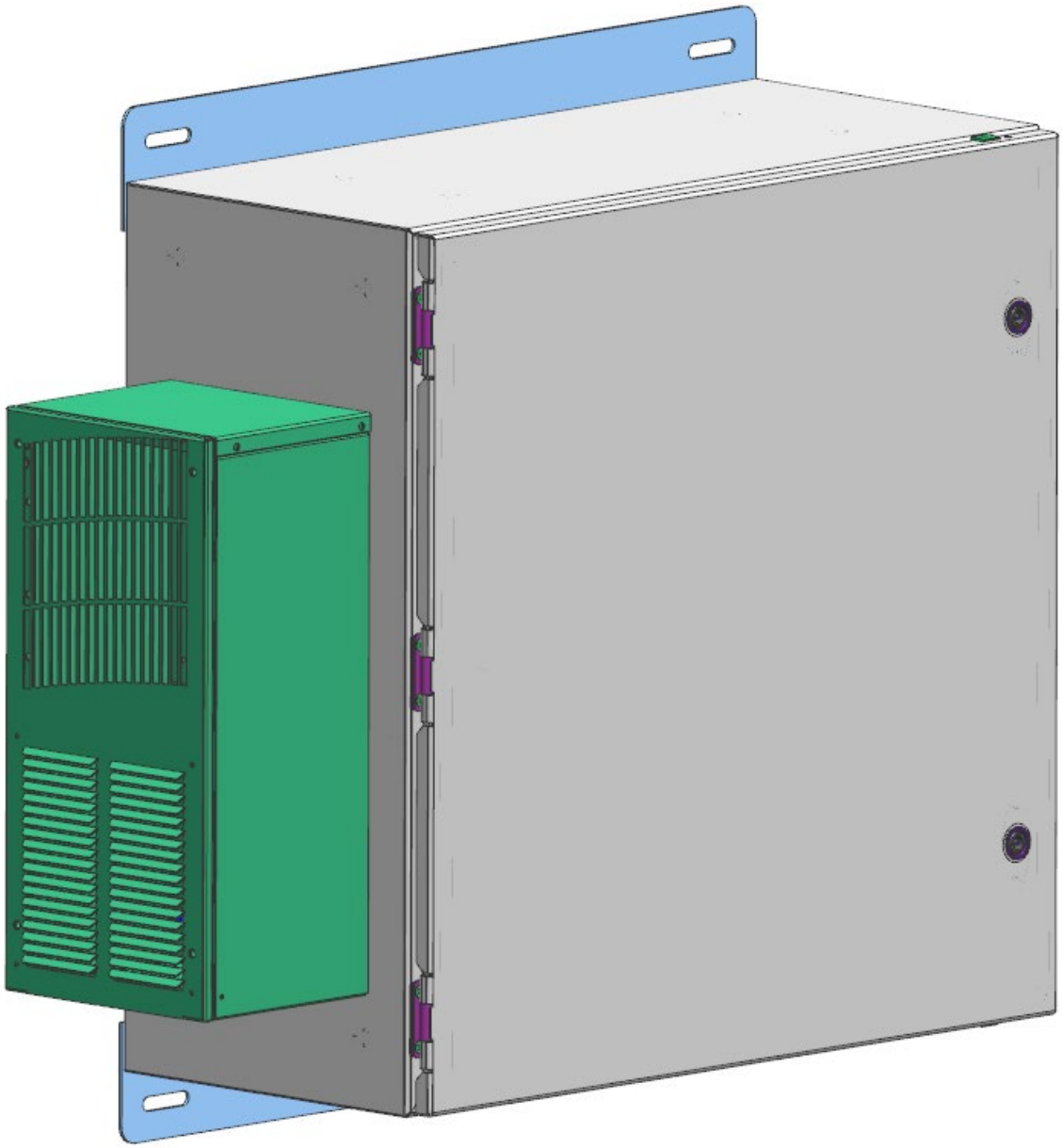


Figure 28: The T15 air conditioner is shown mounted to the hinge side of the Z22 enclosure.

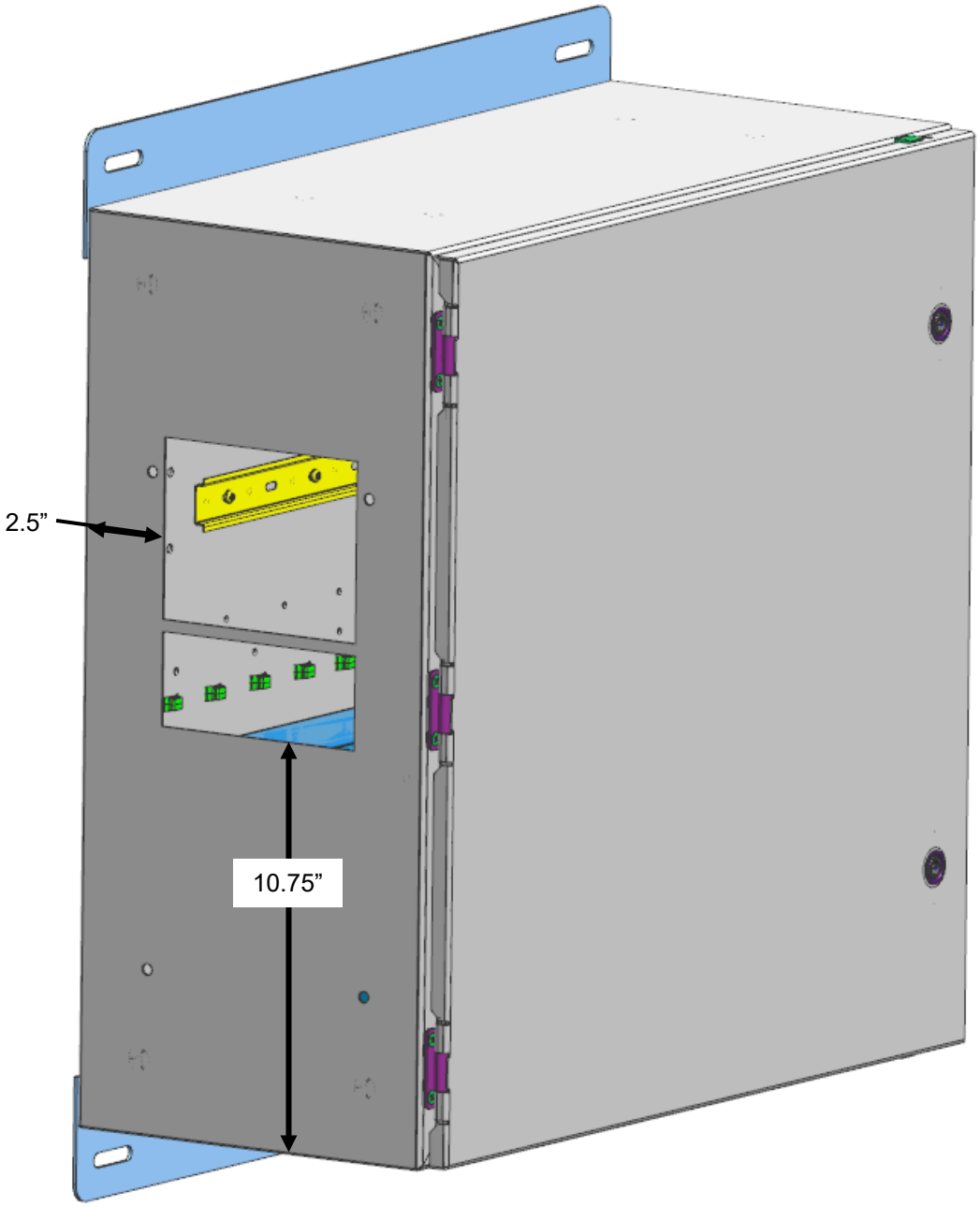


Figure 29: Shows the location of the cutout for the T15 AC unit on the Z22 enclosure. The cutout starts approximately 10.75 inches from the bottom of the enclosure and 2.5 inches from the rear of the enclosure.

Panduit Difference

Panduit is committed to delivering a consistently high level of quality and service the world over. With a presence in more than 100 countries, local Panduit sales representatives and technical specialists offer guidance & support that bring value to your business. Our global supply chain, which includes manufacturing, customer service, logistics, and distribution partners, provides prompt response to your inquiries and streamlines delivery to any worldwide destination.

References

1. HF-Series Fan Specification Sheet:
https://hoffman.nvent.com/sites/g/files/hdkjer316/files/acquiadam/2021-10/Spec-01170.pdf?asset_type=Spec%20Sheet%20/%20Engineering%20Specification

2. HF-Series Fan Instruction Manual:
https://hoffman.nvent.com/sites/g/files/hdkjer316/files/acquiadam/2020-12/89134973.pdf?asset_type=Installation%20Manual%20/%20Instruction%20Sheet

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