Dell PowerEdge Energy Smart Containment Rack Enclosure Deployment Guide

Dell │ Data Center Infrastructure

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Introduction

The Dell™ PowerEdge™ Energy Smart Containment Rack Enclosure is Dell's first product designed specifically for data center cooling. With its simple design, it can be used to help significantly improve the efficiency of raised-floor cooling. Whether you want to increase rack density to 25 kW or more, or you want to implement other cooling improvements, like evening out raised-floor distribution issues or reducing cooling-related energy costs, this guide describes how to deploy the Energy Smart rack in your data center.

Figure 1. **Dell PowerEdge Energy Smart Containment Rack Enclosure**

How it Works

The Energy Smart Containment Rack uses passive front ducting and couples directly to the floor to *participate* in the delivery of air through the raised floor. Unlike typical raised-floor delivery where subfloor pressure determines volumetric delivery, the rack's tight perimeter seal enables the IT equipment fans to govern how much air is drawn from the floor.[1] Figure 2 shows a Computer Room Air Conditioner (CRAC) delivering air to the subfloor and the air being pulled up into the rack.

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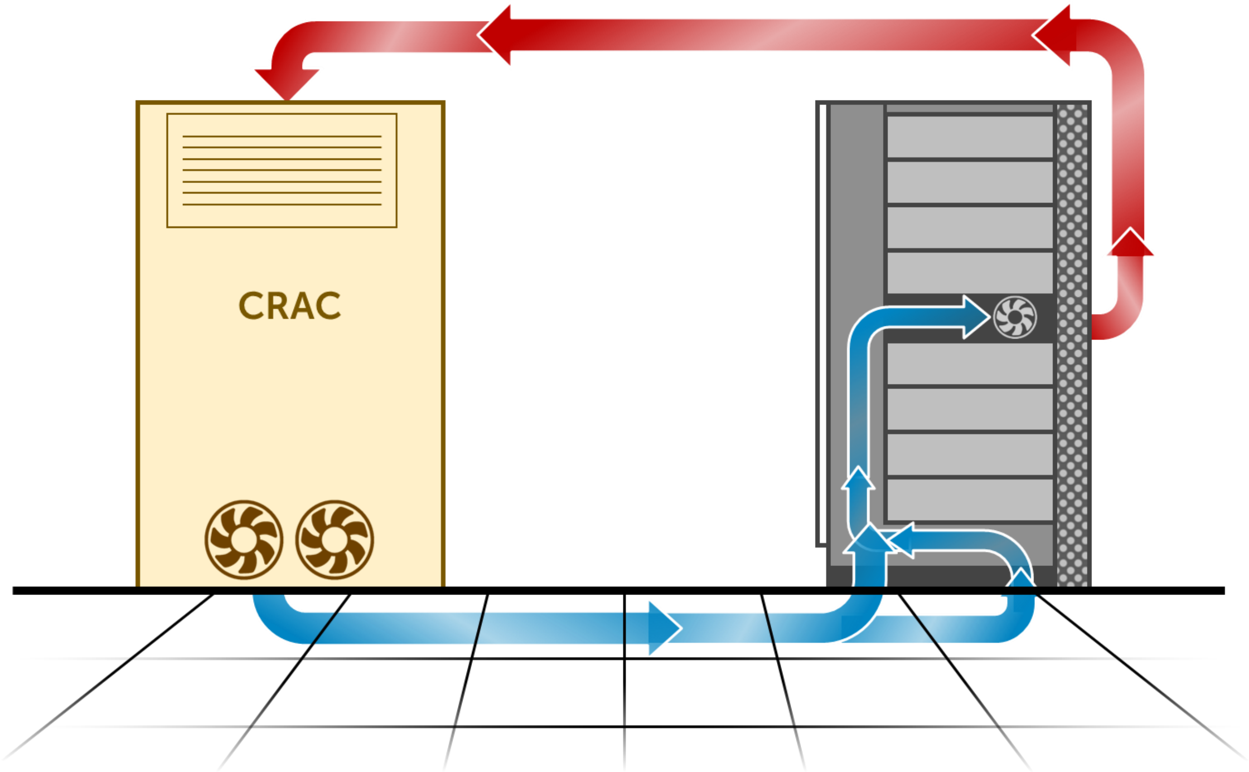
[1] For more information regarding the benefits of the Energy Smart Rack, see "Managing Data Center Costs with Dell PowerEdge Energy Smart Containment Rack Enclosures" by David Moss, Dell Inc., May 2011, available at http://www.dell.com/us/enterprise/p/d/business~large-business~en/Documents~energy-smart-containment-rack.pdf.aspx.

Figure 2. **Energy Smart Rack Operation**



Against pressure, IT equipment fans draw air through the floor venting and up the vertical front duct. Ideally, the floor vent offers the least resistance possible since it becomes an impediment in the path of the air. The duct itself also acts as a resistance to airflow. To maintain the largest duct with the least resistance, IT equipment should be deployed without front bezels installed, if possible.

It is important for blanking panels to be installed in any unused rack space to avoid internal recirculation of hot air to the IT inlets.[2] Following best practices for cold/hot separation can help to reduce data center operating expenses. Not all blanking panels operate equally. Gaps between panels may allow recirculation, especially under high pressures associated with high density, passive, tight containment. The presence of a single blanking panel can offer enough recirculation past its top and bottom surface to affect the equipment immediately above and below it. In one test, the inlet temperature increased as much as 6°C (11°F) at high rack power and flow rates. The presence of numerous small blanking panels may allow enough recirculation of warm air to negatively affect all of the rack's equipment. If there is a significant void in your rack, you might consider installing larger blanking panels to avoid numerous small gaps that allow recirculation.

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[2] For more information on the practice of using blanking panels, see "Rack Blanking Panels—To Fill or not to Fill" by David Moss and Joy Ruff, Dell Inc., February 2011, available at http://www.dell.com/downloads/global/products/pedge/en/dell-white-paper-en.pdf.

Why it Works

IT systems are in a constant state, trying to seek the lowest possible flow rate to minimize airflow consumption and fan power. When in a rack, they have to work against the pressure caused by the rack; this even includes a standard rack with perforated front and rear doors. Tight passive containment systems typically induce even higher pressures on the IT systems; examples of these types of systems are the rear door heat exchanger, chimney systems, and the Energy Smart Rack. The effect of this pressure, external to the IT system, is to slow the flow through the system. The IT system will recognize a decrease in flow rate as an increase in component temperatures. Fan speed control takes over and increases fan speeds to keep components within specified temperature limits.

IT fans are controlled with a duty cycle by a control strategy called pulse width modulation (PWM). Elaborate algorithms take into account multiple temperature sensors and return a PWM value for each fan. PWM values range in 1% increments between 0% and 100%. 0% corresponds to an actual (slow) minimum fan speed. A PWM setting of 100% will deliver maximum fan speed.

IT fans typically operate at speeds much lower than their maximum rating (typically below 50% PWM). It generally takes corner case operation (such as worst-case configuration, highest utilization, and operation at maximum spec temperature) to invoke the highest fan speeds; even then, the fans may not have reached 100% PWM. A typical PWM increase when comparing a heavy configuration to a light configuration is about 25%. A typical PWM increase when moving from 25˚C (77˚F) to 35˚C (95˚F) operation is about 20%. Utilization spikes typically cause about a 10% PWM increase. When not operating at worst case, any, or portions of all three examples would make up the reserve fan capability that is tapped into by the Energy Smart Rack and likewise by other passive containment systems. Average operating pressures in the Energy Smart Rack typically result in a PWM increase of only 5%.

Care should be taken anytime a passive containment solution is applied to equipment operating near the corner case. There may not be enough reserve fan capability to handle the external resistance applied by the containment solution. Operation at the corner case is extremely rare.

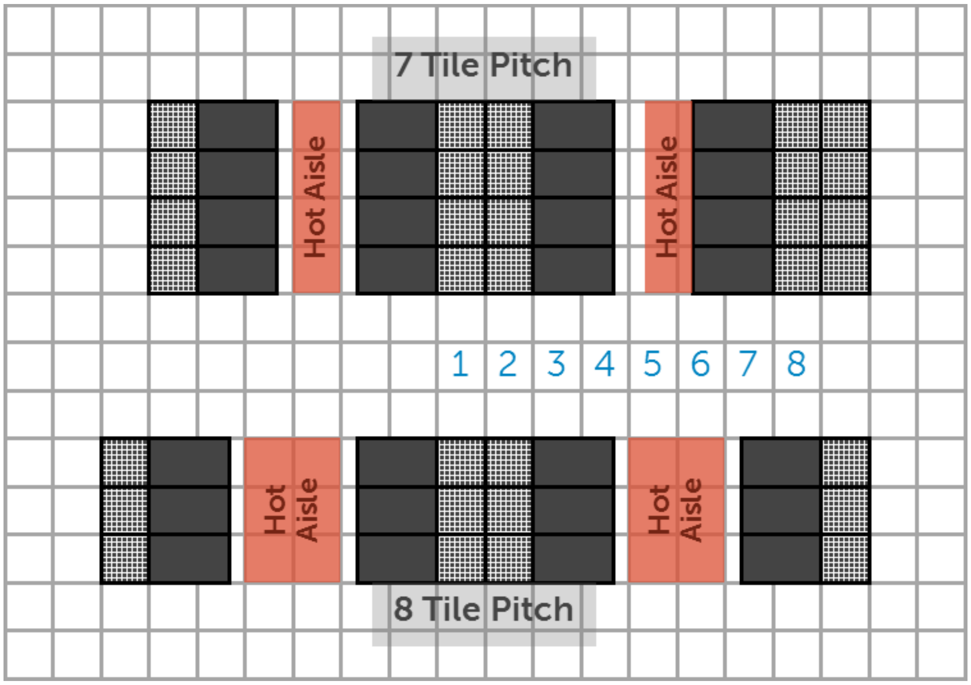
Positioning the Rack

The Energy Smart Containment Rack can be placed virtually anywhere in the data center; it does not require hot/cold aisle orientation. As with any rack that exhausts to the open room, its exhaust should not be positioned in the direction of the inlet of a non-contained rack, but since the front is sealed, there are no issues with having another rack’s exhaust directed at the front of an Energy Smart Rack.

The Energy Smart rack can be placed in an existing data center next to standard racks. It can also be used in the same room with other cold-aisle containment solutions. The primary restriction for using the Energy Smart rack is that it must be deployed only in data centers with raised-floor cooling.

Rack rows are commonly spaced on a 7 or 8 tile hot/cold aisle pitch where the front surface of every other row is either 7 or 8 floor tiles apart.

Figure 3. **Standard Hot/Cold Aisles: 7and 8 Tile Pitch**



In an 8 tile pitch, the 48” (1200 mm) deep Energy Smart Rack occupies two full tiles; the forward tile is a full floor vent (Figure 4). In a 7 tile pitch (Figure 5), the front rack extension overhangs almost 6 inches into what is normally the cold aisle. If opposed by another Energy Smart containment rack, the intrusion into the cold aisle still leaves enough aisle clearance to comply with the wheelchair clearance of the Americans with Disabilities Act (ADA).[3]

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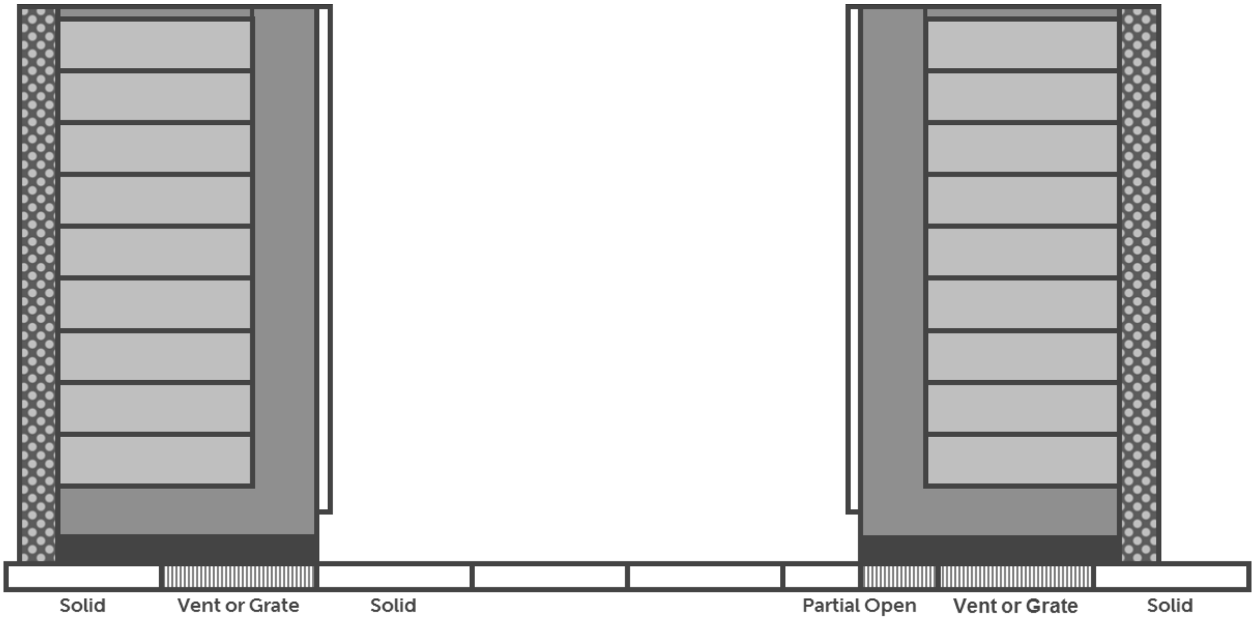
[3] http://www.ada.gov/pubs/adastatute08.htm

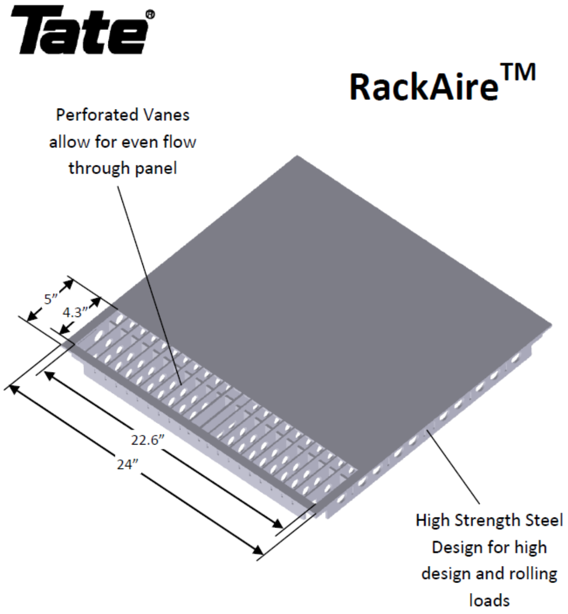
Figure 4. **8 Tile Pitch**

Figure 5. **7 Tile Pitch**



There are several options for handling the airflow requirements in each pitch configuration. For the 7 tile pitch scenario, Dell has collaborated with Tate Access Floors to develop a grate that is partially blocked so that its open area can be positioned under the vertical duct of the Energy Smart Rack.[4] This tile will provide maximum airflow directly in line with the air channel.

Figure 6. **Commercially Available Partial Grate**



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[4] See Appendix B for other options for a partially vented tile.

Vent Types

Dell strongly recommends using grate options with a free air ratio of greater than 50% to limit the amount of external pressure that is applied to the IT equipment, therefore minimizing the incremental fan power required to overcome the pressure. The most critical vent area is the venting placed directly below the vertical front plenum space. This area should be open at 50% or greater for higher density and better performance. Dampered grates should not be used with the Energy Smart Containment Rack.

Numerous combinations of commercially available vents were tested, including the Infinity® Air Grate, the Tate® GrateAire®, the Triad Slotted Ice™, the Tate® DirectAire™, and a standard 25% open perforated panel. The results of the tests are shown in Figure 7. Commercial vent performance typically falls within three ranges based on the resistance to airflow. Typical perforated tiles have an advertised open area around 25%. Metal grates typically fall into two higher performance ranges due to their open area. It is not clear that there is an official standard in estimating a vent’s free area ratio, so it may not be accurate to compare one vendor’s advertised opening percent to another’s. Vendor claims place the highest flow grates in the 60%–70% free area range, while the intermediate range grates are between 50% and 60%. Figure 8 indicates the minimum configuration to support the necessary CFM in the Energy Smart Rack for each region in Figure 7.

Figure 7. **Energy Smart Rack Pressure vs. Flow Rate**

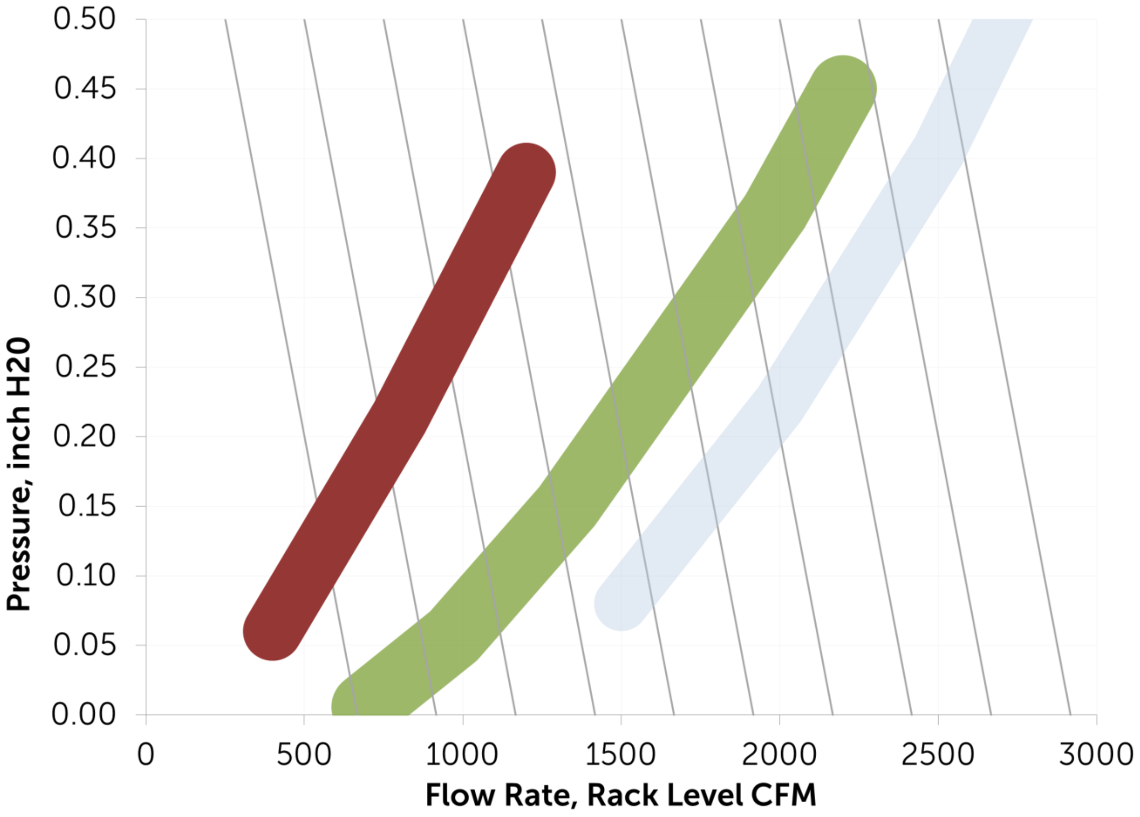


Figure 8. **Minimum Ventilation Requirements for the Energy Smart Rack**

Region 1: **Most Restrictive**	**Region 2:** **Moderately Restrictive**	**Region 3:** **Least Restrictive**
7 Tile Any full vent greater than 25% open combined with no partially vented tile **8 Tile** 25% perforated panel	**7 Tile** Full Triad, Infinity, or 25% perforated combined with 50-60% open partial (modified GrateAire) **8 Tile** Infinity or Triad	**7 Tile** Any full vent 25% open or greater paired with Tate RackAire Tate GrateAire or DirectAire paired with 50-60% open partial (modified GrateAire) **8 Tile** Tate GrateAire or DirectAire

The set of parallel slanted lines of Figure 7 represents typical IT system behavior. Starting at the horizontal axis, if external pressure is applied to a piece of IT equipment, the flow rate slows due to the pressure. If airflow slows, component temperatures should increase, but the IT system's temperature monitoring will typically drive the fans to increase to compensate and maintain proper temperatures. The slanted lines of Figure 7 represent the net effect of increased pressure, slowed flow, and temperature based fan speed increases.

The three regions represent operational characteristics using vent combinations ranging from the most restrictive to the least restrictive. If choosing a vent option in Region 1, density will be limited relative to options of the other two regions, or more IT fan power will be used relative to options from the other two regions.

The exponential rack curves in Figure 7 were plotted from static pressure measurements taken in the front duct of the Energy Smart Rack. The positively plotted pressures of Figure 7, all of which originate around 600 CFM, were actually negative duct pressures, with the IT systems pulling air into and through the rack. At rack flow rates at or below 600 CFM, the raised floor dominates the duct with positive pressure and helps push air through the rack and through the IT equipment. 600 CFM is typically representative of 6–8 kW, and rack loads greater than this will result in the IT equipment helping to extract the air.

Pressure/flow curves are exponential by nature, since pressure varies exponentially with flow rate. A typical fluid (air) flow curve passes through zero pressure at zero flow. With the Energy Smart rack, zero pressure occurs at a positive flow rate, due to the coupling with the floor and the effect of the raised-floor air handlers. The curves in Figure 7 were generated with a sub-floor pressure of 0.02” H_20. Had a higher pressure been used, the curves would shift slightly to the right. Although sub-floor pressure does have limited influence in the operation of the Energy Smart Rack, the choice of ventilated tile has a much larger effect, as shown in Figure 7.

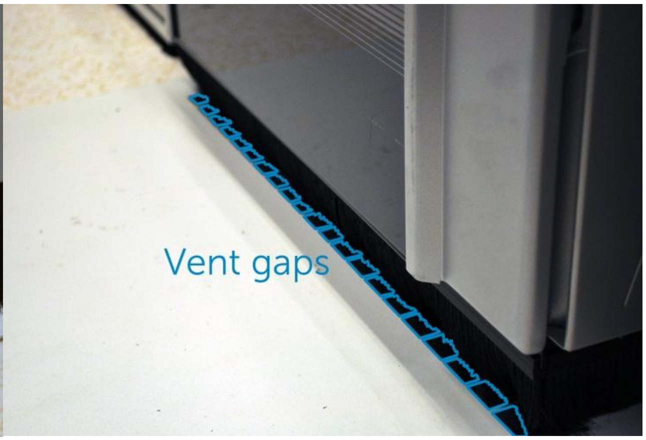
So what is the density limit that the Energy Smart Rack will support? The density is really only limited at each rack by the amount of reserve fan capacity in its IT equipment. Generally, a simple rule of thumb is *25 at 25*—the Energy Smart Rack should be able to support 25 kW at 25°C. Even with a rich configuration run under the heaviest utilization, there is ample fan reserve to compensate for rack pressures if the inlet temperature is 25°C (77°F) or less. For a more detailed explanation of density capability, see Appendix B.

Ensuring the Best Seal

The brush seal on the Energy Smart rack has been designed with enough interference with the floor to maintain a proper seal when the rack is lifted using the rack leveling feet. The bristles were designed with enough length to provide proper clearance as the rack is transported over irregularities, including rolling the rack down the ramps of its own shipping crate. As the rack is moved into position over a floor vent, the bristles may come to rest in a position that creates a gap at the vent or a gap at the corner where two brushes meet. It is advised that you inspect and adjust the brush seal after the rack is secured to close any gaps that might have been created.

Figure 9. **Corner Leak**

Figure 10. **Vent Gaps**



Other Airflow Considerations

Stabilizer feet can be deployed inside the front duct of the Energy Smart Rack. These anti-tip extensions bolt to the front of the structural frame and extend to contact the floor within the front duct. The stabilizer feet block enough air to reduce the airflow performance of the rack—a reduction that is roughly equivalent to the difference between region 3 and region 2 performance. The stabilizer feet are required to ensure the stability of a stand-alone rack. If multiple Energy Smart racks are ganged together, then the front stabilizer feet may not need to be installed.

Figure 11. **View of Front Stabilizer Feet Installed in the Energy Smart Rack**

The Energy Smart Rack is designed to contain the air in the chamber forward of the front mounting flanges. This allows the plenum to maintain containment even when the side panels of the rack are removed. Removing the side panels is necessary to gang multiple racks together.

Care should be used if deploying an Energy Smart Rack directly in front of CRAC units. Flow through the vent should be checked to ensure the flow is not negative back into the floor. The subfloor velocity immediately in front of a CRAC is often too great to allow static pressure to build. It can be fast enough to pull air from the vent and draw it downward into the floor. The Energy Smart Rack has difficulty countering this phenomenon. There are products that can be situated at the exhaust of the CRAC unit that will remedy this situation and allow the Energy Smart Rack to operate effectively adjacent to a CRAC unit, such as the Subfloor Velocity Adjuster™ from Subzero Engineering[5]; there are also other products that block or guide subfloor air that would work equally as well.

Conclusions

The PowerEdge Energy Smart Containment Rack Enclosure is an easy-to-deploy containment solution that supports high density installations and helps to solve some of the air distribution issues common to data centers. With an appropriately ventilated tile positioned beneath it, the Energy Smart rack taps into the IT equipment's ability to control air consumption based on its own needs and scales it to an ideal consumption from the floor.

For more information about this rack enclosure, refer to: Dell PowerEdge Energy Smart Containment Rack Enclosure.

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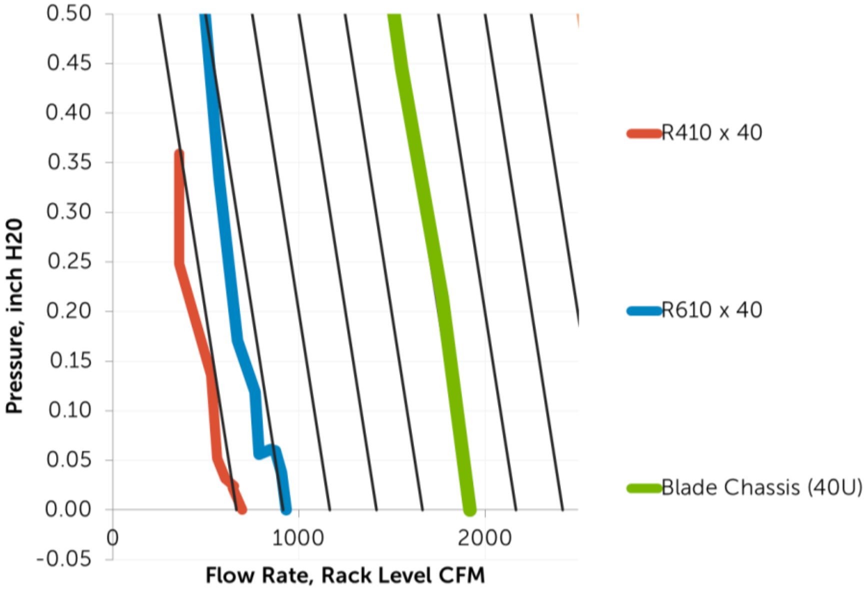
[5] http://www.subzeroeng.com/products/adjuster.aspx

Appendix A: Using the Energy Smart Rack P-Q Curves

The graphs representing pressure and flow are often called P-Q curves where *P* is for pressure and *Q* is for volumetric flow rate. As suggested in this deployment guide, IT equipment generally operates along the slope of the parallel, slanted lines relating pressure and flow rate.

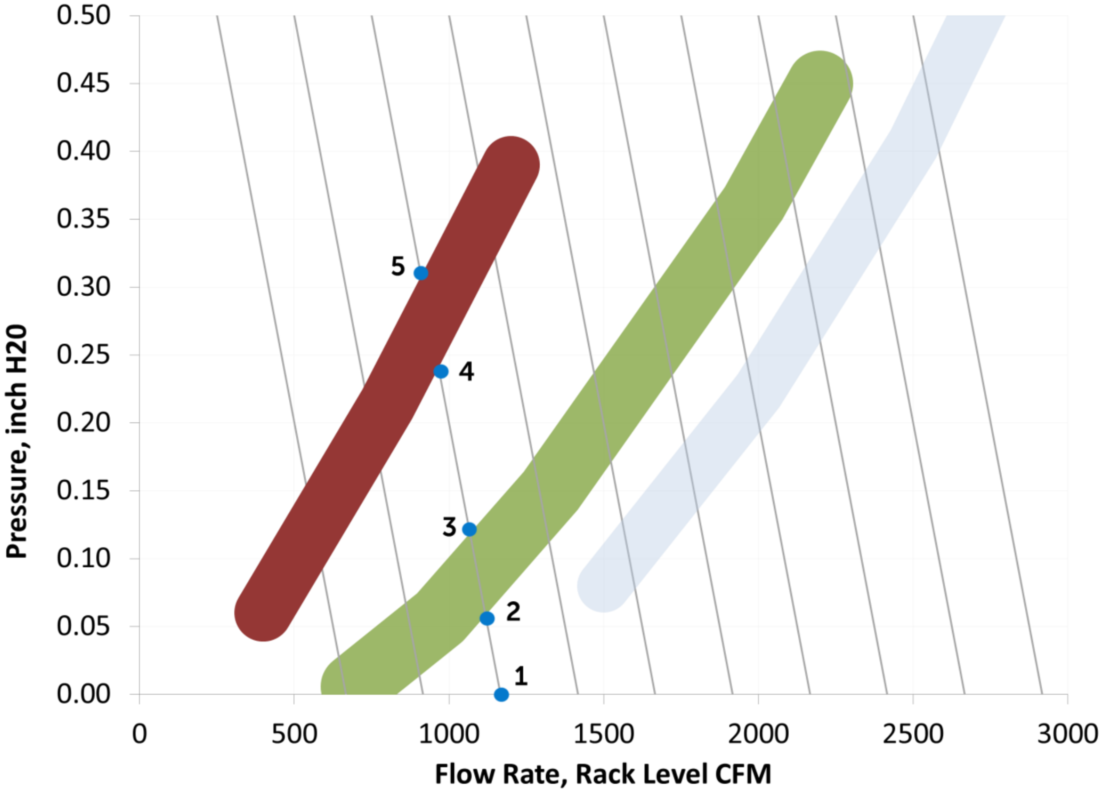
Figure 12. **Measured Server Response to Pressure**



As shown in Figure 12, three servers were measured for their response to external pressure. Each performed with a similar slope resulting in a gradual decrease in flow rate as more and more pressure was applied. Because they perform with a similar slope, it is possible to add up the unimpeded flow rates for a rack full of mixed IT equipment and follow a line parallel to the equipment lines to the point it passes through an Energy Smart Rack curve (delineated per the chosen vent option).

To determine the operational characteristics for a set of IT equipment, refer to Figure 13 and the instructions that follow.

Figure 13. **Pressure/Flow Estimate for a Specific IT Deployment**

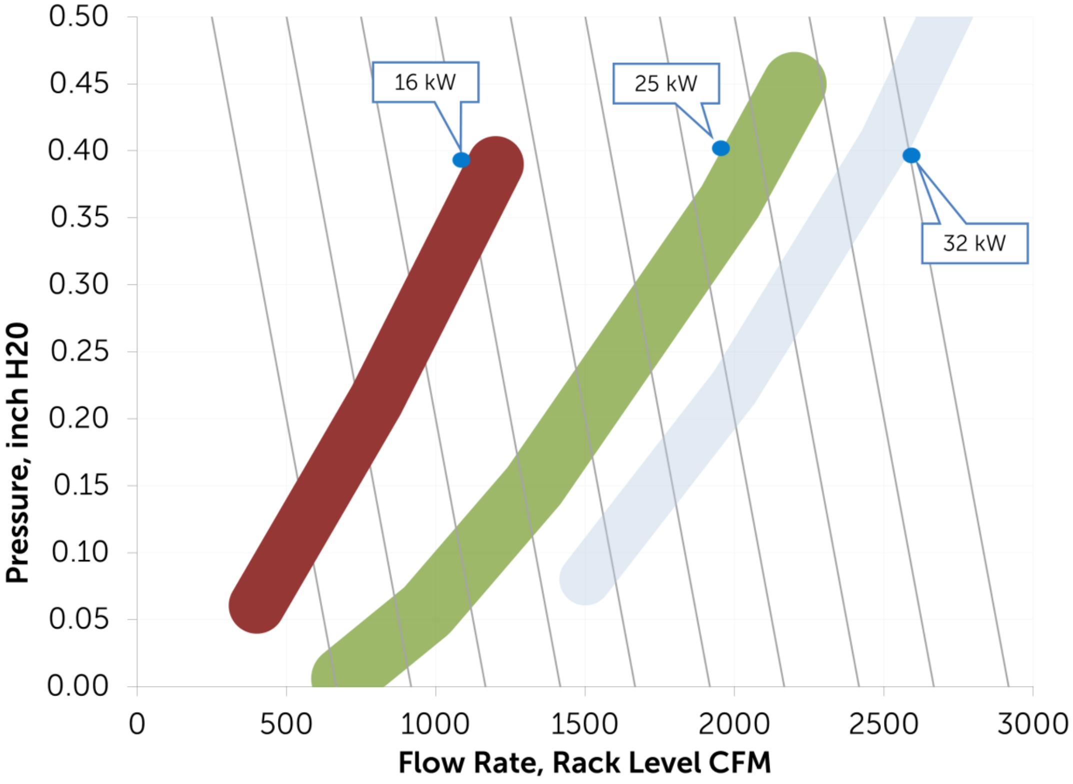


Assume a rack full of forty 1U servers normally consumes 1200 CFM. What would the operation in an Energy Smart rack look like? The unimpeded flow of 40 servers adds up to 1200 CFM. The servers are deployed in an Energy Smart rack in a 7 tile pitch using a full 25% open perforated panel below the rack and a partially open GrateAire aligned with the front plenum. This vent combination falls into region 2. Starting at point 1 on the graph and following it diagonally up to points 2 and 3 of region 2, the operating pressure inside the Energy Smart rack should be between 0.06” and 0.125” H_20. It will be operating with a total flow rate slightly less than 1200 CFM. Let’s say there is no partial vent in line with the rack’s front plenum. It is on a 7 tile pitch with the 25% grate, and the tile below the front plenum is solid. This situation describes a configuration associated with region 1. Moving up to points 4 and 5, operation would be between 0.24” and 0.3”, and the flow rate would have dropped to about 1000 CFM. Working against the pressure of the rack, the 1U servers in this case would have seen an increase in server power due to fan speed increases of less than 1% for the region 2 option and about 2% for the region 1 option. Alternatively, if a vent option from region 3 were used, the system power increase would have been negligible.

Would other vendors’ equipment respond similarly? It is likely, but you should inquire with the vendor about a specific product’s ability to handle external pressure.

Appendix B: Energy Smart Rack Density Explained

Figure 14. **Density Differences of Regions 1, 2, and 3**



General guidance for the Energy Smart rack is that it will support equipment density up to 25 kW at 25°C. This was derived from an example of the thermal performance impact associated with the operation of Dell's mainstream 1U server, the R610, in the Energy Smart rack. The PWM signal (fan speed driver) increases when the server is exposed to increasing temperatures. The internal server configuration with the worst case increase experiences a PWM increase of 24% when comparing 35°C to 25°C operation. When exposed to external pressure, as is the case with the Energy Smart rack and other passive containment systems, the PWM signal also increases. The pressure at which the PWM increases to 24% is about 0.4" H_20. Therefore, a pressure-induced PWM increase at 0.4" is roughly equivalent to the increase the system requires for the 10°C increase from 25°C to 35°C. This point is marked on region 2 in Figure 12 and corresponds to a rack flow rate around 2300 CFM. If choosing vent options of region 3, the density potentially scales up. The least-restrictive options within region 3 would allow approximately 32 kW at the same pressure. On the other hand, region 1 options are much more restrictive, resulting in a lower density capacity. A similar pressure would limit flow rates to approximately 1400 CFM and approximately 16 kW. All kW estimates were based on approximately 90 CFM/kW. Other server form factors should be at least as capable of compensating for rack pressure. As long as a vent option from region 2 or 3 is chosen, the rack should be capable of supporting 25 kW or greater.

Appendix C: Alternative Vent Options

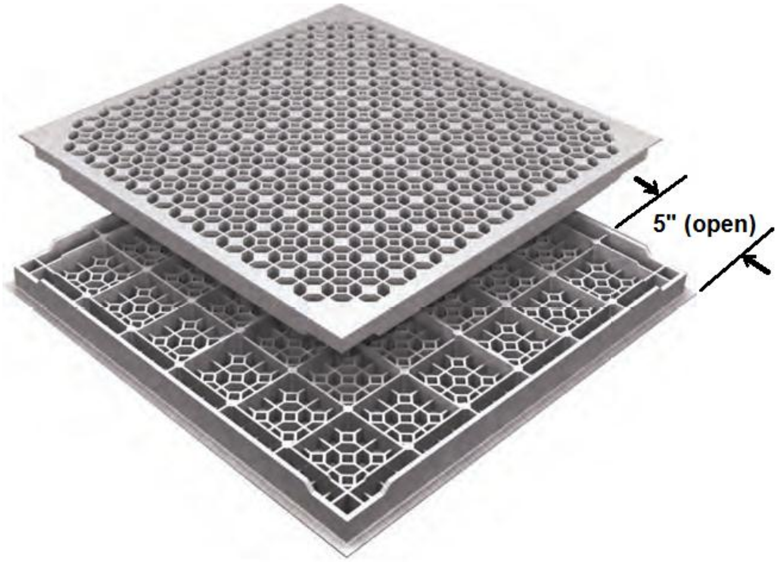
Temporary or Mixed-Use Option

The recommended practice of using a partially vented tile in the tighter 7 tile pitch is aimed at providing venting directly in line with the vertical plenum without having air released into the cold aisle. The Energy Smart rack might be deployed around other standard racks, in which case you may want cold air to still enter the cold aisle. In this instance, a grate in the cold aisle offers direct front plenum access for the portion of the vent under the Energy Smart rack, and it also allows air into the aisle to cool other racks. This option might even be considered on a temporary basis while waiting for receipt of a partially vented tile. The lead time for procuring a partially vented tile should be considered when planning Energy Smart rack deployments.

An Additional Option for the Partially Vented Tile

When positioned properly for the 7 tile pitch, the Energy Smart rack protrudes into the cold aisle no more than 6” (152 mm). The sealed area under the vertical plenum protrudes into the cold aisle by 5” (127 mm). One acceptable option for a partially vented tile would be to block portions of a Tate GrateAire. This grate happens to be segregated on the underside in dimensions that are complementary to the Energy Smart plenum seal.

Figure 15. **Creating Partially Vented Tile Using Tate GrateAire**



Blocking all but 5”, as indicated in Figure 15, would align well with the sealed plenum of the Energy Smart rack.