White Paper

Selecting Outdoor Enclosures for Railway Infrastructure

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Purcell SYSTEMS

1. Introduction

The rail industry was one of the first industries to adopt the use of enclosures and shelters to house wayside controllers and electronic equipment. Traditional uses of enclosures include housing electronics and controllers affiliated with switching stations, signal equipment at road crossings, communication, train location and position reporting.

The latest trend affecting the deployment of outdoor enclosures includes the Rail Safety Improvement Act of 2008 (RSIA), which mandates that Positive Train Control (PTC) be implemented across a significant portion of the U.S. rail industry by December 31, 2015. PTC is expected to be implemented over a total of approximately 70,000 miles of track.

PTC requires the expansion of the railway's private radio network to include a base station every 20 – 30 miles. These bases stations do not exist in the current communication infrastructure of the rail industry. As with public cellular and data networks, as well as private mobile radio networks, base stations require enclosures to house transceiver electronics and power systems.

One commonly overlooked aspect of these new build-outs is enclosures and cabinets needed to house these electronics. Enclosures come in a multitude of configurations, and railroad operators need to understand the long term operating costs affiliated with their selection of features for enclosures and cabinets.

This white paper introduces the features and capabilities offered with enclosures from Purcell Systems, including the range of thermal management systems, power efficiency, acoustic management, security and intrusion prevention, and scalability and flexibility. These features and capabilities have a major impact on the total cost of ownership over the life of the deployment – typically many years – therefore understanding and leveraging them can result in significant operational expense reductions and better security, increased reliability and longevity versus other enclosures that do not support these capabilities.

2. Thermal Management

Most commercial electronic equipment is specified to operate in a – 40 °C to + 60 °C range. For electronic components, for every 10 °C rise in temperature, the average reliability is decreased by 50 percent. In terms of Mean Time Between Failure (MTBF), the MTBF will double if the operating temperature is lowered 10 °C. So maintaining your equipment within the manufacturer's recommended temperature range not only reduces your capital reinvestment on equipment by extending operational life, but also improves the reliability of your network infrastructure.

Thermal management systems are available in a number of technologies and performance ranges to accommodate the heat load from contained equipment and solar radiation. The cooling capacity of a thermal management system is commonly measured in Watts per degree Celsius (W/°C) which is defined as Q/(TI-TA) where;

Q : Heat dissipation (W) from inside of cabinet

TI : Return temperature of internal air circuit (°C)

TA : Ambient temperature of external air circuit (°C)

The thermal management system must properly maintain equipment with an outdoor ambient temperature range between -40 and +70°C. The design of the thermal management system must take into account the operating temperature range of the enclosed electronic equipment, and address the heat dissipation from that equipment plus the total heat load contribution of solar radiation from exposure to direct sunlight.

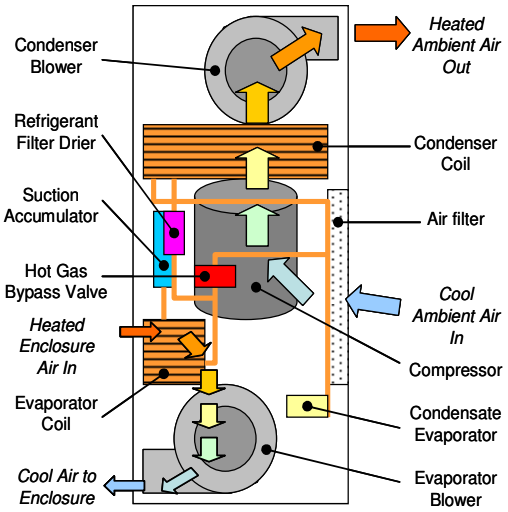
Purcell Systems offers a wide range of thermal system technologies and capacities that allow us to match virtually any thermal management requirement with the optimal combination of technology, performance, reliability and cost. The four most common thermal management technologies Purcell Systems uses for outdoor enclosures are – Direct Air Cooling (DAC), Air-to-Air Heat Exchanger (HEX), Air Conditioning (A/C), and Thermoelectric Cooling (TEC). Listed below are the main characteristics of each of these thermal management technologies.

	Direct Air Cooling (DAC)	Heat Exchanger (HEX)	Air Conditioner (A/C)	Thermoelectric Cooler (TEC)
Closed Loop	No	Yes	Yes or No	Yes
Cool below External Ambient	No	No	Yes	Yes
Extracts Humidity	Limited	No	Yes	Yes
Integrated Heating	No	No	Yes	Yes
Energy Consumption	Low	Low	High	Medium
Acoustic Emissions	Low	Low	High	Low
Failure Rate	Low	Low	High	Low
Repair Cost	Low	Low	High	Medium
Capital Cost	Low	Medium	High	High

Air Conditioner (A/C) - A/C offers the highest performance thermal management technology, able to support very high heat loads and cool the interior of the enclosure far below ambient air temperatures. Most A/C units deployed in support of outdoor enclosures are closed-loop systems based on vapor compression cycle where a refrigerant undergoes a change of state (from a liquid to a gas) that absorbs thermal energy from within the enclosure and transfers it to the outdoor air. This process also removes humidity from within the enclosure.

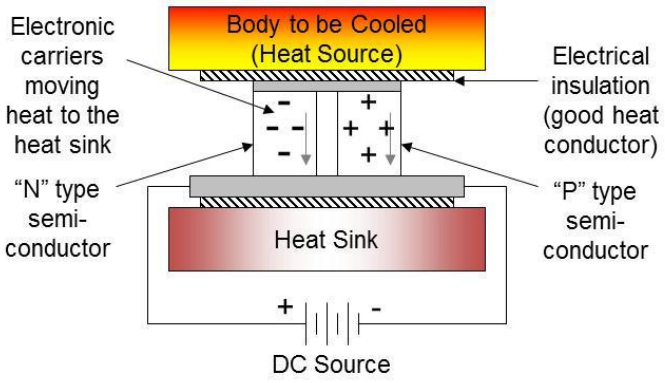
While A/C offers the highest performance cooling, it also comes at a significant price in terms of the relative cost of the technology, high energy consumption, required regular preventative maintenance, and poor reliability and life expectancy, due mainly to many complex components and moving parts operating at high temperatures and pressure.

Due to the high-performance capabilities of A/C systems, many outdoor enclosure vendors tend to apply it for all cooling requirements, which typically results in significantly more cooling capacity than what is actually required. When deployed in this manner, A/C systems will have higher than normal failure rates due to short-cycling, higher energy consumption, and create the potential for flash-condensation due to the air temperature inside the enclosure being significantly lower than the humid air outside the enclosure. When the enclosure door is opened in this condition, the much warmer and humid outdoor air comes in contact with the much colder interior surfaces of the cabinet, causing the humidity to instantly condense in the enclosure.



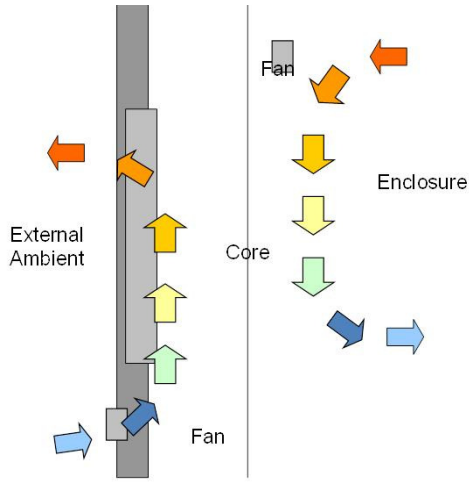
Components and airflow within an A/C System

Thermoelectric Cooler (TEC) – TEC's use the Peltier-Effect, by which current applied across two dissimilar materials causes a temperature differential. TEC's offer variable and scalable small incremental cooling or heating in a compact form factor. TEC's have very high reliability and long life expectancy because the only moving parts are fans to circulate air. TEC's require no maintenance and consume far less energy to operate than A/C.



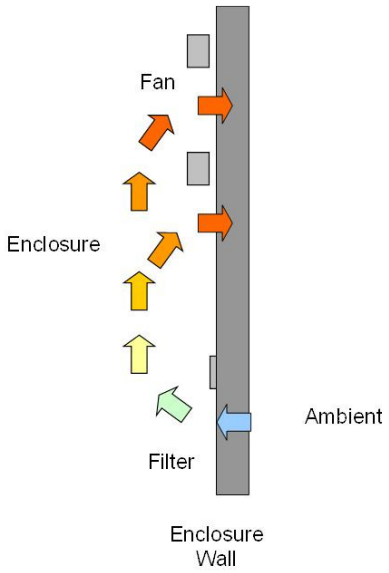
Components and airflow with a TEC System

Heat Exchanger (HEX) – HEX's provide superior above ambient temperature thermal management. HEX units are closed loop systems meaning that they isolate the outdoor ambient air from the air inside the enclosure. Closed loop systems prevent intrusion of any particulate contaminates, such as dust, moisture and humidity from entering the enclosure. HEX's are highly reliable and have long life expectancy since the only moving parts are the fans to circulate air. HEX's require no maintenance and consume very little energy.



Airflow with a HEX System

Direct Air Cooling (DAC) – DAC systems provide excellent above ambient thermal management performance. DAC units are open-loop systems that bring outdoor ambient air into the interior of the enclosure for cooling purposes. DAC systems typically employ inexpensive mesh filters to prevent particulate contamination from entering the enclosure, or alternatively can also be equipped with high-performance hydrophobic filters that prevent moisture entry into the enclosure. DAC systems are highly reliable and have long life expectancy because the only moving parts are the fans to circulate air. DAC systems consume very little energy.



Airflow with a DAC System

Many external factors affect the thermal performance of an outdoor enclosure – primarily the range of seasonal temperatures and humidity, the thermal load produced by the sun, and the thermal load produced by the equipment. More than any other feature, the thermal management system could have the largest impact on the operational expenses. The following parameters should be factored into any thermal management recommendation;

- the range of seasonal temperatures and humidity,
- the thermal load produced by the sun,
- the thermal load produced from each type of enclosed equipment (when fully populated),
- the grouping and segregation of equipment based their range of operating temperatures,
- any restrictions for acoustic emissions, and
- initial capital cost and ongoing operational expense.

When Purcell Systems is presented with a new configuration for an enclosure, we engineer a thermal management solution that optimizes the thermal environment for equipment, and this design will minimize the total cost of ownership over the lifetime of the enclosure. Note that these engineered configurations use off-the-shelf thermal management systems, so the railroad operator does not pay any engineering fees or experience project schedule increases with these solutions. Factors that affect the design of the thermal management system may include;

Equipment Segregation into Cooling Zones – Purcell Systems will engineer the enclosure, and all of its affiliated accessories, to accommodate multiple temperature zones. This design method enables the enclosure to keep one zone at a different temperature than another. By understanding the operating ranges of the groups of equipment in the enclosure, Purcell Systems can design the thermal management system to keep each group of equipment within its specific operating temperature range.

This capability is especially useful for enclosures that house both batteries and electronics. Batteries should be stored as close to room temperature as possible, as any elevated temperatures substantially shorten cycle life. Electronics are more tolerant of higher temperatures, and can operate comfortably between -45 and 65°C. Typical cooling configurations would be a TEC for the battery zone and a HEX for the electronics zone. Without the application of zone cooling, a common chamber containing batteries would probably need A/C to maintain the required temperature range. Note that zone cooling applies to any configuration that includes equipment with different thermal characteristics, not just configurations with batteries.

The enclosure must support the inclusion of a horizontal insulated partition, as well as the mounting of up to three different cooling systems on the door. The FlexAir™ door from Purcell Systems supports up to three different thermal systems, thus creating three different cooling zones. Purcell Systems analyzes and models the thermal environment of each zone, and can recommend the optimal cooling system that complies with the equipment specifications while minimizing operational cost.

Image Caption – Zone cooling is supported with the FlexAir™ door.

Wide Selection of Thermal Systems, Technologies and Capacities - Purcell Systems offers a wide range of thermal system technologies and capacities that allow us to match virtually any thermal management requirement with the best combination of technology, performance, reliability and cost rather than simply putting the highest capacity A/C unit that will physically fit each cabinet.

This range of thermal solutions also enables adaptability to changing equipment configurations that result in completely different thermal requirements. It is not necessary to equip the cabinet with the largest thermal management system that will fit only to try and "future-proof" the deployment. Enclosures with incorrectly sized thermal systems lead to high capital expenditures, failure rates, energy and maintenance costs, and the potential for reduced equipment reliability and service life.

This adaptability also allows for the cost-effective implementation of newer thermal management technologies and solutions as they become available that may provide significant operational advantages and savings while maintaining the investment in the cabinet solution.

Power Efficiency - An often overlooked, but paramount, consideration in assessing outdoor enclosures or cabinets is the power efficiency of the thermal management options offered with the enclosure. The selection of the optimal thermal system, and its affiliated power consumption and cooling capacity, will substantially affect the combined operating and capital costs over the life of the enclosure. Over-engineering the cooling system or selecting an inefficient cooling technology can result in excessive power consumption, increased operational expenses and the potential for premature and increased equipment failures.

Intelligent Controllers - A critical consideration when selecting an enclosure thermal management system is an intelligent controller. An intelligent controller, in combination with multiple temperature sensors, should control the operating speed of the air-movers. These variable-speed controllers regulate the air flow, maintain a more even temperature within the enclosure, reduce energy consumption, and reduce acoustic emissions outside the enclosure. An intelligent controller should also provide alarm reporting and communication capabilities for the thermal system.

3. Security and Intrusion Prevention

Security is a critical concern for any network railroad operator. Unauthorized access to equipment can quickly lead to network downtime and loss of critical communication links. Purcell Systems offers numerous features that provide uncompromising security.

Interior Door Hinges – Hinges on all access doors should be only accessible from inside the enclosure, and reside inside the exterior gasket area of the enclosure so they are protected from exposure to the elements. The hinge should not be accessible when the door is closed. Unlike interior hinges, exterior hinges can be easily knocked off the enclosure, thus allowing the removal of the door and access to the enclosure interior. Exterior piano hinges can easily be defeated with a hacksaw, allowing door removal and access to the enclosure interior as well

Door Latches and Frame – All exterior doors should be locked with a multi-point latching mechanism to ensure that all door corners and edges are secured. Any latching mechanism for the door should be in the enclosure interior. The latching system should also be captive such that when the handle is in the locked position, the latches effectively bond the door to the cabinet. Latches that aren't captive can easily be defeated with a crowbar, screwdriver or other prying instrument. Intrusion by prying the door open can also be prevented with proper design that results in a small gap between the edge of the door and the enclosure frame when the door is latched closed, and a flange along the interior of the door frame.

Door latching hardware and mechanisms should be capable of withstanding torque levels, typically 400 in-lbs, without any physical distortion or loss of functionality. In the event that the exterior handle is compromised, the latching mechanism should not be accessible to external tampering, and stays in the locked position.

Firearms Resistance – Penetration of the enclosure walls by projectiles can cause severe damage to the equipment. Commercial-grade design guidelines suggest outdoor enclosures must be capable of withstanding a point blank 12-gauge shotgun blast without penetration of the cabinet wall by any pellets. Additionally, the enclosure should be resistant to a 22-caliber bullet (long rifle, hollow point or standard lead round nose) fired from 50 feet and resistant to a 30-06 caliber (180 grain bullet) fired from 50 yards.

Intrusion Alarms - Intrusion alarms should provide signaling to a centralized alarm monitoring center of an unauthorized or unscheduled opening of the door.

4. Flexibility and Scalability

The selected enclosure should be able to accommodate your changing application needs and the myriad environments where your equipment is deployed. An enclosure with numerous configuration options enable an railroad operator to standardize on one enclosure model, while providing the flexibility for the different equipment configurations and deployment challenges presented by unique environments. Purcell Systems enclosures are designed with pre-engineered components that offer the ultimate configurability, field upgrades and expansion including additional equipment bays, power and battery backup, and thermal management capacity to meet deployment demands today and tomorrow, without the need for expensive and limited custom development.

Vertical Stacking – Shorter enclosures should offer vertical stacking features or mounting on a raised plinth for easier access. The main benefit of vertical stacking is adding capacity without increasing the depth or width of the footprint, thus maximizing real estate. If multiple enclosures are to be stacked, then an adapter plinth is needed between the enclosures, or the top and bottom of the enclosure must have aligned bolt patterns to enable joining. Another key consideration is meeting seismic zone requirements when enclosures are stacked.

Shorter enclosures should be designed so they can be vertically stacked.

Horizontal Expansion – The enclosure architecture should accommodate the horizontal expansion of enclosures, typically called a line-up. Features that enable horizontal expansion include aligned bolt patterns for mechanical joining of the adjacent walls and alignment of knockouts on the walls that allow cable pass through between connected bays.

Enclosures should be designed so they can be horizontally stacked into line-ups

Field Upgrades of Thermal Systems – Thermal systems can be door, side, or roof mounted. Purcell Systems prefers to mount thermal system solutions to enclosure doors. This allows maximum flexibility to adjust the capacity of the thermal solution to match the deployed equipment. Quick-release hinges allow fast and efficient changes to the thermal management systems that can typically be accomplished without having to remove the cabinet or electronic equipment from service. Door mounted thermal systems also enable upgrades later to implement zone-cooling, or to take advantage of more efficient thermal technologies as they become available.

Side Chambers – Side chambers, which are typically not thermally managed, can be used for many purposes – power termination and distribution (i.e. AC/DC load centers), physical cross-connect of cables, and splicing of cables. Critical features to be considered are; the availability of side chambers for both sides of the enclosure, physical dimensions, NEMA Ratings (3R minimum recommended), the degree of Ingress Protection (IP) rating, cable entry seals and glands, three-point locking mechanisms, options for a secondary grounding bar, and intrusion alarms.

Battery Pedestals and Plinths – As accessories, generic installation plinths with cable entrance provisions and battery compartments are offered for pad mountings. Open air plinths should have accessory wall panels to prevent animal access (i.e. critter guards).

Side chambers provide easy access to physical cable and power connections, so they can be further distributed into the main compartment.

5. Wireless Features

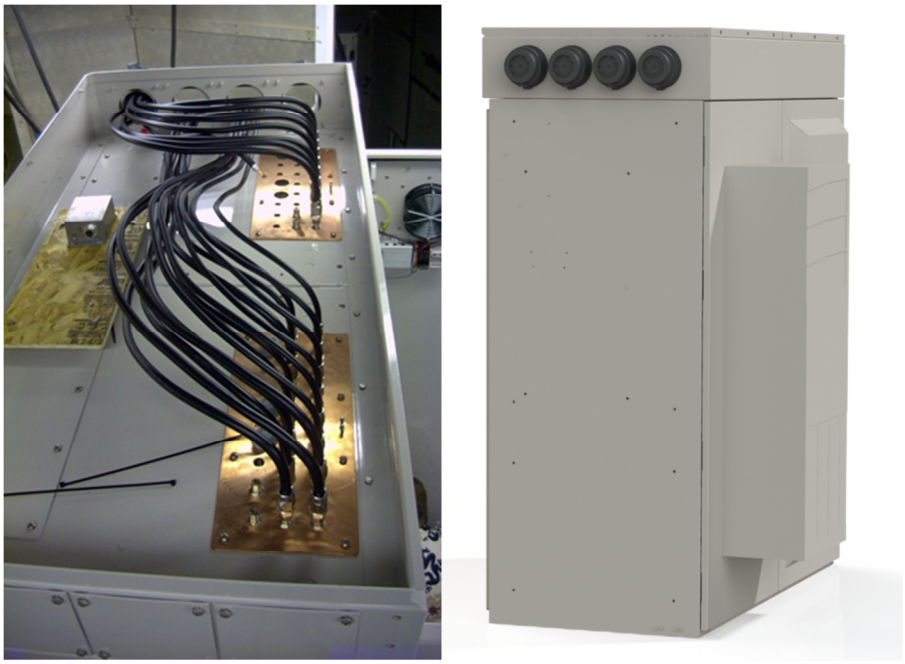
Outdoor equipment enclosures enable railroad operators to save substantial time, labor, space, capital and operational expense while meeting their exact needs for equipment mounting, thermal management, power and battery backup. Listed below are the most notable features that are specific to enclosure configurations that support wireless transceivers.

Grounding – Many transceiver vendors require cell base station grounding at 5 Ohms resistance to ground. IEEE STD 142-1991 and IEEE STD 142-2007 recommends that commercial and industrial substations (which include base stations) have a resistance to ground of 5 Ohms or less. This low resistance is required due to the high potential to earth of the electrical system.

Transceiver equipment housed in enclosures will be directly cabled to the antenna. Therefore, there is a small possibility that a lightning strike may get conducted down the antenna cable into the enclosure. Lightning arrestors (and independent grounding cables) are typically installed with the antennas on the towers. But in the unlikely scenario that these arrestors fail, energy from the lightning strike may enter the enclosure. Therefore, grounding bars, installed in both the main chamber and the side chamber, are a critical component of any wireless installation.

Indoor and Hardened Equipment – Many transceiver manufacturers offer indoor and hardened versions of their radios, and hardened equipment always commands a premium over indoor equipment because it is designed to accommodate severe temperature and humidity environments. Historically, hardened equipment was usually deployed in unmanaged outdoor enclosures. However, the deployment of indoor transceiver equipment in thermally managed outdoor enclosures is a viable and cost effective alternative for the railroad operator.

Cable Entry – Enclosures for base stations typically have antenna cables enter near the top of the enclosure, as well as some land line cables exiting through the side or bottom of the enclosure. If multiple antenna cables are required, then these cables enter near the top and should be organized and distributed through a "cable raceway".



Cable raceways distribute antenna cables across the top compartment of the enclosure.

6. Conclusion

Supporting railway communications will require new and upgraded radio base stations throughout our current railway network. The increased quantity of base stations will challenge the economics of traditional, higher cost, hardened equipment currently deployed in the network.

Thermally managed outdoor enclosures can enable the deployment of lower cost commercial-grade equipment while providing the optimum operating temperatures with high reliability and low Total Cost of Ownership. Thermally managed enclosures maximize equipment security, as well as extend service life by providing an optimal operating environment for communications and power equipment. Additionally, ongoing heating and cooling costs can be minimized by selecting the optimal mix of thermal management technologies.

The features and capabilities reviewed in this White Paper have a major impact on the Total Cost of Ownership, therefore understanding and leveraging them can result in significant operational expense reductions, as well as increased reliability and equipment longevity.

About Purcell Systems

Purcell Systems designs and manufactures innovative, modular, thermally-managed outdoor enclosure solutions to house electronic equipment. Our outdoor enclosures enable our customer to meet their exact needs for equipment mounting, thermal management, cable management, power and battery backup while saving substantial time, labor, space, capital and operational expense as compared to prefabricated buildings or shelters.

Purcell Systems mission is to reduce ownership and operation cost through industry leading design, quality and on time delivery. Our solutions are deployed by customers in the Cable/MSO, Energy/Utility, Land Mobile Radio/Public Safety, Transportation, U.S. Government/Military and Telecommunication Carrier markets. Purcell Systems provides quality products and services with unmatched speed, flexibility, and 24/7/365 Fanatical Service®. Our commitment to on-time delivery, product quality, unmatched customer support and performance to our commitments has resulted in rapid growth and continuous improvement to our capabilities and service offerings.

Founded in January 2000 in Spokane, Washington, USA, and with offices and design centers located in Stockholm, Sweden and Mielec, Poland, Purcell Systems has become a global leader in thermally managed outdoor enclosures with production facilities strategically located around the world.

Using sophisticated engineering analysis, modeling and validation, and with a deep understanding of all aspects of our customers' deployment challenges, Purcell Systems solutions provide the lowest total cost of ownership.

- Product cost
  - Low first deployment and expansion cost
  - Highly configurable, modular solutions using pre-engineered components
  - Common interchangeable components utilized across multiple enclosures
- Installation cost
  - Small footprint minimizes real estate cost – typically less than 3 square feet per enclosure
  - Inexpensive to transport to any site via small truck, ship, rail or air
  - Flexible deployment options: mobile or fixed – pole, wall, H-frame, roof or pad
- Operational cost
  - Low energy consumption through analysis of thermal management requirements and implementation of the most efficient thermal management solution(s)
  - Wide range of heating and cooling system solutions – Direct Air Cooling, Heat Exchangers, Thermoelectric Cooling, Air Conditioning, Zone Cooling
  - Designs for high reliability, minimal maintenance and quick repair for all environments
  - Field upgradeable solutions to add equipment mounting space, thermal management and battery backup

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