Connectivity

Building a heavy-duty connector set

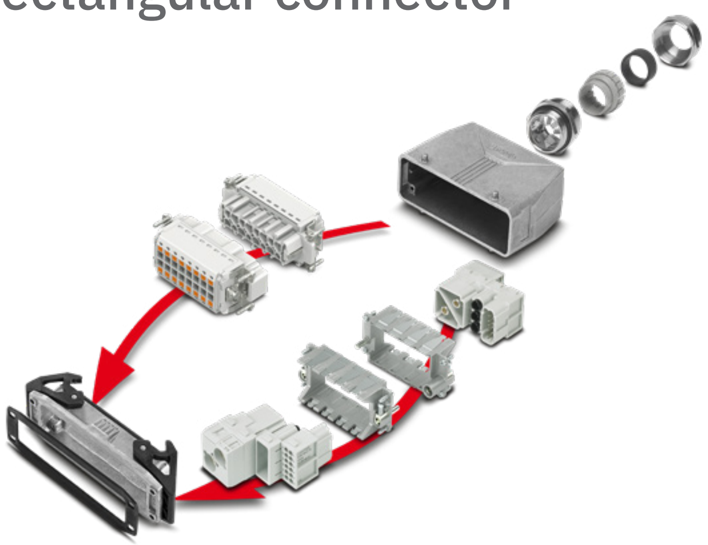
Learn more about

- Heavy-duty rectangular connectors are generally acquired in several pieces that can be mixed and matched to create an almost endless number of different connector configurations.
- These connector systems include three key component categories – connector inserts, cable entries, and housings – and there are numerous factors to consider when selecting each component.
- This white paper walks you through the many different options, so you can specify the ideal heavy-duty rectangular connector for your unique application.

Introduction

Heavy-duty rectangular connectors are generally acquired in several pieces that can be mixed and matched to create an almost endless number of different connector configurations. This is incredibly helpful, given the number of different connection requirements across power, signal, and data transmissions. It can also be incredibly mind-numbing to try to figure out how to choose the right components for the application and be certain they all fit together. Time to try to help break that down, so it feels a little more manageable.

Choosing the right industrial rectangular connector components



The basics

Heavy-duty rectangular connectors are generally acquired in several pieces that can be mixed and matched to create an almost endless number of different connector configurations. This is incredibly helpful, given the number of different connection requirements across power, signal, and data transmissions. It can also be incredibly mind-numbing to try to figure out how to choose the right components for the application and be certain they all fit together. Time to try to help break that down, so it feels a little more manageable.

First, it's important to recognize that there are generally three component types to consider: connector inserts, housings, and cable entry. Together, they will form a complete connector assembly that should match all the electrical, mechanical, and environmental requirements for the target application. All component types will be impacted by each of those requirement categories, but primarily, inserts will address electrical requirements, while housings and cable entry will focus more on mechanical and environmental requirements.

The connector inserts are at the heart of your connection. This is where you will be adding the parts that physically merge the wires you want to connect. This will be true regardless of the type of transmission you wish to convey over those wires, though transmission type and ultimately the electrical specifications will be important when choosing the type of insert for the connection.

The housings are the main carrier for the inserts, as well as the primary means of protecting the inserts from the

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environment. Knowing the environment in which the connectors will be used will be very important in determining the protection level that housing will need to provide.

Subsequently, the cable entry is going to be the transition point for the cable as it enters the housing, and finally, the inserts. Up to this point, the cable (or hose/conduit) managed its own protection from the environment. However, once inside that housing, that self-contained protection will be stripped away in order to allow the individual wires to be terminated into the insert. The housing protects the wires after they are exposed, but the cable entry is needed to effectively relay the protection from the cable, hose, or conduit to the housing.

To ensure the process of choosing these components is as simple as possible, try choosing the components in this order:

1. **Connector inserts**
2. **Cable entries**
3. **Housings**

First, choose the connector insert based on the electrical and size requirements for the connection. This may involve fixed-length inserts, or it may be a set of modular inserts combined to accommodate very different electrical requirements. The insert options will set the stage for the overall size of the connector, so having multiple options ready may be worthwhile.

Next, skip over the housing to think about the cable entry. Depending on how the wiring is being delivered to the connector assembly, there are several options. A single jacketed cable is easily managed by a cable gland. If coming in with a bundle of unjacketed individual wires, there may be a sleeve or tube that can be added to create a more consistent surface, but ingress between the wires should also be addressed if necessary. If using modular inserts, it's possible to have different cables that simply can't be combined to form a consistent surface for a cable gland. In that case, a hose or conduit may be deployed. Whether using a cable gland or hose/conduit adapter, the size of those components will lead to a thread size which the housing will need to accommodate. There are also specialty housings that incorporate modular cable entry systems that can deploy a variety of different diameter seals for different cables right at the point of entry to the connector.

Finally, now that the insert and cable entry have defined the size of the entry and exit of the transmissions, a housing that can accept both can be chosen. The insert drives the overall size, while the cable entry defines the thread or interface. The housing options can be narrowed down based on that criteria before moving on to other considerations such as durability and environmental protection.

While several manufacturers offer online configuration tools to guide you through different options, it's always best to go into those with a basic understanding of the target. They are usually more helpful as a compatibility check after all the components have already been chosen. They also work great for compiling the BOM in one place and accessing complete drawings and models of the entire assembly.

Industry standards and approvals

Another point to consider throughout this process is the industry standards and approvals with which the connector will need to comply. This can depend greatly on where the connector is installed and where it will be deployed. One of the most common standards organizations is IEC or the International Electrotechnical Commission. Being an international platform is critical for the widely interconnected (pun intended) world we live in, and it is quite often the guiding platform for standard connector design. However, it's up to individual companies to design their product to comply with those standards with no third-party review. Of course, there are plenty of reputable companies out there that legitimately confirm compliance with this standard, but there is also the possibility that some may choose to bend the rules, and a couple that might just break them.

Because of that, third-party review and approval has become commonplace throughout the industry. In the United States, UL, or Underwriters Laboratories, is the leading organization for testing and approval of manufacturer components. If third-party approval is required or desired for a project, this group's approvals can be an important checkbox for the design. Still, there are other third-party organizations out there that can be considered as well. In Canada, there is also the government-run CSA, or Canadian Standards Association, which provides certifications of compliance under their standards for safety and performance.

Diving in

Want to know more details about choosing each of these components? Going forward, we will delve deeper into the considerations for each part of the connector. In the upcoming sections, connector inserts, cable entry, and all the possible housing options will be discussed.

The connector inserts

Next, let's take a closer look at the connector inserts, and the considerations that can be taken when trying to choose the right insert for the application.

When attempting to choose the connector insert, there are three things to be aware of: conductor size, current requirement, and voltage requirement. A couple of additional considerations are overall size (including the space the protective housings may consume) and wire termination method, but there can be several other requirements that also come into play depending on the application. Still, it's best to start with size, current, and voltage first, and work from there to see what options are available.

Current and voltage specifications are straight-forward and are given as a maximum value, usually at ambient temperature. The current specification should be accompanied by a derating curve based on temperature, so it's worth a look to see what can be expected of the insert at higher or lower temperatures. Voltage can be variable, based on the pollution degree applied to the spec, so depending on the scenario, that may be worth reviewing as well. However, unlike the considerations taken when designing a circuit, the current and voltage specifications for a connector are independent of one another, meaning the max current rating does not change based on the applied voltage and vice versa.

As for the wire size, you will need a contact that has a similar mass in comparison to the wire. If a certain amount of copper is required to carry an electrical transmission, then it's fair to say that the contact would need similar mass to carry the same transmission. Given that, expect that the contacts are going to be as large as, if not larger than, the wire itself. Plus, those contacts need to be spread out to proper creepage and clearance distances to prevent short circuits when in unmated condition. ■

Choosing the termination method

Wire size also leads to another aspect that needs to be addressed: termination method. While screw terminals and crimp contacts are the most common, there are a variety of methods available on the market. Spring contacts are ever-increasing in popularity, especially as the mechanisms have been and continue to be refined to be more reliable and secure, even surpassing screw terminal reliability. There is also IDC, or Insulation Displacement Connection, which provides quick and easy wire connection. Choosing the termination method can make a big impact on productivity and quality, though it's important to recognize that not every termination method will be available once other factors are considered.

Looking closer at each of these termination methods, let's start with crimp contacts. Crimp contacts are great for large-volume production, especially when available in reeled form to facilitate automated crimping, though it is possible to automate the crimping of machine-turned contacts as well. Stamped-and-formed contacts (or punch-rolled) are easily provided on reels, and often accept a range of wire sizes. Machined-turned contacts, while more durable, are usually only designed to accept a very small wire range or a single AWG (American Wire Gauge). Still, because the retention method for holding the contacts in the insert is contained tight within the contact, this type of wire termination can also yield the highest density, meaning more wires can be stacked into a smaller overall package.

Next on the list is screw terminations, whose popularity cannot be denied. These terminations don't involve the need for any special tooling, and the preinstalled contacts accept the widest range of wire sizes. While it is recommended that wires be ferruled and that the screws be tightened to the manufacturer's recommendations using a torque driver set, reality tells us this isn't always going to be the case. However, not doing so can easily lead to quality issues down the road, such as inconsistent wire terminations – an inconsistency that can be avoided using a different termination method.

Spring contacts have had quite a journey over the last few decades, and they come in many forms. They accept a wide range of wire sizes into preinstalled contacts. The principle is that a spring-loaded barb or beam is displaced as the wire is inserted into the contact. Once the wire is in place, the spring force pushes the barb or beam into the wire (or ferrule, as is generally recommended) to secure it in place. If the wire is fully inserted, the retention forces should meet, or as is often the case, exceed that of a traditional screw termination. The mechanism itself, however, varies from one manufacturer to the next, so it is important to test these out to see which one will work best in your manufacturing environment.

Finally, one of the most controversial termination methods is IDC. IDC contacts are also preinstalled in the carrier but can generally only accept a very limited range of wire sizes. The termination method involves using a cut, unstripped wire that is pushed down into opposing blades that cut, or "displace," the wire insulation. At the same time, the blades are far enough apart to avoid cutting into the conductor. While this is extremely convenient and especially useful for field installations, it does lead to concerns with quality and performance. For one, if the individual conductor strands are too small, there is a risk that the blades will cut through the wire as well. It's a fine line between creating a set of IDC blades that are close enough to provide a gas-tight connection, and blades that are so close that they cut into the strands. Because of this, the tolerance range for the wire size can be very limited, and specifications for strand count are

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important to identify when using this termination style. The other concern is in limiting the current-carrying capacity. There can be a large disparity among third-party approval organizations and industry standards regarding the max current specification. The disparity lies within the debate regarding the surface area of the connection point. Because this is a cutting blade edge making minimal contact with the wire itself, all the current being transmitted needs to be pushed through that “choke-point,” which can lead to significant heating of the contact and subsequently, the surrounding area.

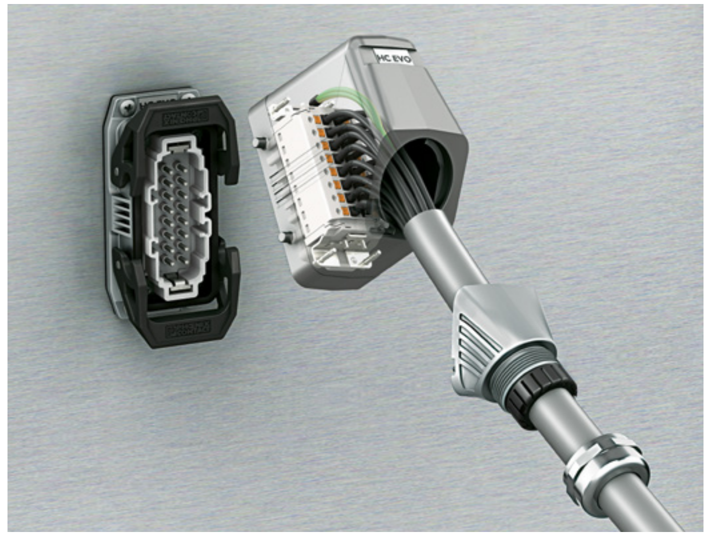
Additional considerations

Even after taking all that into account, there may be other criteria to evaluate specific to transmissions other than a typical single copper wire. Coaxial connections can involve shielding and impedance specs, and data transmissions may need to comply with any one of a variety of different protocols. There are even insert sets for handling non-electrical transmissions like pneumatic hoses.

Connector inserts are also not necessarily a one-piece solution either. That’s not to say that there aren’t plenty of fixed-length inserts that mount directly inside a housing, but there is also a vastly popular offering of modular inserts available on the market. If the application requires a mix of very different transmission types, modular inserts can be mixed and matched to create almost any set of connector inserts. This can mean instead of needing to spread out across multiple connectors, it’s possible to bring everything together within a single disconnect. Sometimes too, modular inserts can offer an opportunity to achieve a higher-density contact arrangement than is available using fixed inserts. It is not uncommon to stack a connector full of the same modular insert simply to achieve a smaller connector footprint.

Once having taken all of this in and finally choosing the insert options that may be used, the next step is to consider the cable entry.

The cable entry



The entry point for the cable is where to transfer protection of the wiring from the outer jackets or conduit to the connector body itself. Once the wiring passes through this point, it can then be exposed inside the connector housing and terminated to the inserts.

The cable entry can come in several different forms, but it will attach to the housing using either a particular threaded adapter or a specialty interface. The type of cable entry will depend on the structure of the incoming cable or cables and the required level of environmental protection. From here, we will look at a few different types and the reasons you might choose one or another.

Cable glands

The simplest adapter is going to be a cable gland. Cable glands are typically used to seal tight against a uniform surface, like the insulation of a jacketed multiconductor cable. They can be constructed using various materials (plastics, nickel-plated brass, zinc, stainless steel, etc.) to yield different levels of durability, sealing properties, and environmental resistance. While cable glands were originally designed for direct panel mounting to seal feed-through cables, they’ve also been adopted to seal the cable entry in rectangular connectors. Since panel-mounted connector housings are generally considered enclosures in and of themselves, it was an easy transition.

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While high levels can be achieved of Ingress Protection (IP, also known as International Protection) with cable glands, those protection levels can quickly become compromised if the wiring is not enveloped within a round, uniform surface. For example, if you pass a bundle of discrete wires through a cable gland, you may get it tightened down well, but there are still going to be several gaps between each of the wires and the seal itself that will allow liquids and possibly solids to seep into the connector body.

Another point of concern, in this case, is strain relief. A cable gland provides some strain relief for the individual wire terminations inside the connector. Still, with a bundle of cables, that strain relief doesn't necessarily extend to the wires near the center of the bundle.

Another scenario that has become quite common with the popularity of modular inserts is the need to seal up around multiple individual cables, often separately jacketed multiconductor cables. In this case, it is sometimes possible to use a cable gland that includes a seal with multiple bore holes – that being a rubber grommet with multiple, possibly differently sized, holes to accommodate each individual cable.

The drawback is that the possibilities for cable outside diameter (OD) combinations is nearly endless. It's often very difficult to find a gland with holes that include at least the specific cable OD set required for any one assembly. In addition, the IP level will be less with multiple bore-hole seals than with a single hole, mainly because the pressure on multiple bore holes isn't as uniform as with a single hole. Given these difficulties, most designers end up considering the next solution.

Hose and conduit

Feeding cabling through hose and conduit would be the next best solution when trying to seal and protect multiple cables as they enter an enclosure or connector housing. In this case, all of the cabling is fed loosely through the inside of the hose or conduit up to a thread adapter. That adapter then provides the sealing action between the end of the hose or conduit and the housing. Typically, the outside diameter of the hose or conduit will drive the size of the adapter, and consequently, the thread size that needs to be accommodated on the housing.

To determine the correct size for the hose or conduit, you need to consider the size of everything being pushed through it. This isn't as simple as grabbing one OD like with a cable gland. Here, you need to look at the OD for

every cable, along with how they will fit alongside one another, before trying to determine what the best-case overall diameter would be for the bundle. There are some online tools to help with this, or you can use a CAD program to lay out the different ODs as circles before dropping one final circle over the group to find the minimum inside diameter for the hose or conduit. One point to note, though: consider leaving some extra space inside for ease of feeding the cabling, especially if using any pre-terminated cables, like an RJ45 patch cable.

Next, you need to look at what kind of protection the cabling will require. IP ratings and durability are the main points to consider, but there are others, like flexibility, heat resistance, etc. If you require something highly durable, like a steel hose, along with more stringent IP ratings, your options may become limited, but you can usually find the needed combination. Still, if you're only using the conduit to achieve an IP rating to match the connector

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assembly, something like corrugated plastic hose may provide more than adequate protection.

Combining all this, look at the available size options for the hose or conduit choice, and start with one that gives you room to work. Note the OD for that hose or conduit and find an appropriate thread adapter to match. Once you have the thread size, use that to determine the correct housing for your new connector assembly.

This is the path you would follow for sealing multiple cables passing through inlets most of the time. However, while this is a perfect solution at the end of the hose or conduit closest to the connector housing, the other end of that can get interesting. If you're creating a complete harness assembly with the same connector on both ends, this can be very clean. However, if the intent is to split those cables out to a variety of end points, then the sealing problem has just been pushed from the connector assembly to wherever the hose or conduit needs to end to allow the cabling to split out in multiple directions. There aren't many options for definitively sealing that separation point, but that doesn't stop many folks from getting "creative" in how they accomplish it. Still, some companies are coming up with better ways to seal multiple cables as they exit the connector housing individually.

Specialty interfaces

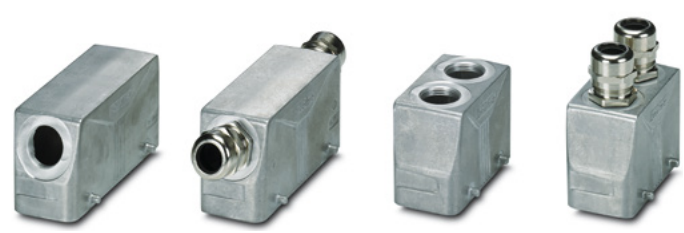
That leads to another possible solution: the use of a frame assembly that accepts a range of various modular sealing glands. While not necessarily practical for large numbers of discrete wires, it can be the perfect solution for a smaller number of individual, jacketed cables. The type of frame and how it's deployed in conjunction with a connector housing vary, but the principle is that the frame will fit on the housing opposite the mating face. Once you determine the cable ODs and the number of cables that need to be sealed, you choose the mix of sealing glands needed to secure each of them. Those glands are then fit into the frame that is married to the housing. The sealing glands could be split-grommet sleeves that wrap around

each cable, or they could be a gland with an adjustable diameter (via removal of rings or clipping of a stepped cone) to match a variety of cable ODs.

There are not as many options regarding the environmental protection afforded here, but they're generally dustproof with varying protection against water ingress. The main advantage is the ability to provide a clean answer when sealing multiple cables coming from different locations.

Alternatively, if you still want to go down the road of cable glands or hose/conduit adapters, you could use a customized housing with special inlet configurations for whatever combination of multiple cable glands and adapters are needed. Most rectangular connector housings are cast as blanks with no inlets. Then, they are drilled and tapped for a standard set of options. Most suppliers are willing to work with you to create a set of inlets that fit your specific needs, but those solutions are generally not stocked and require a commitment to minimum purchase quantities.

At this point with the insert options and the cable entry requirements, you can use this information to move forward and choose from a wide variety of different housings on the market. Next up, how to land on a set of housings to complete the protection and locking of your final connector assembly. ■



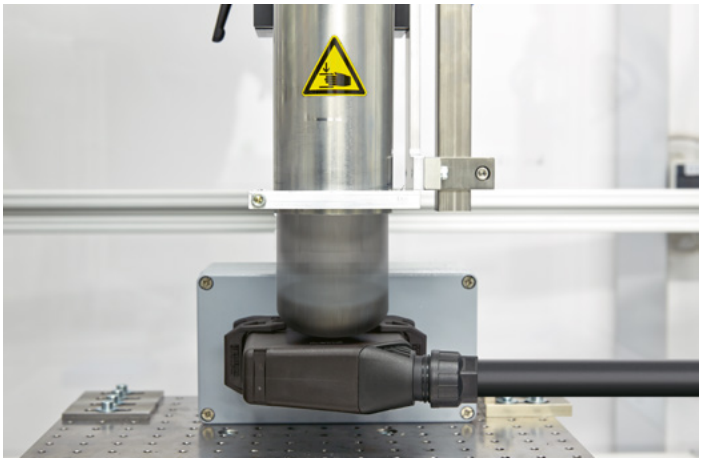
The housing

The time has finally arrived to pull in the last component needed to complete the rectangular connector – the housing. Let's see how all of that comes together to help drive the housing choice.

The housing is the primary means of protecting the inserts from environmental concerns. While it can have some electrical qualities, mostly in regard to shielding, it is primarily a mechanical component. The insert and cable inlet have already defined the housing size, but there are still several other points to consider. Most of the focus will be on the environmental and physical properties to march through the possibilities. This is also the point where you might start to feel like the assembly can be a bit of a juggling act, as you may need to reevaluate the insert and/or cable entry choices based on available housings.

The first question to start with is what environmental protection is required? For example, is there a set IP rating (International Protection, or more commonly referred to as Ingress Protection) that needs to be met, or is there some other industry standard, like UL (Underwriters Laboratories) that has a predefined rating requirement for the application? Quick tip: It can sometimes help to think of the housing as less of a connector body and more like a miniature enclosure, especially when many of the applications for heavy-duty rectangular connectors are on the side of a larger enclosure, making the connector an extension of that enclosure. Let's explore some of the ratings methods in more detail.

IP ratings are one of the most common requirements, and for rectangular connectors, the minimum rating needed is generally going to be IP54 (protected against dust and splashing water). However, more often than not, IP65 will be required (dust-proof and protected against jet water spray). While the protection level generally becomes greater with the higher numbers (first digit is for solid material, second digit is for liquid), that's not entirely the case. IPX7 and IPX8 are different tests altogether from the other liquid ratings as they focus solely on submersion, with no reference to spray protection. IPX7 is a specific submersion test requiring protection to be maintained for 30 minutes at a depth of 1 meter. IPX8 protection has no standard submersion test, but rather is defined by the manufacturer. The manufacturer then has the responsibility to clarify the conditions of the test when claiming an IPX8 rating. Because these tests do not address spray water, a dual IP rating is usually applied. For example, if you see something with IP66 and IP67 ratings, you will know that both of those spray and submersion conditions have cleared testing successfully.



While IP ratings are more globally accepted, there are several regional industry standards that can define environmental protection as well. For this white paper, UL Type Ratings are going to be the primary focus, but make sure to become familiar with whatever standards organization is prevalent in your area. UL Type Ratings were originally derived from NEMA Type Ratings, but were then modified in some instances. This is important to point out because NEMA and UL are not completely interchangeable. Also, NEMA is a manufacturer's self-certification while UL is a third-party testing organization that offers an independent review of a manufacturer's product. While there are several Type Ratings available, the most common ratings for rectangular connectors are Type 12, 4, and 4X. Type 12 is for indoor use only, while Types 4

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and 4X are for indoor or outdoor use. Type 12 will provide protection against dirt and dust and splashing water. Type 4 adds protection for directed water and ice formations. 4X then goes another step further to require saltwater corrosion resistance. You should understand if any of these Type Ratings are required based on the location of the connection and the conditions it will experience.

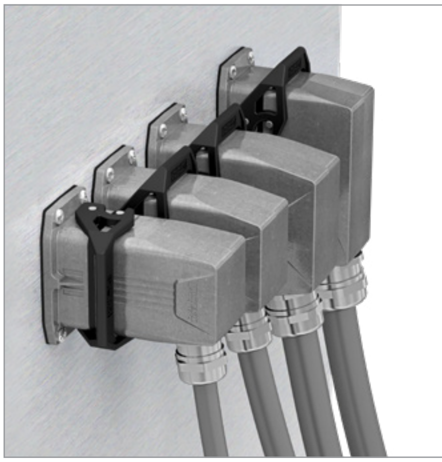
If nothing has been predefined with regard to the environmental requirements, then it is important to have a thorough understanding of the conditions the connector will experience and find a housing that will meet or exceed the protection levels needed for those conditions. You may find that a Type 12 rating or maybe IP54 or IP65 might be more than sufficient and allow you to find a more cost-effective housing solution. On the other hand, the environmental demands may be rather extreme, and a housing with more extreme approvals may be needed to ensure your electrical connections remain protected for the life of the installation.

While the environmental conditions are a huge part of the considerations, there are still several other points to evaluate. Understanding the location of the connection and the physical limitations that the surroundings impose on the connector will be important. If the connector is attached to a panel or cabinet wall, a panel mounting base will be in order. If this is part of a distribution network outside of an enclosure, a surface mounting base may be the way to go. If it is an in-line connection somewhere in the field that is unmounted, then a coupling housing would be the housing of choice.

Then there is the cable entry. While the size of the cable entry may already be known, the direction is still a consideration. For a panel mounting base, there is only one way to lead the wires to the housing assembly. For surface mounting bases, both cable entries are on the sides of the housing, but understanding which inlet to use, if not using both, can impact how the housing is mounted. Coupling housings and plug (also called sleeve) housings will usually have options for top or side entry. While some unique designs like HEAVYCON EVO allow the installation of the cable gland or adapter as top or side entry using the same components, generally you will need to know which direction is required before deciding on the correct housing to purchase.

The locking mechanism is another point to pay close attention to. Most rectangular connectors involve some sort of toolless latch for locking the mating connectors together, but there are tooled locks available as well. While security is certainly one point driving the need for a tool disconnect, more often it comes down to accessibility. If the connection is more of a one-and-done situation, only being removed for initial installation and infrequent maintenance, then a tool disconnect can often provide better environmental protection and even better cost over manually latching equivalents. However, if the connector will experience a significant number of mating cycles, then a manual latch would be much easier and more convenient to operate.

If looking at manual latches over tooled disconnects, then the orientation of the latches may also be important. Oftentimes a single or dual latch configuration will be available. Single latches will run along the long side of the housing, while dual latches are fixed on the short ends. Factors that can drive you to one or the other would be one- or two-handed operation and direction stacking of multiple connector sets. Multiple single-latched connectors would be best stacked end-to-end, while dual-latched connectors are best stacked side-to-side to allow free access to the latches themselves.



The base material is going to play a part in this as well. Usually, the options are going to be plastic or an aluminum

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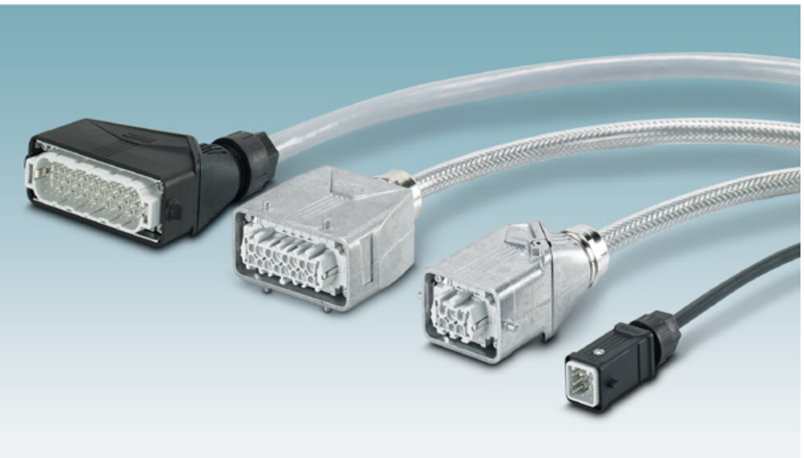

alloy. The environmental requirements will need to be met by whatever material is chosen, but general ruggedness, corrosion resistance, shielding, aesthetic appearance, and cost can all impact this choice as well. Plastic housings need to be strong simply because these are heavy-duty industrial connectors, but aluminum is obviously more rugged. However, aluminum is more at risk to corrosion than a plastic housing, and it will cost more. You can mitigate potential corrosion issues by either using aluminum housings with corrosion resistance engineered into the alloy or with a coating of some sort. At the same time, though, an aluminum alloy is generally limited to saltwater corrosion, and coatings, regardless of how good they are, can be worn away. A shielding requirement could also drive you to an aluminum housing, as a plastic housing would not be conductive in and of itself.

Aesthetics and cost are variables that aren't necessarily linked to performance but can certainly be motivating factors. If the connector is in a more publicly visible area, a nice plastic housing or aluminum housing with a coating can make all the difference. Cost will always come up in some fashion, so understanding that you will want to target a housing that most closely meets your technical needs versus one that is well over-the-top is important.

As you explore the housing options, you may find that no housings meet your requirements and align with the chosen insert and cable entry. This is where the balancing act comes into play. You may need to go back and reevaluate your insert and cable entry options based on the set of housings that will meet your other requirements. It may be helpful to choose multiple options for inserts and cable entries from the onset, making it easier to pivot to a viable housing.

I realize that building one of these assemblies may still feel a bit difficult to realize given the number of variables and choices to accommodate them, but therein lies the beauty of heavy-duty rectangular connector systems. They are so versatile and comprehensive in their coverage that it is rare to come across a scenario for which there isn't at least one conglomeration of components to satisfy the demands of the connection. Also, don't forget that you aren't alone in your search. Whether you are using an online configuration tool (like **www.phoenixcontact.com/heavydutypluginselect**) or just talking to a representative from a particular manufacturer, there is always someone that is an IM, call, or email away that is willing to help you with your search. ■

About Phoenix Contact

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