WhitePaper:
How to Specify a Break-Away Connector

OPTIONS AND OPPORTUNITIES FOR DESIGN ENGINEERS

The majority of electronic connectors deployed today are components intended to connect two objects together so securely that the attachment—whether between a cable and a device or two cables to each other—might even be stronger than the weight of the device itself or the limits of the cable holding them together. That is, for example, in an application such as a surgical intervention, the medical team might demand that an accidently snagged cable tug at a device rather than unexpectedly de-mate at the connector interface and suddenly stop that device from working during the procedure.

These familiar “manual” connectors—ubiquitous in industries as diverse as medical, aviation, petroleum, IT, automotive, and really anywhere that electronic equipment is used—are designed to release only with specific user intervention, such as with a push-pull or full or

partial turn(s) initiated directly at the connector interface. They are otherwise engineered to hold tight, sometimes demonstrating the capability to withstand a pull force of dozens or even hundreds of pounds.

However, there has also long been a need in many applications for connectors that walk a finer line—those that are engineered to hold tight up to a pre-determined point and then, when that force is reached, smoothly and cleanly "let go." A few examples of applications for these "break-away," "quick release" or "quick disconnect" connectors might include:

- a pilot with helmet, headset and other worn items attached by cables to multiple displays and communications instruments on a cockpit console who would not have time to manually disconnect them all in case of an emergency ejection;
- a recovery room patient on a mobile bed attached to carted monitoring equipment that could be snagged or pulled in movement and cause injury;
- an unmanned vehicle needing to ensure release of a payload;
- a motorsport driver attached to the steering wheel for stability who needs to quickly separate from the vehicle in case of incident; or
- an infantryman with multiple uniform communication connections who needs to avoid dangerous snags on passing objects.

BUILDING IN SAFETY...AND CONVENIENCE

Interestingly, although it seems that safety in emergency situations is often the main motivation for specifying break-away connectors in many applications—that is, "engineering in" the ability to "automatically" and without intervention break-away if and only if there is a

sudden emergency pull—in the real world it has become clear that once users are aware that they have this option they will often stop manually disconnecting their cabling and opt to "pull it" even in ordinary, non-emergency situations. One could readily see this being done by a busy hospital orderly moving multiple beds or a weary warfighter at the end of a patrol. Similarly, the ability to disengage in a non-emergency situation could also be exercised in tight medical treatment rooms or utility cabinets or behind IT equipment where even physically reaching a connector to manually disconnect it would be challenging.

Whether driven by simple human nature or practical necessity, this "convenience factor" suggests a valuable opportunity for product designers and other specifiers—the opportunity to build in a way to make jobs easier and more productive, certainly no small value-add. It also suggests that designers could consider this sometimes unintended "secondary" usage a positive effect—as opposed to, for example, the vacuum cleaner designer who cringes when a user yanks the plug out by the cord rather than at the plug interface—and plan for this de-mating strategy, perhaps even as a primary usage.

In addition, this observation is of vital importance to a designer's selected connector manufacturer, as it also means that break-away connectors would need to provide similar levels of pin and housing durability and number of successful mating cycles as their purely manual counterparts, just one of many variables that a specifier might need to understand and ensure.

In the industries mentioned above and many others, evolving market needs and challenges are providing ever increasing opportunities for innovative product engineers and designers to develop new, previously un-envisioned electronic product solutions and enhance existing ones, and break-away connectors should likely be an element in their toolkit as they create designs to solve the practical and technical issues associated with these developments, whether driven by safety, convenience or other desired factors. This paper will describe some of the diverse capabilities and issues related to break-away connectors toward helping specifiers understand

and evaluate their options, giving them a basic working knowledge so they can have more fruitful discussions with their connector manufacturer partners and make even better strategic use of these components for greater benefits to themselves and to their customers.

THE BREAK-AWAY CONNECTORS TECHNOLOGIES PORTFOLIO

When creating a break-away connector solution for any application, once the number of pins is known, determining the desired amount of force needed to successfully de-mate the connector from what it is attached to and how to achieve it is one of the first and most important design considerations. Too *little* force could lead to overly frequent and counterproductive de-mating, and too *much* force—such as an improper amount specified for a break-away connector attached to a helmet—could contribute to bodily injury or equipment damage. As a rule of thumb, the greater the number of contact pins, the greater the inherent friction in the design, which creates an immediate minimum amount of force that must be overcome.

In practice, most break-away connectors are spec'd with forces between 4 and 15 pounds, although some can go much higher—70 pounds or more—for specialized applications. It is important to note that break-away connections are almost never spec'd at an exact figure (i.e. "5 pounds") but rather a narrow range ("4-6 pounds") to allow for small variances. Rarely are these variances an issue in real world applications.

Once the force range is decided upon, there are a number of technologies that can help to reach this goal. Often, the optimum technology selection will also be impacted by a variety of additional design requirements including environmental usage factors and performance demands, and there will always be trade-offs to consider.

One common technology is the latched break-away. In most "manual" connectors, the force holding the connector in is created by latches or tabs that grip the inside of the housing, and are only released by the intervention of the user. These mechanical grips can be made extremely strong; as noted, even stronger than the cable to which they are attached. In the

break-away version, these latches are specially engineered and machined to precise tolerances to release when the specific level of force is reached. Hence, they are often referred to as "reduced latch force" connectors.

Another group of technologies rely upon friction rather than mechanical means to create the releasable connection and are sometimes referred to as "latchless" solutions. They are precisely engineered to create the amount of drag to provide the desired level of minimum break-away force, often using rubber or plastic o-rings or canted coil springs to achieve it.

For example, one or several O-rings can be utilized in connectors to achieve the desired range of break-away force. They are usually wrapped around grooves machined into the housing of the connector, and a high degree of accuracy and tight tolerances need to be ensured by the manufacturer. Depending on the material spec'd, use of o-rings can also help add sealing and water-resistance, as well as temperature resistance and other properties. For example, Viton® rubber is highly resistant to jet fuel and other chemicals, EPDM elastomer is radiation resistant, and silicone can be resistant to temperatures ranging from -50°C to 200°C, so o-rings of these materials and others are often spec'd for use in break-away connector applications accordingly.

Connector Examples

Snap-ring

O-ring

Lanyard

Canted coil springs are deployed similarly, designed into the housings of the connectors to provide the desired break-away force. They can provide higher retention forces as compared to

o-rings, although they also rely upon friction, rather than latching mechanisms, to achieve it. They too can be specified using a number of different materials, often metals such as brass, copper, or tungsten, and, in addition to providing excellent temperature resistance, can potentially provide a host of electrical and EMI/RFI shielding properties as well.

Another technology, snap-ring design, works roughly like the snap-on fastener on an article of apparel, with the connector clicking in, holding securely and sliding back out over the connector only when appropriate force is exerted. These types can be engineered to create greater break-away forces as well.

Another feature available for break-away connectors should also be noted: lanyard technology. In this method, a lanyard or ring-shaped wire is added to the outside of a connector that must otherwise be released at the connector juncture by means of the standard push-pull or rotation means. A pull on this lanyard will override the manual de-mating method and allow a quick release of the connector. The lanyard may be marked with a tag or label for easy visibility, and can likewise be engineered to meet particular de-mating force requirements. Lanyards are also easily manipulated with gloves or other low dexterity means, such as a robot.

When not specified, identifying the optimal range of de-mating forces and the proper technology to bring to bear can be an art and a science, and a full-service manufacturer can work with the designer on creating a pull test to identify the proper balance that will keep your users safely connected, and smoothly disconnected only at the proper time.

PINPOINTING THE DEMANDS OF THE APPLICATION

As noted, identifying the desired de-mating force is only one factor in creating a break-away connector solution that will best meet the requirements of the new or enhanced product design.

Also vital is to examine the environment in which the connector will be deployed, taking into account not only such factors as indoor, outdoor or mixed use but also potential exposure to heat, flame, cold, sand, mud, salt water, rain, radiation, chemicals, vibration, ice, RFI/EMI, crushing forces, unusually large pulling forces, cutting forces, and other threats. All of these and more can be mitigated in large degree by proper component specification. Of course, functional and aesthetic issues relating to the application will also loom large, including pin count, wire size, need for color, as well as any limitations on shell size and weight.

The break-away connector manufacturer will help with fine-tuning this large and diverse group of product properties that can address the application, and determine the optimum balance. These variables can include the following topics below including: Materials, Plating, Color, and Shell Size.

MATERIALS

A wide variety of materials can be used in the manufacturer of break-away connectors, including various plastics and metal alloys, each delivering their own set of pros and cons. For example, plastic can provide lower weight and lower cost over time, but requires an investment in tooling. Aluminum is more resistant to wear than most plastics, and is relatively lightweight compared to other metals, but it is less corrosion resistant. Other

MIL-SPEC BREAK-AWAYS- WHEN YOUR HANDS ARE (POSSIBLY) TIED

The MIL-DTL-38999 standard and similar categorizations speak to both manual and break-away connectors, and relate to components with common quality characteristics usually sold primarily on price or logistical concerns. If a proposed project demands the purchase of a Mil-Spec break-away product exclusively, then this dictum, of course, must be followed. However, it should also be noted that some military/defense projects allow commercial off the shelf (COTS) solutions that provide the designer with more flexibility. It should also be noted that there are many manufacturers who have developed break-away connectors with performance that meets or exceeds the 38999 spec in many categories, including resistance to heat, flame, cold, sand, mud, salt water, rain, radiation, chemicals, vibration, ice, RFI/EMI, crushing forces, unusually large pulling forces, cutting forces, and others. These have been successfully tested to these standards, even if they are not officially designated as such. Product designers should consider confirming on a case by case basis if a particular project exclusively requires a Mil-Spec solution, and, if it does not, consider the possibility that they can build a better—and perhaps even less costly—product by weighing a wider variety of COTS options.

metals such as stainless steel or brass might start out heavier but can offer higher degrees of wear resistance, durability and corrosion resistance.

PLATING

In many cases, these base materials can be plated to provide additional properties or overcome limitations. For example, the low weight and other properties of aluminum might seem very beneficial for a particular marine application, but the designer would have to reluctantly avoid specifying it because the metal tends not to corrode faster in salt air. Fortunately, some manufacturers are expert in plating or similar surface treatment technologies that can overcome this vulnerability and give specifiers the best of both worlds. A common choice is chrome plating to provide durability, aesthetics, corrosion resistance or other desirable properties.

COLOR

A black matte finish for glint reduction is probably the most common but not the only use of color in the manufacture of break-away connectors. Plating and/or painting, utilized in various ways, can often be chosen for both functional and aesthetic uses. For example, connectors might be colored to match their mating partners for visual guidance in a multi-cable environment, or they might be colored for brand differentiation. In a guidance-type application especially, the color may appear as small dots or markings. In any use of color, an important question to ask the manufacturer is the degree to which their colors can be expected to maintain their appearance over time, resisting wear, handling, cleaning, chemicals and other impacts of use.

SHELL SIZE

A general rule of thumb is that the more pins that must be in the housing, the larger the shell size needs to be. Similarly, the larger the force value required, the larger the shell size needs to be. However, the extent to which this is true is not universal and not all manufacturers are the

same. There can be large differences in relative abilities to pack more pins or greater forces into smaller connectors, based on factors including sizes of a connector manufacturer's housings and mechanism designs as well as pure machining and engineering skills. It might be advantageous to shop around when trying to find a partner to handle a challenging customized small connector project—you might get several "no ways" before finding one who can readily say "no problem."

MATING CYCLES AND CONSISTENT PERFORMANCE

As with all mechanical components, the edges of the pins, housings and other friction-exposed parts of break-away connectors can naturally get blunted and worn over time, leading to increased de-mating force minimums as well as increased electrical resistance. However, the number of mating/de-mating cycles in which this starts to happen can vary considerably by manufacturer and model, with higher quality connectors rated at several thousand cycles. Most manufacturers offer a guide or even a guarantee as to the number of cycles their products should be expected to perform, a rating based upon such factors as materials and engineering quality, as well as testing and field experience. Further, the longevity of electrical contacts can be bolstered through such features as gold plated contacts, and, of course, providing tight tolerances to begin with. Much of this also depends on the requirements of the application—some break-away connectors might be built to be de-mated several times a day over several years of service; others might be intended to be put to work on equipment with significantly shorter life expectancies, and offer life cycles to match, so you can shop accordingly.

CABLE ASSEMBLY

It's axiomatic to note that every connector that is specified will ultimately have a cable attached to it. While it's certainly not easy to do high quality cable assembly, the market place has become quite genericized, with perhaps thousands of companies offering cable assembly services at highly varying levels of quality. Connector manufactures, on the other hand, can be a more sophisticated business with higher barriers to entry and far fewer players. A company

that offers *both* high-quality cable and high-quality connectors, as well as a seamless integration of the two, can provide a number of valuable benefits, including the ability to ensure more accurate tolerances, gain tighter quality control of the finished product, simplify your logistics, and secure the convenience of working with a single point of contact. Properly specifying cable is a science unto itself and obviously outside the scope of this paper, but working with a representative with expertise in the operational relationship between cable and connector in the early stages of design might be beneficial.

CABLE INTERFACE REINFORCEMENT

A common concern among product designers is the strength of the termination point between the connector and the cable, especially in applications that can expect heavy force pulls. How can it be ensured that the connector will de-mate as expected rather than rip the cable and wiring out of the connector when there is a sudden yank of 50, 60 or more pounds? Or, for that matter, will the joint be reliable when exposed to extreme vibrations or crushing forces? Additional reinforcement methods such as overmolding and potting can be used to further protect the cable terminations from damage. Fortunately, the customer and the manufacturer partner have a number of technologies in their portfolio that can be applied individually or in tandem to meet the needs of the application and help ensure product performance and success.

CONNECTOR AESTHETICS

Connectors can vary in the quality and professional “look and feel” they deliver. If the connector is to be placed invisibly on the back side of a heavy, immobile device, that might not matter much, but if it is on the front of a high-quality piece of equipment, or on a piece of equipment that will be carted and will be in constant view of customers and staff in high-end applications, then a greater degree of visual quality might be more important. Some of this might simply be selecting the right “name” brand—less expensive connectors might likely look cheap placed side by side with better quality components.

LIFE-TIME COST OF COMPONENTS

Cost, of course, is always a factor in every purchase, but it is important to consider total cost of ownership; a part that can provide several thousand more life cycles but is priced slightly higher than a similar part might be well worth the investment of a few extra dollars. Also important is the value-added services that might be related to a purchase, such as access to knowledgeable technical or repair expertise, or product traceability. There are numerous concerns with specifying cheap alternatives over proven name brand solutions, such as the "hidden" costs of equipment damage and warranty issues, safety and liability issues, inflicted downtime and loss of business and professional reputation. Another insight that could inform the budget setting process is the relationship between the cost of the device being sold and the relative cost of the connector, which tends to be quite modest considering its importance to the ongoing operation of the equipment, especially in the case of break-away connectors. For example, specifying a low cost connector on a $500,000 portable x-ray machine where accuracy, long term durability and patient confidence are vital might not be considered an efficacious business decision.

THE VALUE OF CUSTOMIZATION

These are just a few of the major specification opportunities and options for break-away connectors, but there are many others as well. There are connectors with shielding that resists electromagnetic radiation or radio interference. There are connectors that can provide break-away capabilities from not one but several different angles. There are connectors that can be made "touch-proof" to further protect the user from the possibility of shock at the connector interface, with leading connector manufacturers even testing their products using conductive wands shaped like small fingers.

In fact, there are so many possible permutations among the numerous variables that will likely go into the application that the truly "best case" component might very well be unique, and might not yet be in existence as listed in any product catalog. In fact, a connector sales

representative stated “I’ve worked with product designers on dozens of break-away connector projects in my career, and I don’t think I’ve ever produced the same one twice.” Fortunately, there are a number of quality break-away connector manufacturers who are able to work in partnership with the design engineer to ensure that the best break-away connector is available for new or enhanced products, taking into account every conceivable element of both performance and value.

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