Miniaturized Ethernet Connector for Subsea Applications

A subsea Ethernet connector is a specialized connector designed for underwater applications, typically used in subsea oil and gas exploration and production. These connectors are built to withstand the harsh conditions of the subsea environment, including high pressure, low temperatures, and corrosive salt water. They are used to transfer data, control signals and power between subsea equipment and surface control systems. Subsea Ethernet connectors typically have a rugged design with multiple sealing and pressure equalization mechanisms to ensure reliable performance in deepwater environments. They are also designed to be easily mated and unmated for rapid deployment and maintenance of subsea systems. Currently, efforts are underway to develop a hybrid control connector with a dedicated Ethernet module. This 12-pin connector is qualified for control applications but has recently been re-qualified for simultaneous low-speed data and power use.

Here is a development that aims to replace the existing 12-way connector by reducing cost and lead time and improving communication performance, i.e. data bandwidth. The following describes the potentially novel features of a miniaturized Ethernet connector for subsea applications. The Ethernet connector follows the well-established dual barrier CE (Controlled Environment) layout, but as a direct result of its significantly reduced physical size, has freedom from shuttle pins and associated components, while following the good practices required for impedance matching within a connector intended for high-speed electronic data transmission. It is called a µCE. Two different methods for solving µCE functional requirements, a typical designer's belt and braces approach, and additional feature sets common to both methods are described here. In general, features that are considered new are marked (*C) in the figures. A working knowledge of the operation of a CE connector is assumed.

Case A of the µCE has no shuttle pins. It is hypothesized that if the pin diameter is small enough, i.e. <0.8mm, it should be possible to create a repeatable seal around the pin without the partnership of a displaceable slave pin or shuttle pin to fill the void in the seal after the pin is removed, i.e. the elastomeric properties of the seal are capable of providing sufficient stretch between the size of a fissure and the pin diameter without exceeding the % stretch capability of the material. This method is analogous to a hypodermic needle breaking the seal in a vial of medical product, the seal being able to protect its contents from atmospheric bacterial contamination during storage and use. It should be noted, however, that unlike the hypodermic needle, the pin is not intended to cut its own path through the seal each time, but rather a pre-formed fissure in the elastomer is able to open and close with sufficient reliability to contain the relatively viscous dielectric fluid when closed and repeatedly expand to the size of the pin when open. The advantages of a shuttle pin free sealing method are reduced complexity, reduced component count, reduced overall length and diameter, elimination of stuck shuttle pins, but all of these advantages are of greater importance when attempting to design a very small subsea rated electrical connector, particularly one with the requirement for closely matched impedance characteristics.

This second case uses pseudo shuttle pins. Given that case A is proposed with some speculation, i.e. until the technique can be clearly proven through practical testing, it follows that little is known about the reliability or robustness of the method at this time, so it is prudent to have a back-up plan. Case B is a more space-efficient variant of a regular shuttle pin-based seal design but is more complex than the first case. The typical female contact part in this iteration is rearranged to make face-to-face contact rather than diametrical contact with the pin and is spring-loaded to move axially to maintain contact pressure. Functionally, the process performs both shuttle pin and contact functions in a single element. Not all of the advantages of Case A can be realized here, but crucially, the reduced diameter and overall length are consistent with the requirement for an impedance-matched connector. This method, like Case

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A, also allows for a consistent diameter between the conductors in the plug and receptacle, which is not traditionally possible when the shuttle pin passes through a cylindrical contact in the style of a single-component swing-arm design, a critical feature for impedance matching. To prevent exposure of the plug contact element to seawater, a sealing strategy such as Case A is added to protect the contact tip.

Both cases A and B share several common techniques that contribute to the uniqueness of μCE. Rather than explaining them in the context of each case, i.e., twice, a single description is made using the most expedient or current CAD (Computer Aided Design) models, where details may not be available for each case. Commonalities are marked with *C. The mating sequence for case A is shown in Figures 1 through 14 to provide context for the supporting features. Note that the models are concept quality and the connector backends are not completed. Figure 10 shows the second alternative seal to Figure 8. The seal has a localized containment to compensate for volume swell in the elastomer.

For convenience, the mating sequence for Case B is not detailed as Case A, but the underlying principle is nearly identical and can be read across. Figure 15 shows the de-mated connector for case B. Like Case A, Case B includes a dry-mate transition to fully mated. See Figure 2 and Figure 3 for an indication of how the sequence will appear. Figures 16 and 17 show a detailed view of the demated plug and socket respectively.

To produce a high-speed data connector, it is critical that the impedance measured at any point along the length of the connector and termination to the cables is consistent and matched to the cable value. Typically, 100 ohms is selected for the Ethernet standard. The impedance at any point through the connector and cable is typically given by the interaction of two physical parameters, capacitance, and inductance. To achieve uniformity, these parameters should also remain uniform, but as seen in the previous figures, absolute uniformity is nearly impossible to achieve when it is necessary to incorporate mechanisms that support subsea operation. Step changes in impedance within the connector contribute to insertion and return losses that degrade the quality and strength of data reaching the receiving end of a system. To mitigate this, the plug and socket inserts are typically designed with careful pin spacing, controlled dielectric and uniform distance from an earth screen. This is more easily achieved in an atmospheric connector where the gap between the inserts is small, < 1 mm. In the case of a CE subsea connector, the gap has sealing and volume compensation elements that dictate a larger gap, i.e. 6–9 mm. Part of the perceived novelty of the μCE is the way the gap region is configured to perform sealing and compensation functions while maintaining impedance matching. The sketch below shows how the ground plane is positioned relative to the pins and gives an indication of the configuration in the gap. Ground continuity in the gap is generally provided by multiple elements, which are identified as such in the figures above. Note that although the ground plane is shown as a stepped line in Figure 18, the ground plane is actually wrapped around the connector.

The potential novel features of a miniaturized Ethernet connector for subsea applications were described.

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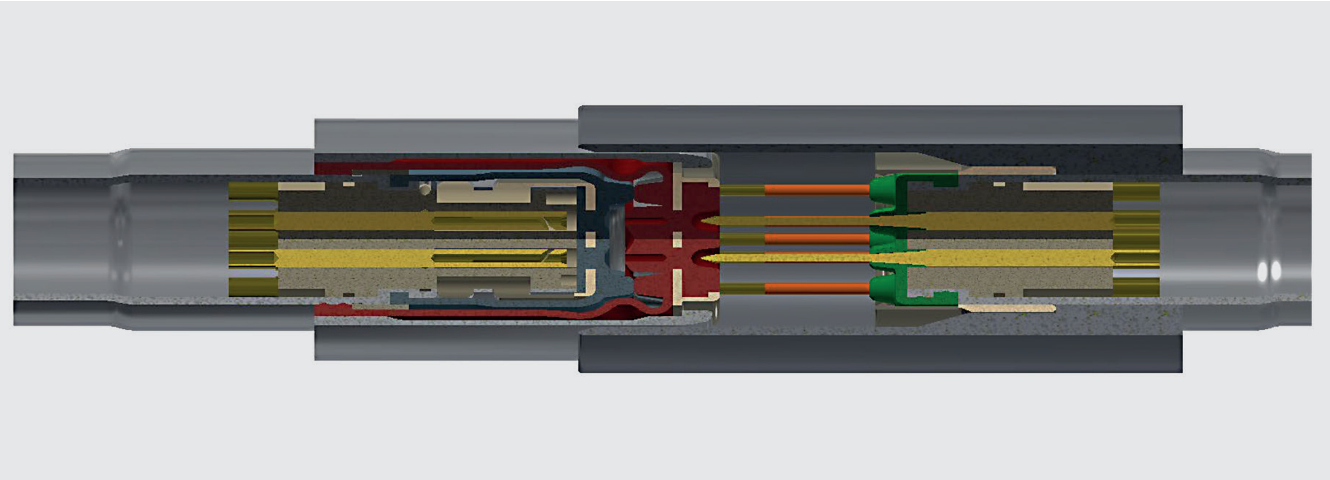

Figure 1: De-mated connector

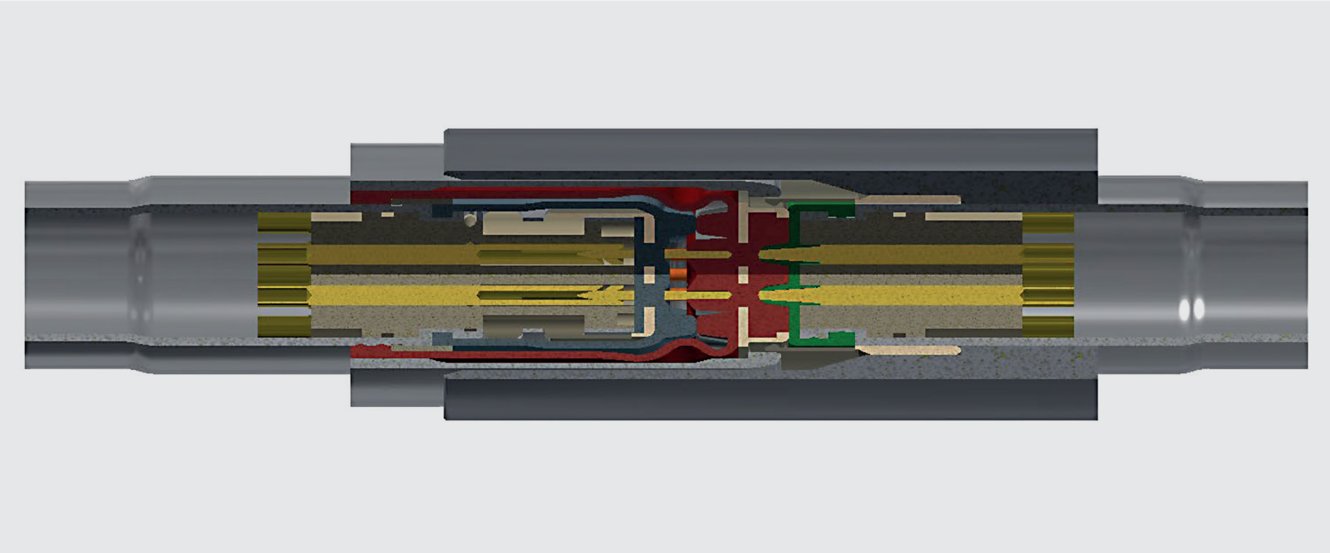

Figure 2: Dry-mated connector with pins penetrating primary and secondary seals

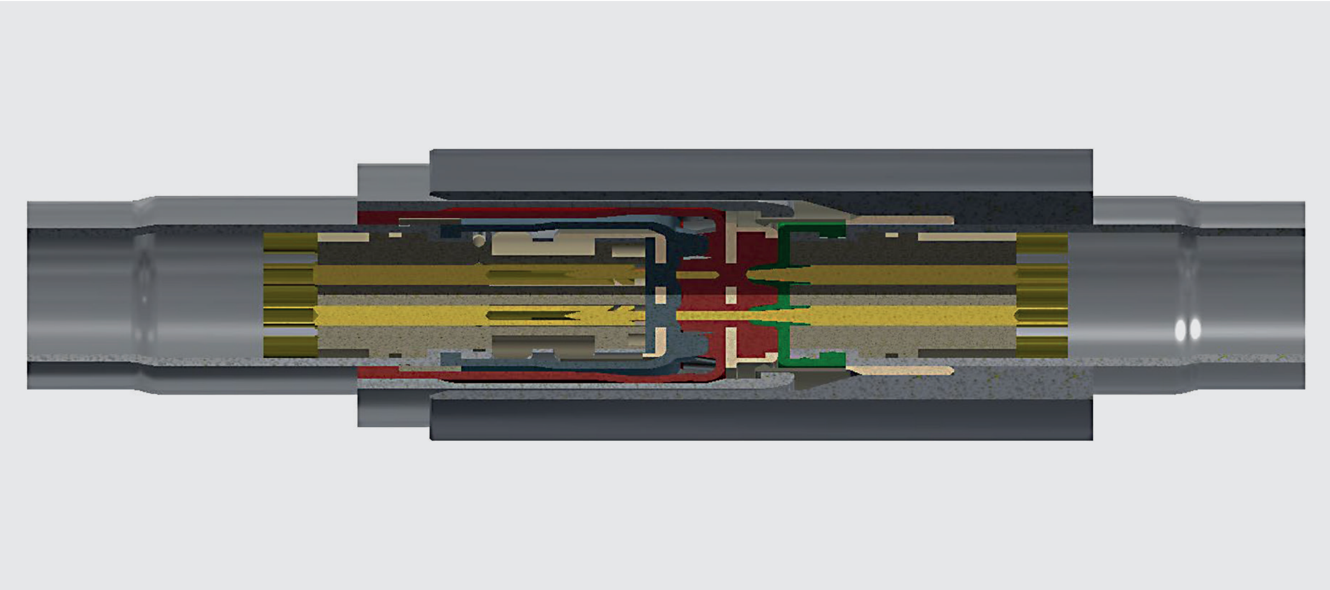

Figure 3: Fully mated connector with pins protected from breach in primary chamber

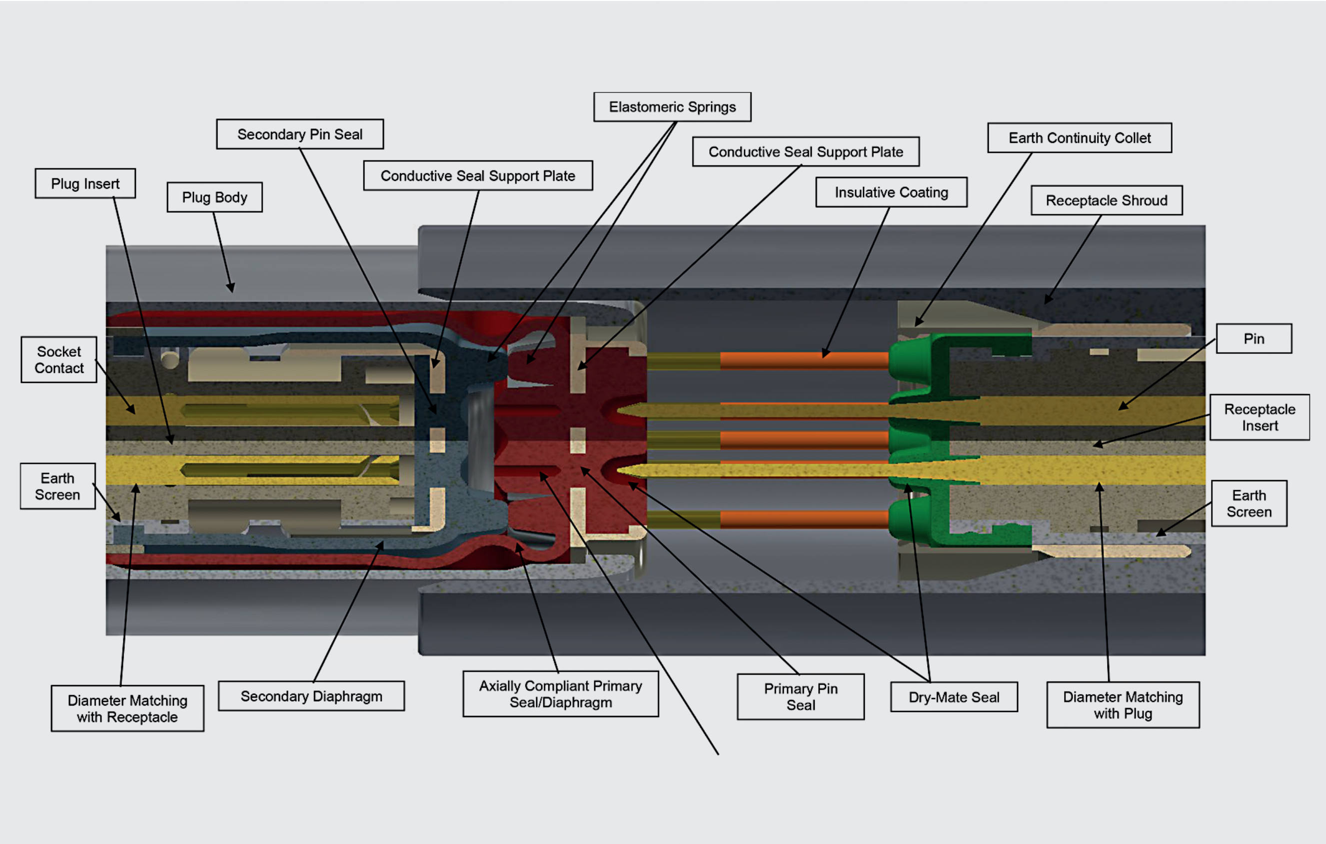

Figure 4: Detail view of the de-mated connector

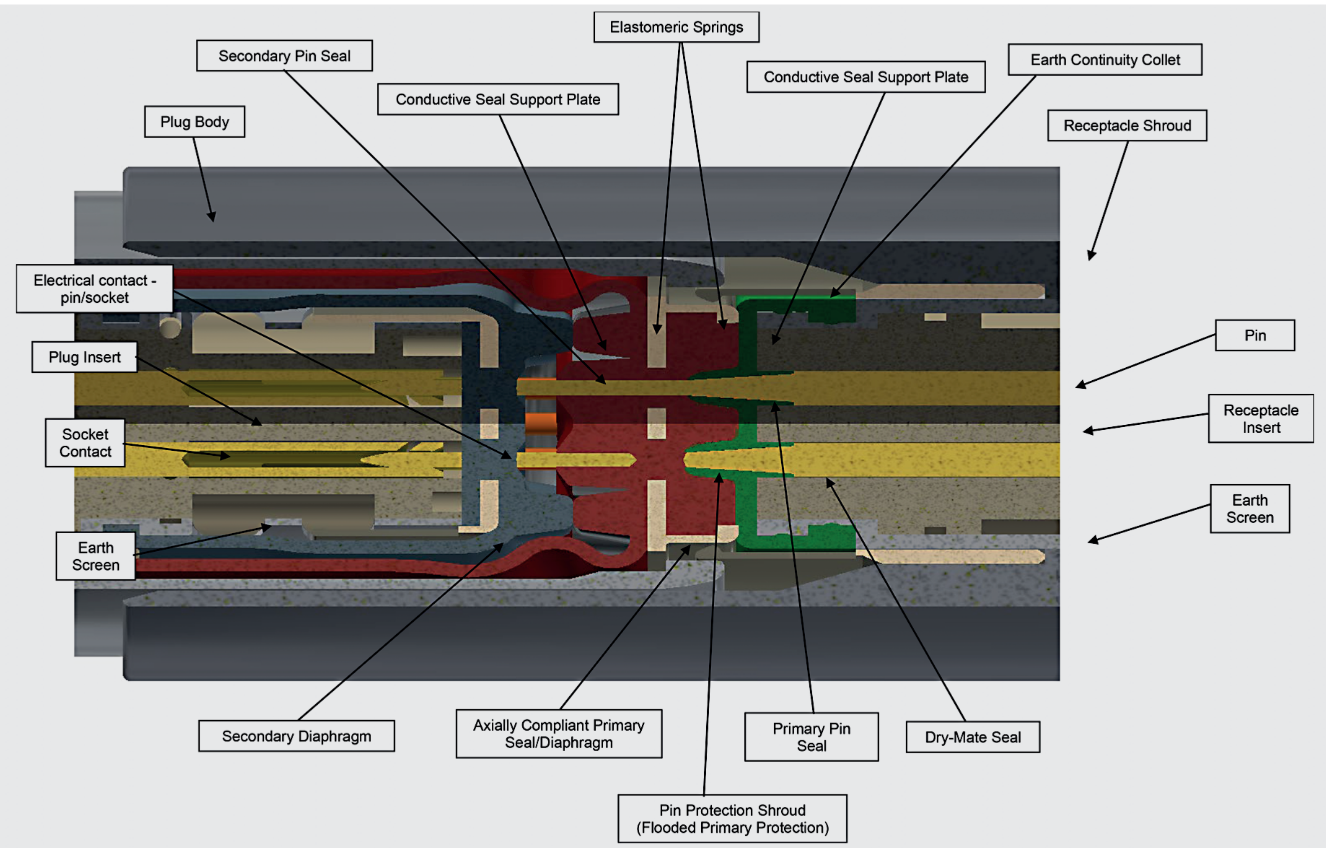

Figure 5: Detail view of the dry-mated connector

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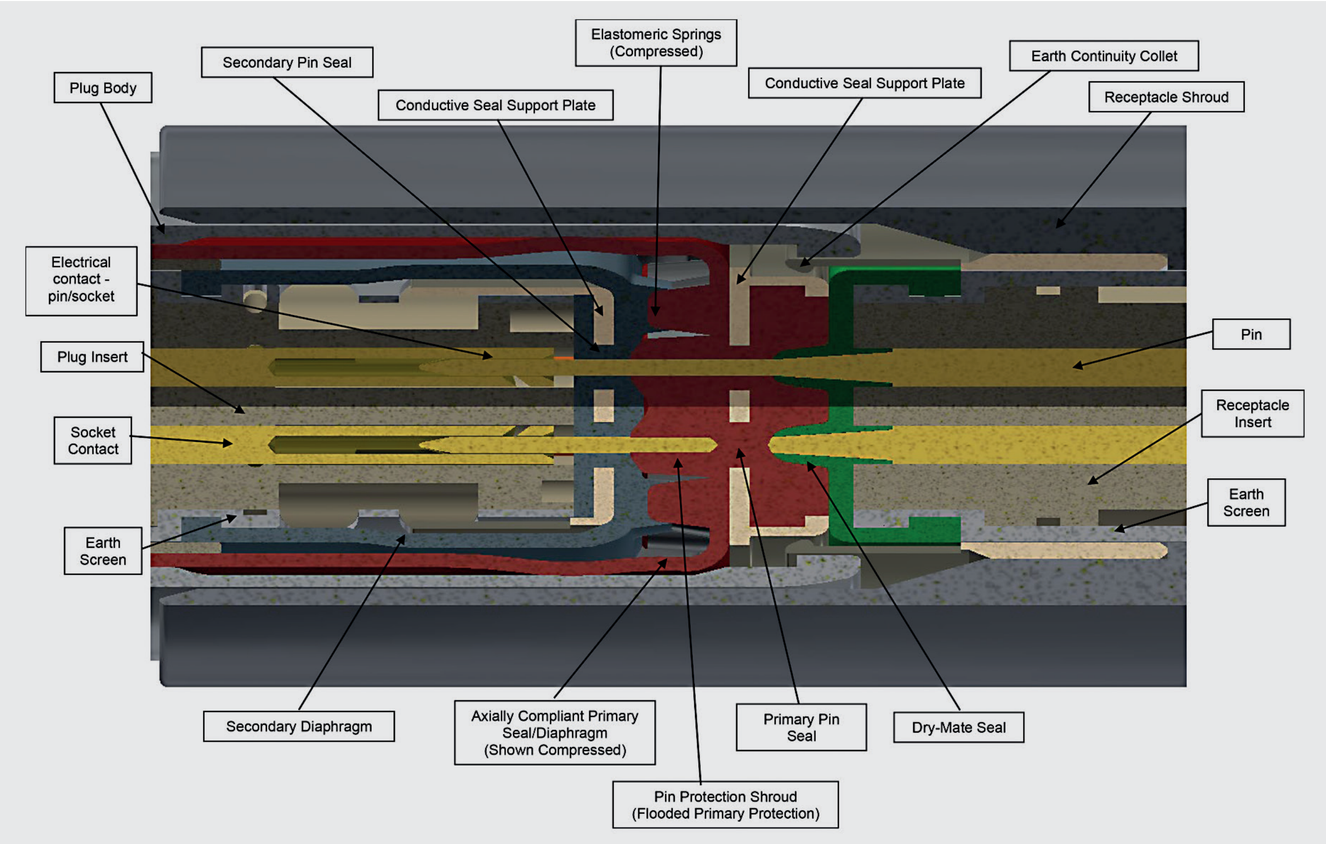

Figure 6: Detail view of the mated connector

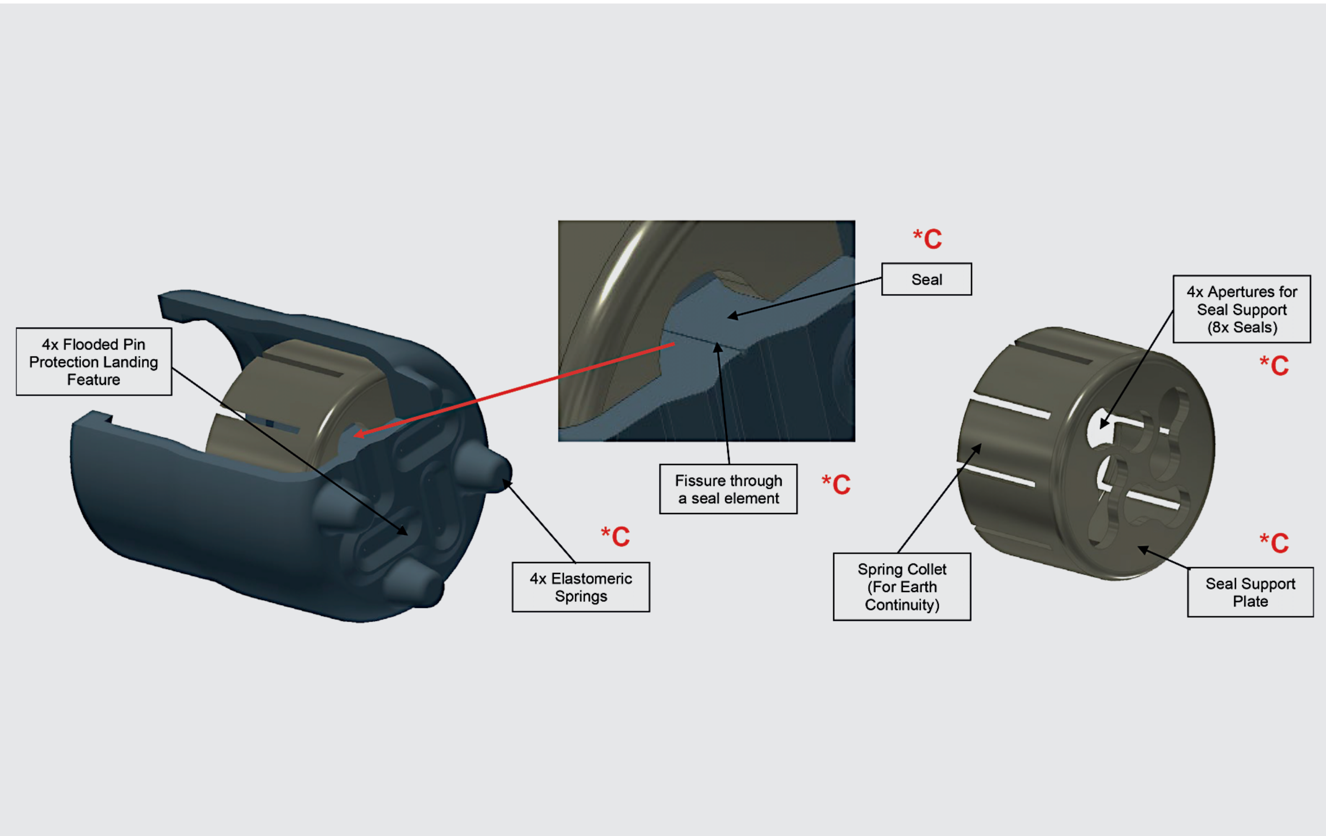

Figure 7: Secondary seal/diaphragm and overmolded conductive support plate

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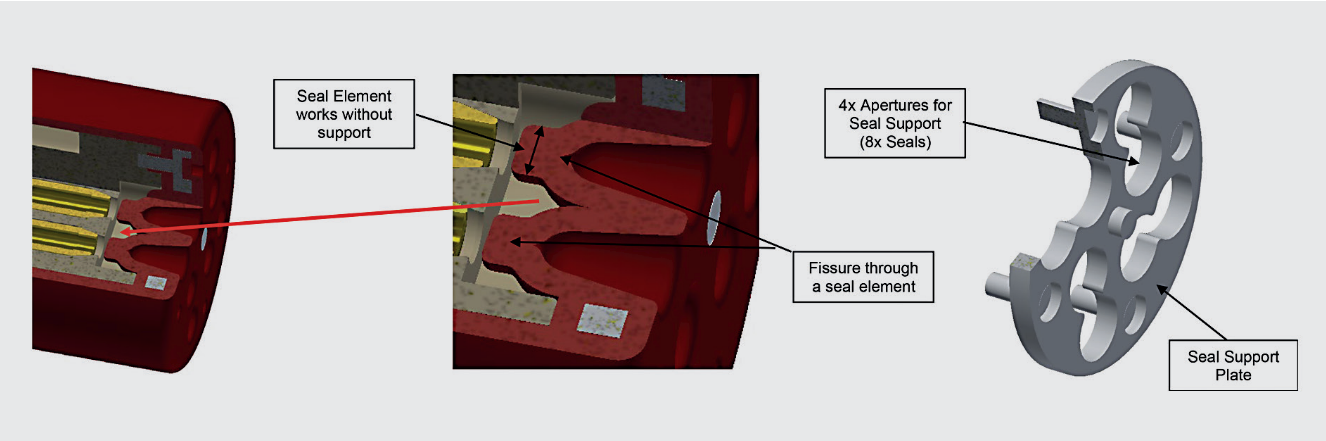

Figure 8: First seal/diaphragm with an unsupported seal element and overmolded conductive support plate

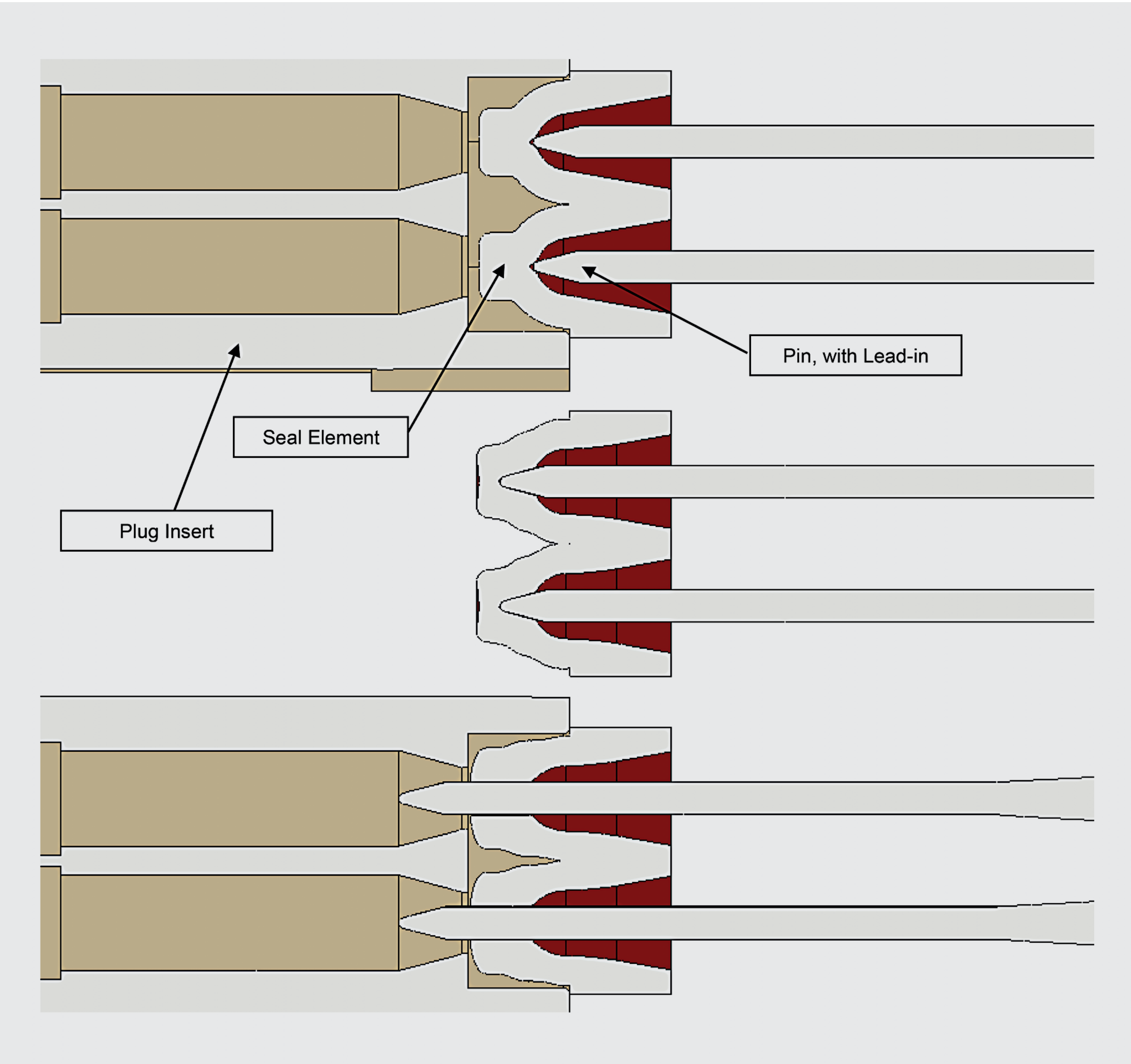

Figure 9: First seal/diaphragm design mating operation

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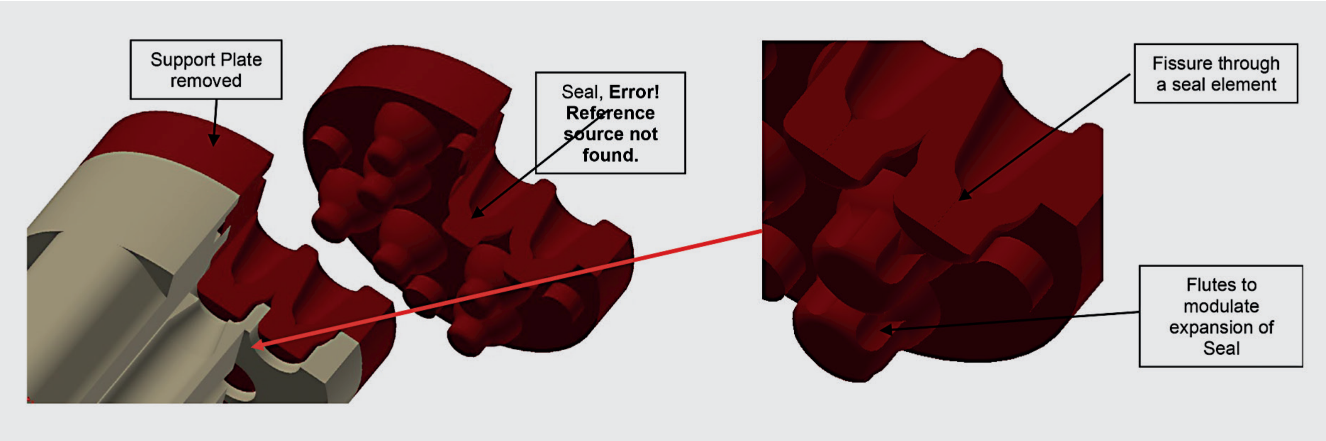

Figure 10: Second alternative seal

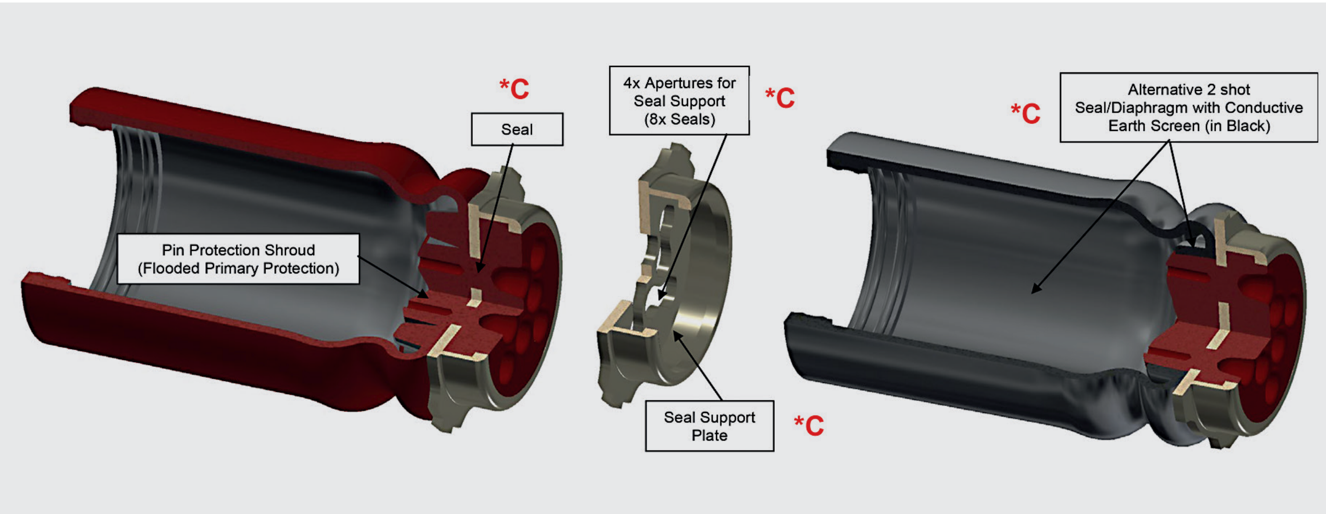

Figure 11: Primary seal/diaphragm with overmolded conductive support plate and sealing method of Figure 7

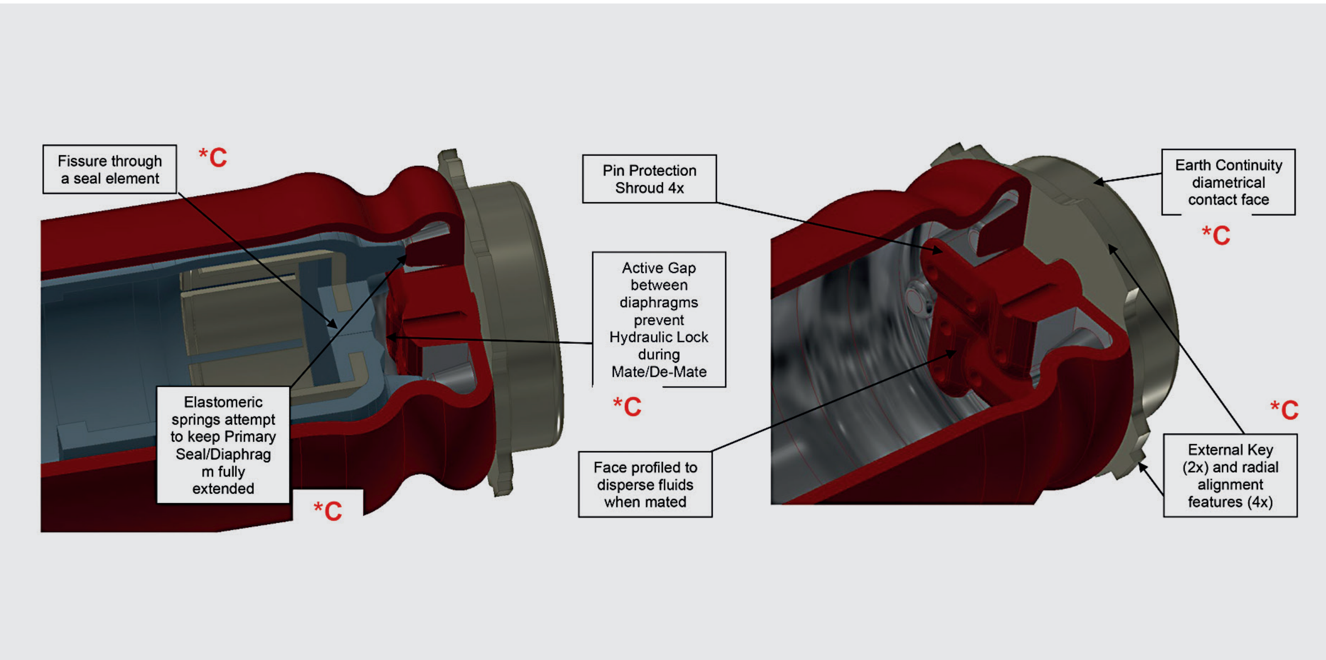

Figure 12: Inside view of pin protection shrouds with mated/de-mated gap

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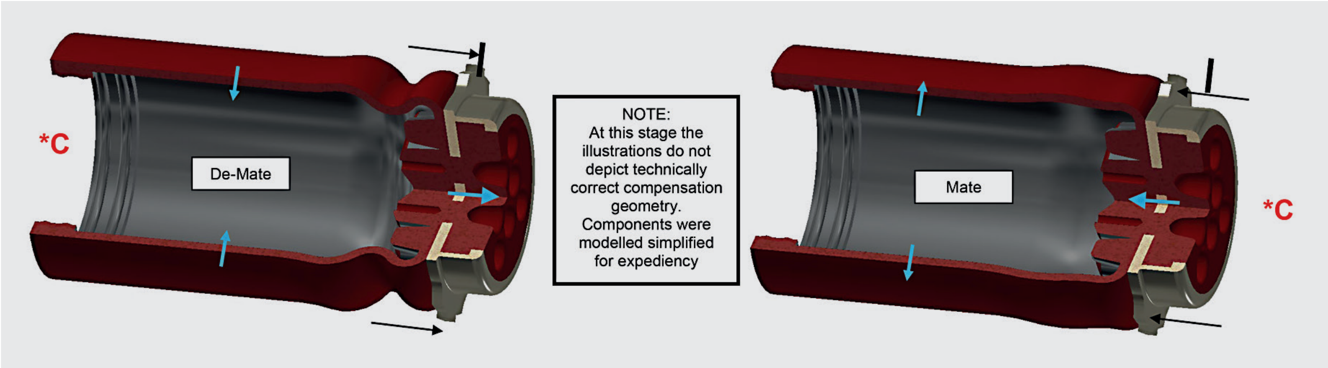

Figure 13: Seal/diaphragm with the ability to simultaneously compensate for volume change and axial compliance

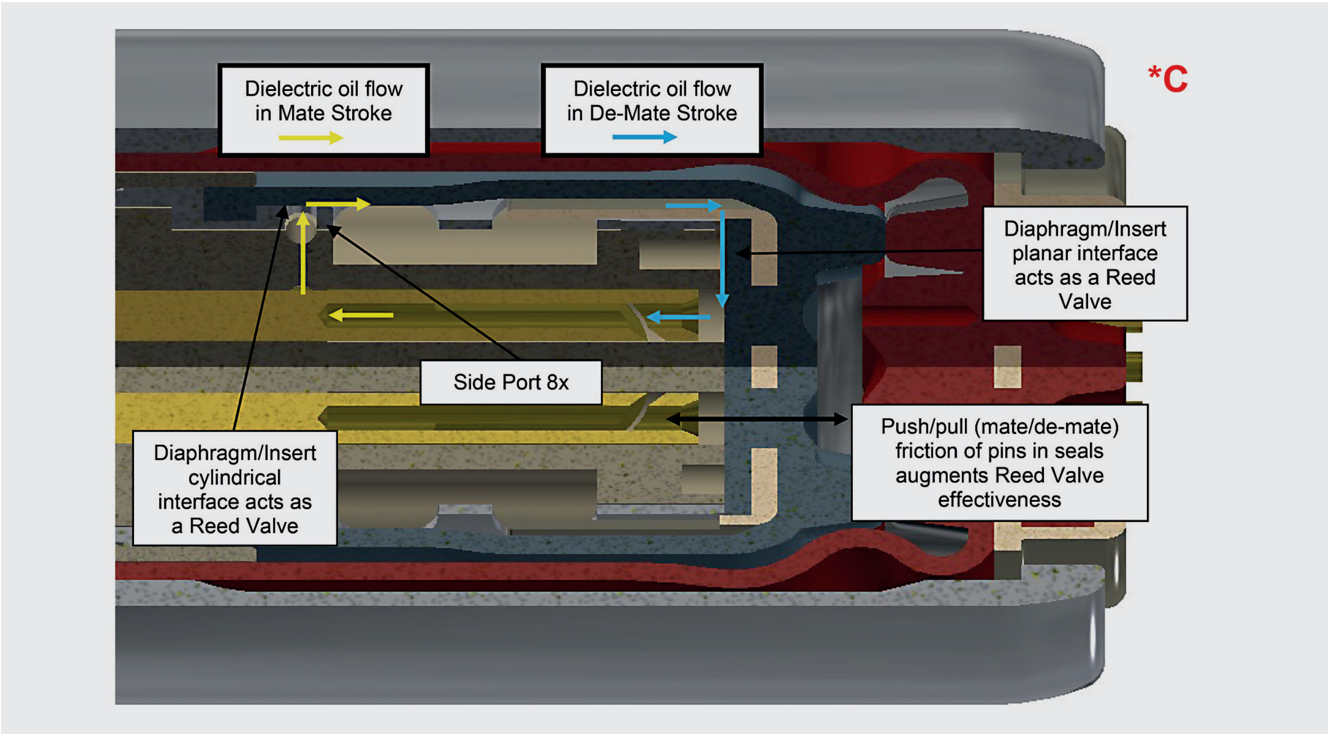

Figure 14: Features to promote the agitation of the dielectric oil flow during the mating/mating cycle

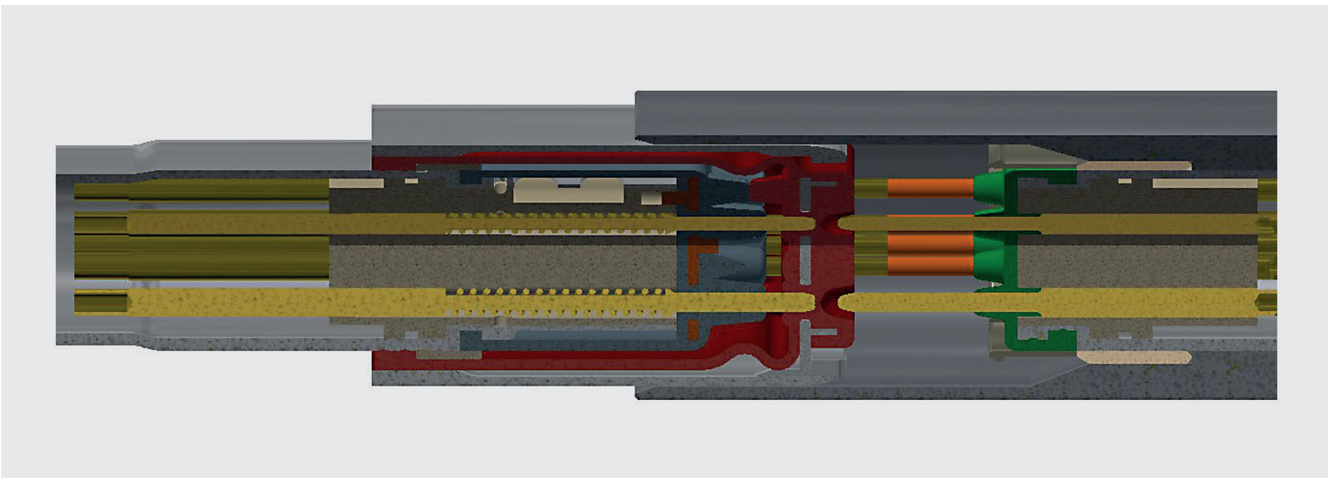

Figure 15: De-mated connector for case B

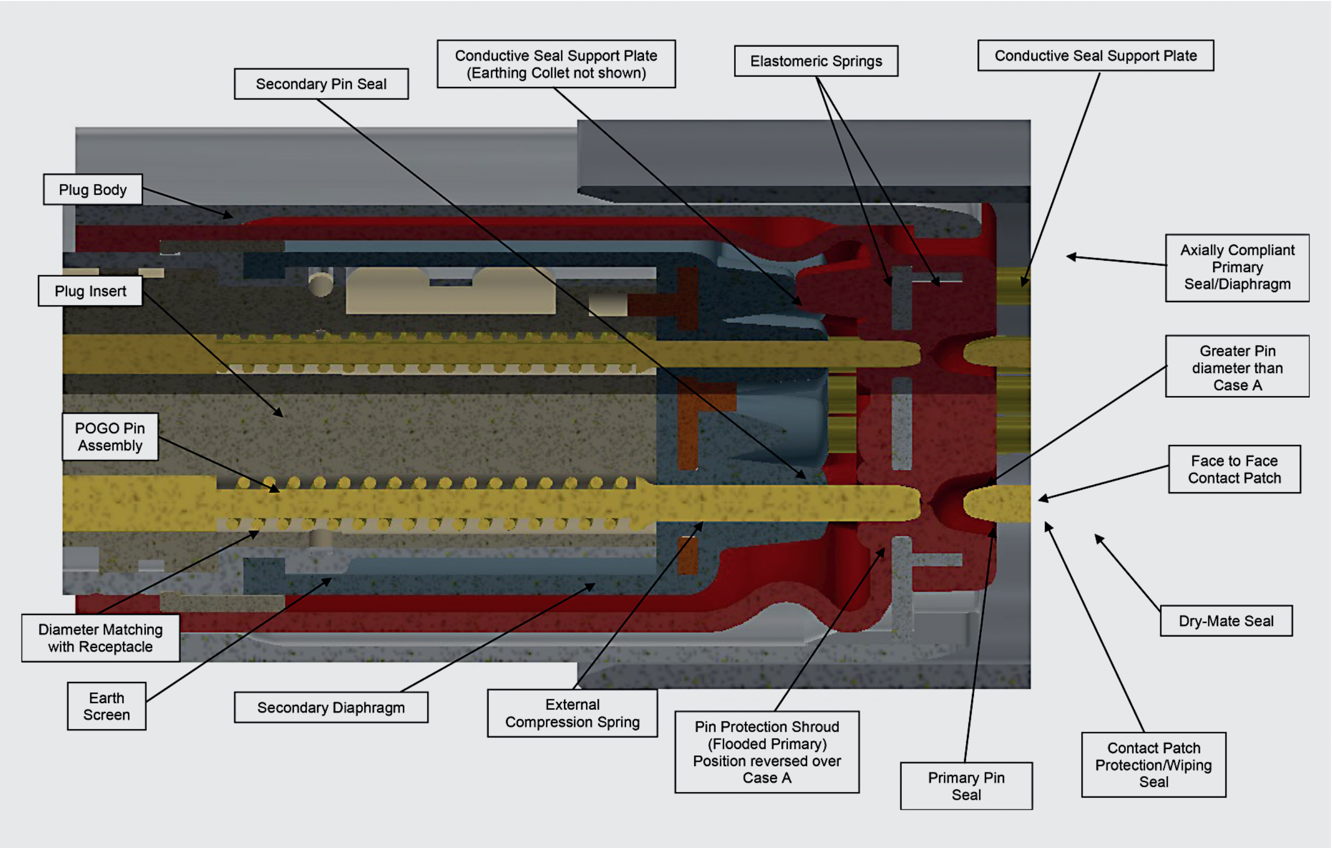

Figure 16: Detail view of de-mated plug

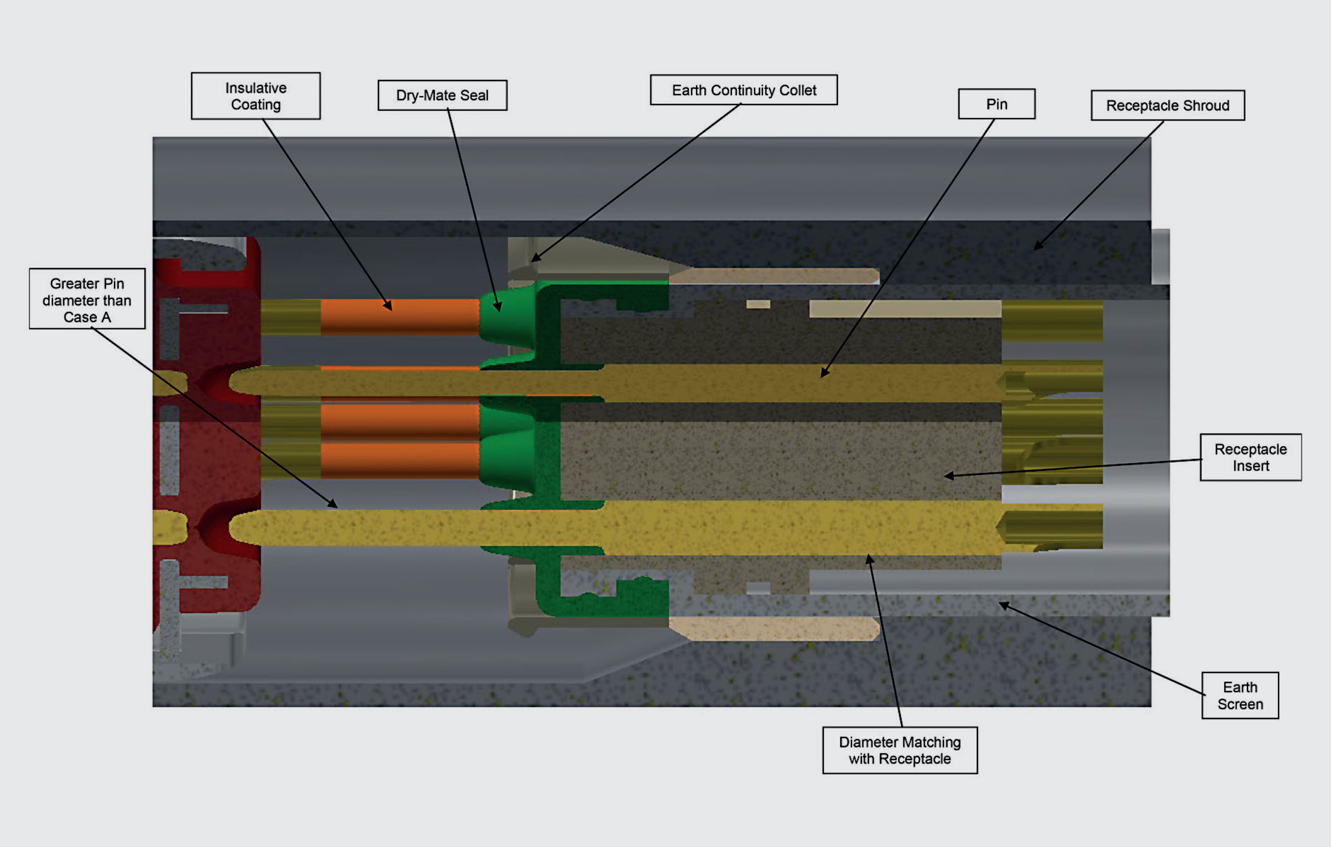

Figure 17: Detail view of de-mated socket

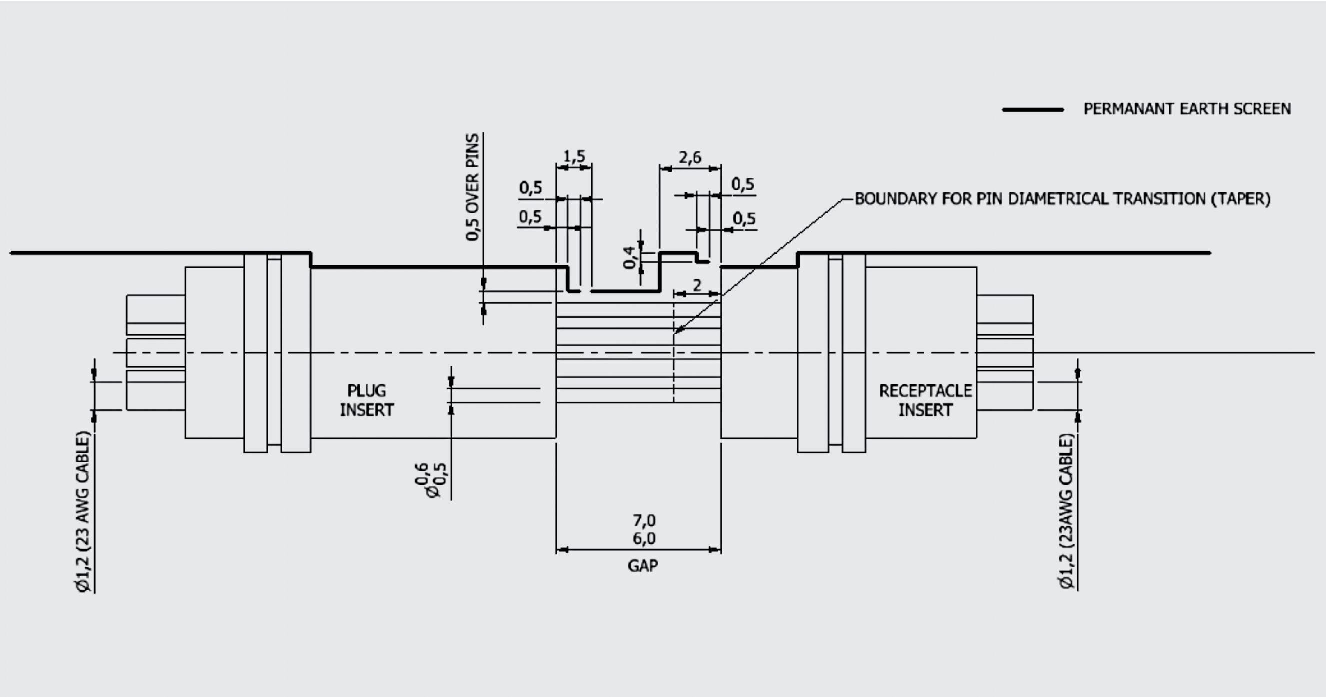

Figure 18: Typical placement of the ground shield in the µCE connector