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Solving a Ceramic to Metal Seal Breakdown Problem Using Electric Field Modeling

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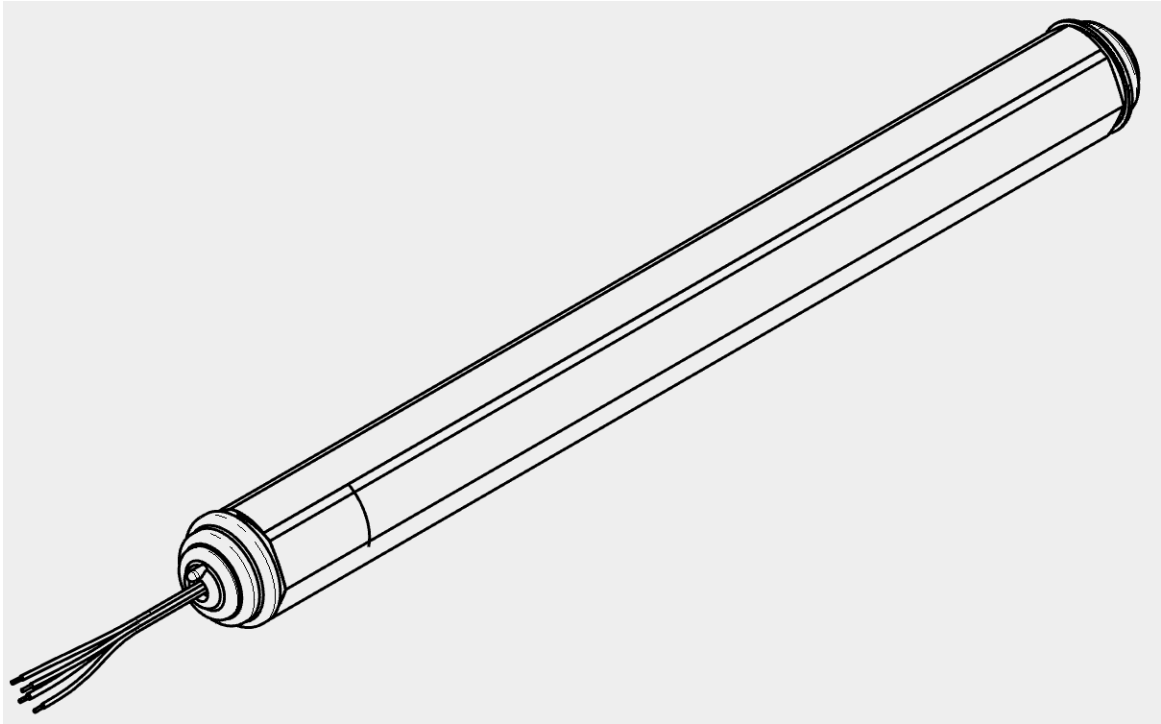
Product Under Study

- The product is a gamma detector for measuring radiation while drilling for oil.
- It uses a gamma scintillation crystal to convert gamma photons into light. An integrated photomultiplier (PMT) then converts the light to an electric pulse.
- The scintillator and PMT are mounted in a hermetically sealed enclosure.
- PMT requires over 1000 VDC and this voltage along with the signal are routed between the sealed volume and the outside via ceramic feedthroughs.



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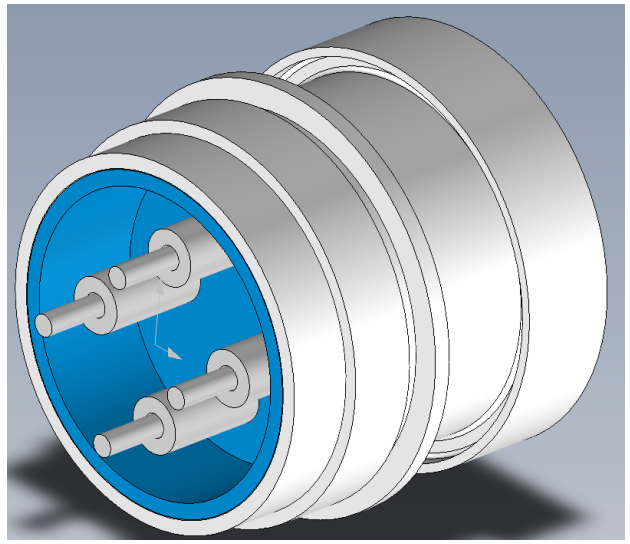
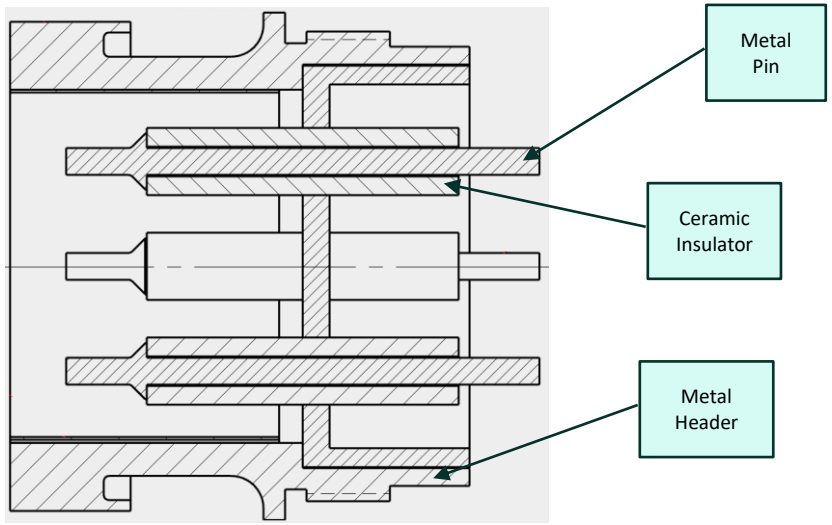
Detector Header Assembly

- The header implements the hermetic feedthroughs that connect electrical power and outputs between the inside and outside of the enclosure.
- The assembly incudes 4 feedthrough seals, of these 3 are used for power, signal and PMT high voltage.
- High voltage for the PMT is over 1000V.
- Each feedthrough consist of a ceramic tube with a metal pin going through the ceramic tube.
- Upper figure shows the complete assembly and the lower figure is a header cross section.
- For reference the header is 0.8” in diameter





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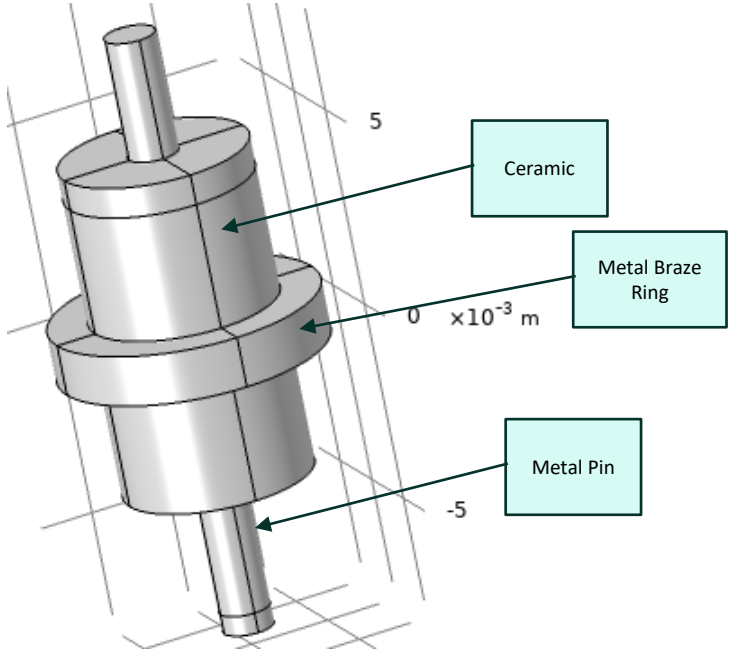
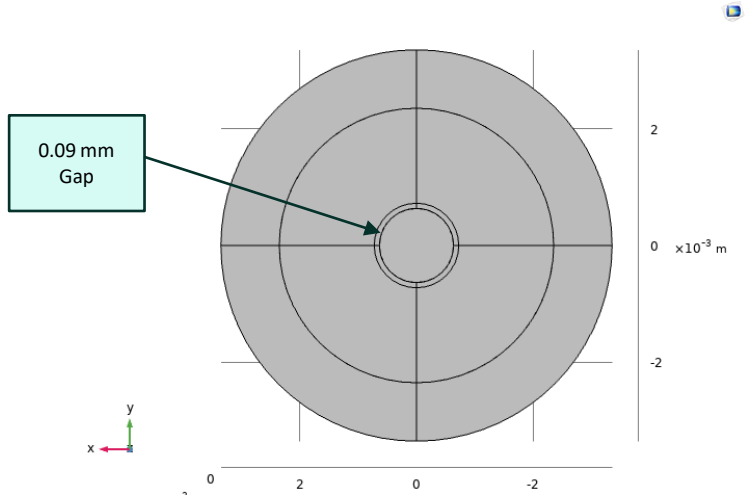
The Problem

- Periodically the detector generates output pulses that are not related to gamma radiation.
- If the high voltage bias to the PMT is turned off, the pulses go away.
- By a series of experiments the root cause was determined to be in the seal.
- Purposed theory was a breakdown of the ceramic due to contamination.
- Addition cleaning steps appeared to help but the results were not consistent and “cleaned” seals could go from passing to failing over time.

Ceramic Seal

- Seal assembly consists of a cylindrical ceramic body with a hole in the center. A metal pin runs though the hole to carry high voltage and signals.
- A braze ring is attached to the OD of the ceramic so that the seal assembly can be brazed to the metal header.
- The metal pin has a slightly smaller outer diameter than the ceramic tube's inner diameter.
- This gap between the pin and ceramic is about 0.09 mm.





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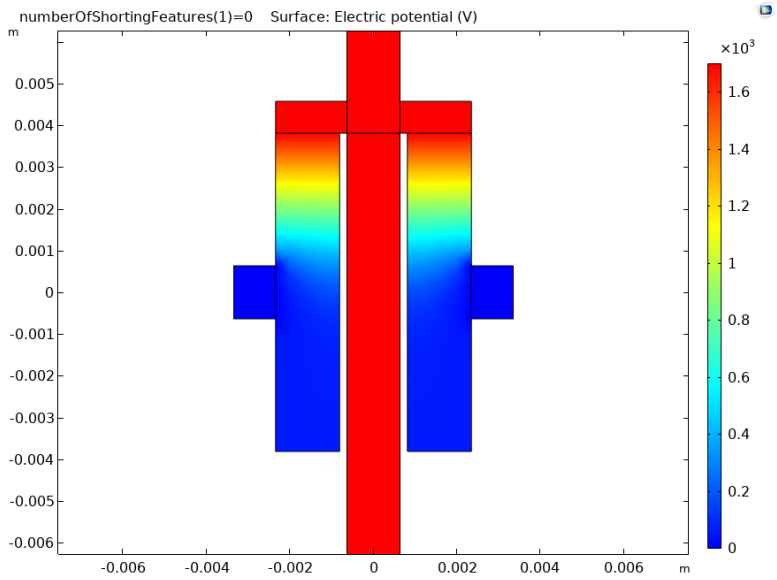
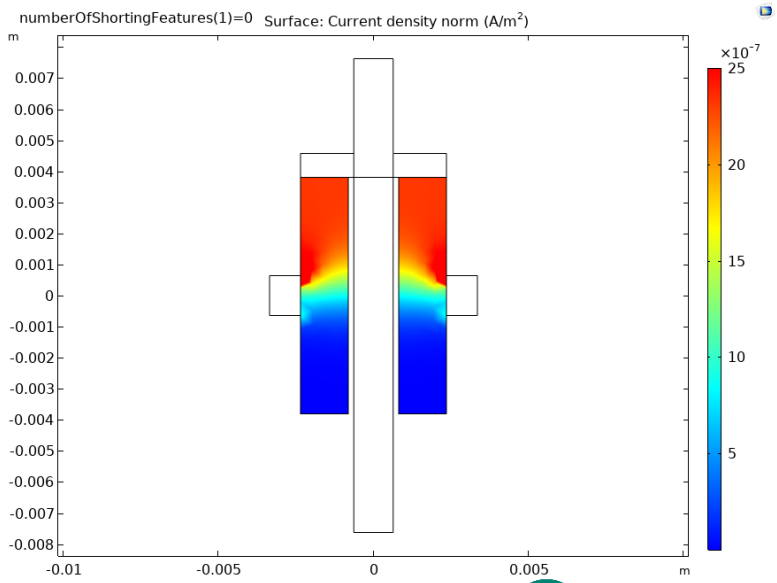
Electric Field Modeling

- Evaluating the static electric field did not show any issues since the fields within the ceramic were not high enough to cause breakdown.
- Due to the high bulk resistance of the ceramic the current density in the bulk ceramic were very low and nowhere near levels that would cause a problem.
- The initial concerns of leakage on the ceramic surface could not be studied due to un-modelable surface characteristic





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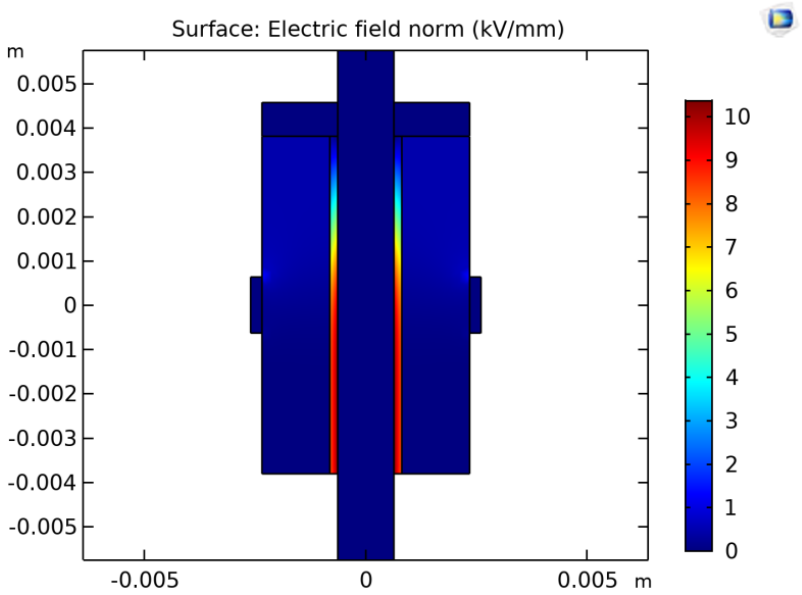
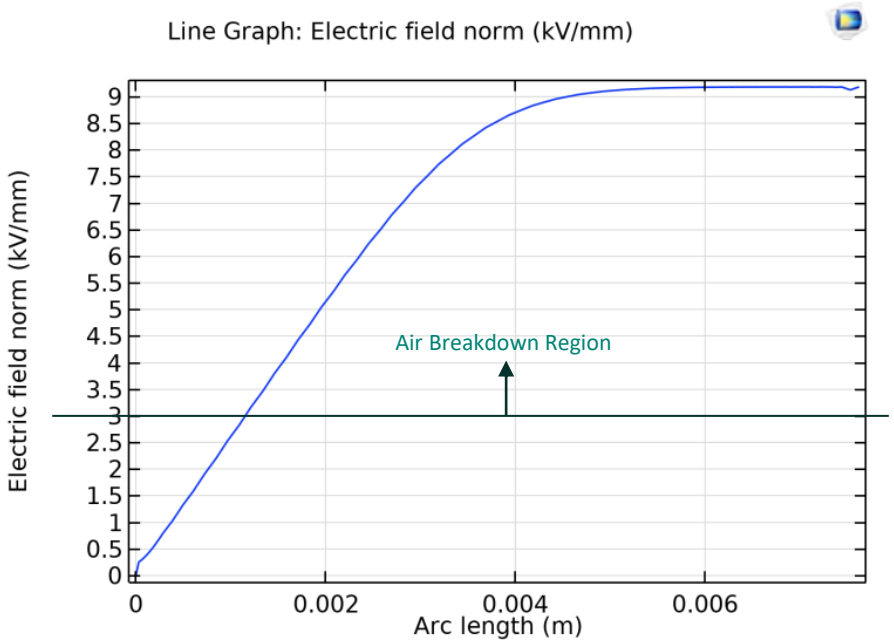
Electric Field In The Gap

- The next feature studied was the electric field in the gap.
- Plots to left show a 2D field plot along with a 1D plot of the field in the gap vs vertical distance.
- Plots show a very high field concentration in the gap.
- Field exceeds the breakdown voltage for air by a significant amount.





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Conclusion

- Following the analysis it became clear what the problem was that small gaps concentrate the electric field.
- In retrospect the answer seems obvious but without the incite from the model we went off in other directions delaying the solution and product delivery.
- Further work could be done using the COMSOL Plasma Model which provides a measurement of the electric field breakdown characteristics.
- The solution to many problems is not always a complex one and modeling will often lead to the insight that points to a solution

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