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Providing a Compact Cost Effective 3kV Electrical Connector

Long Step Out, Single Phase

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Subsea Wet-Mate Connectors
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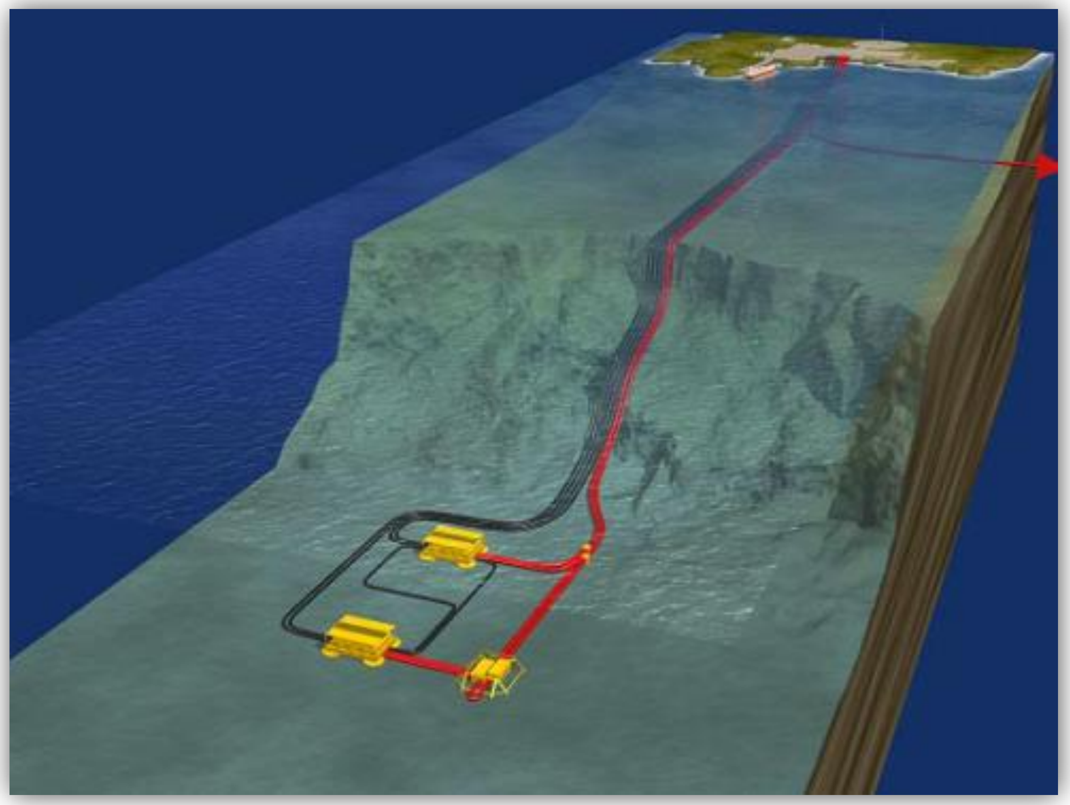
What is the intended use?

Siemens Subsea identified the need for a single phase compact cost effective connector for long step out applications.

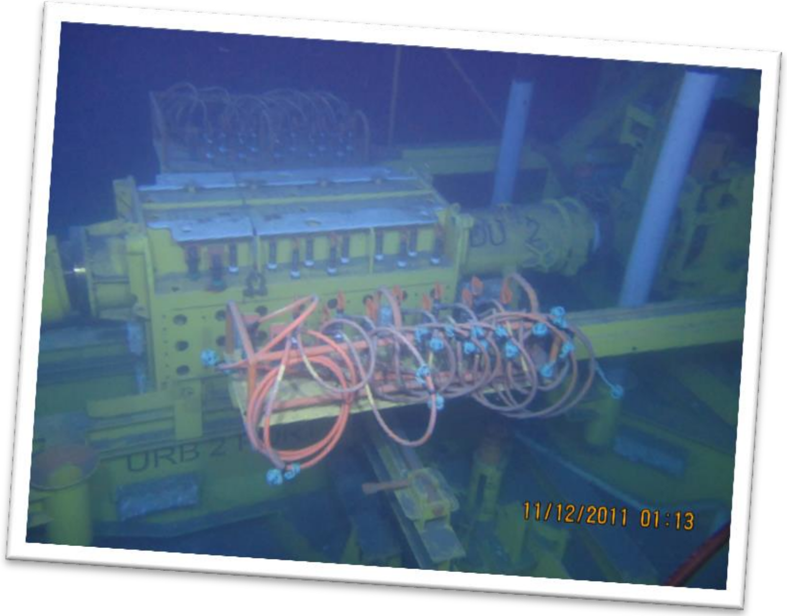
Continuous dialogue with customers and logging of requests lead to the following understanding:

- Primarily single phase AC for controls.
- Space constraints and the associated costs are of upmost importance.
- Usually long step outs.
- Require higher voltage ratings due to the increase in distance travelled (power losses).
- Specifically 1.8kV Uo, 3.6kV Um.
- Future for DC voltages.



What does DigiTRON3 do?

- The connectors role is to supply power from the main umbilical to the relevant subsea architecture or to infield umbilical's.
- It needs to operate over a 30 year design life.
- Withstand general use, misuse and abuse!
- To do so with the upmost reliability.
- Meet amalgamated specification of TR2390/SEAFOM TQP-02 and SEPS SP-1001



Reliability
Knowing our materials

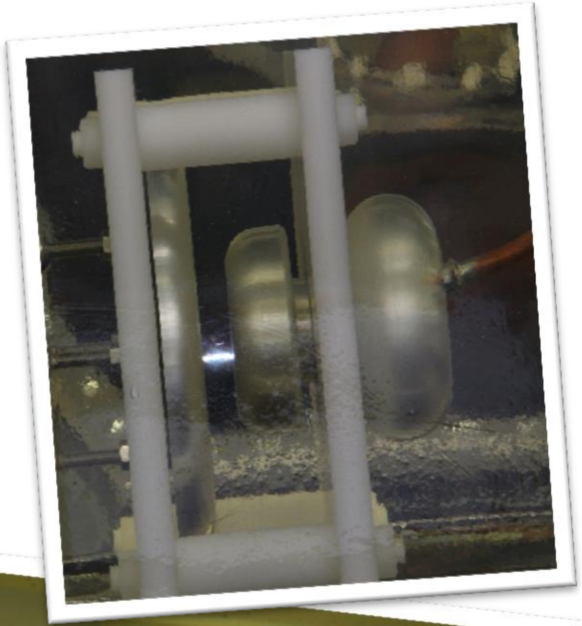
- Advanced material data has been collected, both lab based and operational, for over 38 years.
- Elastomeric, polymeric insulation and dielectric oils.
- Virgin and aged.
- This information is utilised in calculations and simulation tools in designing connectors.
- This body of data leads to a reduction in development timelines.

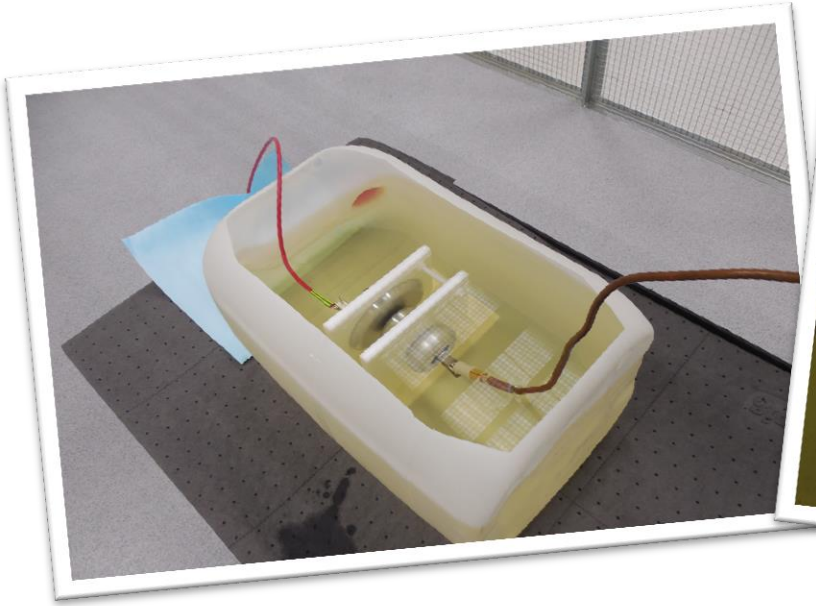
Permittivity

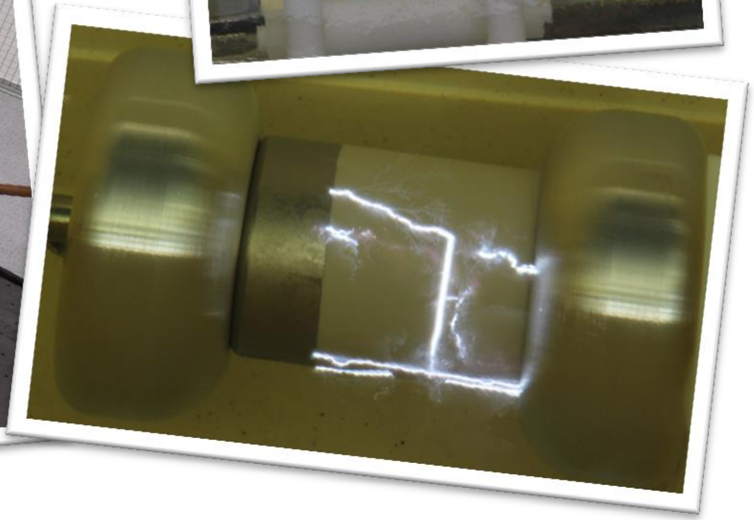
Electrical Breakdown

Surface Resistivity

Volume Resistivity







Reliability
The importance of qualification

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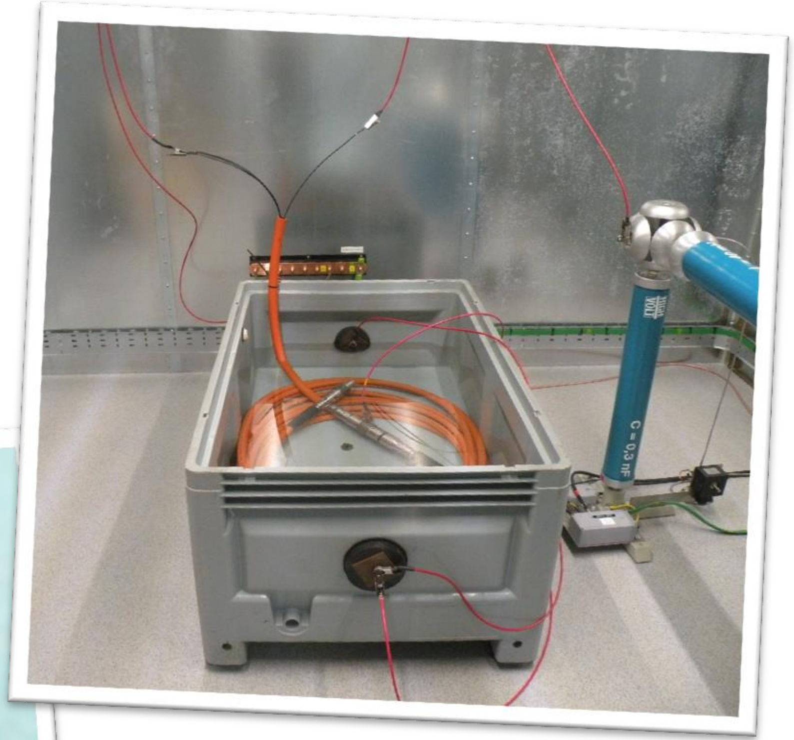
- Statoil TR2390/SEAFOM TQP-02 and SEPS SP-1001.
- To prove the design.
- To qualify way in excess of the operating conditions to confirm safety factors.
- Conform to industry standards.
- Confirm repeatability of the manufacturing process and design.
- The results of the tests are a critical factor in assessing the system’s readiness for production.
- Find your breaking point!



Gives real values to design too!

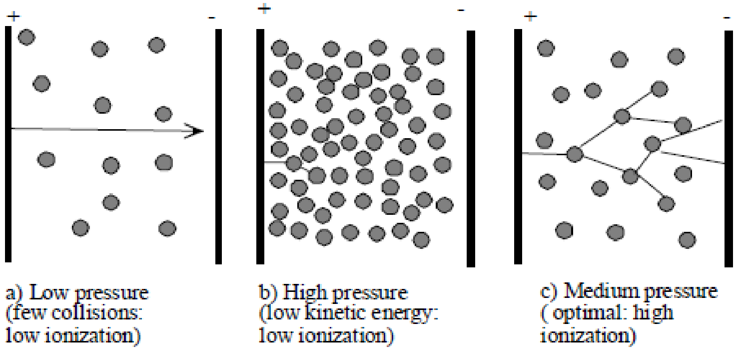
Understanding the fundamentals

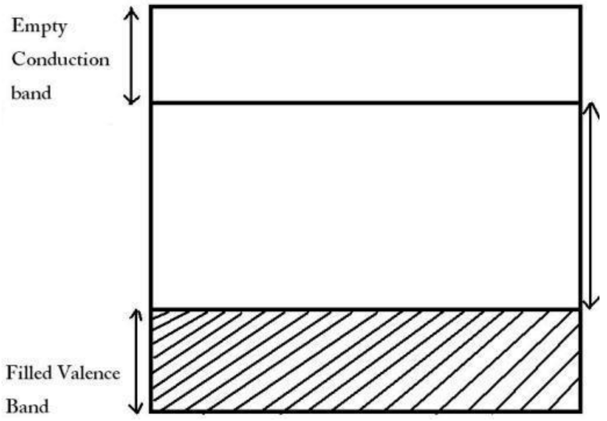
Complexity: Simply a build up of the basics.

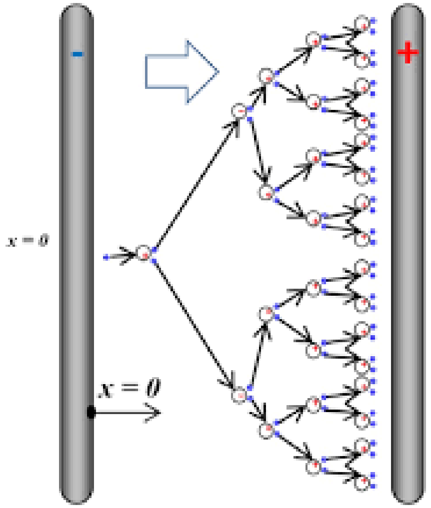
Partial Discharge

Band Theory

High Voltage Breakdown







Paschen

Insulation Resistance

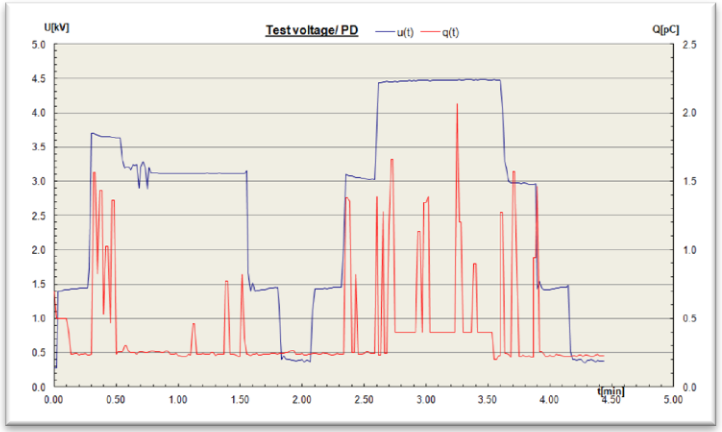
Townsend

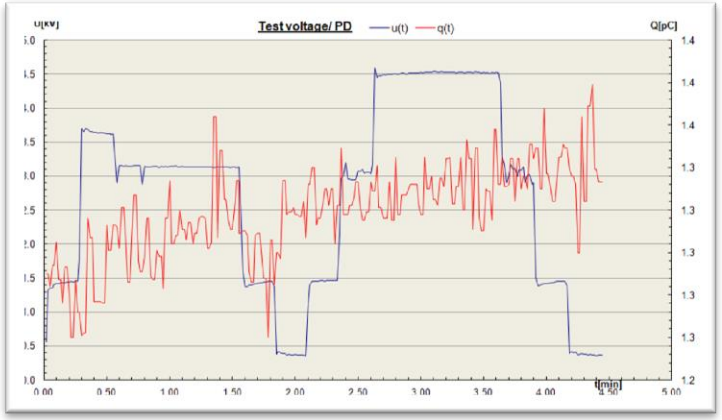
Ohm

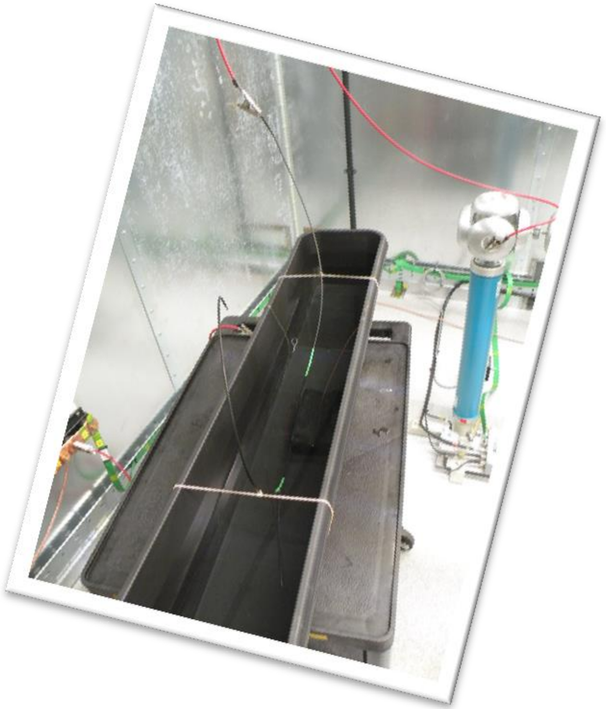
High Voltage Holds

Knowing where to improve
Data Gathering

- Calculations showed that the DigiTRON+ connector would be suitable for a 1.8kV Uo system.
- DigiTRON+ was tested unmodified in order to see which areas needed optimisation to allow operation at higher voltages.
- Small incremental steps were taken during testing.
- Repeated.
- Analysed.
- Compared to calculations.







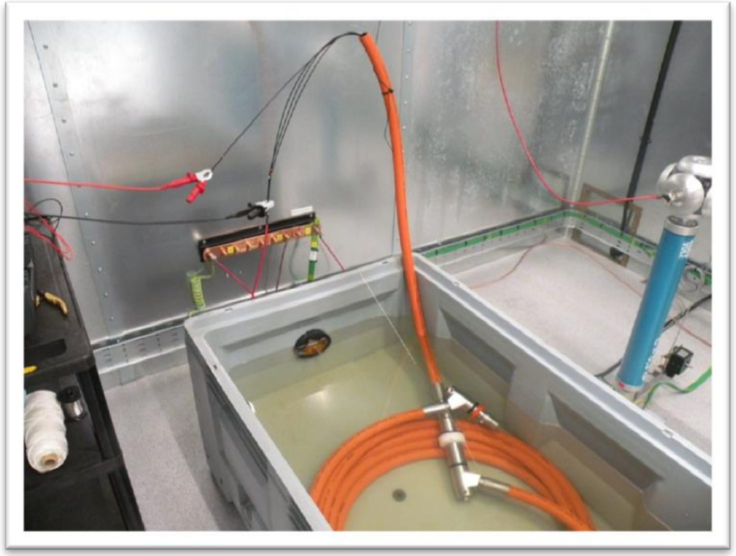
Front End Integrity ✓

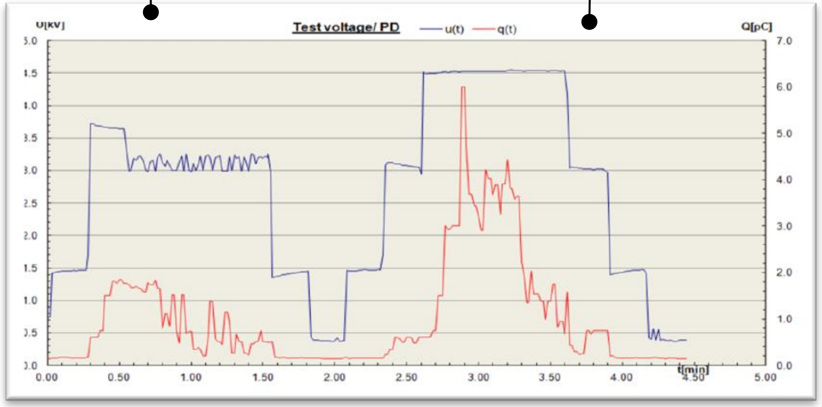
Wire Integrity ✓

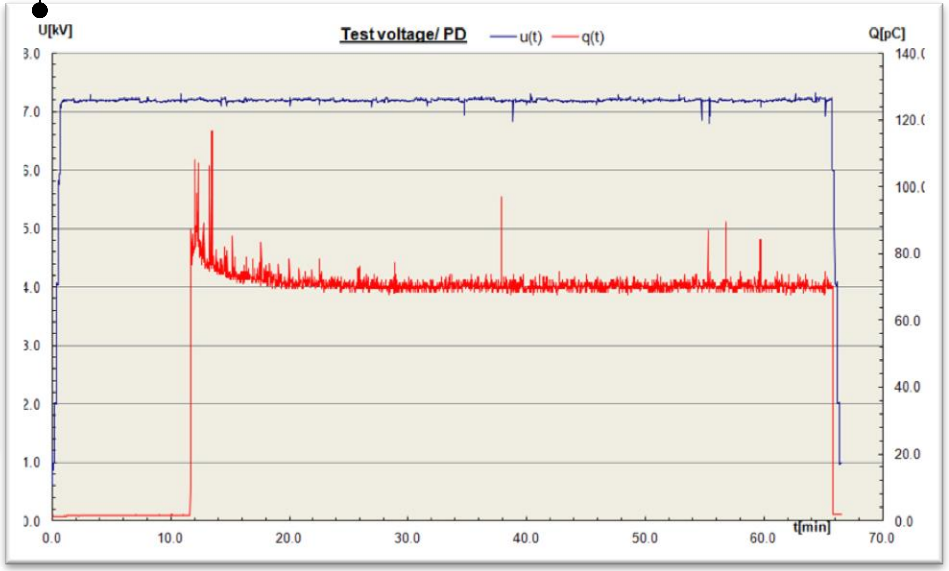
Knowing where to improve
Data Gathering

- Understanding the full system.
- Highlighted areas which could be optimised.
- Monitoring PD continually.

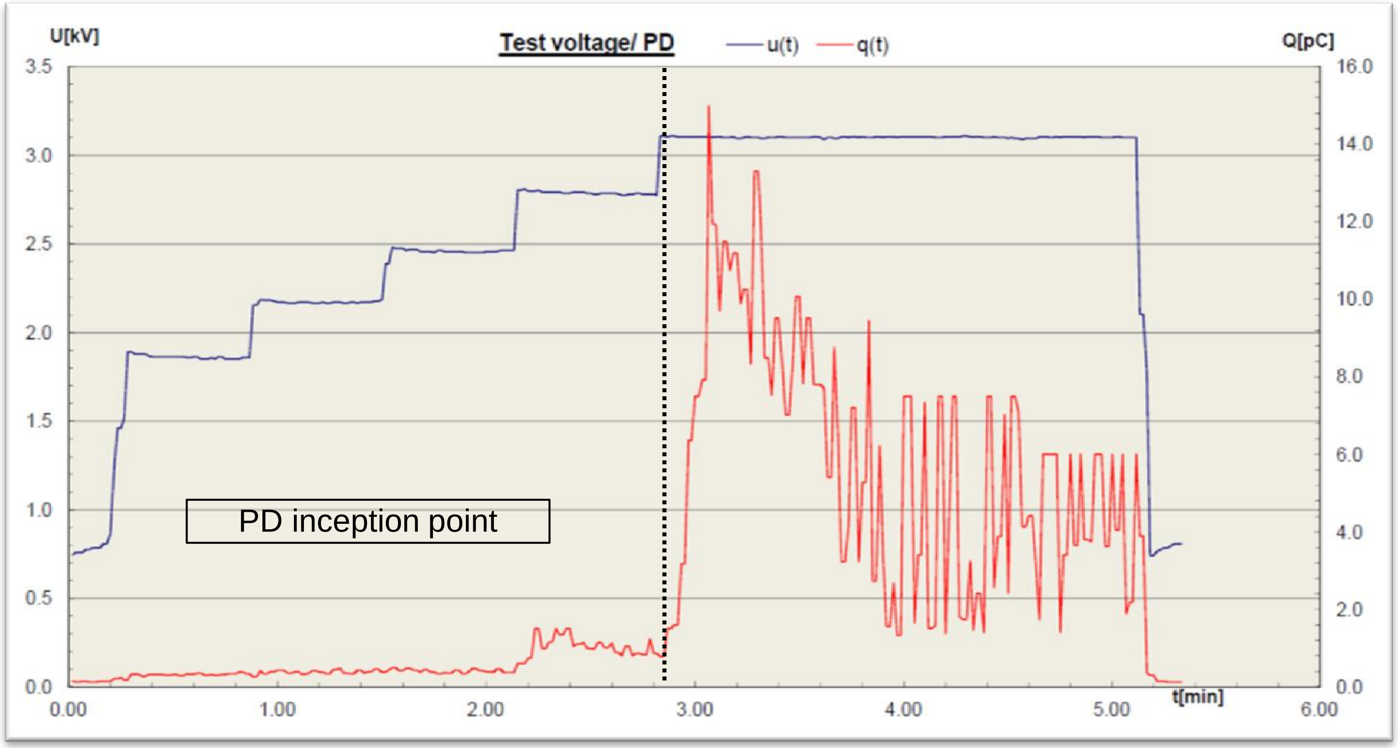
Step	Test	Test level	Reference
1	Helium leak test	See test method	7.4.1
2	Static pressure test - penetrators	See test method	7.4.16
3	Contact resistance	See test method	7.4.2
4	Insulation resistance	See test method	7.4.8
5	PD test	1.73 x U_0 (10 pC)	7.4.5
6	PD test	2.50 x U_0 (200 pC)	7.4.5
7	High voltage AC test	4 x U_0 (1 hour)	7.4.6
8	PD test	1.73 x U_0 (10 pC)	7.4.5
9	PD test	2.5 x U_0 (200 pC)	7.4.5





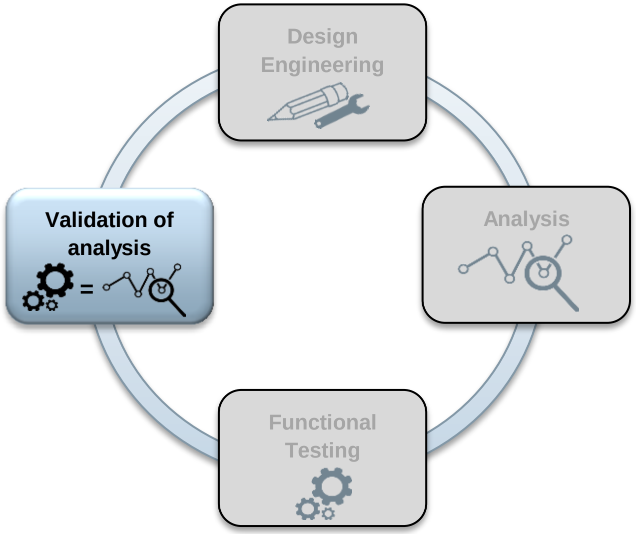


Knowing where to improve
Validation



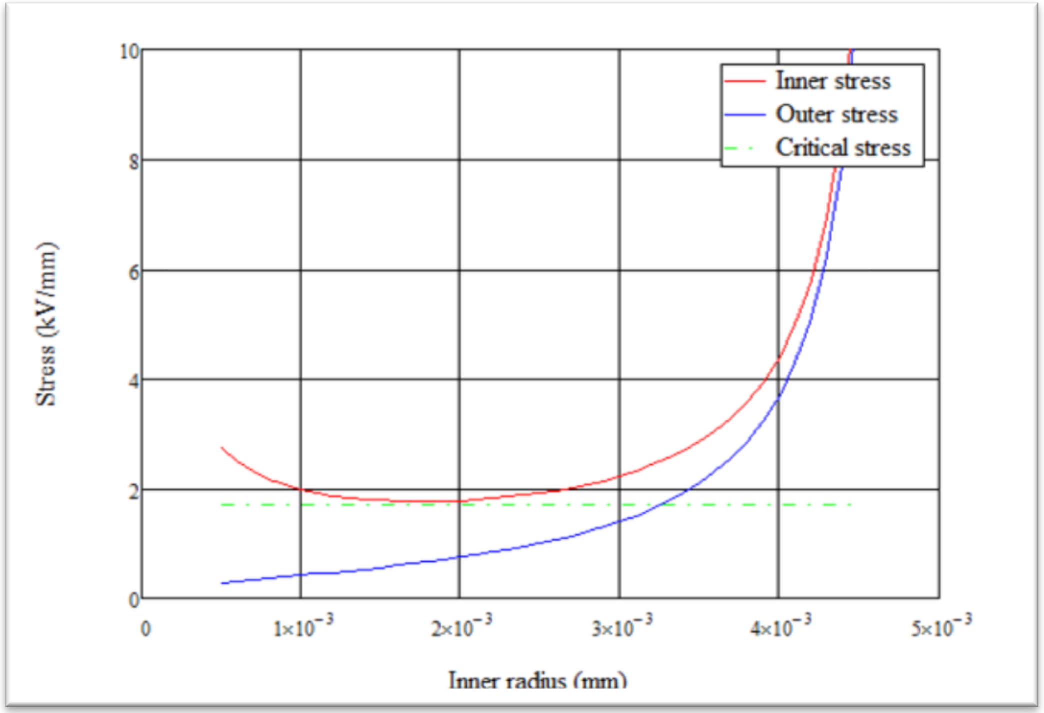
Optimising the Future Designs

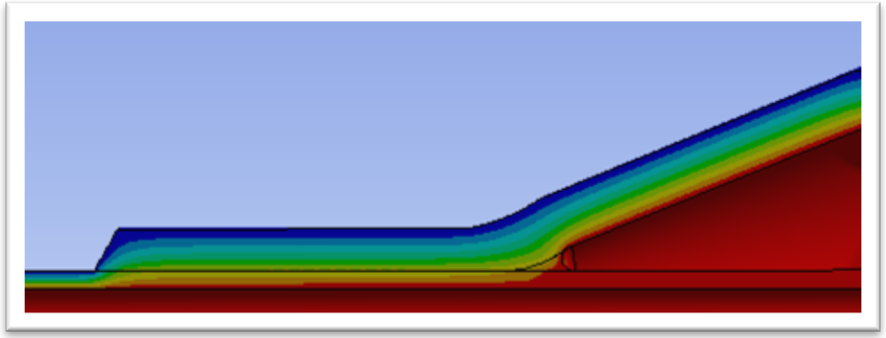
$$E = \frac{2.4kV}{(2,92/2).\ln\left(\frac{(4,65/2)}{(1,85/2)}\right)} = 1,78 kV/mm$$

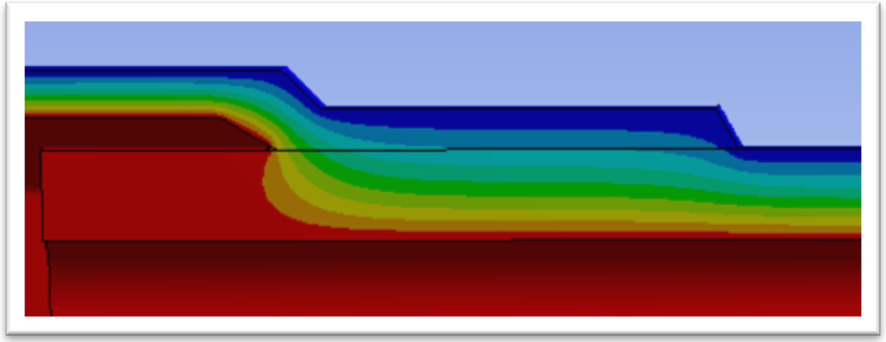


Design and Analysis

- Within any electrical system insulation is required.
- More insulation does not necessarily mean a better design.
- It matters less about the amount of insulation and more about the quality and the position of said insulation.



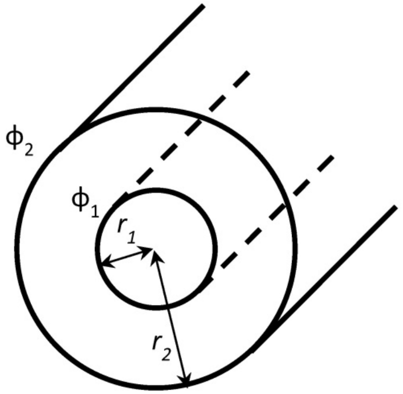


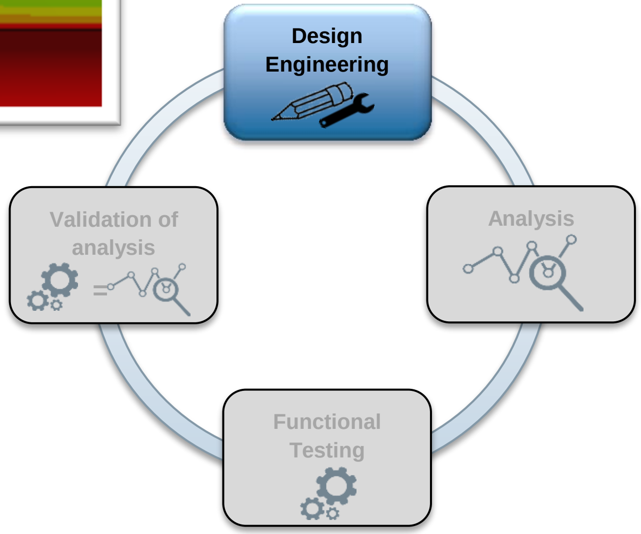


$$E = \frac{Vo}{r1.\ln(\frac{r2}{r1})}$$

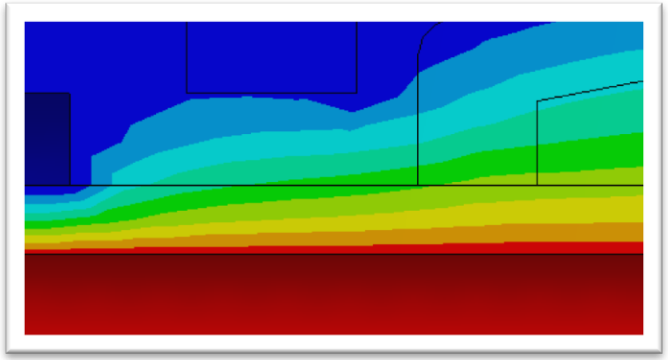
$$E = \frac{Vo}{r2.\ln(\frac{r2}{r1})}$$

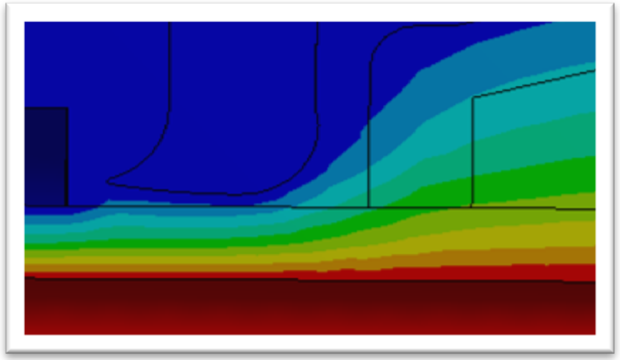
$$E1 = \frac{V}{d1 + d2.(\frac{\varepsilon 1}{\varepsilon 2})}$$



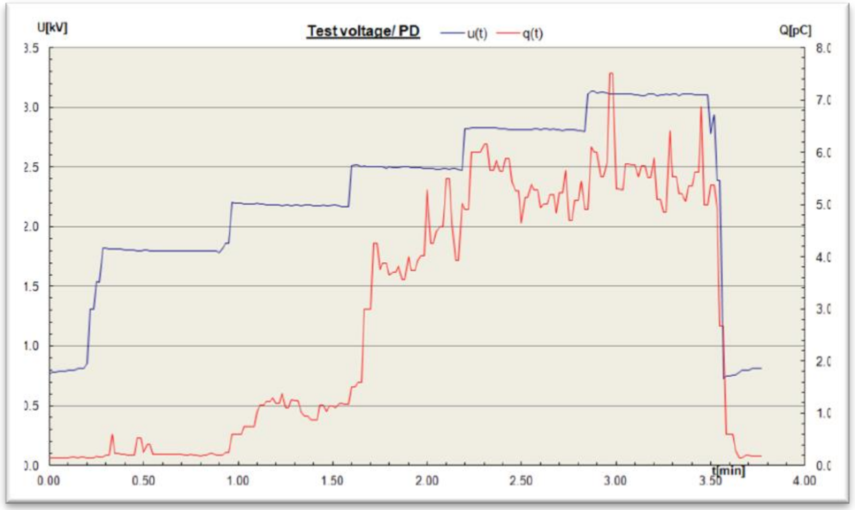


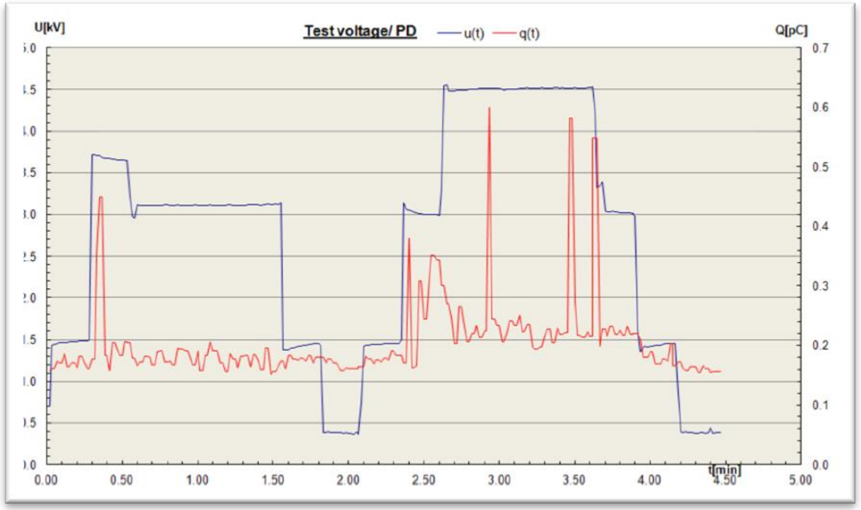
Design and Analysis

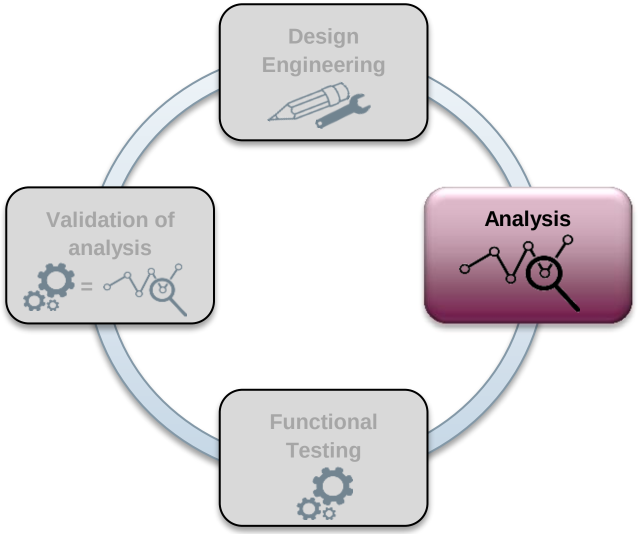




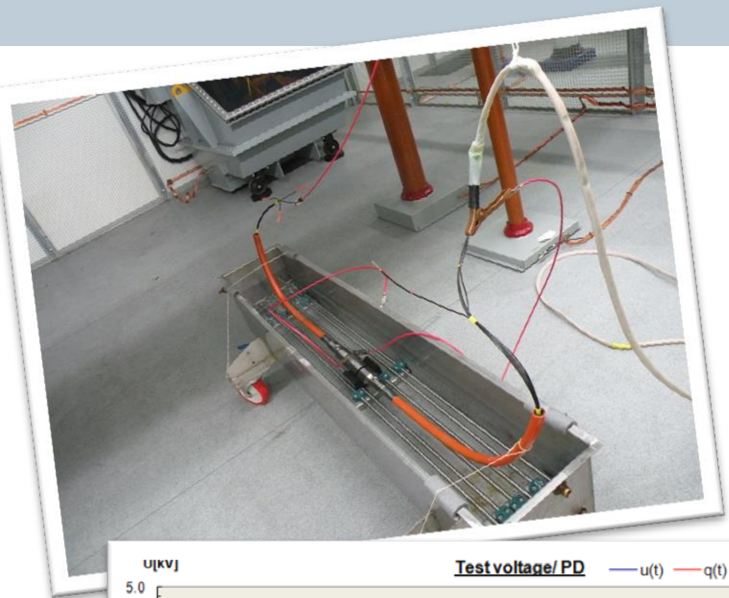
- Electrical stress controls can be used to re-position high stress points.
- Doing so can increase the average stress but decrease the peak electrical stresses.
- Doing so in areas where air entrapment or contamination are possible is critical.



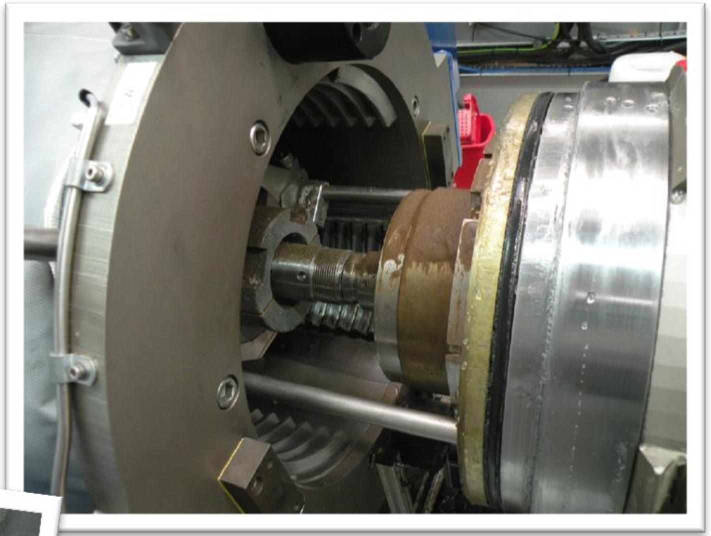


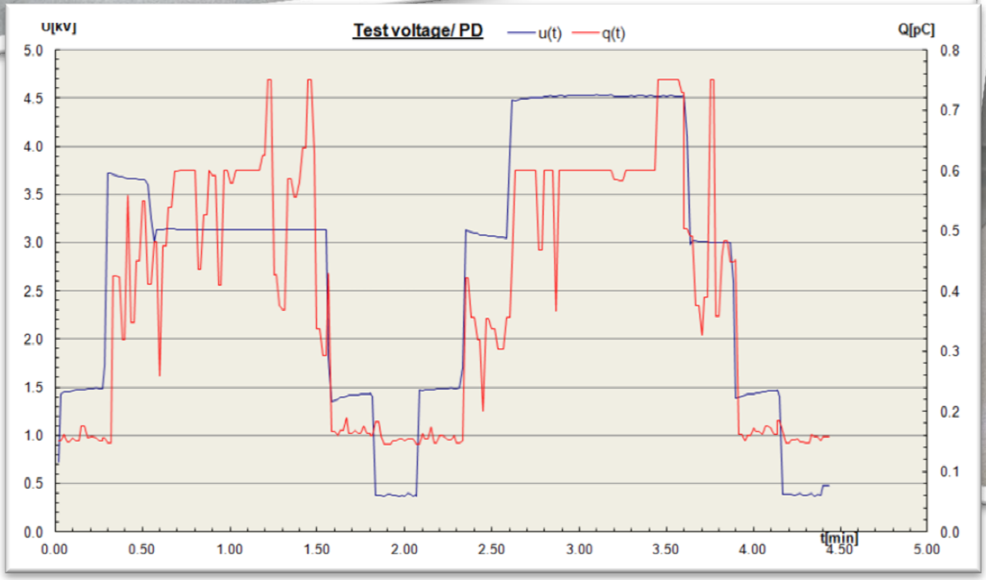


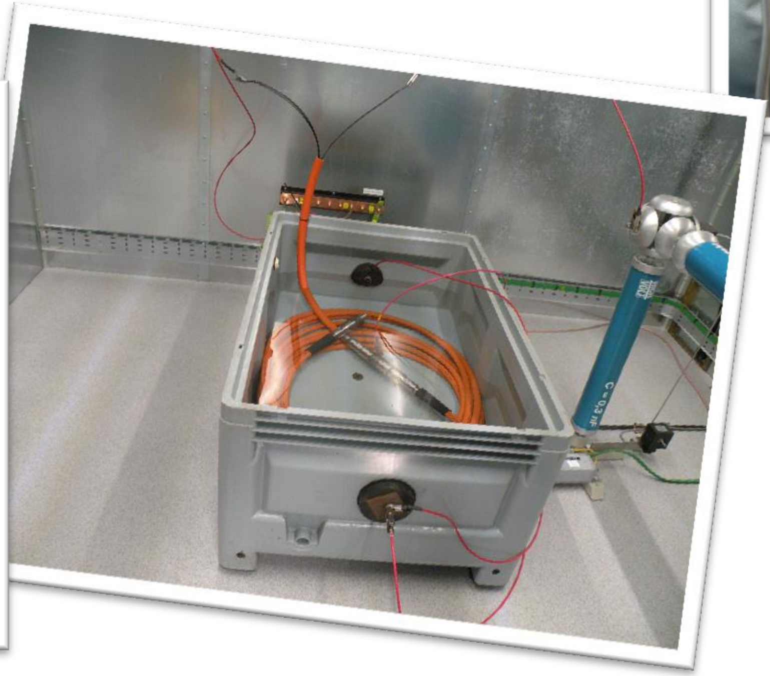
“Testing, 1, 2, 3”

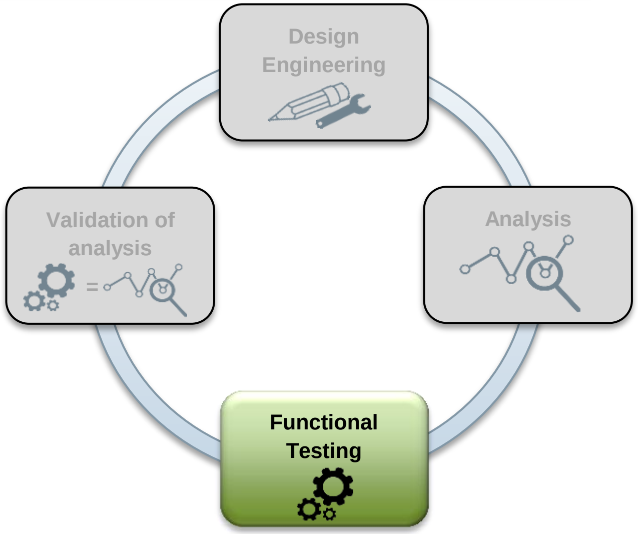


- Over 5 months of testing.
- 3 full sets of connectors used for each of the 15 electrical integrity qualifications.
- Monitored electrical values continuously rather than pre and post.



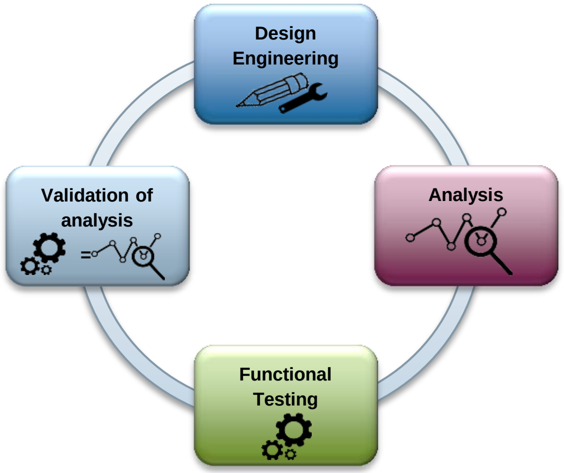






Conclusions

- One of the most challenging parts of any development is understanding the needs of our customers.
- Understanding the fundamentals and proving these through functional testing enabled a focused development.
- Following a structured design processes and utilising our extensive materials data reduces development lead-times.
- Continuously building our material properties data drives development efficiency and engineering knowledge.
- The advantage of following this methodology is that developments become pro-active rather than re-active.



The future...

Reduction in operational costs

EPC standardisation

DC

DCFO

Long step outs

Voltage ratings

Uo/U (Um)

Thank you for your time
Any questions?

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