LOCA and Post-LOCA Qualification of PEEK insulated cables

Sven-Olof Palm, Forsmarks Kraftgrupp AB

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My original thought

The success story about an EPA qualification

(EPA =Electrical Penetration Assemblies)

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What happens?

Planning

VS

Real Life

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Background

- **The Swedish Radiation Safety Authority have a regulation SSM FS 2008:17 §17 that stipulate:**

- **Environmental tolerance and environmental impact**
- **Section 17**

  The barriers and equipment belonging to the safety systems of the nuclear power reactor shall be designed so that they withstand the environmental conditions that the barriers and equipment can be subjected to in the situations where their function is credited in the safety analysis of the reactor.

  Equipment in the nuclear power reactor shall not have such an environmental impact that the performance of the reactor's safety functions is reduced.

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Background

- On the electrical and I&C area this lead to the requalification of about 70 different types of components
- Also mechanical and civil structure component is handled under the §17 work.

- The requalification is done according to modern demands:
  -Low acceleration factors
  -Partly new environmental description (LOCA/Post-LOCA profiles)
  -New function demand time (longer Post-LOCA)
  -In some cases also submergence
  -Severe Accident
  -Traceability (Identity) between originally qualified component and component produced today

- A majority of components were not approved

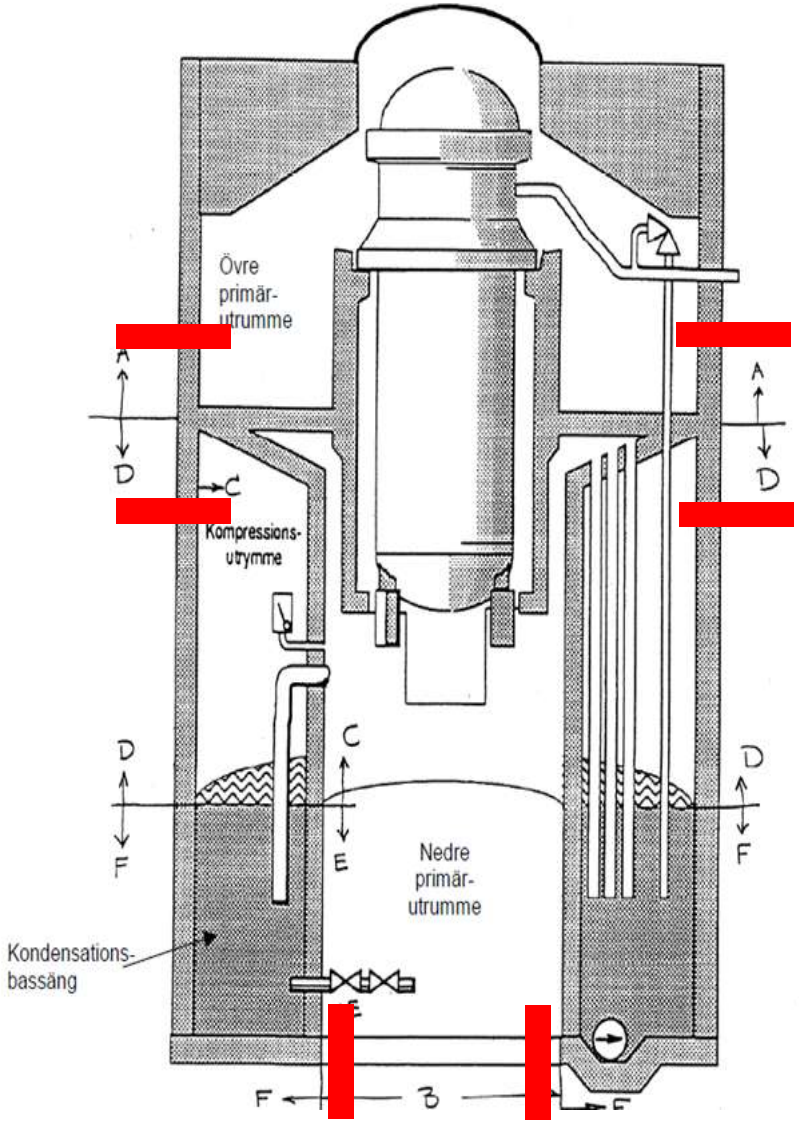
Background

- **One of the component not approved was the EPA at Forsmark 3**

- **Main reasons are:**
  -Accelerated LOCA profile
  -No submergence verification
  -No 30 day Post-LOCA
  -No severe accident/H5 verification
  -Only one test specimen

- **After a design review it was decided to not perform a requalification of the original component**

Location of penetrations at Forsmark Unit 3



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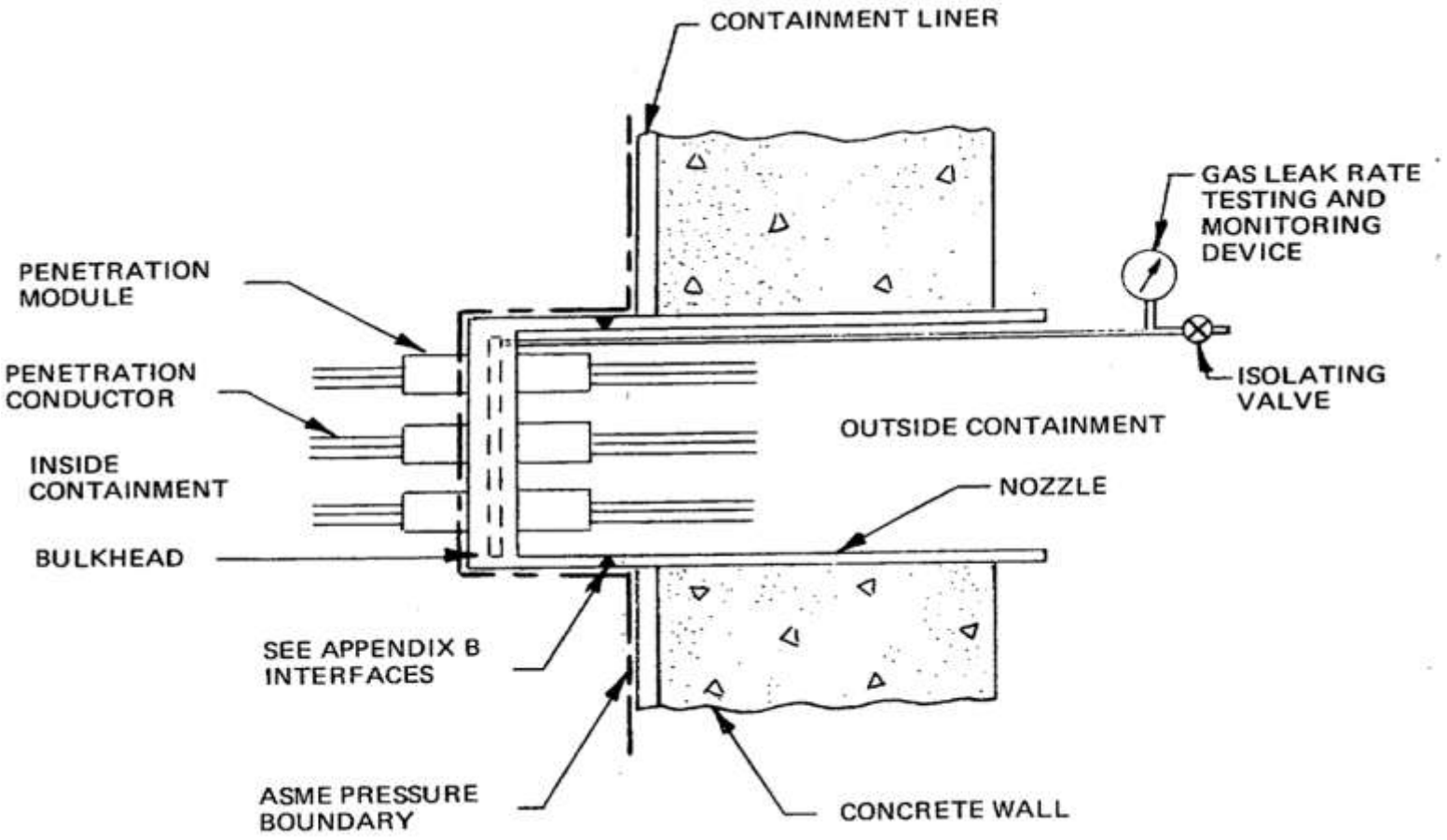
Principal drawing of containment penetrations



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Cubical in the lower DW

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Original I&C module from Forsmark Unit 3

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Cubical in the Mock-up

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Demands at the new qualification

- **DBE**
  Demand of Electrical functionality and mechanical integrity.
  - **DBE profile according to TBE 102:1 BWR 2. Post DBE 30 days.**
  - **Submergence profile later in the presentation.**
  - **Operation and Accident dose 30 days 7.4 kGy.**

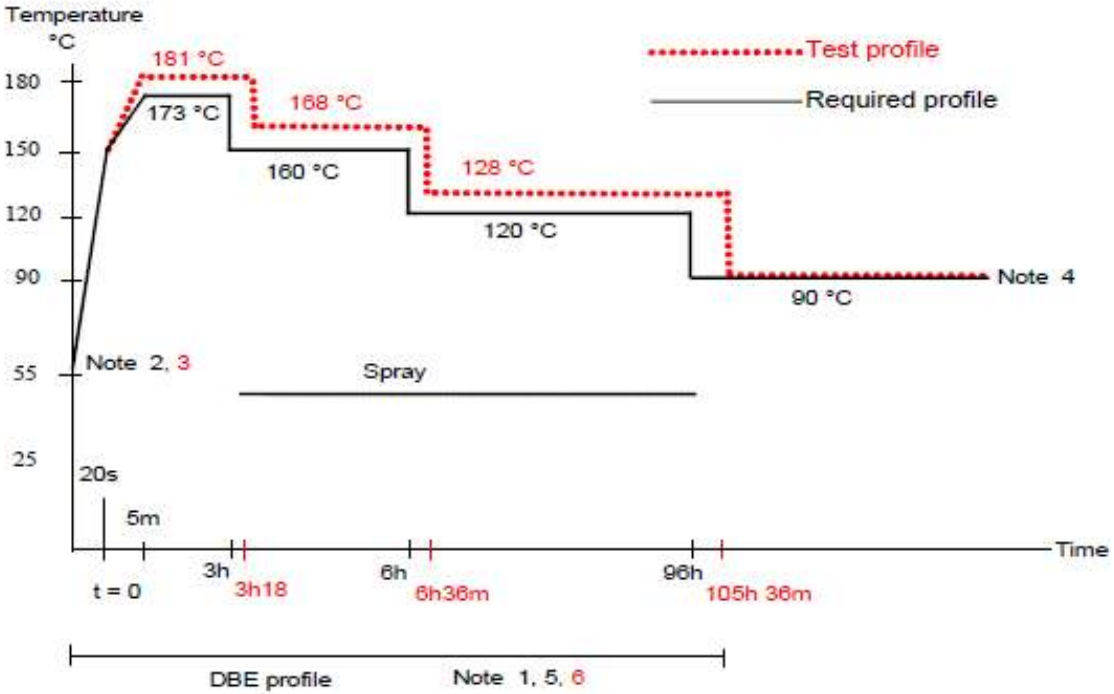
(TBE= Technical Requirements for Electrical Equipment)

Demands at the new qualification

- **Severe Accident/H5**
  - **Only mechanical integrity.**
  - **Integrity verified >30 days.**
  - **Max temperature 185°C.**
  - **Max Pressure 8.3 Bar.**
  - **Accumulated dose during 30 days 1.7 MGy.**
- **Profile (including submergence) later in the presentation.**

LOCA-profile

BWR 2/BWR generic, Inside Containment Accident Conditions



Note 1 Values for temperature and pressure given above shall be achieved or exceeded.
100% RH are valid for required profile and test profile.
Rise and fall times shall be as short as possible.

2 Rise time: max 20 s up to 150°C and 5 min up to 173°C. Time t = 0 starts at 173°C.

3 Rise time: max 20 s up to 158°C and 5 min up to 181°C. Time t = 0 starts at 181°C.

4 Time for Post DBE shall be according to Techical Specification.

5 The pressure 0,5 Mpa abs shall be kept for at least 6h.

6 The pressure 0,55 Mpa abs shall be kept for at least 6h36m.

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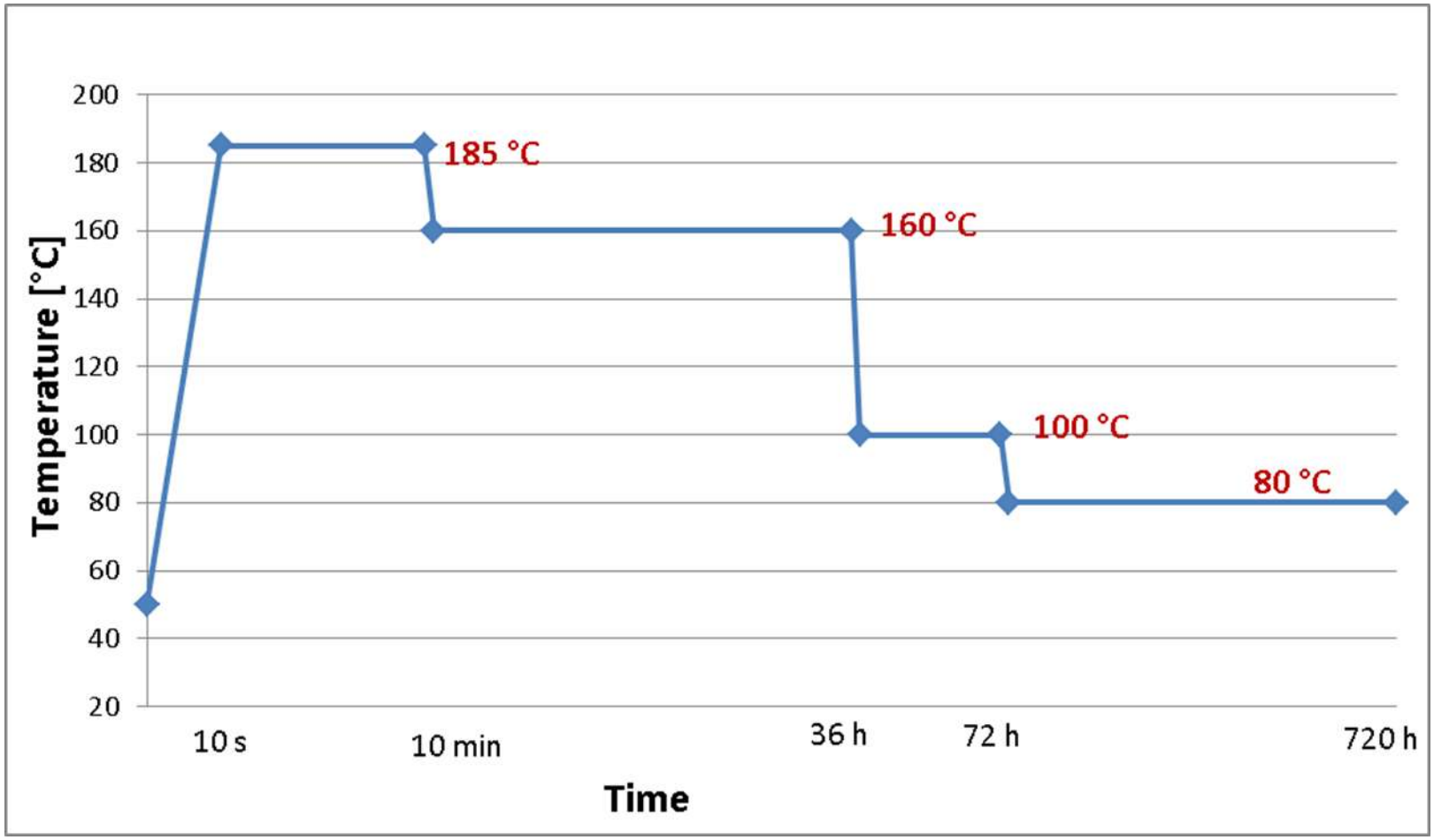
Temperature profile Severe Accident/H5



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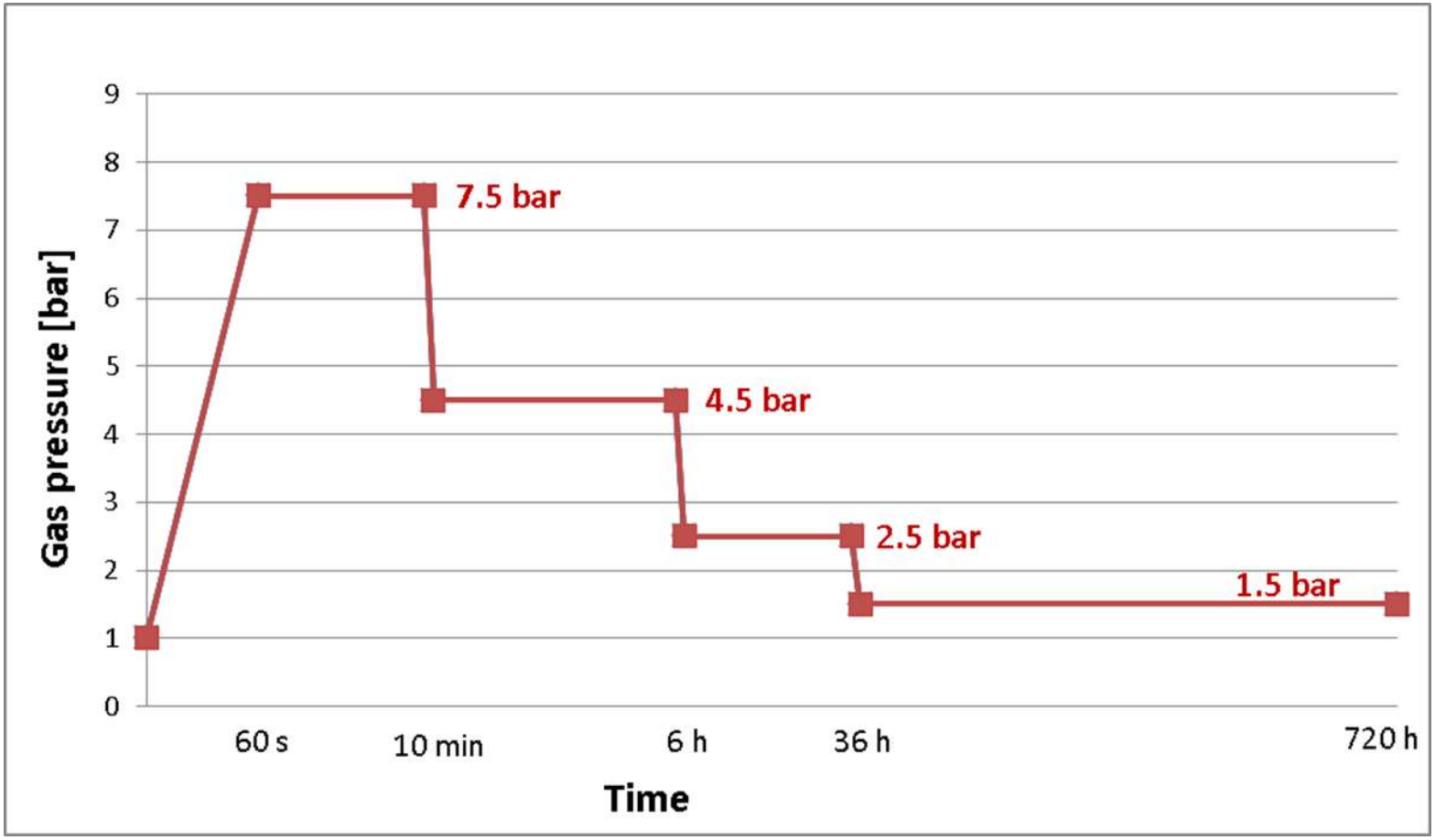
Pressure profile (gas phase) Severe Accident/H5



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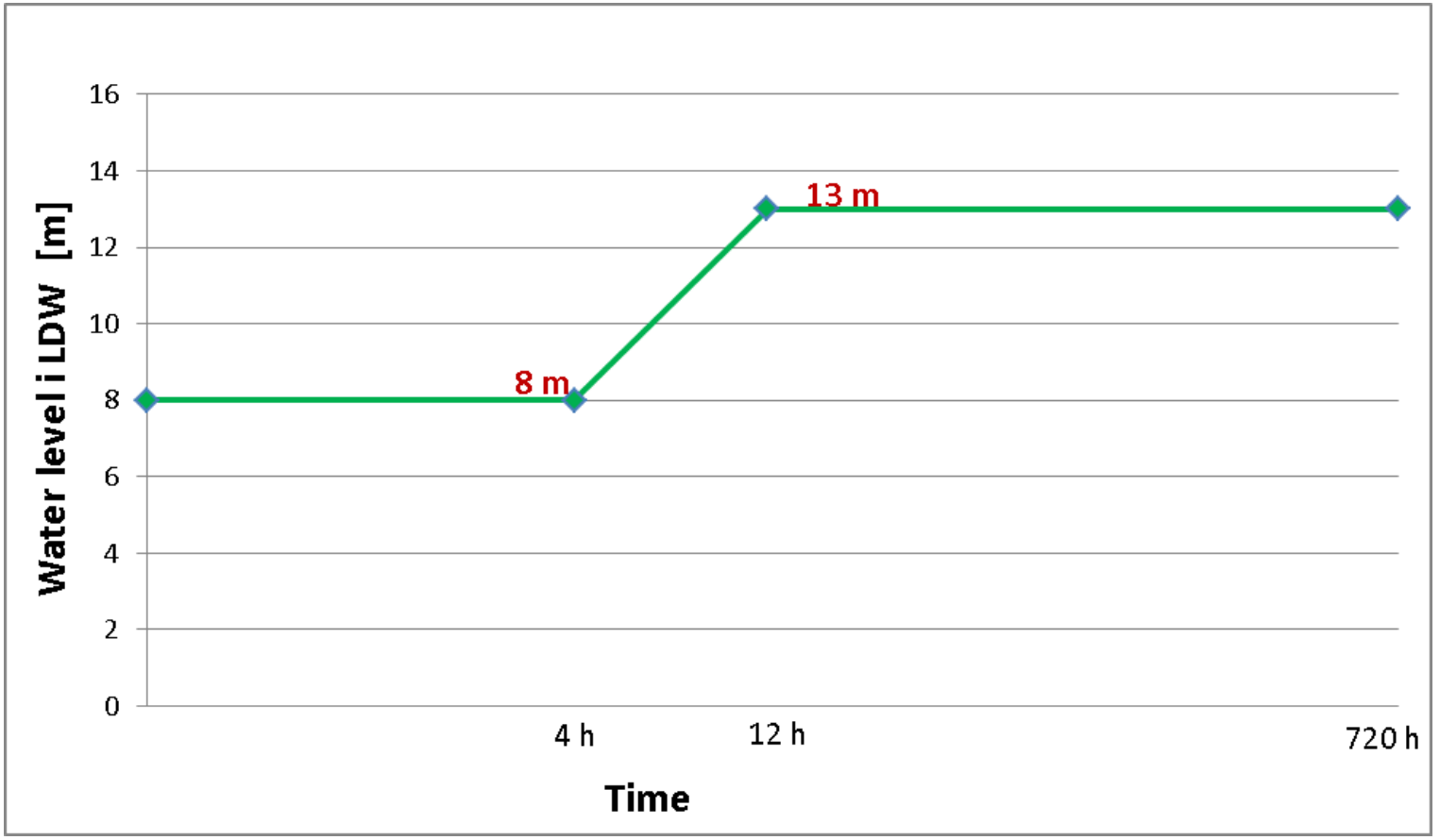
Submergence profile Lower DW



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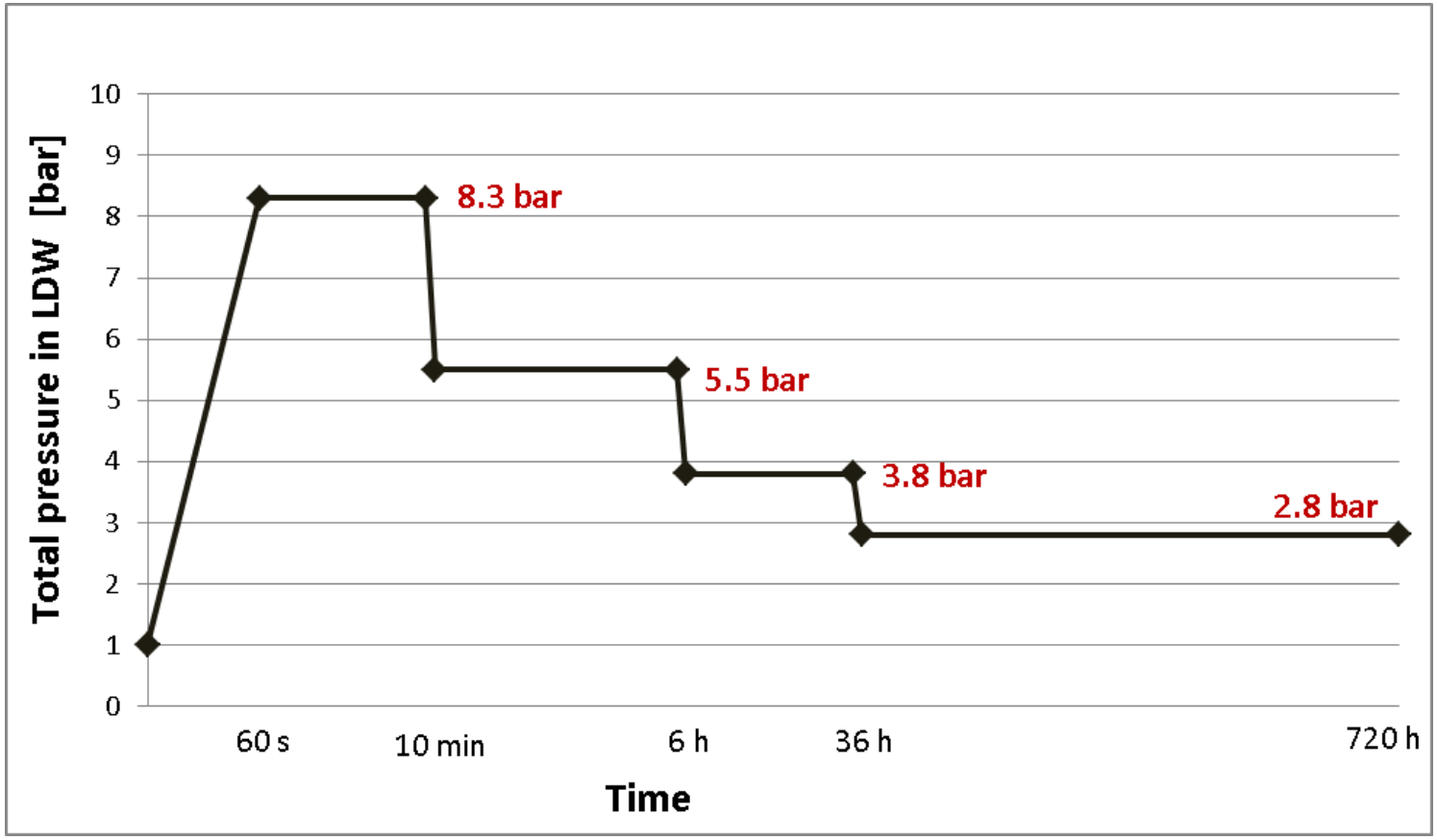
Pressure profile (water phase) Severe Accident/H5



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Qualification of new EPA

- **Contract in 2012**
- **Modification of the original design to reduce risk of corrosion**
- **Discussion about the choice of Pigtails**
  -Zero Halogen
  -Possibility to withstand Severe Accident
- **Possibility to envelope the LOCA and Severe Accident test**

Choice of cable

- **PEEK Cable. Qualified for LOCA and Post-LOCA 30 Day. 40 year of operation at 90 degree C.**
- **LOCA Curve exceeding the Forsmark 3 demand, Post-LOCA slightly below our requirement.**
- **Radiation: Total dose >2.5 MGy**

- **No indication of problem from qualification test or other applications.**

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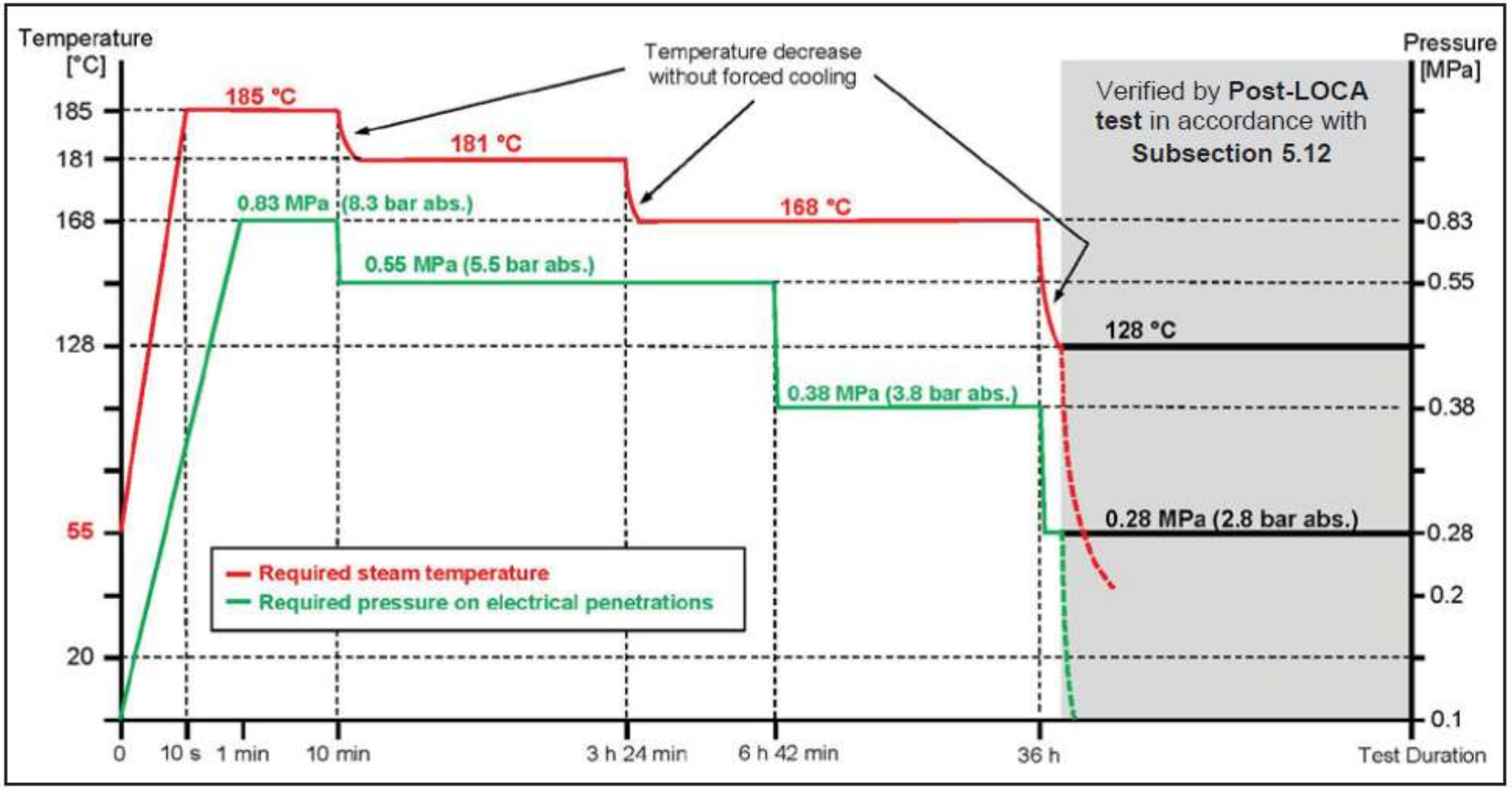
Combined LOCA/Severe Accident profile



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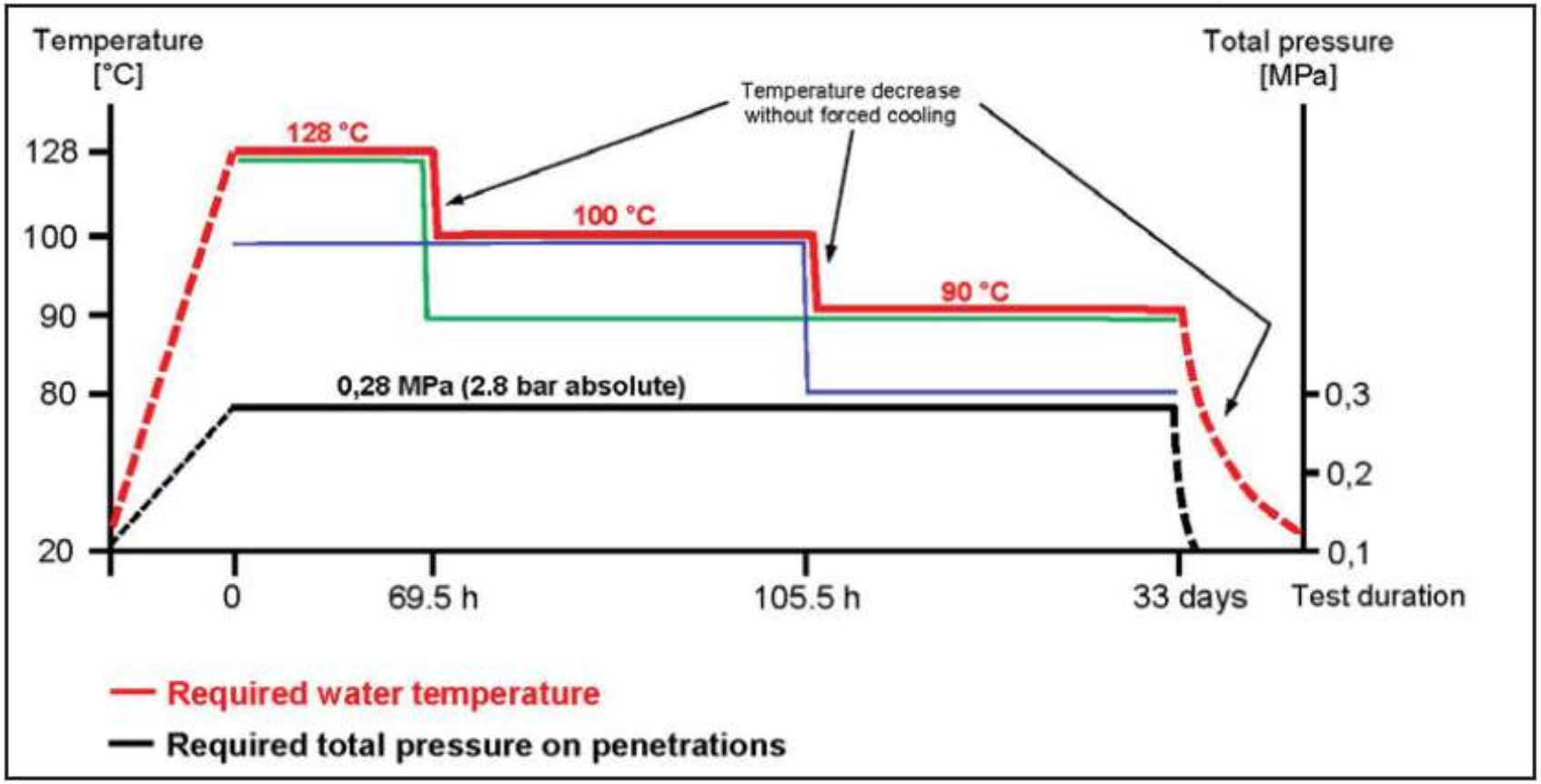
Combined Post-LOCA/Severe Accident profile



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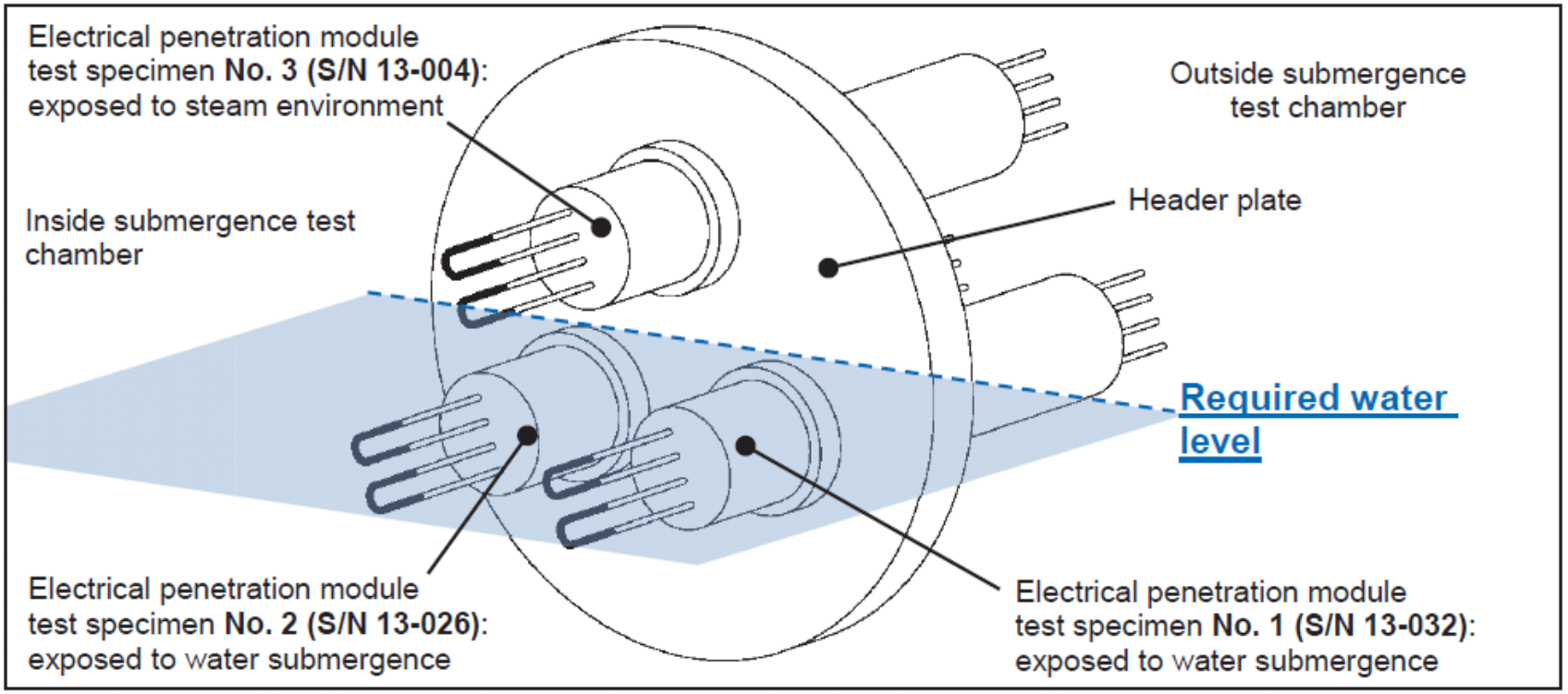
Combined Steam and Submergence test



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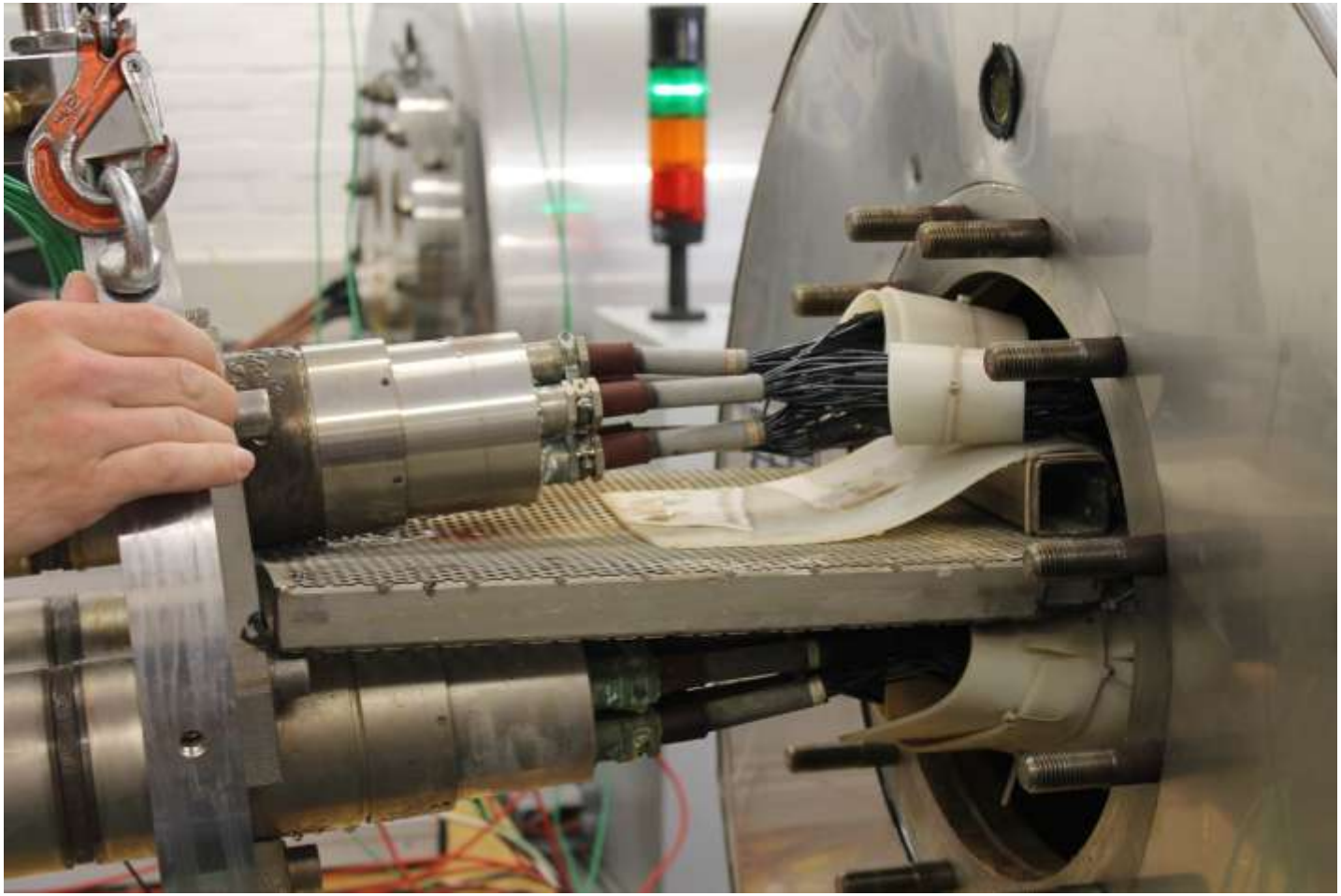
Problem started to occur at submergence

- **Fluctuating leakage current after submergence**
- **For 660 V the problem started immediately after submergence**
- **For 250 V the first problem occurs later**

Test specimens after Post-LOCA



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Test specimens after Post-LOCA

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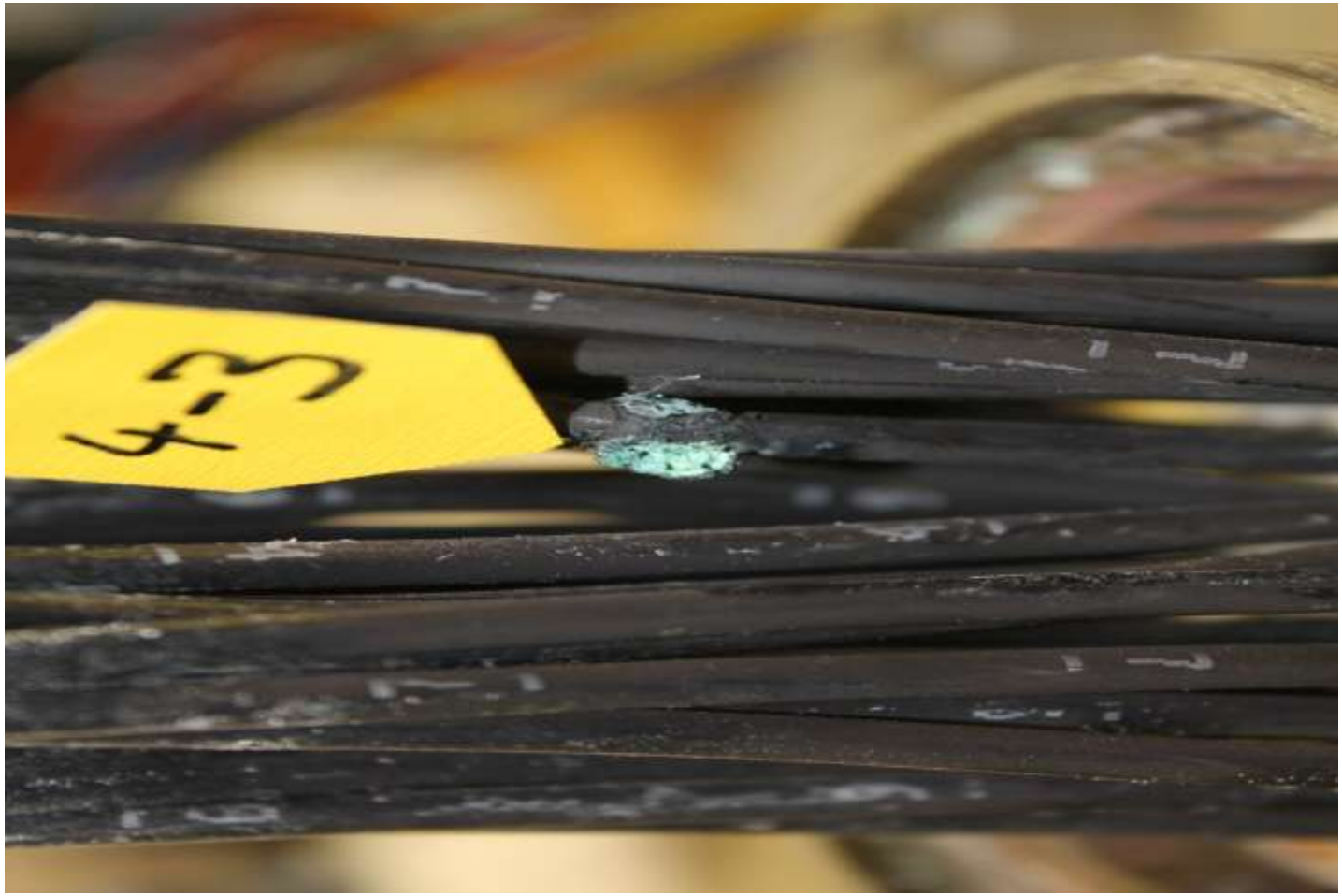
Test specimens after Post-LOCA



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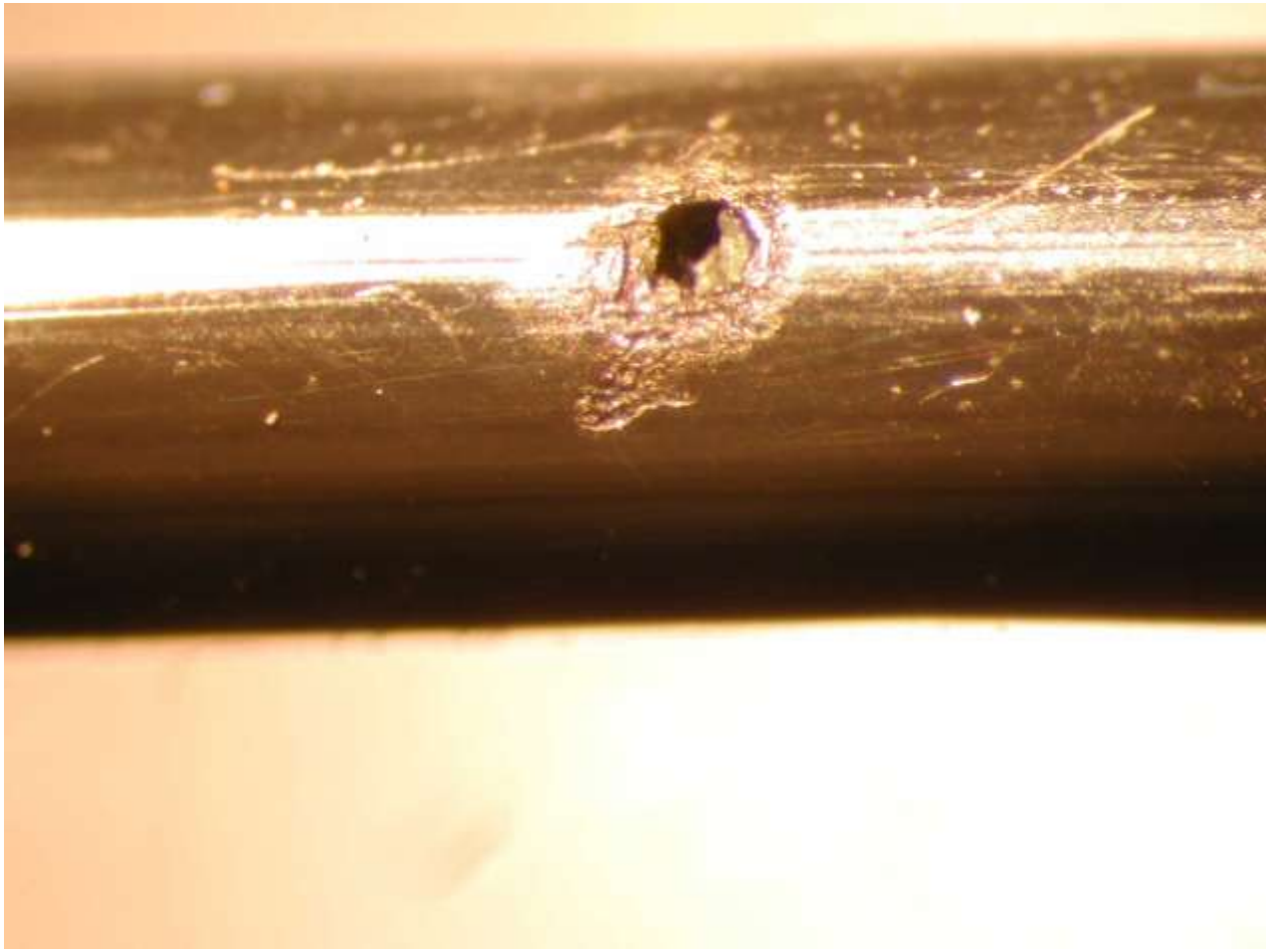
Trying to find the reason to failure

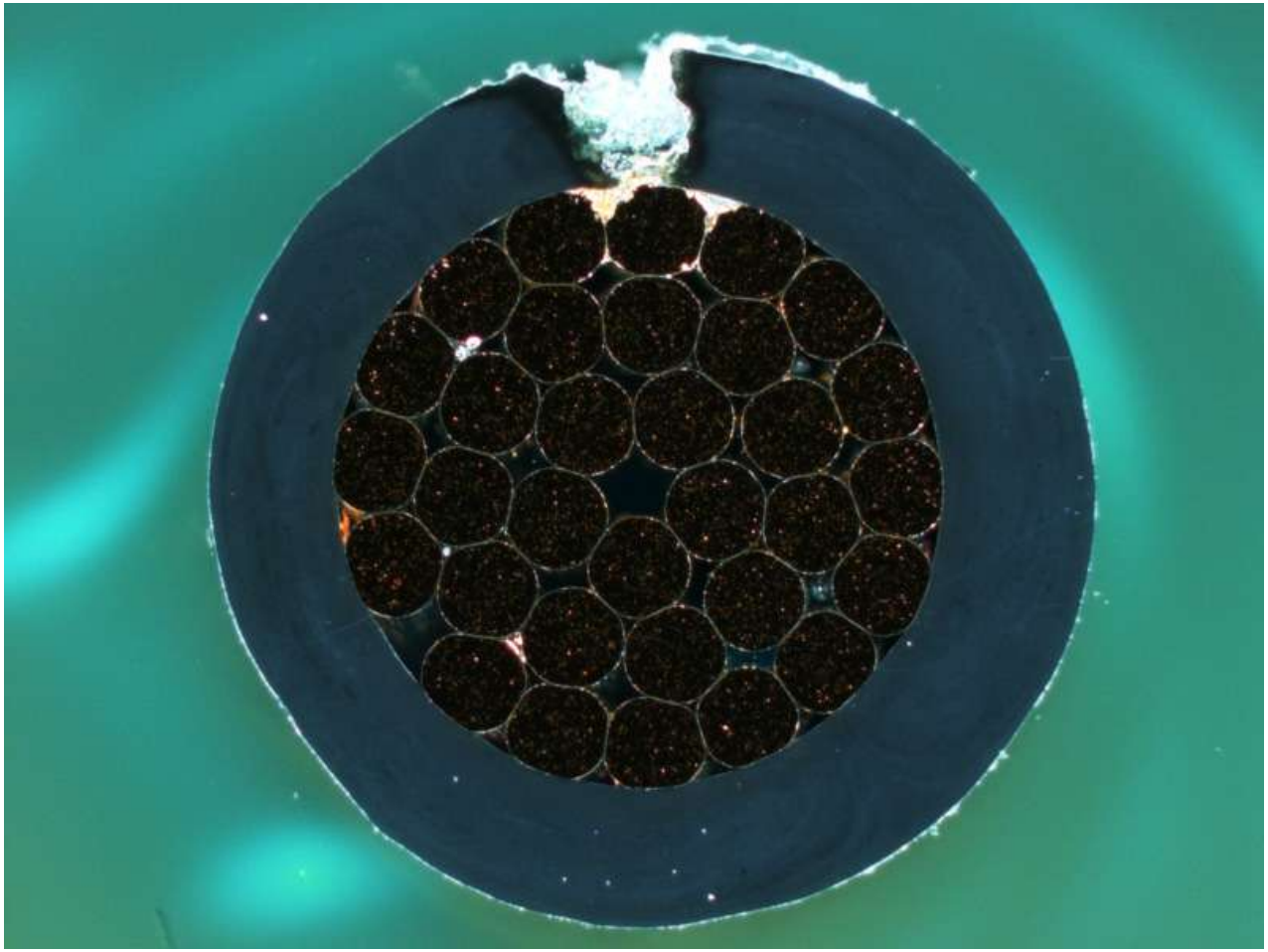
- **Were carbon black the reason to the problem?**

  -Original qualification was on insulation without any pigment

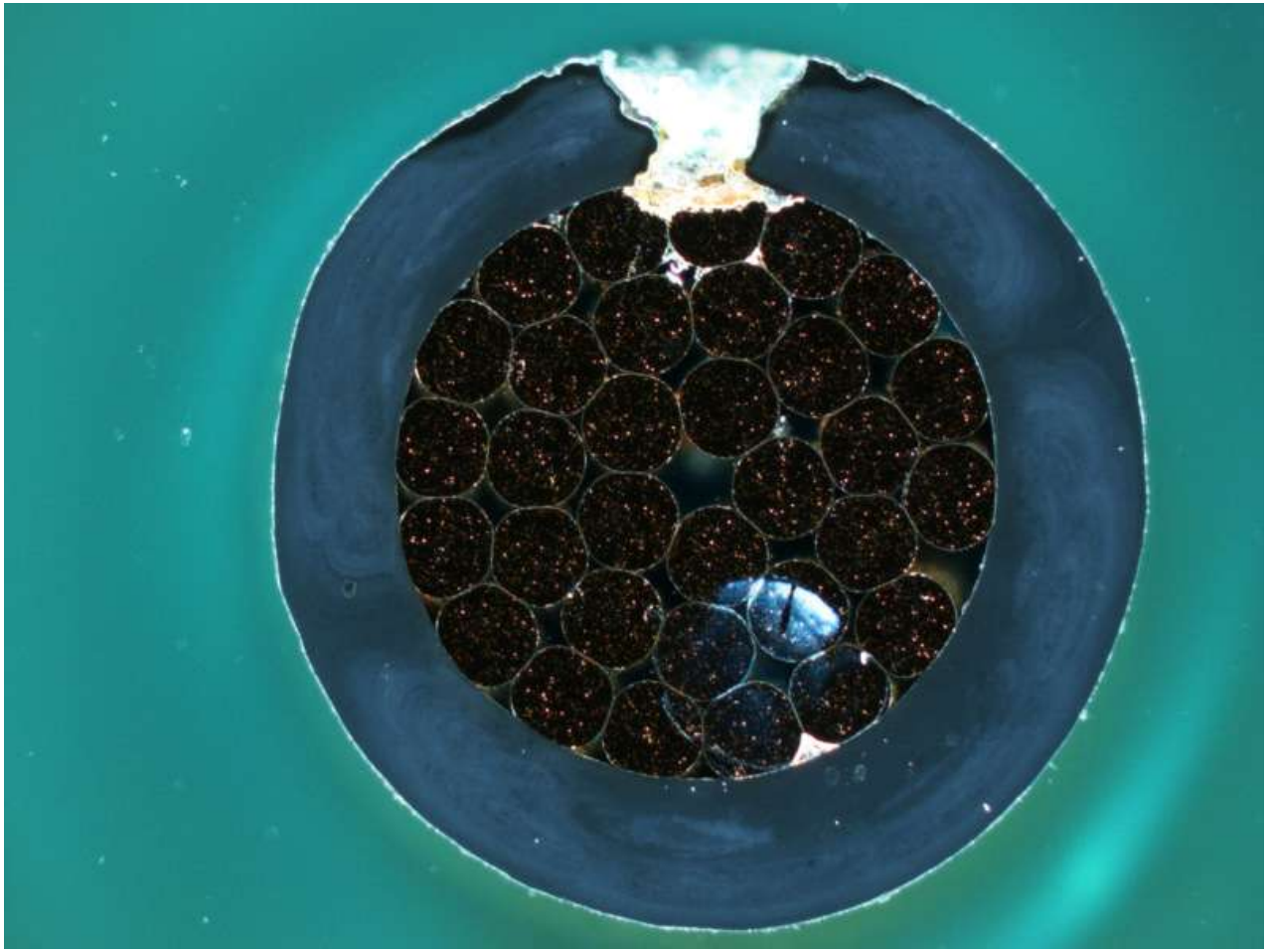
Result of LOCA test with submergence on PEEK insulated wires.



PEEK with Carbon Black pigmentation



PEEK with Carbon Black pigmentation



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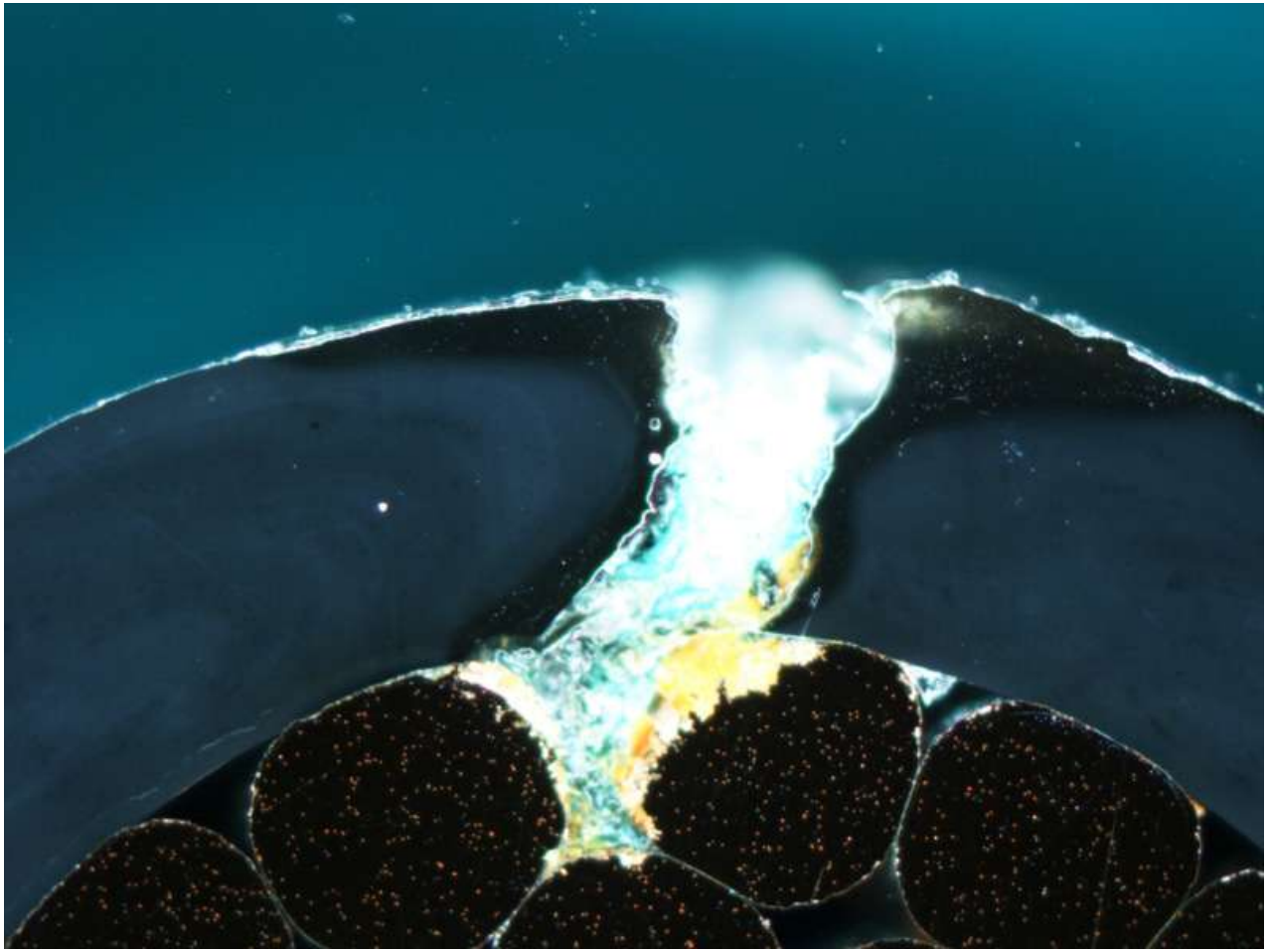
PEEK with Carbon Black pigmentation



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Test on insulation with and without different types of pigments

White, black and naturally coloured insulted wire

What will happen???

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PEEK without any pigmentation

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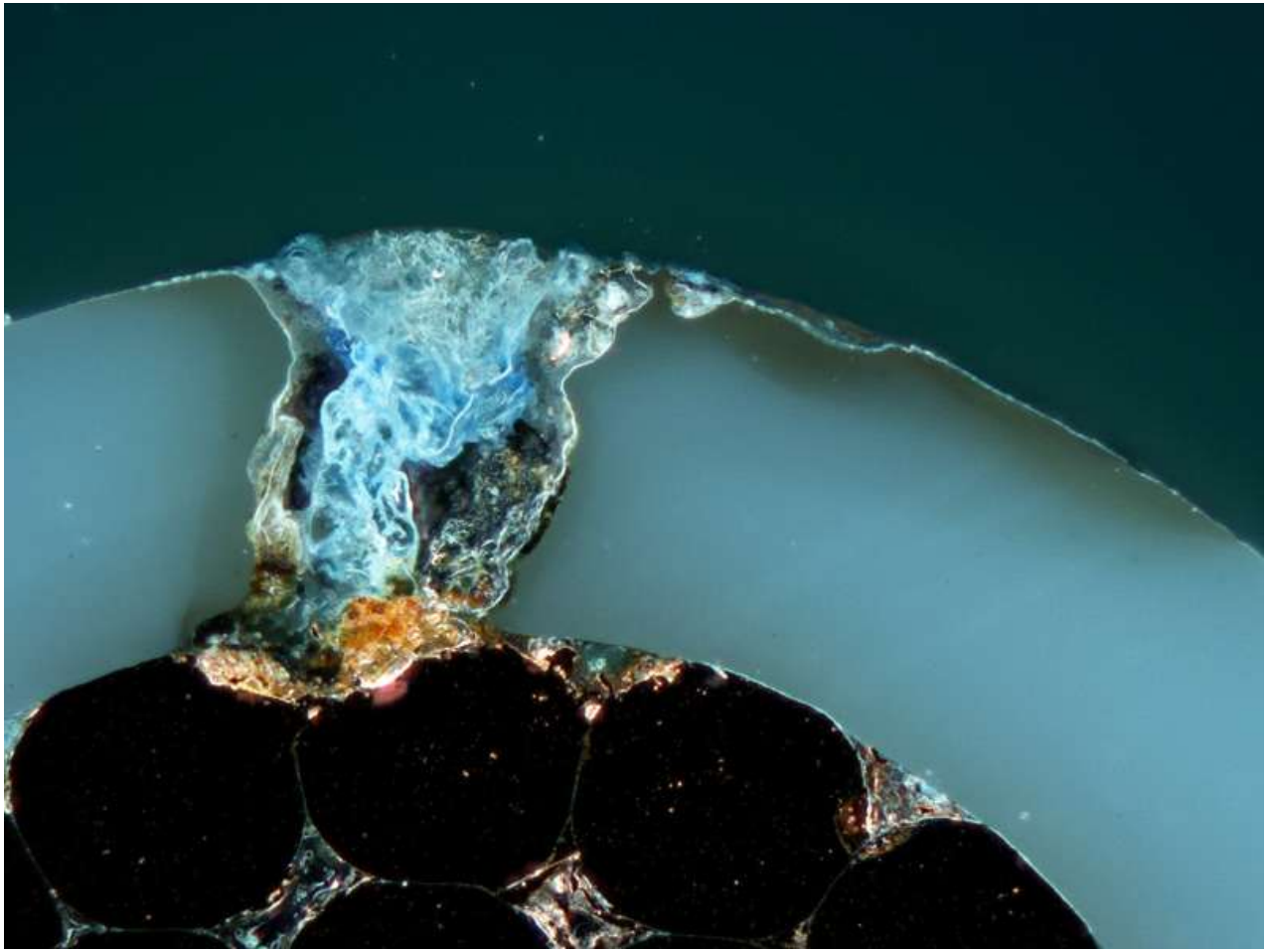
PEEK without any pigmentation



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Test together with the cable manufacturer

- **Samples was 10 single wires in each test Submerged in water**

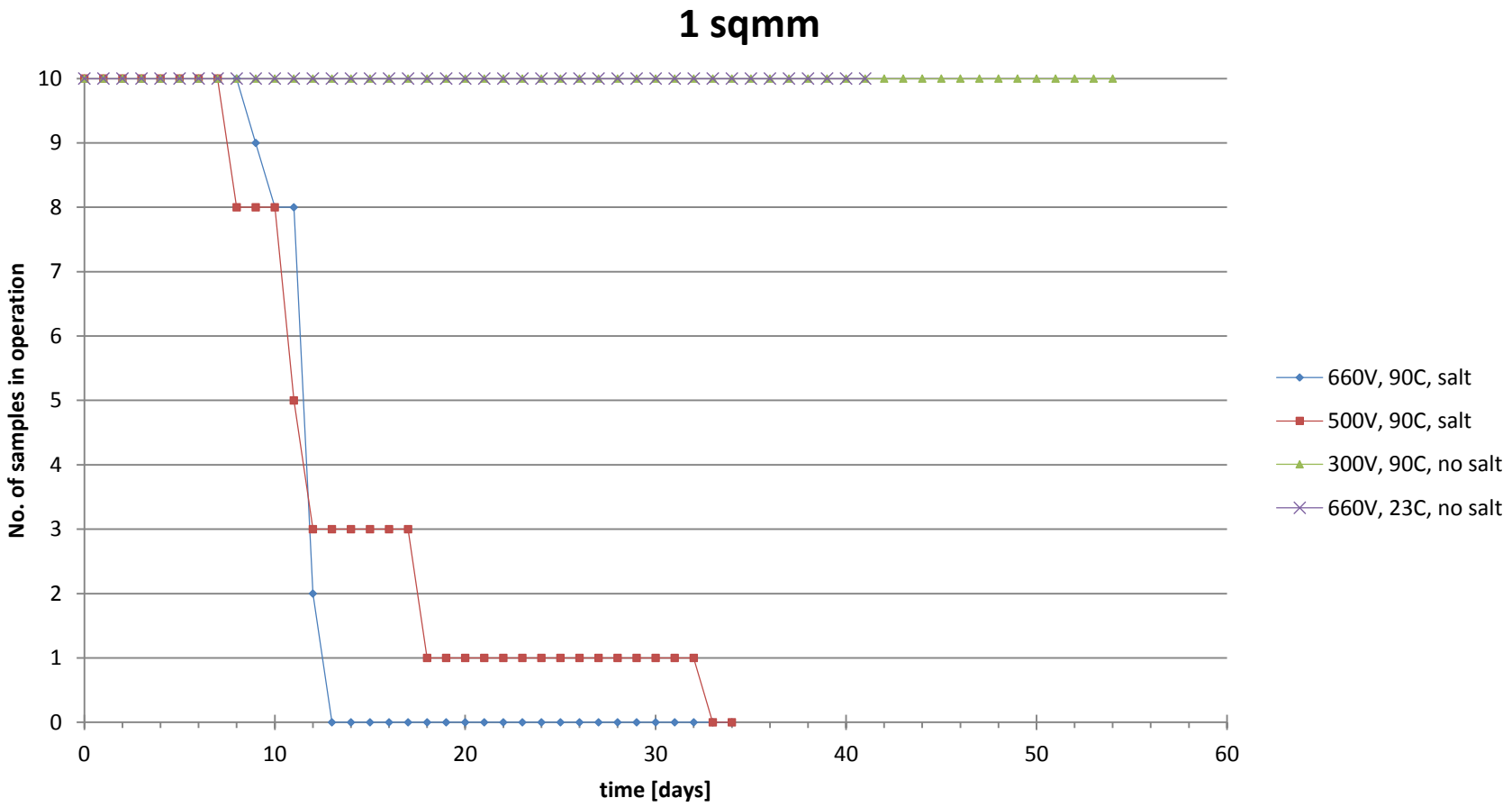
  -Different sizes 1, 2.5, 6 sqmm

  -Different voltage level 300-660 VAC

  -Different conductivity in the water

  -Different temperature in the water

  -Amorphous and Crystalline phase of the PEEK material



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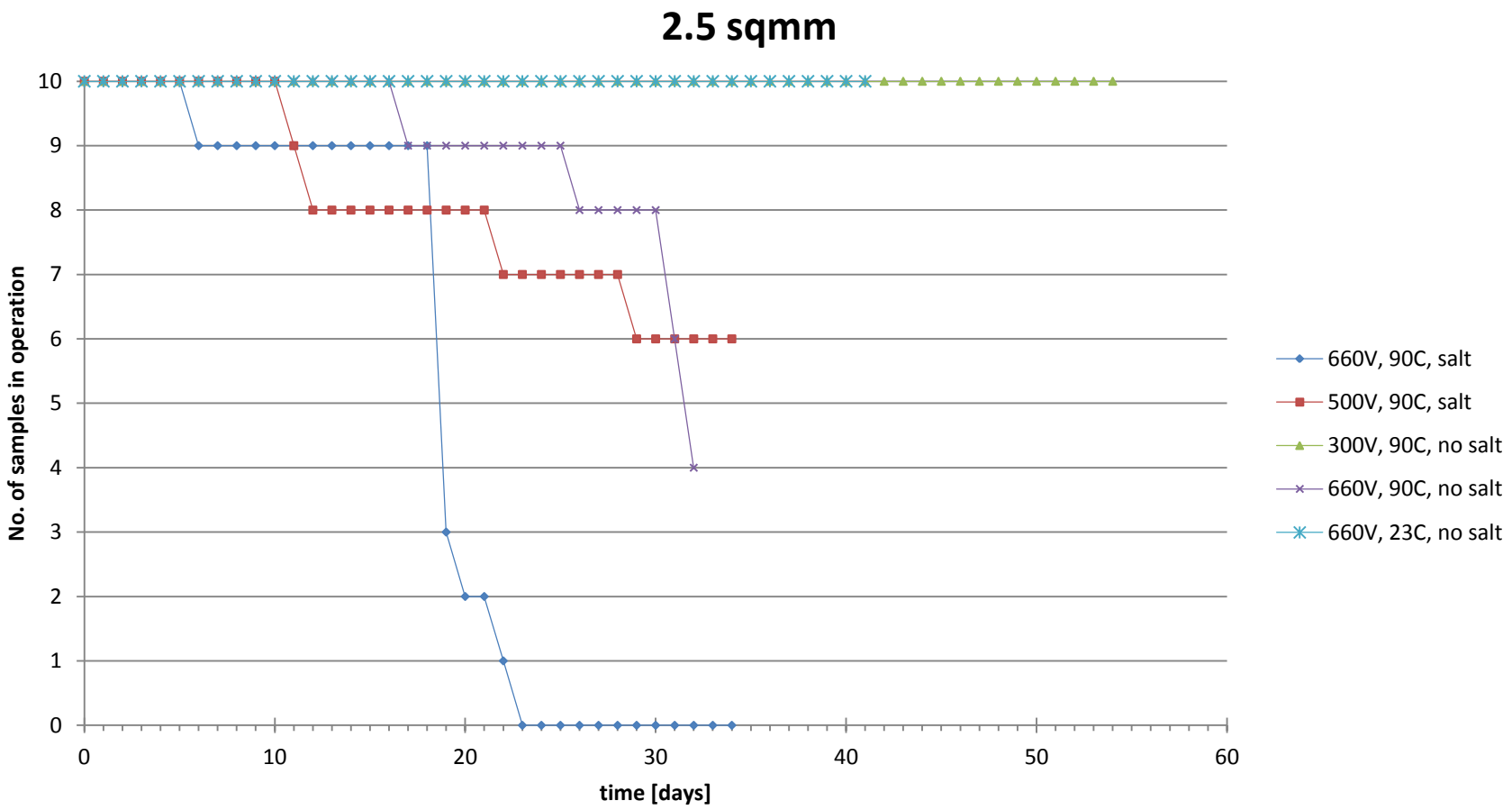

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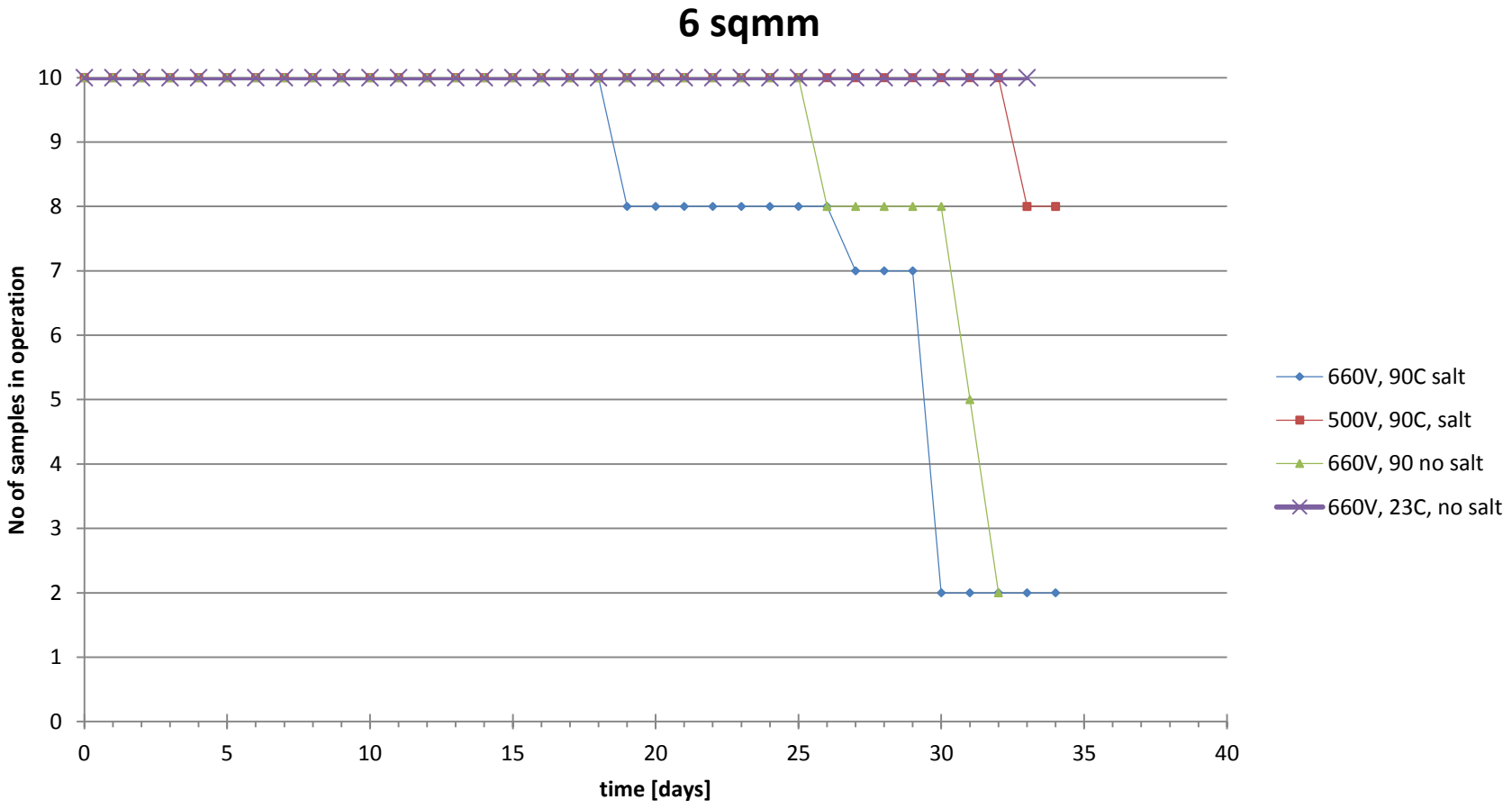

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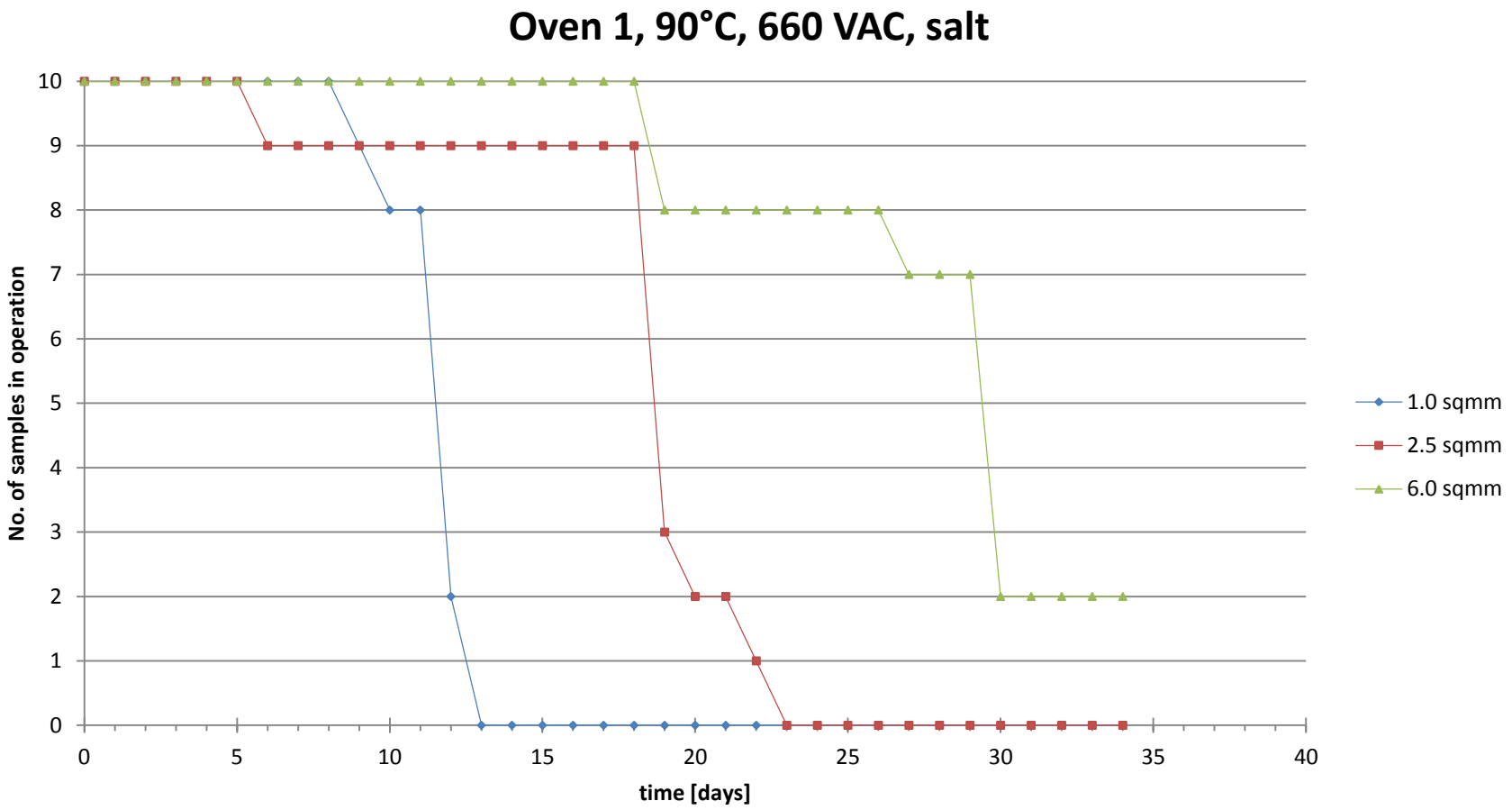

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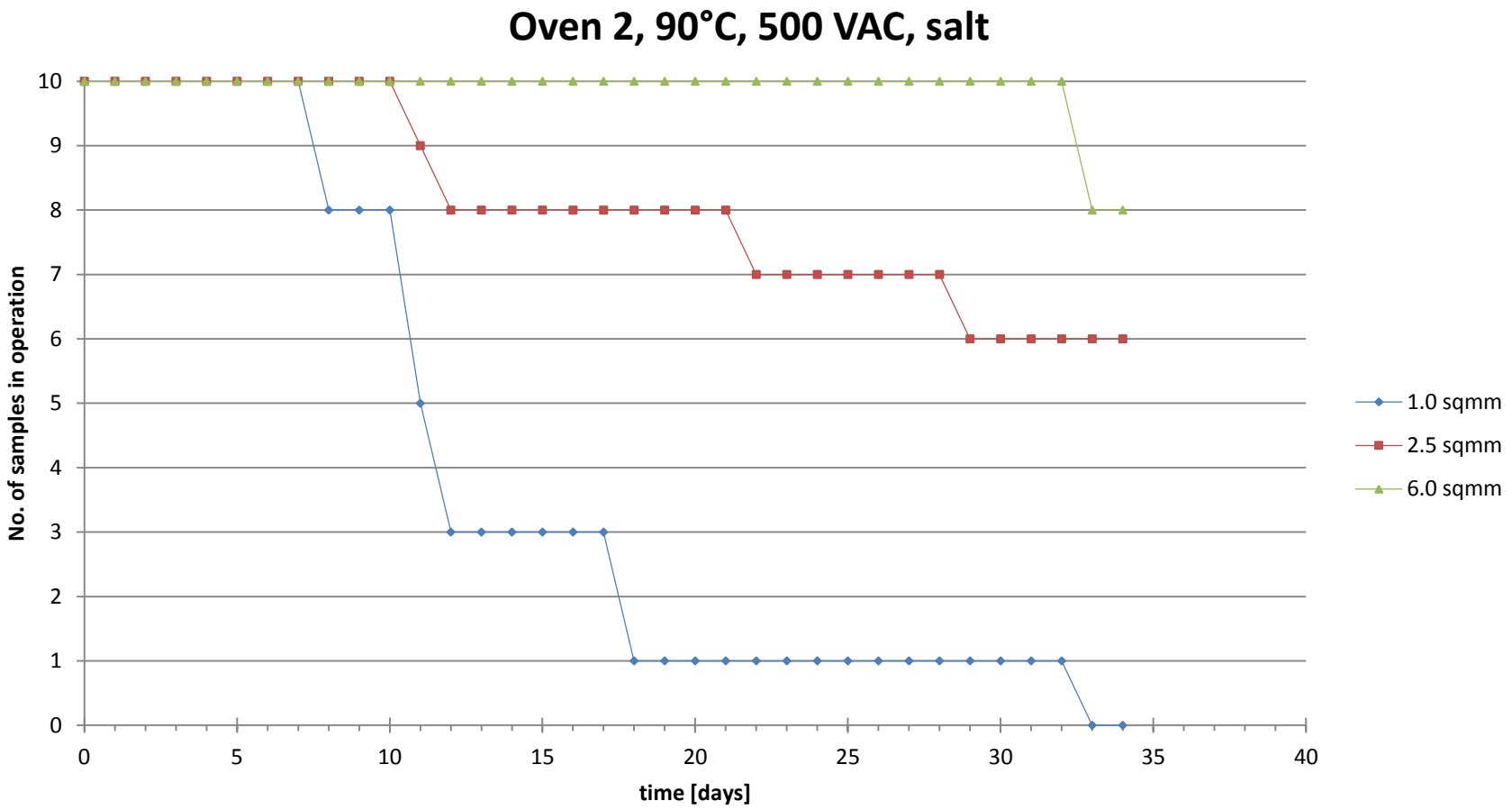

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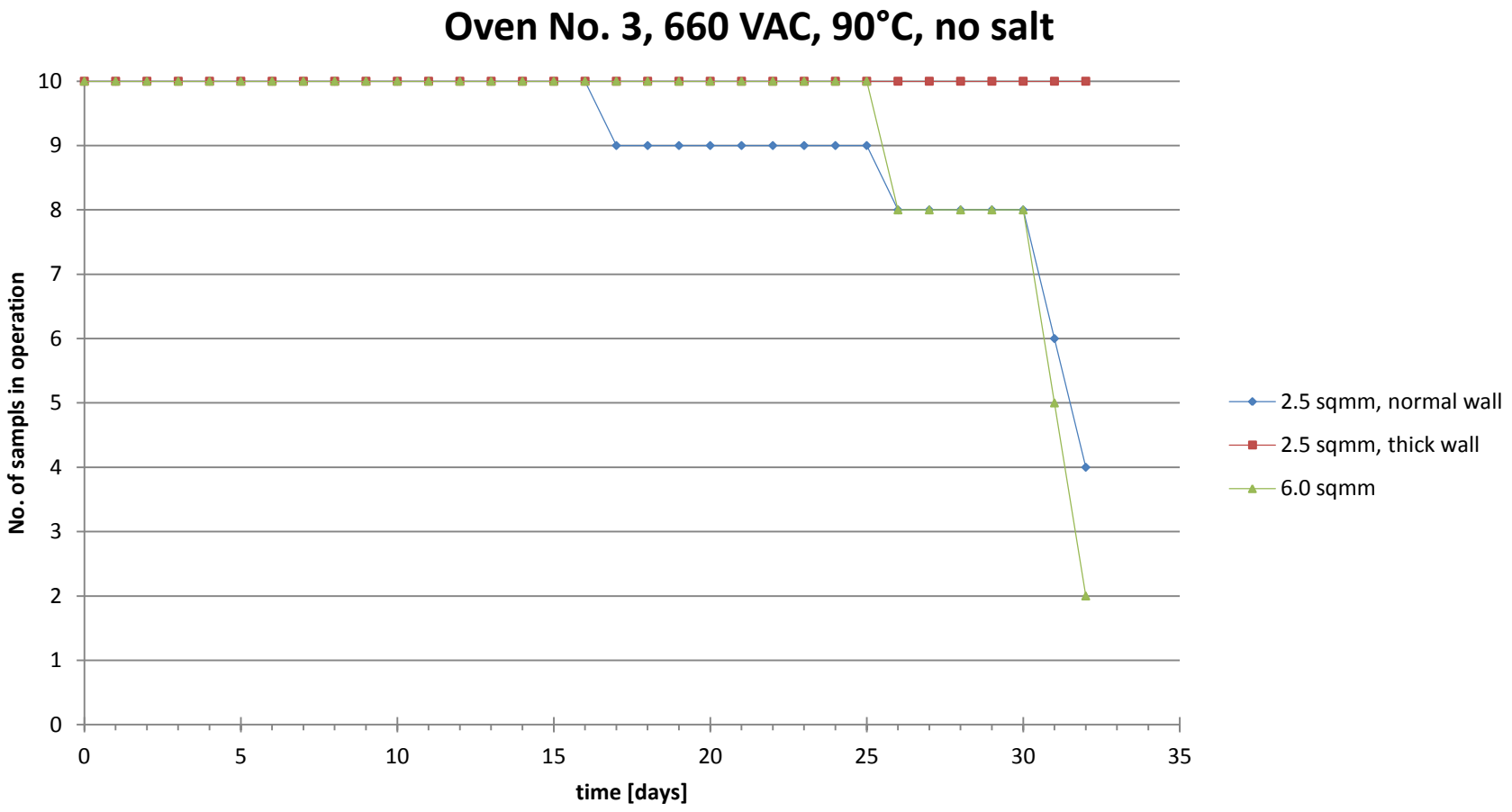

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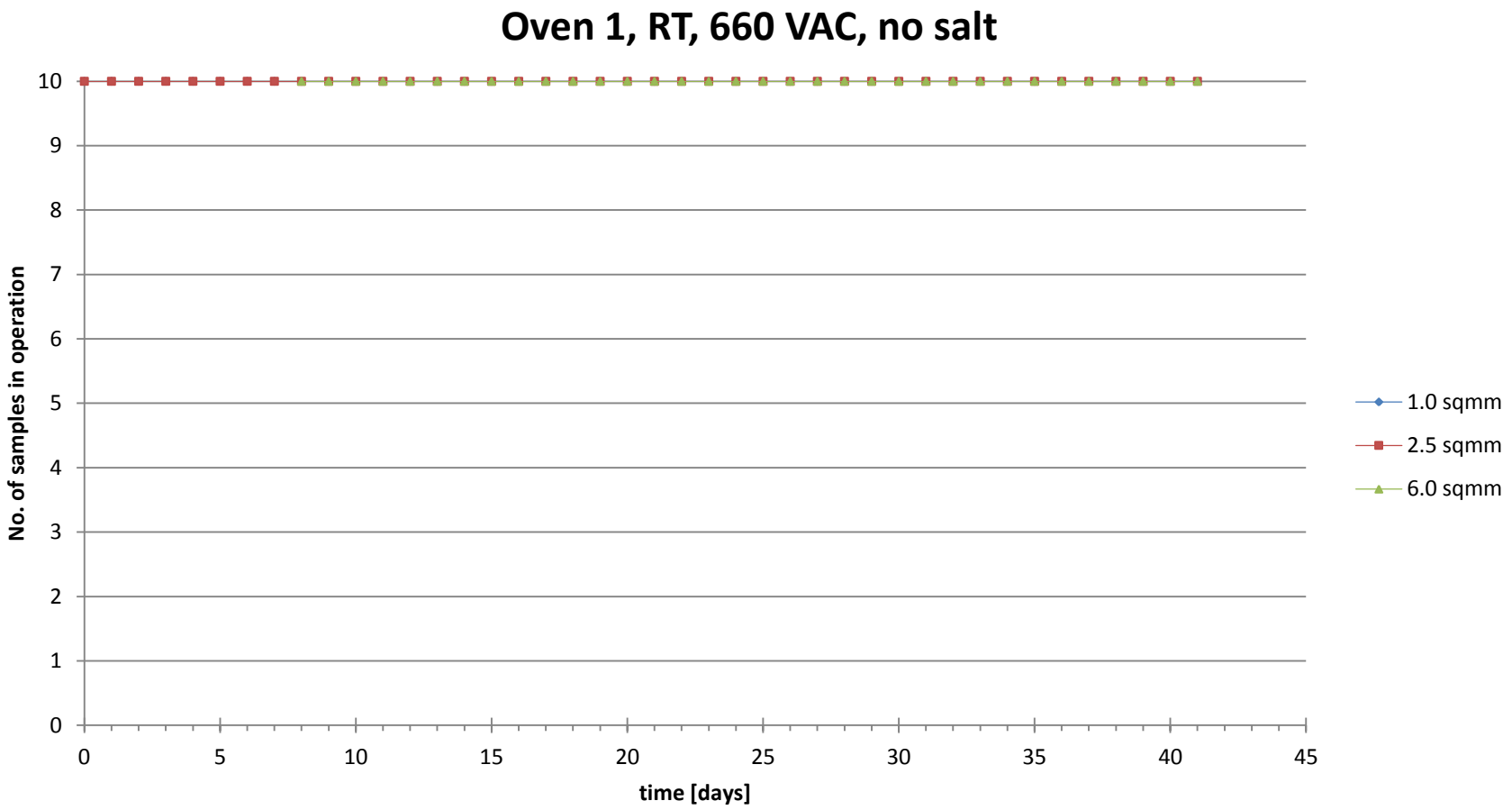

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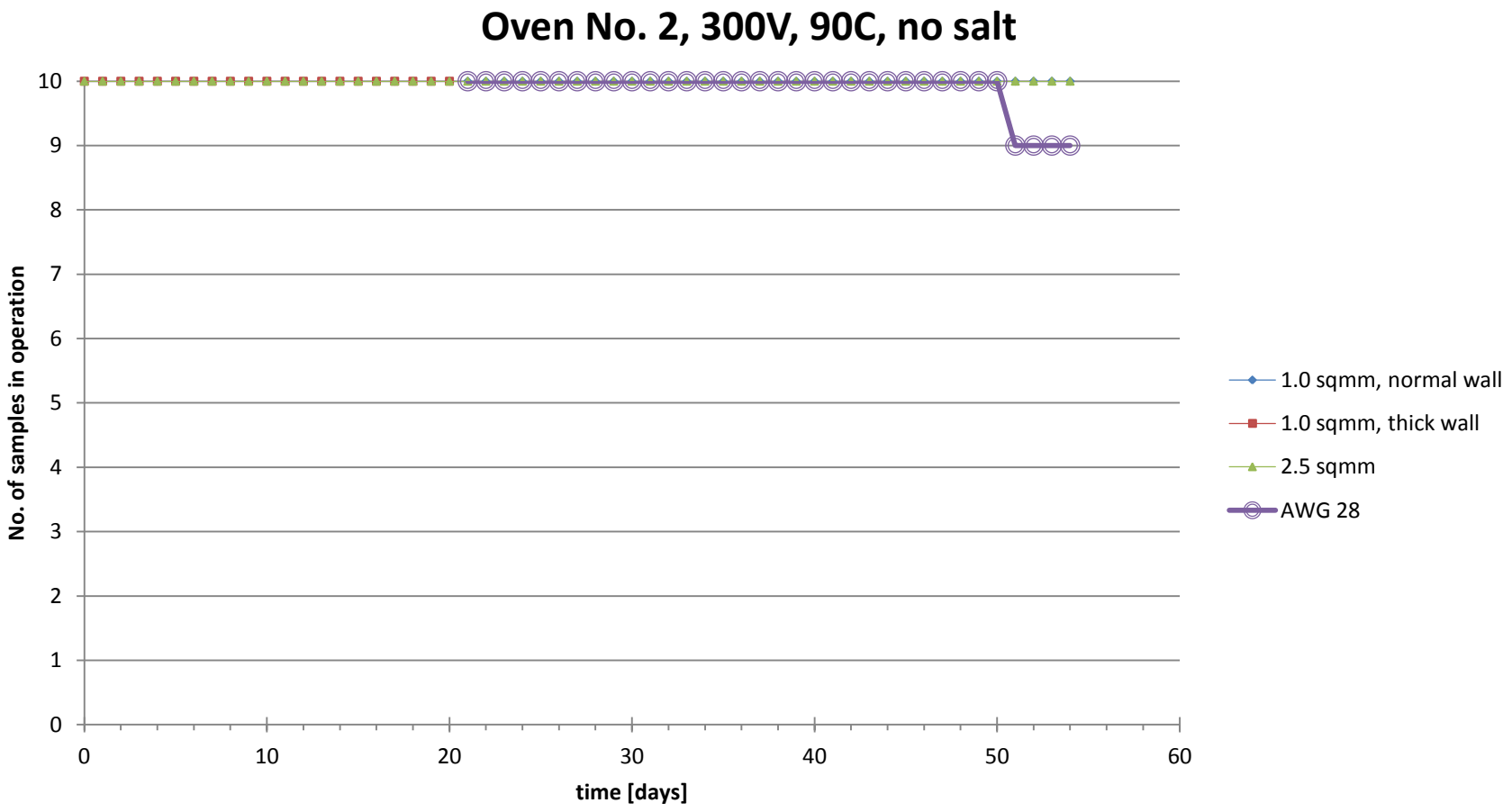

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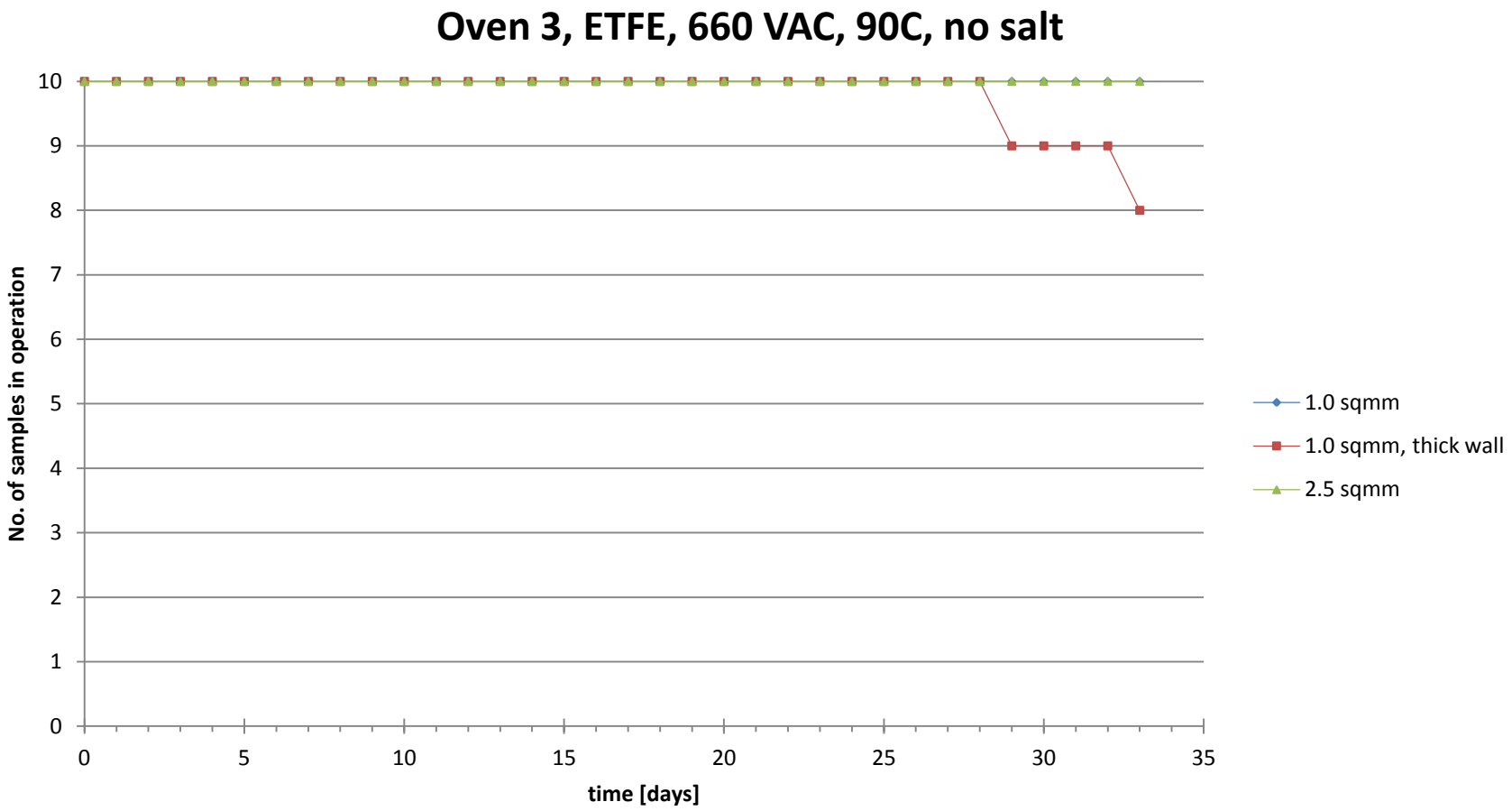

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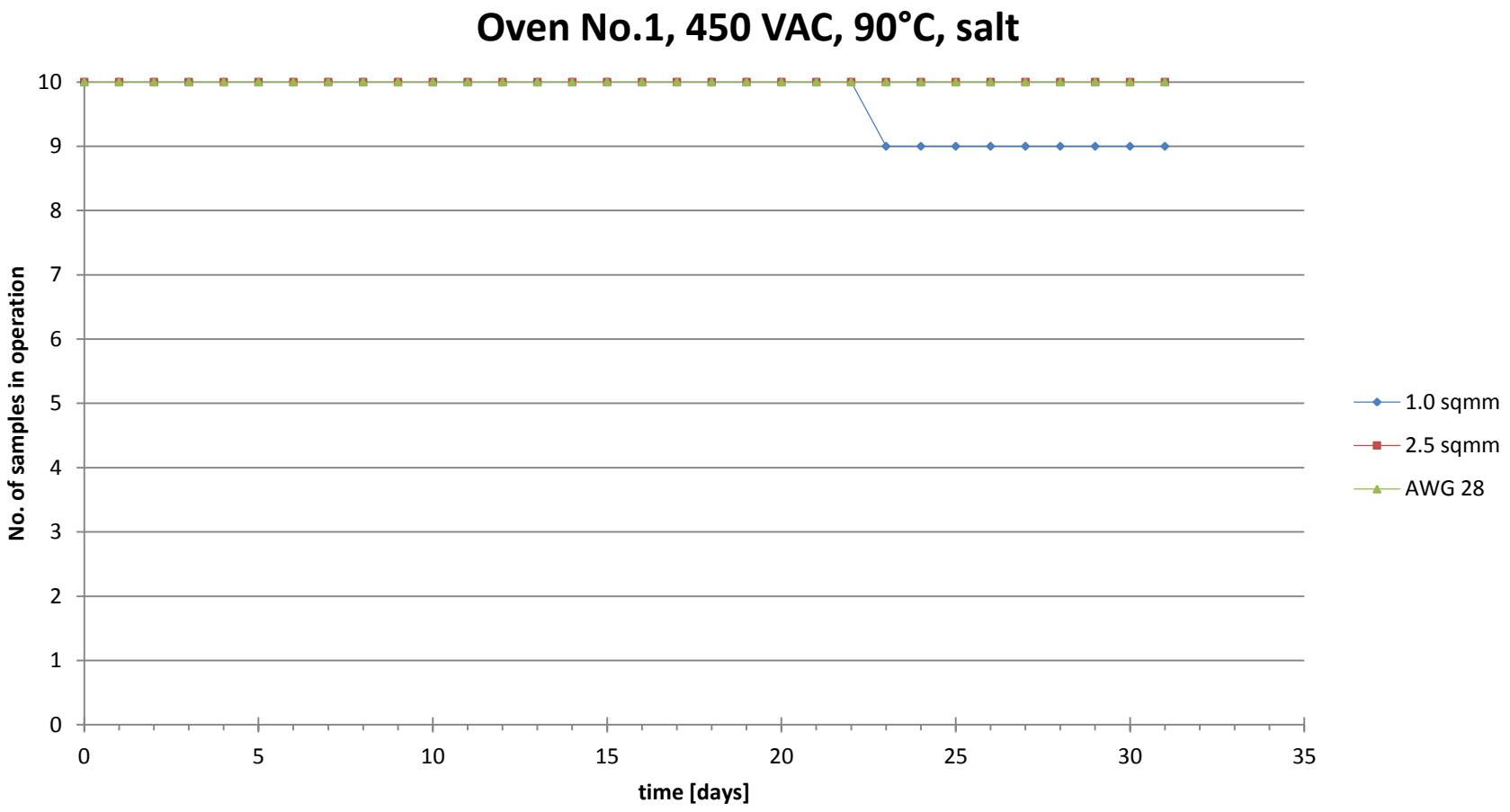

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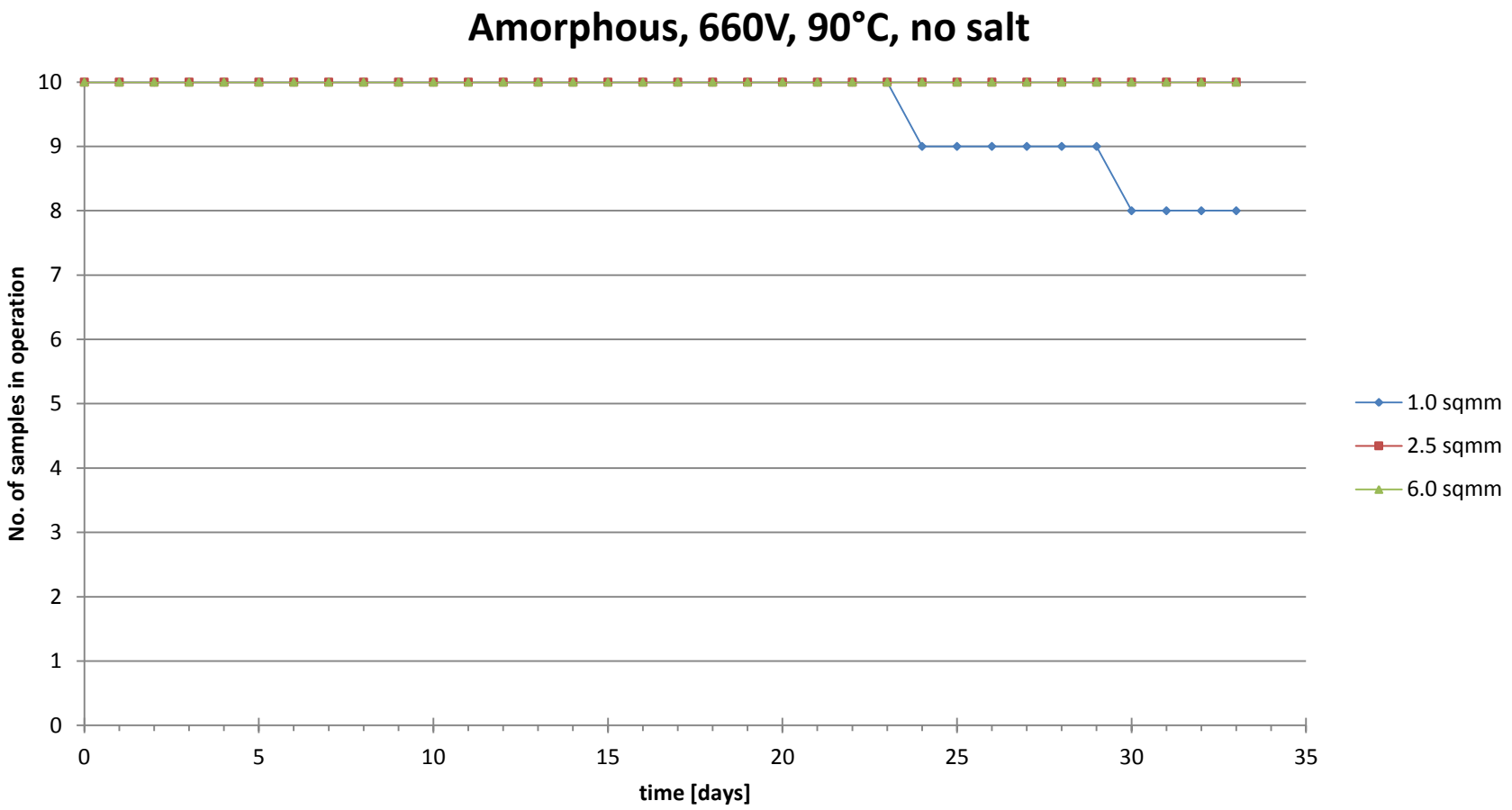

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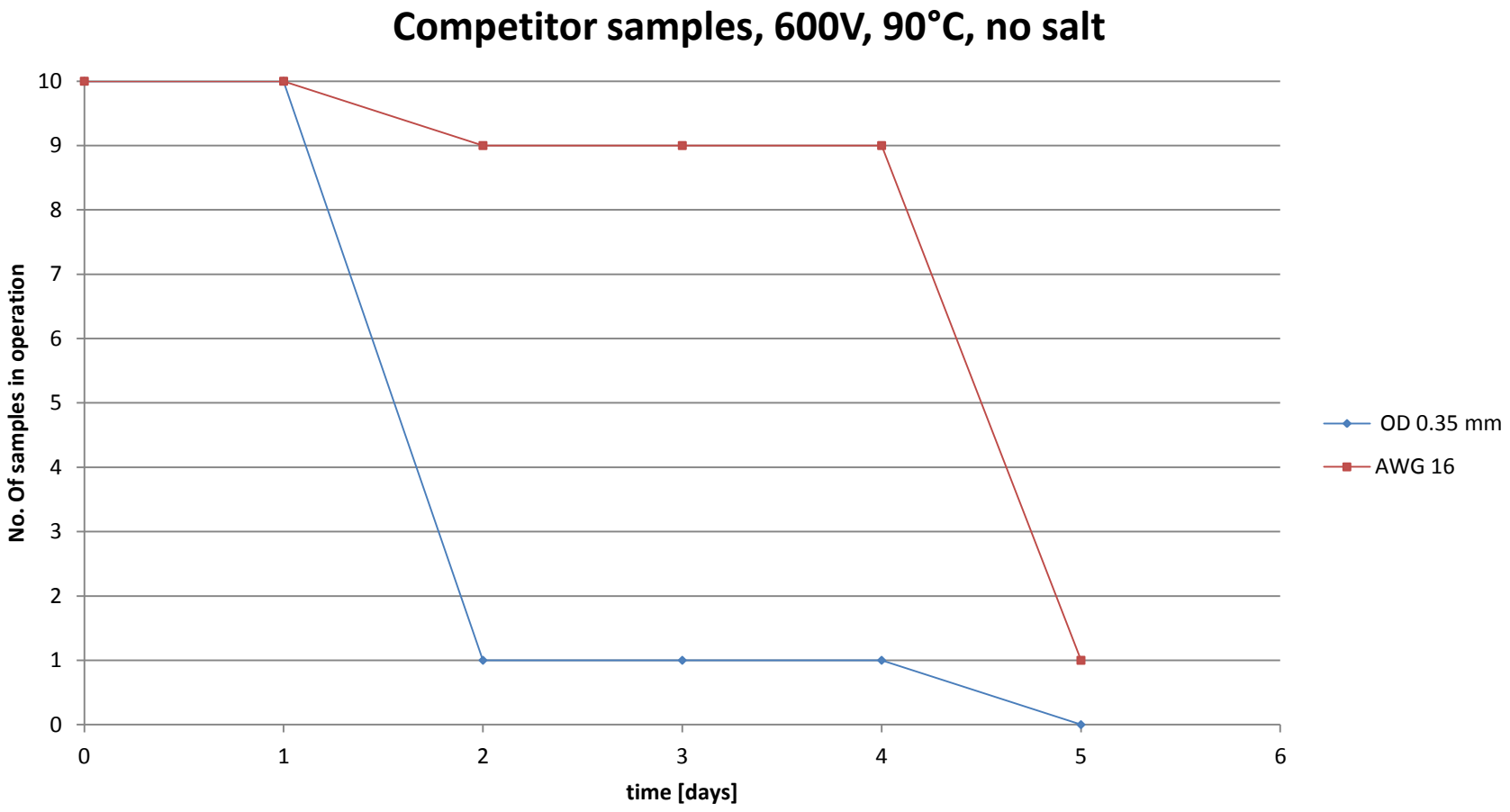

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Conclusions

- **I didn’t know enough about PEEK when starting this work**
- **I had a general assumption that steam atmosphere is tougher for electrical component than submergence**
- **Focus on Carbon Black made the project lose time and money**

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Status today

- **The problem is highly voltage dependent**

  -Safe level below 250 VAC??

- **The thickness of the insulation is an important factor**

  -There will be future test, too thick insulation gives too stiff wire

- **Amorphous PEEK handle the submergence better than crystalline PEEK**

  -PEEK will be crystalline during an LOCA event

- **PEEK is no alternative for power application?**
  PEEK could be a alternative for I&C application?

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Future questions

- Similar problem with thin insulation material (PEEK, ETFE, xxx)?
- Do we have “submergence” condition in other applications inside containment?
- Same damage regardless 660 VAC and 660 VDC?
- Overpressure during LOCA simulation?

The End/Questions

Its very interesting

to work with

Environmental Qualification

(Real Life supersede planning)

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