Study Committee D1

Materials and Emerging Test Techniques

Paper D1-PS2-10400

DIELECTRIC PERFORMANCE OF ARAMID PRESSBOARD IN INSULATING LIQUID

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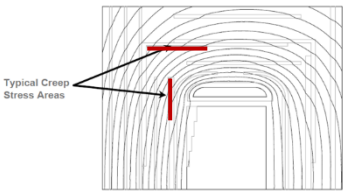
Motivation

Detailed dielectric characterization of aramid-based insulation systems is important in the design of power transformers with rated voltages beyond 100 kV and reaching 400 kV class, or with power ratings exceeding 100 MVA. For two reasons:

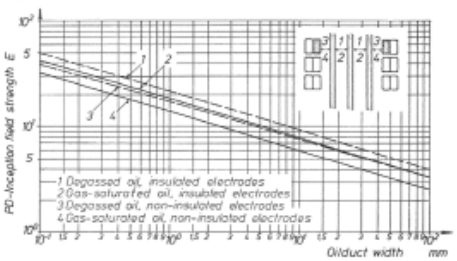
1. To ensure there are no hidden risks associated with use of aramid insulation at specific field strengths.
2. To allow optimization of dielectric design for aramid-based insulation systems vs. cellulose-based ones.

Approach

- A dielectric study was performed to characterize the creep strength performance of high-density aramid pressboard in comparison to high-density cellulose pressboard in mineral oil.
- The test program was based on the work previously performed on high-density cellulose pressboard, which has become the reference for later studies and comparisons.
- The test arrangement included a unique electrode configuration incorporating both paper and high-density board in a geometry that eliminates the wedge effect and concentrates the highly non-uniform electric field along the interface between the liquid and solid on the pressboard surface.



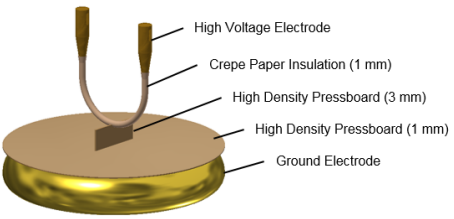
Examples of dielectric creep stress



Weidmann curves for strength of oil gaps

Test program

Test device configuration:



Insulation systems tested:

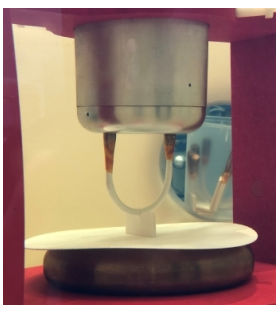
1. 100% Nomex® insulation system
   - Nomex® crepe paper,
   - 3 mm Nomex® 994 spacer,
   - 1 mm Nomex® 993 ground insulation disk.
2. 100% cellulose insulation system
   - Cellulose crepe paper,
   - 3 mm T-IV spacer,
   - 1 mm T-IV ground insulation disk.

Test voltage:

- 60 Hz AC Step-by-Step per ASTM D149; 5 kV steps with PD measurements,
- Full-wave negative lightning impulse per ASTM D3426; 25 kV steps

Creep length: 10, 20, and 35 mm

Number of tests: 20 for each voltage type and creep length.



Specimens placed into test fixture (Nomex® insulation system)

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Test results

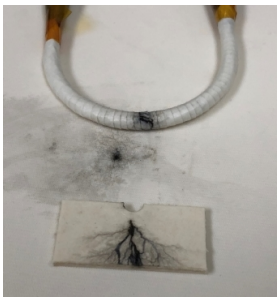


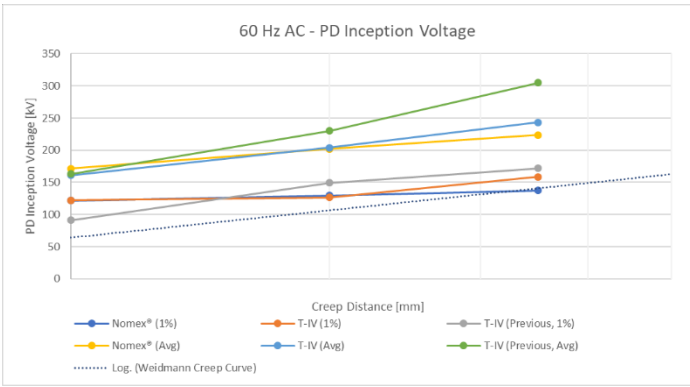
Illustration of creep breakdown effects on Nomex® insulation system (left) and cellulose insulation system (right)

60 Hz AC - PD inception summary

Creep Length [mm]	Quantity of Tests with PD Inception Prior to Breakdown	
	Nomex	T-IV
10	1	2
20	6	2
35	1	0

60 Hz AC - Test results based on PD inception voltage

60 Hz AC - PD Inception Voltage						
Creep Length [mm]	Weibull Analysis (1% Probability)			Average		
	Nomex® (1%)	T-IV (1%)	T-IV (Previous, 1%)	Nomex® (Avg)	T-IV (Avg)	T-IV (Previous, Avg)
10	122	122	91	171	161	163
20	130	127	149	202	204	230
35	138	159	172	224	243	305



AC results discussion

- For failure determination a PD inception level of 2 pC was used. If no PD was detected, then the values of breakdown were recorded.
- Majority of test specimens resulted in the breakdown occurring without prior PD inception.
- The results are plotted for both tested insulation systems (Nomex® and T-IV board) together with a reference historical data. For both insulation systems, at the creep distance of 20-35 mm, the tested PDIV is lower than historical creep data for cellulose board. This might indicate some difference in sample construction or test method.
- The results for both systems are very similar at the same electrode distances, which indicates that the voltage stress calculations (equipment design criteria) for cellulose could be used for aramid, too.

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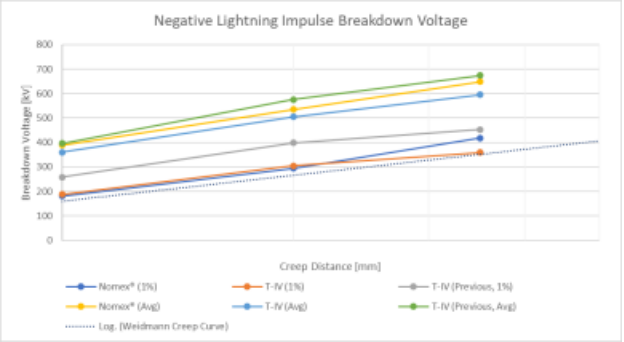
(continued)

Negative wave lightning impulse breakdown test results

Negative Lightning Impulse Breakdown Voltage						
Creep Length [mm]	Weibull Analysis (1% Probability)			Average		
	Nomex® (1%)	T-IV (1%)	T-IV (Previous, 1%)	Nomex® (Avg)	T-IV (Avg)	T-IV (Previous, Avg)
10	181	188	259	390	380	398
20	294	305	399	535	505	576
35	419	380	453	649	595	674



Impulse results discussion

- The results are plotted for both tested insulation systems (Nomex® and T-IV board) together with a reference historical data. For both insulation systems, the 1% probability curves are again below the historical creep data for cellulose board. This might confirm some difference in sample construction or test method.
- The results for both systems are very similar at the same electrode distances, which indicates that the voltage stress calculations (equipment design criteria) for cellulose could be used for aramid, too.

Impact on transformer design rules

- There is no significant difference in dielectric creep performance of aramid-based insulation system as compared to the cellulose-based insulation system.
- If the conservative approach from this current study was used, the acceptable design creep stress at higher distances might need to be reduced to ensure desired design confidence (for both tested insulation systems).
- If one assumes that the current design rules are well proven by numerous successful transformer designs, there is no need for adjustment, and the current rules are safe enough for continued application. The design criteria for the creep strength of cellulose pressboard in mineral oil available today can be used for high density aramid pressboard, as well.

Conclusions

- The historical test method developed by Weidmann can be applied to aramid insulation materials.
- With both tested insulation systems giving similar results, it could be concluded that the values lower than historical results should rather be associated to the test methodology used in this test program or specific sample design or make, rather than the actual different performance of the currently tested materials vs. the materials tested in the past.
- This emphasizes the necessity of comparative testing of different insulation systems in the same test program. This proves the right approach taken in this test program when both systems were tested in parallel.
- There is no significant difference in dielectric creep performance of aramid-based insulation system as compared to the cellulose-based system. It is suggested to use the same creep strength design criteria for both systems.
- It is desired to develop design guidance for creep strength for both tested insulation systems in esters. That is the aim of the authors future research.