IEEE Aging Study

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ILSC

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- Purpose of the Study
- Aging Criteria from IEEE
- Distribution Transformer Sealed Tube Test
- Power Transformer Sealed Tube Test
- Dual Temperature Sealed Tube Test

Purpose of the Study

- The recently approved IEEE C57.100 established a new relative aging procedure for sealed tube testing to establish life curves.
- This procedure requires evaluation of the industry proven system (mineral oil, upgraded kraft paper and nitrogen blanket) along with a candidate system.
- This test is designed to provide a first attempt at conducting the industry proven system test (control) for each of the three possible sealed tube tests. This test could then be compared to the results seen by other testing laboratories. Eventually an expected “control test” could be added to the annex of future revisions of IEEE C57.100
- Additionally, due to the novel nature of the new test method, if any issues come up, this could be established early and perhaps an addendum or revision to the new method could be completed early in the process (or as part of a new IEC method which is under development (IEC 62332-2).

IEEE Aging Criteria

Table A.1—Aging times and temperatures for three-point aging

Insulation System	Expected Increase in Thermal Rating	Aging Time Number 1 4434 hours	Aging Time Number 2 1316 hours	Aging Time Number 3 424 hours
Industry Proven System		150 °C	165 °C	180 °C
Candidate System	10 °C	160 °C	175 °C	190 °C
	20 °C	170 °C	185 °C	200 °C
	30 °C	180 °C	195 °C	210 °C
	40 °C	190 °C	205 °C	220 °C
	50 °C	200 °C	215 °C	230 °C
	60 °C	210 °C	225 °C	240 °C

Table B.1—Sealed tube materials ratios

	Transformer Type	
Material	Power	Distribution
Insulating Liquid	200 cm^3	200 cm^3
0.05 to 0.10 mm Conductor Insulation	6.4 cm^3	
0.13 to 0.38 mm Layer Insulation		11.2 cm^3
1.00 to 3.00 mm Low Density Pressboard		1.2 cm^3
2.00 to 8.00 mm High Density Pressboard	16.4 cm^3	
Ratio – Liquid to Solid	8.8 to 1	16.3 to 1

Industry Proven System Tests

- Control test for dual temperature, power transformer and distribution transformer sealed tube tests (three points per Table A.1 in Annex)
- Follow up testing at shortest time (highest temperature) to investigate pressure effects and to add evaluation of wire enamels.
- Both sealed tube tests gave similar results (higher liquid to solid ratio somewhat better), however pressure seems to have a major effect.
- Dual temperature testing was similar to that seen with DuPont Weidmann study (i.e. near 50% retention).

Testing Results

	Expected	Aging Time	Aging Time	Aging Time			
	Increase in	Number 1	Number 2	Number 3			
Insulation System	**Thermal Rating**	4434 hours	1316 hours	424 hours			
Industry Proven System		150°C	165°C	180°C			
							Second Set
		Aging Time	**Aging Time**	**Aging Time**			**7 psig**
		Number 1	**Number 2**	**Number 3**	**Overall**		**Number 3**
Insulation System		4434 hours	1316 hours	424 hours	**average**		**424 hours**
Sealed Tube - Distribution	Test One		9.91	12.00	10.96		22.14
16.3 liquid to solid ratio	Test Two		20.48	4.24	12.36		26.60
	Test Three		13.18	4.68	8.93		28.84
	Average Result		14.52	6.97	10.75		25.86
		4434 hours	1316 hours	424 hours	average		
Sealed Tube - Power	Test One		5.22	5.97	5.60		
8.8 liquid to solid ratio	Test Two		6.30	7.14	6.72		
	Test Three		6.84	6.89	6.87		
	Average Result		6.12	6.67	6.39		
		4434 hours	1316 hours	424 hours	average		
Dual Temperature	Test One		50.41	41.74	46.08		
with Oil Temperature	Test Two		56.68	45.52	51.10		
of 105C	Test Three		48.27	51.57	49.92		
	Average Result		51.79	46.28	49.03		

Testing Results part 2

	Percent Tensile		
	165C	180C	Avg
Sealed Tube Power	6.12	6.67	6.39
Sealed Tube Distr.	14.52	6.97	10.75
Dual Temp	51.79	46.28	49.03
Sealed Tube @ 7psig		25.86	
	Moisture Content after aging, ppm		
	165C	180C	Avg
Sealed Tube Power	552.1	345.2	448.7
Sealed Tube Distr.	360.9	383.1	372.0
Dual Temp	4.2	15.5	9.9
Sealed Tube @ 7psig		326.8	

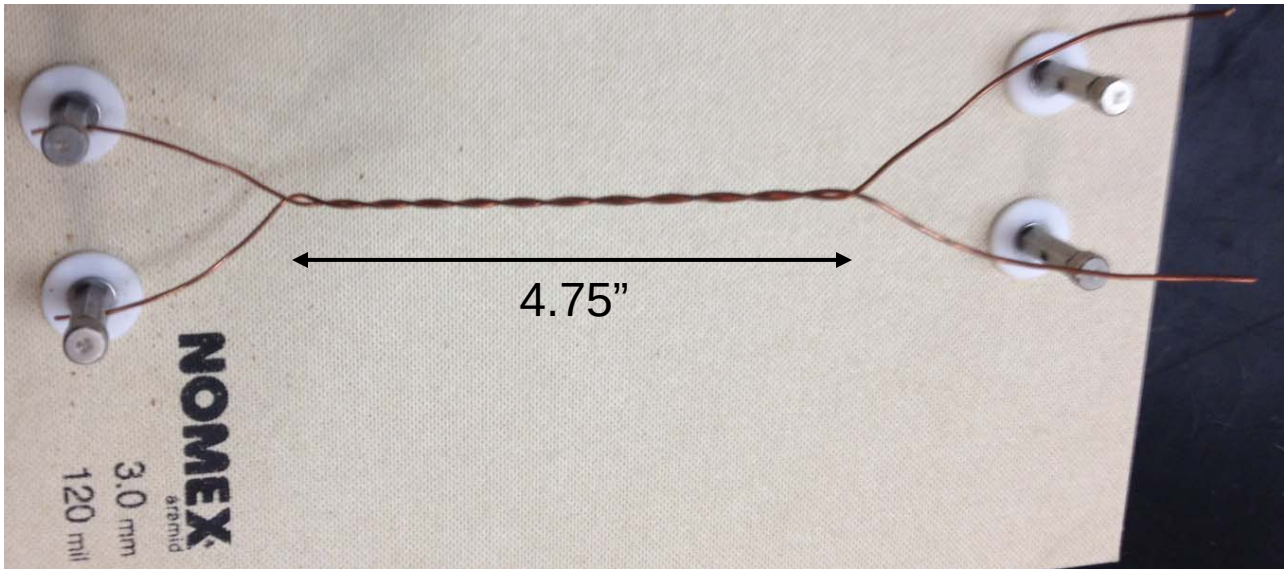
- Ratio of materials appears to have some effect – may be related to thickness of paper being tested.
- Pressure of sealed tube has a major effect.

Path Forward

- Complete control tests using initial set (allowing high pressure).
- Discuss results with key people to see what should be done (10 psig like in equipment standard?)
- Retest a new control
- Evaluate further the magnet wire test methods – current ASTM/NEMA tests describe methods, but times /temperatures have no relation to any of our past or present insulation life curves.
- Work in parallel is going forward for new IEC test method along the lines of sealed tube testing – use this as a way to better study the possibilities and gain data for potential revision/amendment to IEEE C57.100

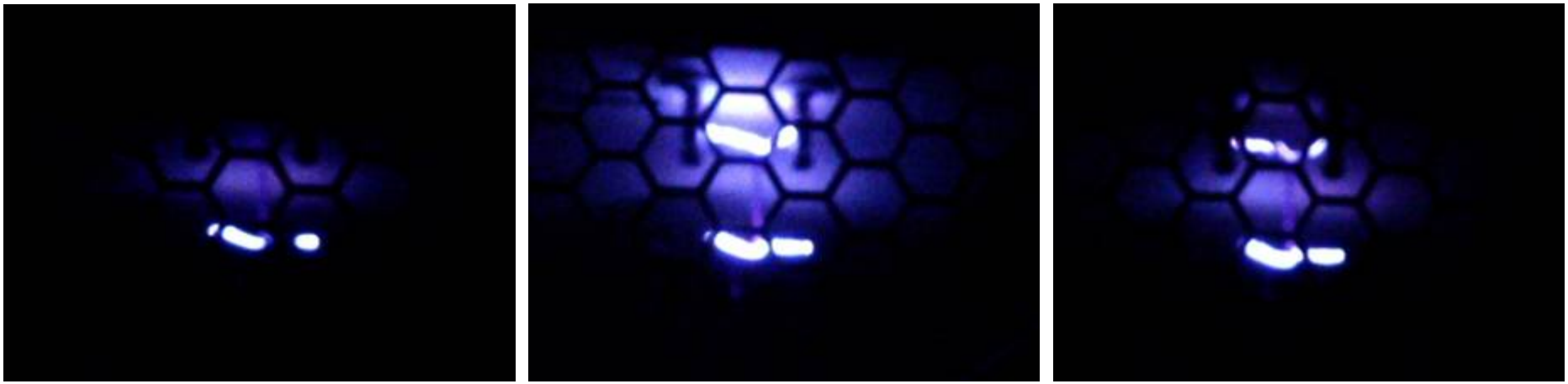
Addition of Magnet Wire

- Decided to repeat testing of industry proven system at 434 hours and 180C (with 7 psig pressure relief valve) but to add PVF magnet wire.

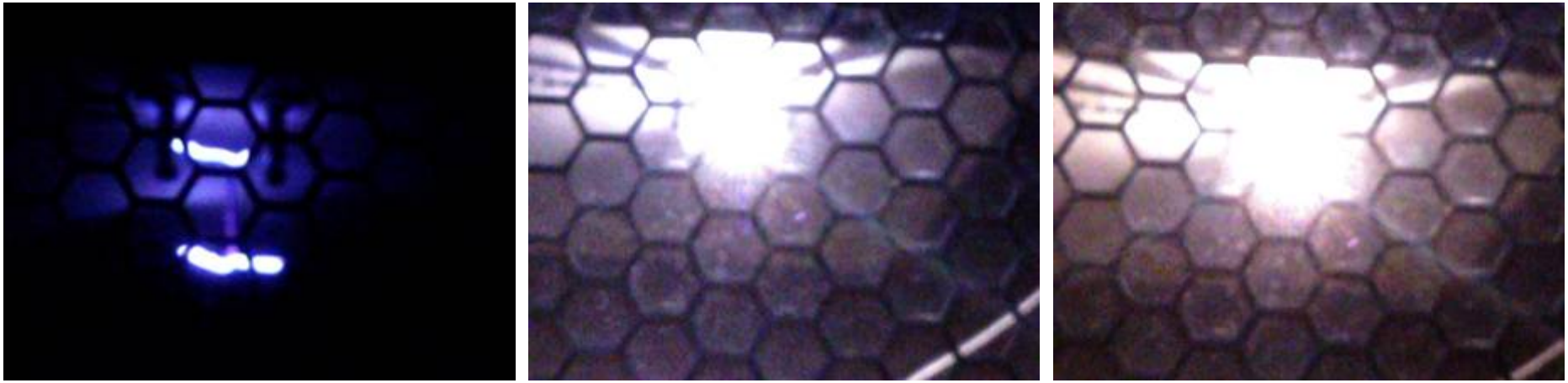


- Testing underway. Testing prior aging of two different magnet wire types show potential issue of high voltage tracking (need for longer wire samples)

Test 1 (with lights off)



Initial tracking – individual flashes (separated by time) from video



Final breakdown – images back to back from video

Control Testing Detail

- Back Up Slides

Distribution ST Aging

- 16.3 to 1 Ratio
- 180C control (424 hours)
  - Six ranging from 3.07% to 12.00% (5.35 w/o 12%)
    - High value from test low pressure at end of test.
    - Pressures typically in the range of 80 psi, but as high as 200 psi. Moisture from around 390 ppm
  - Three cells with 7psig limit ranged from 22.14 to 28.84% (25.86). Moisture around 330 ppm.
- 165C control (1316 hours)
  - Three ranging from 9.91% to 20.48% (11.55 w/o 20.5%)
    - Higher result had low pressure at end of test. Other two tests were around 80 psi. Moisture around 360 ppm.
- 150C control (4434 hours)
  - Testing Underway – complete middle of May.
- Average control (to date)
  - 8.45% with full pressure
  - 25.9% with low pressure
- Ratios in test: 112cm3 10 mil paper, 12cm3 3 mm HiVal, 168 in2 Cu, 78.8/81.1 in2 core steel (using scraps – aim around 80 in2), 2 liters mineral oil
- Oil Sampling conducted “hot” at the end of the aging experiment.

Power ST Aging

- 8.8 to 1 ratio
- 180C control
  - Three ranging from 5.97% to 7.14% (6.67%)
  - Pressures ranging from 80 to over 200 psi
  - Moisture ranging from 500 to 600 ppm
- 165C control
  - Three ranging from 5.22% to 6.84% (6.12%)
  - Pressures failed in all three cells
  - Moisture around 350 ppm
- 150C control
  - Testing Underway – complete middle of May.
- Average control (to date)
  - 6.40% (high pressure)
- Ratios in test: 64cm3 3 mil paper, 164cm3 6 mm T-IV, 168 in2 Cu, 82 in2 core steel, 2 liters mineral oil
- Oil Sampling conducted “hot” at the end of the aging experiment. If DGA is needed – also taken hot.

Dual Temperature Aging

- 180C control
  - Three sets ranging from 45.17 to 54.5% (51.16% avg.)
  - Three sets ranging from 40.56 to 49.94% (46.59% avg.) using only inner strips
  - Average of 13.1 ppm moisture
- 165C control
  - Three sets ranging from 53.56 to 57.29% (55.51% avg.)
  - Three sets ranging from 51.41 to 54.25% (52.71% avg.) using only inner strips
  - Average of 4.2 ppm moisture
- 150C control
  - Testing Underway – complete middle of May.
- Average Control (to date)
  - All strips = 53.39%
  - Inner strips only = 49.65%
- Ratios in test: similar to power transformer. Conductor is m-loop, no core steel added (but could if needed).
- Oil Sampling conducted after cell cools down. If DGA is needed – taken hot.