IEEE/PES Transformers Committee
Insulation Life Subcommittee
Un-Approved Meeting Minutes

The Insulation Life Subcommittee met in Memphis, TN on October 26, 2005, at 8:00 AM. There were 36 members and 71 guests present, with 15 guests requesting membership in the subcommittee.

The minutes of our meeting in Jackson, MS on March 16, 2005 were approved as submitted.

1.1 Chair's Report

A request was made for disclosure of any patents related to the work of the subcommittee. No patents were reported.

The Chair reported that reaffirmation of two standards needs to be completed by the end of 2005. They are:

- IEEE 1276-1997, IEEE Guide for the Application of High-Temperature Insulation Materials in Liquid-Immersed Power Transformers – The negative ballots were withdrawn. This guide will be submitted to REVCOM this week.
- IEEE 1538, IEEE Guide For Determination Of Maximum Winding Temperature Rise In Liquid Filled Transformers – This guide was submitted to REVCOM last Monday. There was one negative ballot concerning changes to the tables. This issue will be addressed in the next revision.

The Chair also reported that the following standard needs to be dealt with by the end of 2006.

- C57.119, Recommended Practice for Performing Temperature Rise Tests on Oil Immersed Power Transformers at Loads Beyond Nameplate Ratings – Everyone is asked to review this document and provide any comments to Don Platts. A volunteer for a chair is needed by the next meeting.

1.2 Project Status Reports

1.2.1 Reaffirmation Ballot 1276-1997 IEEE Guide for the Application of High-Temperature Insulation Materials in Liquid-Immersed Power Transformers

Don Platts reported that Mike Franchek had resolved the negative comments on this guide. The next step is submitting this guide to the Standards Committee and completing the necessary paperwork.

1.3 Working Group and Task Force Reports

1.3.1 Revision to C57.91 Loading Guide - Tim Raymond

The WG meeting was called to order at 1:45 PM on Tuesday, October 25, 2005 by the working group Chair, Tim Raymond.

There were 23 members present and 48 guests with 6 guests requesting membership to the WG. Guests requesting membership were:

Jim Thompson
Don Angell
Joseph Cheung
Miguel Medina
David Barnard
Pritpal Singh

The IEEE Patent disclosure requirements were discussed and a request was made for disclosure of any patents that may be related to the work of the WG. There were no responses to the request for disclosure.

Approval of minutes from the March meeting was requested. The minutes were approved.

Chair's Comments:

New in Draft 4:

- Cleaned up the temperature calculations.
- Old Annex G calculations were moved into the main body of the standard.
- The old Clause 7 was moved into an Annex.
- Minor cleanup

Draft 4 will be posted to the website for review.

PAR was approved last spring.

Last meeting:

- Discussed TV Oommen's gas evolution model and agreed to keep it. Nick Abisamra and TV Oommen will review.
- Agreed to add wording to clarify issues with moisture content. (Glenn Swift)

Present Meeting:

Goal for this meeting is to produce a "feature list" of things to do.

Insulation Aging:

- One major point of confusion and misunderstanding when performing loading calculations and making loading decisions is the discussion of percent loss-of-life (in percent total life expectancy) and in the discussion of the end of life or life remaining.

- Aging equations fail to consider condition variables.

Would like to propose some minor modifications due to paper aging.

End of Life:

- In rough terms, the "end of life" for an insulation system is the point at which the insulation no longer performs reasonably.

- For electrical insulation, this means the point at which the insulation system no longer maintains a majority of its original dielectric strength.

- As insulation ages, the dielectric strength of the paper does not decrease significantly until well after the paper has become brittle.

- Therefore, the point at which the paper loses enough strength to withstand the mechanical forces is the practical end of life for the insulation system.

- Given this, a precise definition becomes difficult because this is dependant upon the application of the material, both electrically and mechanically.

Presented a Failure Rate vs. Age Curve and suggested that the end of normal service life is dictated by thermal aging.

Insulation Aging:

Current draft discusses age acceleration factor F_{AA}. By integrating this over time, you get an equivalent aging hours. Equation for % loss of life is still there for those that wish to use it.

Asked if anyone has a strong opinion on whether the material for 55C-rise transformers in Annex A be moved into the body of the standard? Will the document still be readable or should there just be a reference to the Annex. Agreed to add a reference in the Aging and Loading of Power and Distribution transformers clauses (referring to temperature limits).

Life vs. temperature? TV Oommen asked if we can add a life curve. Tim indicated that you can have a plot with aging rate vs. temperature.

Joe Foldi indicated that we still need to come up with a finite expected life value. Don Platts indicated that we have been trying to include the requirement of the 180,000 hours in C57.12.00. C57.100 will outline how insulation values are tested or proven. We will let C57.12.00 set expected insulation life. For now, we will word it so that the user must select a value.

Affects of "condition":

- We know that moisture content of the paper has a profound impact on the insulation aging rate (roughly, doubling the moisture doubles the aging rate).
- Aging tests done at roughly 0.5% moisture. Current equations are based on this.
- Oxygen also has a profound impact.
- Given that the format of the equations in the current guide, users are unaware of this. Adding rough factors to aging equations makes this difficult to miss.

If someone were to look at the loading guide and use the formulas, they would not be aware of the effect of moisture content and Oxygen have on the results. Tim indicated that he has added two multiplying factors to the age acceleration factor, moisture content and Oxygen content. For moisture content there would be multipliers for Dry, Moist, and Wet. For Oxygen content there would be a low and a high level. These are open to discussion and tweaking.

It is well known that insulation aging rates increase with the presence of increased moisture and oxygen. The original equations in the Loading Guide are based mostly upon sealed tube aging tests with moisture contents less than 0.5% and presumably lower oxygen contents. This does not reflect the reality of operating transformers and misleads the user on the actual aging rate. The importance of keeping transformers dry and oxygen free are not reflected in the guide and are best addressed by including quantitative estimates of the effects of moisture and oxygen in the aging equation. It is proposed that this be done by applying multiplying factors to the "Age Acceleration Factor" calculated as follows:

$$F_{AA} = k_{H_2O} k_{O_2} \, e^{\frac{B}{\Theta_o + 273} - \frac{B}{\Theta_{HS} + 273}} \qquad (1)$$

Where the factors are determined as follows:

Moisture Content (roughly)	K_H2O
Dry (<0.5%)	1
Moist (0.5-2.5%)	2
Wet (>2.5%)	4+

Oxygen Content	K_O2
Low	1

High	3-5

The factors developed in the table were derived from data published by Emsley, Lundgaard and McNutt. They are approximations, however, insulation aging calculations as a whole are gross approximations.

By applying these factors directly in the equation, users are well aware of the importance of moisture and oxygen, and are given a method for evaluating the impact of moisture and oxygen, as well as estimated life consumption for transformers with moisture contents in paper greater than 0.5% and with increased oxygen levels.

Joe Foldi asked what designates low and high for the Oxygen content. Tim agreed that Oxygen limits need to be identified and discussed.

Comment that thermally upgraded paper makes a significant impact as well. Comment on whether the multiplying factors should be in the exponent or in front. This will need to be reviewed. (Note: Chair reviewed this following the meeting. The factor belongs in front of the equation, not in the exponent. Tim commented that the factors given apply to thermally upgraded paper as that is what is in the guide. Factors for standard kraft can also be developed.

Tim asked for a show of hands on who would agree to include multiplying factors for moisture and Oxygen. Many in agreement, only three in disagreement on the issue.

Present Power Transformer Limits:

Would like to propose new limits for Moisture, Oxygen, Methane, Ethane, and Ethylene with three levels of Good, Moderate and Marginal. Which would then be used to create a condition based limit table for the top oil temperature, hottest spot conductor temperature, and short time loading limits.

	Good	**Moderate**	**Marginal**
Moisture	< 0.5%	0.5%-1.5%	> 1.5%
Oxygen	< 3% TDG	3%-5% TDG	> 5% TDG
Methane	< 120ppm	120-400ppm	> 400ppm
Ethane	< 65ppm	65-100ppm	> 100ppm
Ethylene	<50ppm	50-100ppm	>100ppm

		Normal	**LTE**	**STE**

Condition			(>4hrs)	(<4hrs)
GOOD	**Top Oil**	95	105	110
	Hot Spot	120	140	160
	LOL (hrs)	24	-	-
		Normal	**LTE (>4hrs)**	**STE (<4hrs)**
MODERATE	**Top Oil**	95	105	105
	Hot Spot	120	130	140
	LOL (hrs)	24	-	-
		Normal	**LTE (>4hrs)**	**STE (<4hrs)**
MARGINAL	**Top Oil**	95	100	100
	Hot Spot	110	120	120
	LOL (hrs)	24	-	-

There was quite a bit of discussion both pro and con to the proposed limits. Some were concerned with the implementation of this and that this may cause deratings based upon perceived condition.

Tim will attempt to take a cut at implementing this and then it can be further discussed.

Add Overload "Checklist":

Example:

- Gather Information
  - □ Factory Test Report
  - □ Nameplate Drawing
  - □ Outline Drawing (if available)
  - □ Maintenance History
- Perform Field Inspection
  - □ Check and calibrate gauges
  - □ Check gaskets and seals
  - □ Look for discolored paint
  - □ Check pumps and fans for proper operation (and rotation if possible)
  - □ Check oil level
  - □ Inspect oil preservation system (N2 pressure, check bladder, oil level gauge)

- □ Check alarm and trip levels on temperature, if equipped
- □ Check radiators or heat exchangers for blockage. Clean if necessary.
- □ Draw sample for DGA and oil quality

- Post Loading
  - □ Draw sample for DGA and oil quality

Other Items for consideration:

- Cooling stage switching and impact on shorter duration overloads/ratings
- Three winding transformers?
- Enhanced sections on risks and increased maintenance considerations with higher or more frequent overloading (ie gaskets, DETC or LTC contacts, oil)
- Specs and the Loading Guide – Several members volunteered to send portions of their specs.
- Distribution transformers – Need at least two volunteers!
  - Tom Holifield w/ Howard Industries volunteered
  - Still looking for one more

Meeting adjourned at approximately 3:00 pm.

Tim Raymond, Chair

1.3.2 Working Group Revision C57.100 – Roger Wicks

1.3.2.1 Introduction and Rosters
The working group met on Monday, October 24, 2005 at 9:30 AM with 12 members and 36 guests attending. Five guests requested membership in the working group.

1.3.2.2 Approval of minutes from March 14, 2005 meeting
The minutes of the March 14, 2005 meeting in Jackson were approved as written.

1.3.2.3 Patent Disclosure
The chairman asked if anyone knew of any patents which could pertain to this project. There were none.

1.3.2.4 Discussion IEC – 62332 – Electrical Insulation Systems (EIS) Thermal Evaluation of Combined Liquid and Solid Components

The chair noted that this document has now been published as a final document. The chair then solicited input from the working group related to how one could get approval from IEC to allow us to use this document for a starting point in discussion related to model testing.

Don Platts agreed to help make this contact. Likely contact will be through Charlie Zegers at ANSI. Bill Simpson, who was a member of the working group also was volunteered as well.

Portions of the document were then shown to the working group, including showing a schematic of the aging cell, which allows for aging of materials with dissimilar thermal capability. (Such as high temperature fluids and cellulose, or high temperature solids and mineral oil). The aging philosophy was then discussed, whereby there are suggested times/temperatures established in the document, where there are specific criteria for evaluation of both the solids and the fluids, and whereby there is a method described for establishing the ratio of materials within the aging device.

Jin Sim asked if there was moisture content and/or oxygen content specified in the method (as they are in the other methods to some extent), and it was agreed as a group that this should be in our final method.

This led to a discussion regarding adoption of IEC by IEEE and whether portions could be adopted, after the discussion (Jin Sim, Hasse Nordman, and Patrick McShane), that partial adoption with appropriate reference has been done in the past.

1.3.2.5 Discussion of DuPont-Weidmann test of Model using Thermally Upgraded Kraft

The chair then described a test current just beginning by a joint team from DuPont and EHV Weidmann – using this model to evaluate different thermally upgraded papers, ranging in Nitrogen content from 0% (non-upgraded) to 3.4%. A single test was conducted in the last couple of weeks as DuPont was finishing installation of new oil processing equipment, which gave results similar to expected data. The plans are to age all four papers at three different temperatures to both validate the aging model, but more importantly to help the community address issues regarding how to evaluate thermally upgraded kraft (more than just the QC test for percent Nitrogen). Jin Sim noted that they feel this test is necessary to then buy into the Nitrogen content as a release test.

Jin noted that we need to specify oxygen and moisture content in these tests, and the chair will discuss and note in the test plan.

Jin Sim noted that there is a lot of confusion by users who only casually read the documents in reference to the number of hours listed. For example, if one uses 50% tensile retention, you get 65,000 hours, if one uses 200 DP, you get around 150,000 hours and if you use the C57.100 method (Lockie test), you get 180,000 hours. Jin suggested the criteria be more clearly stated.

1.3.2.6 Work Going Forward

The chairman asked for volunteers with experience with either of the two methods to look at the C57.100 document. Patrick McShane agreed to look at it. The chair will also circulate the document to working group members with this assignment.

Jin Sim asked if other IEC documents could be useful in this work, and Jane Verner agreed to search to see if she could find other work.

Jin noted that the requirements in C57.100 for short circuit testing and dielectric testing were very useful, but very difficult to do on a large scale. Hasse Nordman then described actually life of transformers with non-upgraded life with known hot spot temperatures not meeting expected life from aging curves in standards (non-upgraded kraft with only 90ºC hot spot in a GSU application, for example). He feels that if there are lab tests which can provide "derating" based on factors it would be very useful.

1.3.2.7 Adjournment

The meeting adjourned at 10:35 AM.

1.3.3 Task Force for Revision to Temp Ratings in C57.12.00 – Dennis Marlow

The Task Force met on Tuesday, October 25, 2005 at 11:00 AM. There were 8 members and 20 guests in attendance.

The minutes from the Jackson March 15, 2005 meeting were approved as submitted.

The task force was formed to make recommendations to the Insulation Life SC concerning the 2 proposals for temperature rise changes to C57.12.00 clause 5, submitted by Dennis Marlow at the Amsterdam meeting in April 2001.

The Chair did not review the IEEE patent disclosure requirements.

Proposal 1 dealt with changes to the average temperature rise for ODAF cooling from 65°C to 70°C

- At the last meeting the TF decided, based on the large number of negatives and the limited applications for this proposal to NOT recommend its inclusion in C57.12.00 at this time. Since then, there has not been any comment on that decision. The proposal has been archived for possible inclusion in other standards in the near future.

Proposal 2 dealt with changes to the average temperature rise of two windings that were located one above the each other.

- The TF again discussed the individual comments received from the Jan 2005 survey results using the initial observations and comments made by the TF Chair as a base.
- After making one editorial modification to the wording in the second sentence "temperature limit" changed to "temperature rise limit", the TF unanimously agreed to recommend to the IL SC that this proposal be included in a suitable section (Annex) of C57.12.00 or C57.12.10
- The final wording is per the following:

Final Proposal Oct 2005

"In transformers with concentric winding arrangement, two or more separate windings may be situated one above the other. In this case, the average winding temperature rise limit shall apply to the average of the individual readings for the stacked windings if they are of equal size and kVA rating and similar design. If they are not, the evaluation should be subject to agreement between the user and the manufacturer. For all rated loading conditions that are evaluated, a hot spot temperature rise limit of 80°C shall still apply to all windings"

The TF will not meet again as their work is complete.

NEW BUSINESS

There was no new business
The meeting adjourned at 11:40

Respectfully submitted,

Dennis Marlow. Task Force Chair

1.3.4 Task Force for Temperature Rise Test Procedures Section 11 of C57.12.90 - Paulette Payne

The Working Group met October 24, 2005 at 11:00am in the Forest Room of the Peabody Memphis Hotel. There were 13 members and 37 guests present. Mr. Oleh Iwanusiw was announced as a new corresponding member; membership is now 37. The Chairperson introduced the new Vice Chair, Juan Castellanos and informed attendees that we are seeking a volunteer for the position of Secretary.

Members were provided the opportunity to identify or disclose any patents believed to be essential for the use of Clause 11.0; no patents were identified or disclosed.

Discussion focused on the three action items: time to re-energize, duration for data collection, and equation for data regression.

Time to re-energize less than 1-hour if the 4 minute limit of resistance measurement after shutdown is not achievable or when another terminal pair needs to be measured. The WG agreed on returning the transformer to the stabilized top oil temperature. **Don Platts will word the proposed statement.**

Time duration for data collection. Several members indicated based on their experience it typically takes 10 – 12 minutes to collect the data. Discussion focused on concerns that enough data points be measured to be statistically significant for plotting an accurate curve whether a distribution or power transformer. **Bob Ganser will prepare a proposed statement.**

Equation for data regression to time zero. Tim Raymond, Bob Ganser and Vasanth Vailoor volunteered to help Thang Hochanh developed the equation for data regression to time zero. **The equation will be submitted before the next meeting.**

New Business

Mark Perkins' email on measuring the gradient on a Delta winding transformer was discussed. There is concern for a temperature blockage on another phase. DGA was identified as a diagnostic as well as testing methodologies identified. Don Platts mentioned that Mark is seeking to standardize winding resistance measurement for cold resistance and hot resistance. **The Chairperson will follow-up with Mark Perkins.**

Pierre Riffon's proposal for eliminating top oil rise stabilization correction instead using the average oil method like IEC was discussed. It was noted that average oil measurement is difficult to achieve and depends on physical dimensions. A poll of the attendees indicated that both the top oil rise and average oil methods are used and some favor one method over the other.

Subhash Tuli's proposal on the measured loss at cutback was read, but not discussed. The Chairperson will follow-up with Subhash to clarify the proposal and submit it with the meeting minutes for subsequent discussion.

As there was no other new business, the meeting was adjourned at 12:15pm.

Vice Chair – Juan Castellanos
Chairperson – Paulette Payne

1.3.5 Task Force Definition of Thermally Upgraded Insulation. – Don Platts

1.3.6 Task Force on Winding Temperature Indicators - Phil McClure

This task force did not meet.

1.4 Old Business:

Jin Sim submitted the following proposal for a task force.

Task Force: Moisture Estimation in Transformer Insulation

Subcommittee: Insulation Life

Committee: IEEE/PES Transformers

TF Members: TV Oommen, Tom Prevost, Mark Perkins, Don Platts, Jim Thompson, Andreas Garnitschnig, Barry Ward, Oleg Roizman, Valery Davydov

TF Chair: H. Jin Sim

TF Proposal to the Insulation Life Subcommittee

During the IEEE Transformers Committee meeting at San Diego, CA, March 2004, a panel session was organized and sponsored by the Insulating Fluids Subcommittee. This panel session highlighted most of the methods available to estimate the moisture content of liquid immersed transformer insulation. In addition to this, there are large amount of technical references available from previous conferences such as Doble, CIGRE, EPRI, etc.

The TF proposes to write a technical paper, which can become a basis for a future IEEE guide, on the subject. This paper will describe, as a minimum, the following.

- Why is moisture content important?
- List of methods available today to estimate the moisture content
- TF review and recommendations on each of these methods
- Practical method(s) that can be utilized by a technician in field environment
- How moisture gets into the insulation
- How moisture is removed from insulation in the field
- Definition of moisture parameters of a transformer paper-oil-gaseous headspace complex
- Loss of life of paper and oil due to moisture
- Distribution of moisture in transformers

The TF will present the paper through IEEE/PES Conference or General Meeting. The TF will also recommend if there should be an IEEE guide on the subject at the end of this project.

1.5 New Business:

Tim Raymond presented information on the age acceleration factor. He calculated two factors based on papers by Lundgaard, Emsley and McNutt for upgraded paper and non-upgraded paper. The results indicate that a simple approach may not be appropriate. Anyone with additional data or research on this subject should contact Tim.

Subhash Tuli expressed the following concern.

To: Paulette Payne Powell
Working Group Temperature Rise Test Section 11.0 of C57.12.90

Often a Thermal Test is performed based on the constant I_{TC} by the equation $I_{TC} = I_L [(\text{Cu losses} + \text{Fe losses/Cu losses})]^{1/2}$ to obtain thermal constants such as oil and winding time constants as per C57.119.

If the total actual measured losses at the time of oil stability is much greater than the calculated total losses (Cu losses + Fe losses) the top oil temperature rise may be affected. Does the top oil rise thus obtained warrant correction of the top oil temperature by the equation $T_d = T_b [(W/w)^n - 1]$
where

T_d = liquid rise correction (^oC)
T_b = observed liquid rise (^oC)
W= required loss (W)
w = actual loss (W)
n = 0.8 for ONAN, 0.9 for ONAF and OFAF, and 1.0 for ODAF?

Please Clarify.

1.6 The meeting adjourned at 9:00 AM

Don Platts
Chair, Insulation Life Subcommittee