Insulation Life Subcommittee - Un-Approved Meeting Minutes
October 17, 2007 – Minneapolis, Minnesota

7.4 Insulation Life Subcommittee – Don Platts, Chairman

The Insulation Life Subcommittee met in Minneapolis, Minnesota on October 17, 2007 at 8:00 AM. There were 49 members and 90 guests present, with 13 guests requesting membership in the subcommittee.

The minutes of our meeting in Dallas, Texas on March 14, 2007 were approved subject to adding the meeting minutes for the Working Group for the Revision to C57.91 Loading Guide.

7.4.1 Chair's Report

7.4.1.1 The Spring 2008 IEEE Transformers Committee Meeting will be held in Charlotte, N.C. in March. The Fall 2008meeting will be held in Portugal in October.

7.4.2 Project Status Reports

7.4.2.1 Reaffirmation Ballot C57.119, IEEE Recommended Practice for Performing Temperature Rise Tests on Oil-Immersed Power Transformers at Loads Beyond Nameplate Ratings

Subash Tuli is working on resolving the negative ballots.

7.4.3 Working Group and Task Force Reports

7.4.3.1 Working Group for the Revision to C57.91 Loading Guide - Tim Raymond

The working group was called to order by Don Platts, standing in for Chair, Tim Raymond, at 9:30 AM on Tuesday, October 16, 2007. Secretary Susan McNelly was also present.

There were 35 members present and 48 guests with 5 guests requesting membership to the WG. Guests requesting membership were:

Luiz Cheim
Prodipto Ghosh
Shaumaun Hakim
Gael Kennedy
Chuck Simmons

Agenda:

1. **Minutes approval and patent announcement**
2. **Plan to Complete Standard**
3. **Changes since 1995 revision**

Approval of minutes from the Spring 2007 meeting in Dallas was requested. The minutes were approved as written.

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.

Carlo Arpino had previously volunteered to be the Vice-Chair, and was officially identified at this meeting as the new Vice Chair.

The plan or the standard is to finish cleaning it up by December and send it to the WG and IL SC for a straw ballot before February of 2008 and discuss any comments at the March 2008 meeting in Charlotte. It would then go out for the official ballot next Spring/Summer.

Changes since 1995 revision:

- **Moved Annex G thermal model to main body, recommended for transformers with rated bottom oil rise**
  - Generally accepted that model gives better results than Clause 7 eqs.
  - Bottom oil rise required on test reports since 1999.

  Comment (Barry Beaster) - if someone wants to do more analysis, they would have to tweak the program. The ability to edit values in the program would be valuable. He also indicated that the spreadsheet has both the Clause 7 and the Annex G equations.

- **Kept old Clause 7 equations for cases where bottom oil rise is not available**
  - Units manufactured prior to 1999 most likely will not have bottom oil rise on test report.
  - Added computational complexity of Annex G eqs. May not be justified for distribution transformers where unknowns outweigh any gains in computational accuracy.

  Comment: The WG needs to decide whether for continuity purposes if we need to revert back to the original equations. The modifications that have been made will get you to the same results, but there is a concern that changing the equations may result in negative ballots.

  Comment: The original Clause 7 equations contain an adjustment for the oil time constant that then new revised equations do not.

  Comment (Don Duckett): The time constant for aluminum is different from copper and the question was asked as to whether this has been addressed. Don Duckett will submit a comment on this. Jin Sim commented that for power transformers this was not a concern.

- **Moved 55C rise information into main body, add temperature limits for 55C rise transformers**
  - Many users have 55C rise transformers in service
  - Guide is not just for new units, but those currently in service

Comment: It was not clear what limits were added and where. Jin Sim indicated that it appears that an effort was made to bring back 55C application into the document, but there are areas that have been missed and need to be addressed. Jin recommended and made a motion to take refererences to 55C back out of the guide and move them back into the annex. The 65C rating is the present standard. There was overwhelming agreement that the 55C information should be moved back to the annex.

- **Expanded background material on insulation aging, bringing much of the informative annex in.**
  - Insulation aging is an area where numbers have changed over the years. It's important to retain how those numbers have changed and why.
  - Without background, it's difficult for users of an equation to gauge the precision and reliability of the answers.
  - Question: Is the Aging section (Clause 6) readable? Does it have too much or too little information?

Comment (Don Platts): This has unnecessarily complicated the document. It would be more appropriate that this be in the Annex. A question was asked as to whether moving information from the Annex to the main body, if it would leave the standard more open to receiving negative ballots. Don Platts indicated that that the content would be the same regardless of where it is.

A recommendation was made that a survey be prepared to obtain what the general consensus of what should be in the main body and what should be left in the Annex. Jin Sim commented that there is too much tutorial information in the main body.

A proposal was made to keep the information that was in the Annex previously in the Annex. Only clarifications or corrections as needed should be made to the main body. An attempt to reduce the size of the main body should be made.

- **Added equation for bubble evolution temperature**
  - Eqn in Section 7.2, Based on EPRI Projects by Westinghouse, ABB 1988-92 Proj. Leader: T. V. Oommen

$$\Theta_{bubble} = \left[\frac{6996.7}{22.454 + 1.4495 \ln W_{WP} - \ln P_{pres}} \right] - \left[\left(\mathrm{EXP}^{(0.473 W_{WP})} \right) \left(\frac{V_g^{1.585}}{30} \right) \right] - 273 \quad (6)$$

where θ_{bubble}: Temperature for bubble evolution, ^{o}C

P_{press} : Total pressure, mm of mercury

W_{WP} : Percent moisture in paper (dry basis)

V_g : Gas content of oil, % (v/v)

- In 2005, the issue was put to a vote: "Overwhelmingly the consensus was to keep the formulas and add some wording describing the variations that could be seen depending on moisture."
- In 2006, the issue came up again: "Concensus was that the information should be moved back to an Annex."
- A final decision is needed.

Comment (Jin Sim): Indicated that if this equation is included in the standard that he would vote negative. His concern is with the application of the equation. Jim Thompson asked the question that if the equation is valid, should it be included with a caution on its use? Don Chu indicated that he would recommend that it be put back in the Annex.

As a result of the discussions, a group vote on each of the following items was requested as to whether they should be kept in the main body of the standard or moved back to the Annex. Results of the votes are provided below.

55C – Back to Annex
Insulation Aging – Back to Annex
Bubble Evolution – Back to Annex

- **Added factors to insulation aging equation to account for accelerated aging with increased moisture content or oxygen exposure.**
  - We know moisture and oxygen have a profound effect on aging rate. Current equations do not recognize this.
  - However, because of difficulty in estimating moisture content and the variability of moisture both spatially and with load, difficult to account for.

- **Added temperature limits for power transformers based on condition (more later)**

Rough Estimates of Moisture and Oxygen

Apply multiplying factors to age acceleration factor:

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

Moisture Content (roughly)	K_H2O
Dry (<1.0%)	1
Moist (1.0-2.5%)	2
Wet (>2.5%)	4

Oxygen Content	K_H2O
Low	1
High	3 - 5

Potential problems with this:
- Moisture is difficult to estimate
- There would be a sharp discontinuity between moisture levels (for example, between 0.9% and 1.0%
- My opinion – it's better than nothing

This was discussed and the general consensus is that if there is no supporting documentation for these numbers that there would most likely be negatives on this in ballot.

There are also tables with transformer condition in general provided in the latest draft.

Mark Perkins had the following comment: Moisture in the paper and oxygen in the oil both affect the aging rate of the cellulose, but it is difficult to estimate the affect on the aging at the hot spot of the transformer. The hot spot is typically located as an inner layer of paper where there are many layers, and the paper at the hot spot has moisture content that is considerably less than the bulk insulation. In addition, oxygen in the oil does not have direct contact to the paper at the hot spot paper as it does to the outer wraps of paper. So the affect of moisture and oxygen on aging at the hot spot will be different than the affect on the bulk insulation or on sealed tube samples used in formulating aging factors. In addition, it is very difficult if not impossible for a user to estimate the temperature of the hot spot, the bulk insulation moisture, and the oxygen in the oil due to the lack of specific design information and variability in diagnostic test data. As a result, the effect of moisture and oxygen on the aging rate should be shown only for sealed tube insulation samples to demonstrate the physical processes involved and to show the user the necessity of maintaining low moisture and oxygen conditions in the transformer. The user should be cautioned about applying these factors directly to the aging calculations.

The meeting was adjourned at 10:48 am.

Respectfully Submitted

Don Platts for

Tim Raymond
Working Group Chair

7.4.3.2 Working Group On Thermal Evaluation Of Power And Distribution Transformers (C57.100) – Roger Wicks

7.4.3.2.1 Introduction and Rosters
The working group met on Monday, October 15, 2007 at 11:00 AM with16 members and 66 guests attending, with 4 guests requesting membership. This brings the number of members to 58.

7.4.3.2.2 Approval of minutes from March 20, 2006 meeting
The minutes of the March 12, 2007 meeting in Dallas were approved as written.

7.4.3.2.3 Patent Disclosure

The chairman asked if anyone knew of any patents that could pertain to this project. There were none.

7.4.3.2.4 Discussion of DuPont-Weidmann test of power transformer model.
The chairman gave a presentation to the working group of the dual temperature aging model. He gave a brief background of the model and then proceeded to present some of the recent test results. A copy of the presentation will be posted on the IEEE PES transformers committee website. Some specific topics were presented with the data that has been collected so far. These include:

- Testing of "wet" vs. "dry cells"
    - Moisture levels of ~0.1%, ~0.5%, and ~1.5% were discussed
    - Chairman Wicks presented the method of increasing the moisture content of the solid insulation in the cells. This was done by adding moisture to the oil followed by a week of thermal cycling. This was effective for the ~0.5% cells but when attempted for ~2.5% cells the moisture was vented to the gas header. Modification of the aging cells is being done to prevent this.
    - Results of "wet" insulation to "dry" insulation was presented which compared the results of sealed tube to the dual temperature aging model.

7.4.3.2.5 Work Groups for Draft 1.0
The chair then presented an overview of work that must be completed to revise the existing C57.100 document. The chair asked for volunteers from the working group to develop a draft for review before the next meeting. A summary of the specific tasks and volunteers follows:

- Distribution Transformer Test Model (Lockie Test)
    - Jin Sim, Jerry Corkran

- Model test (IEC 62332)
    - Roger Wicks, Rick Marek, Bill Simpson

- Sealed Tube Test (Annex)
    - Tom Prevost

- Standard Test Conditions
    - Roger Wicks

- Housekeeping (Style, references etc.)
    - Juan Castellenos, Don Platts

Chairman Wicks will send a word version of the present document to the above listed working group volunteers. All sections should be complete and sent to the chair by the end of January 2008.

7.4.3.2.6 Adjournment

The meeting adjourned at 11:56 AM

7.4.3.3 Working Group for Temperature Rise Test Procedures Section 11 of C57.12.90 - Paulette Payne

The Working Group met at 11:00am October 16, 2007 in Marquette/Lasalle of the Hilton Minneapolis, Minnesota. In attendance were fourteen members and forty-two guests. There were no patent disclosures.

The minutes of the March 11, 2007 meeting were approved as written.

The major topics of discussion were: a presentation by Hasse Nordman regarding average oil temperature rise in distribution transformers, hot resistance measurements time interval, and a review of an old business proposal for correction factors to be applied to constant current temperature rise.

First item was the presentation by Hasse Nordman showing inconsistencies in the results from a heat run of a distribution transformer with cooling ribs. The test was done according to IEEE standards, but the oil temperature readings at the end extremes of the cooling ribs were very different than internal sensors. Mr. Nordman asked for a correction factor that should be developed and applied to the oil temperature results of distribution transformers with cooling ribs. The chair asked for additional information on this subject.

Second item was a review of the proposal of the hot resistance measurement time interval. The initial proposal from Mr. Mark Perkins was to measure resistance every ten seconds for those points taken before four minutes, and every thirty seconds for the points taken from four to ten minutes. There was concern that 10 seconds could be impractical for manual data taking, and a change was done to the proposal to take readings every fifteen seconds for the whole period. A show of hands favored using 15 seconds through the whole period from before four minutes and up to ten minutes. The proposal with the corrections will be send to the WG for comments.

Old Business – The proposal of applying correction factors to the oil temperature for constant current temperature rise test, based on lower than rated winding temperature rises, will be referred to the C57.119 revision group, since C57.12.90 only calls for “constant losses” test.

New Business – A question was raised by Mr. Joe Melanson regarding which would be the applicable correction factors for temperature rise tests done with ambient temperatures outside of the standard 10°C - 40°C range. More information is needed on this subject.

The meeting adjourned at 12:15pm.

Respectfully submitted,

Paulette Payne Powell, Chair
Juan Castellanos, Co-Chair

7.4.3.4 Task Force: on Moisture Estimation in Transformer Insulation – Jin Sim

Task Force chairman, Jin Sim, reported that the latest effort to identify a method to determine moisture content of conductor insulation within a reasonable accuracy did not result in an acceptable conclusion. Jacques Aubin developed and presented a CIGRE paper on the subject (Paper No. 27, BRUGGE 2007) to identify further investigations needed to achieve this goal. While he still believes the path he is taking is the most promising method, we still do not have a number to characterize the accuracy.

During the Fall 2007 Insulation Life Subcommittee meeting, TV Oommen, Tom Prevost, and Don Fallon expressed their agreements in the difficulty of moisture content determination. While organizations such as CIGRE, EPRI, and others proposed alternative approaches to address the issue, we still need to determine the moisture content of the paper to support many IEEE standards and guides dealing with aging and bubbles where it is one of the critically important variables.

After substantial discussions on the subject, the Subcommittee chairman, Don Platts, directed the TF to document what we have so far in a TF report. Jin Sim indicated that he will start with the original TF members to draft a report with a goal of publishing it as an IEEE Conference paper.

7.4.3.5 Task Force on Furan Testing – Kent Haggerty

The Task Force on Furan Testing met Monday Morning, October 15, 2007 with 32 people attending.

Chair, Kent Haggerty commented that while the task force currently is sponsored by the Insulation Life Subcommittee, close communication and interaction with the Insulating Fluids Subcommittee is needed.

The purpose of the meeting was to discuss whether there are sufficient data for development of a technical paper, guide, or standard on Furan Testing.

Tom Prevost shared a presentation that was given by Marie-Claude Lessard on the work that the CIGRE Task Force has done with evaluating diagnostics with Furanic Compounds. Evaluation of Furanic compound contents vs. different parameters such as loading, design, paper insulation type, age, type of oil, type of cooling, etc was performed. CIGRE currently plans to issue a technical paper of Furan Testing by summer 2008. Data collected have been found to be specifically related to thermal degradation of the cellulose insulation. The problem becomes one of determining how the Furan values should be interpreted, the correlation to DP, Normal aging vs. Fault data, remaining life, etc.

Luiz Chiem of Brazil reported that nearly 30,000 data points have been collected from 12 different countries including some data from the US. About a third of the data collected was

not complete and had to be discarded. Over half of the data could be correlated to transformer age. CIGRE has a commitment to have their paper published next year.

Don Platts shared a presentation on a users' perspective of Furan Testing, which raised many questions including:

- How to interpret the Furan Test values
- Correlation to DP
- Normal aging vs. Transformer Faults
- Remaining Insulation Life

Since CIGRE has a commitment to produce a technical paper on Furan Testing by the end of 2008, Tom Prevost indicated that there would be copyright issues we should be aware of when the Transformers Committee develops a Furan technical paper. One suggestion was made that the team may want to develop a technical paper or guide on the limitations associated with Furan Testing.

The team concluded that more data from North American utilities, testing companies, and users are needed before a technical paper or guide could be developed.

The task force meeting was closed at 10:45 AM Monday, October 15, 2007.

Additional Information

After our official task force meeting, Luis Chiem, Shuzhen Xu, and Kent Haggerty met to discuss next steps for the team. It was felt that a survey format needs to be developed to provide guidance for obtaining complete Furan and Transformer data. Luiz Chiem also commented that the CIGRE task force will be modifying their survey format and resending to gather more complete data points. Current path forward is to send out a survey to utilities, testing companies, and users requesting more data within North America and share information with the CIGRE task force. When sufficient data has been established, a technical paper or guide will be developed.

Respectfully submitted,

Kent Haggerty
Task Force Chair

7.4.3.6 Task Force on Winding Temperature Indicators - Phil McClure

The Task Force has not reported any progress in producing a paper.

7.4.4 Old Business:

Don Platts updated the Subcommittee on the status of the ballot comments on C57.12.00 and C57.12.90. The Ballot Resolution Group agreed that the comments should be addressed. A draft of the suggested language will be circulated in the Subcommittee.

7.4.5 New Business:

Don Duckett provided a brief introduction of a presentation that will be put on the agenda for the Subcommittee Meeting.

7.4.6 The meeting adjourned at 9:10 AM

Don Platts
Chair, Insulation Life Subcommittee