Task Force on Particle Counts in Transformer Insulating Fluids

Omni Houston Hotel

Room: Regency AB

Monday, March 8, 2010

8:00AM – 9:15AM

IEEE/PES Transformers Committee / Insulating Fluid Subcommittee – Spring 2010 Meeting – Houston, TX

Agenda

1. Introductions & Roster
2. Patent Disclosure
3. Purpose
4. Activities to Date
5. Particle Basics
6. Standards / Calibration
7. Available Guidance
8. Test Results of New Oil
9. Survey
10. Open Discussion
11. Invitation to Participate
12. Adjournment

Introductions & Roster

- Chairperson

  Mark Scarborough
  Electrical Engineering Consultant, ETCG
  DuPont Engineering
  Wilmington, DE

- Vice-chairperson

  T.V. Oommen
  ABB (Retired) / Consultant
  North Carolina

- Secretary

  (Open)

Patent Disclosure

- The IEEE's patent policy is consistent with the ANSI patent policy and is described in Clause 6 of the IEEE-SA Standards Board Bylaws;

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- Disclosures made of such patents may not be exhaustive of all patents that may be essential for the use of standards under development, and that neither the IEEE, the WG, nor the WG Chairperson ensure the accuracy or completeness of any disclosure or whether any disclosure is of a patent that, in fact, may be essential for the use of standards under development.

Patent Disclosure Cont'd

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Patent Disclosure Cont'd

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- Don't discuss ongoing litigation or threatened litigation
- Don't be silent if inappropriate topics are discussed… do formally object.

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This slide set is available at http://standards.ieee.org/board/pat/pat-slideset.ppt

Purpose

- The Insulating Fluid Subcommittee is the parent committee.
- TF was chartered after the Spring 2008 meeting in Porto, Portugal.
- TF was established to investigate the issue and determine if there is a need to develop a standard for particulate limits in new fluid, as received in new equipment, and continued use. (Currently, focus is on new fluid in new equipment.)

Activities to Date

- Small group was formed with representatives from the following groups:
  - Transformer manufacturers.
  - Purchasers / owners of transformers.
  - Laboratory service providers.
  - Transformer component suppliers.
  - Insulating fluid manufacturers and refiners.
- ~ 20 participants so far – looking for more.

Activities to Date Cont'd

- We have had five (5) teleconference calls / web meetings.
  - September 11, 2009
  - November 17, 2009
  - February 8, 2010
  - February 22, 2010
  - March 3, 2010

Activities to Date Cont'd

- Quickly determined that we needed to do some research on particle counting.
- Decided to focus mainly on mineral oil at this time.
- Gathered information on test methods and calibration methods.
- Tried to determine what has been done by the IEC and CIGRE communities.
- T.V. Oommen (ABB, retired) was identified as a TF member that has worked with particles in oil since the early 1980's. He provided a list of publications on the topic of particle count in transformer oil.

Particle Basics

- What size?: Talking about the 1 to 150 micron (micrometer or 1 x 10^{-6}meter) size range. A strand of human hair is about 70 µm wide.

- Sources?: Contaminates from the fluid refining process, fluid shipping process, cellulosic dust and fibers, dirt, iron, copper, other metals, paint, etc…..

- Why test?: Research has shown that high levels of particle contamination can lead to transformer failure. Particles affect dielectric strength. There is a also a relationship between particle count, dielectric strength, and moisture content. Research has also shown that particle size, material type, and shape have an affect.

- How to test?: Typically use optical particle counters that use laser diodes or white light technology. Most instruments are based on light blocking principles.

Available Test / Reporting Methods

- **ASTM D 6786-08** "Standard Test Method for Particle Count in Mineral Insulating Oil Using Automatic Optical Particle Counters"

- **IEC 60970: 2007** "Insulating Liquid – Methods for Counting and Sizing Particles"

- **ISO 4406:1999** "Hydraulic fluid power - Fluids - Method for Coding the Level of Contamination by Solid Particles"

Calibration Standards

- **ISO 11171: 1999** “Hydraulic fluid power - Calibration of Automatic Particle Counters for Liquids”

- **ISO 4402:** (Replaced with ISO 11171)

Calibration Test Media

- Prior to the late 1990's, Air Cleaner Fine Test Dust (ACFTD) was used to calibrate particle counters. Production of the material stopped.

- ISO Medium Test Dust (MTD) is the replacement and used for calibrating all particle counters today.

ACFTD to MTD

ACFTD Size µm	MTD Size µm
1.0	4.2
2.0	4.8
3.0	5.1
4.0	5.8
5.0	6.4
6.0	7.1
6.0	7.7
7.0	7.7
8.0	8.4
9.0	9.1
10.0	9.8
12.0	11.9
15.0	13.6
20.0	17.5
25.0	21.2
30.0	24.9
40.0	31.7
50.0	38.2
100.0	70.0

- Need conversion to be able to compare test results from particle counters calibrated to ACFTD (late 1990's) to results from particle counters calibrated to MTD.

- For example, a particle size measured in 1985 was 5 µm; the same particle measured in 2010 would be 6.4 µm.

Current Reporting Systems

ISO 4406:1999 Code Chart			
Range Code	Particles per milliliter More than		Up to / Including
24	80000	-	160000
23	40000	-	80000
22	20000	-	40000
21	10000	-	20000
20	5000	-	10000
19	2500	-	5000
18	1300	-	2500
17	640	-	1300
16	320	-	640
15	160	-	320
14	80	-	160
13	40	-	80
12	20	-	40
11	10	-	20
10	5	-	10
9	2.5	-	5
8	1.3	-	2.5
7	0.64	-	1.3
6	0.32	-	0.64

ISO 4406 Reporting Standard:

R_4 / R_6 / R_{14}

ISO 24/22/19 for this example.

Example Particle Count			
Size µm (c)	Particles per ml	ISO 4406 Code Range	ISO Range Code
4	150500	80,000 - 160,000	24
6	37890	20,000 - 40,000	22
10	8200		
14	5000	2,500 - 5,000	19
21	1000		
38	150		
70	20		

ASTM D 6786 reports the average particle count runs as the cumulative number of particles per mL >4, >6, >10, >14, >21, >38, >70 µm.

Particle Count Guidance

- **IEC 60422: 2005** "Mineral Insulating Oils in Electrical Equipment - Supervision and Maintenance Guidance" (Annex B)

- **CIGRE Brochure 157: 2000** "Effect of Particles on Transformer Dielectric Strength"

CIGRE Brochure 157 by Working Group 12.17

- Primarily concerned with EHV transformers.
- Discusses particles and particle testing and how it varies from country to country and laboratory to laboratory.
- Provides the common testing methods at the time.
- Extensive discussion of two “round robin” tests that were performed.
- Recognized improvements needed in reproducibility of results between labs.
- Provides a table indicating particle contamination levels typically encountered in transformers.

CIGRE Brochure 157 Table 8 Summary

- **Low** contamination:
  - 1,000 particles per 100mL greater than 5µm
  - 130 particles per 100mL greater than 15µm

- **Normal** contamination:
  - 32,000 particles per 100mL greater than 5µm
  - 4,000 particles per 100mL greater than 15µm

- **Marginal** contamination:
  - 130,000 particles per 100mL greater than 5µm
  - 16000 particles per 100mL greater than 5µm

- **High** contamination:
  - Anything above the Marginal level.

- Note that the above particle sizes and reporting method is in accordance with obsolete ISO 4402. In addition, ACFTD was used as the calibration media at the time.

“Particle Contamination Levels in Oil-Filled Large Power Transformers”, IEEE May 1983, T.V. Oommen and E.M. Petrie

- A detailed study of particle levels in 200 samples taken from factory and installed large EHV transformers.

Based on ACFTD calibration

- Average: 1500 particles per 10mL between 3 – 150µm.
- Marginal: 3000 particles per 10mL between 3 – 150µm.

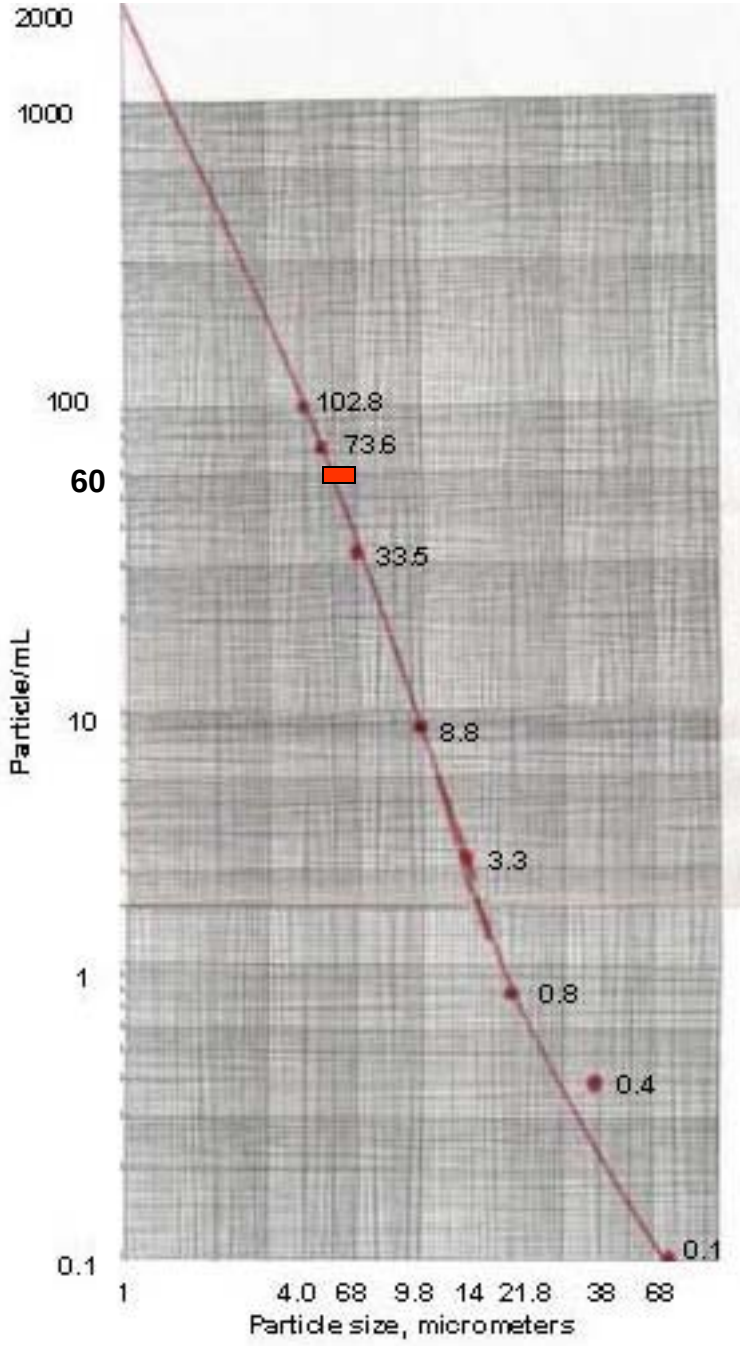
Based on MTD calibration

- Average: 150 particles per mL >5.1µm.
- Marginal: 300 particles per mL >5.1µm.

Test Results on Type II Mineral Oil Direct from Refiner

- Tested a sample of new oil from a refiner's bulk storage for particle count.

Type II Oil New Oil Test



Plot of Vacuum Avg.

- **Calumet refinery oil samples after filtering thru 0.5 micron filter.**

- **Particle count log-log plot of lab data.**

- **Average particle count / mL on vacuum samples (count per MTD calibration).**

Indicates particles / mL greater than 5 µm, approximately 60.

- **Per 1983 study, the average number of particles in 200 factory and field transformers was 150 particles per mL >5 µm (MTD).**

- **Per CIGRE 157, LOW contamination level contamination in factory / new transformer would be 10 particles per mL > 6.4 µm (MTD).**

- **Per CIGRE 157, NORMAL contamination level contamination in in-service transformers would be 320 particles per mL >6.4 µm (MTD).**

So That's The Background – SURVEY TIME

- TF has developed a SURVEY to gather data on what various companies have defined as their particle count limits in transformer insulating fluids.

- Primarily focused on "new" transformers but survey is designed such that in-service limits can be collected also.

- Gathering information on filtering practices also.

- We know the limits exist, please share!!!!

SURVEY

- Web based.
- Survey service has been used by other IEEE organizations to gather data.
- Access to results is restricted.
- Survey will be open for about two (2) months.
- Results to be shared at the Fall 2010 meeting.
- http://www.surveymonkey.com/s/ieeexfmrtfpartcount

Open Discussion

- Please make sure you enter your information on the rosters.
- We invite you to participate in the TF.
- Comments?

Adjournment

Thank you for attending!!