

# ***Case Study:*** **Investigation into Transformer Failure and Positioning of On-Line Moisture Probes**

*Prof. Valery G. Davydov*  
*Consultant*  
*Melbourne, Australia*

**WG PC57.162 Moisture in Insulation Systems**  
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# Note

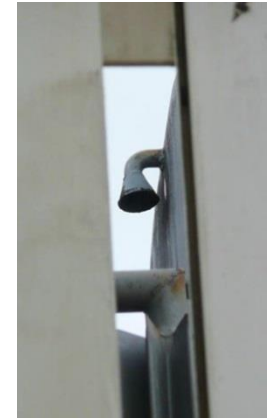
- **This presentation outlines a portion of case study reported in the CIGRE paper A2-302\_2016:**
  - V. G. Davydov, “Post-Failure Evaluation of Dielectric Performance of Winding of 38-y.o. Transformer Enhanced by On-Line Moisture Monitoring”, CIGRE General Session, Paris, August 2016

# Goal of Moisture Assessment of a Transformer *(as presented at S16 Mtg)*

The goal of moisture assessment of a transformer is to assess the three major risks associated with moisture:

1. The risk of bubble emission from winding paper
2. The risk of accelerated paper ageing due to moisture
3. **The risk of the relative saturation (RS) reaching high levels that would compromise the breakdown voltage of oil**

# Zone Substation ONAN Free-Breathing Trf, Australia: Failed on 3 Feb 2005

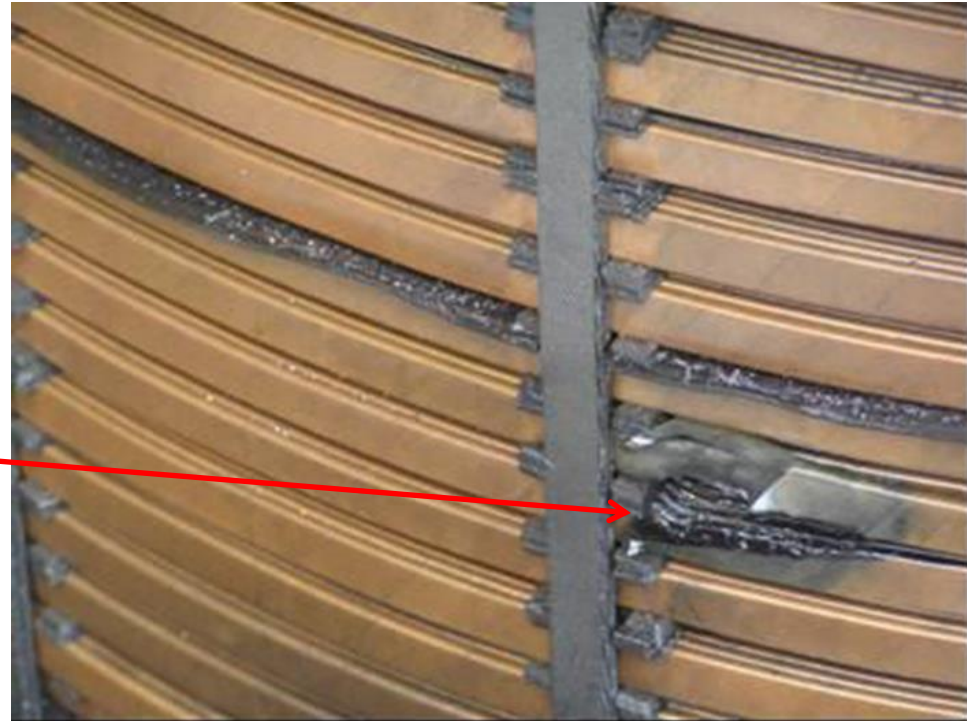




# Damaged HV Section (2005)



**Close-Up View:**



# Melted Copper Balls & Traces of Water (2005)



**Melted Copper Balls**

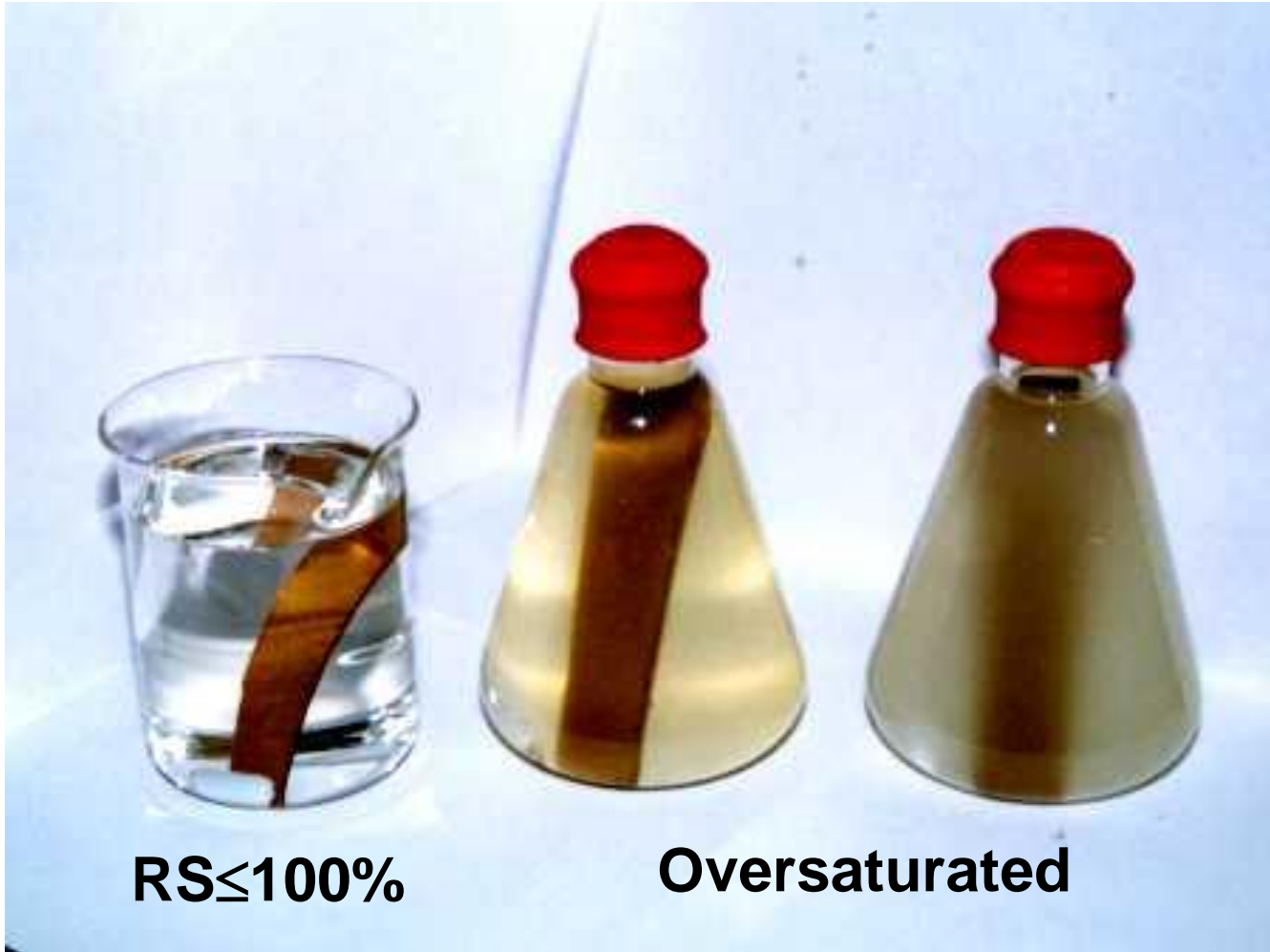


**Traces of Water**

# A Hypothesis Suggested during Failure Investigation of 2005-2006

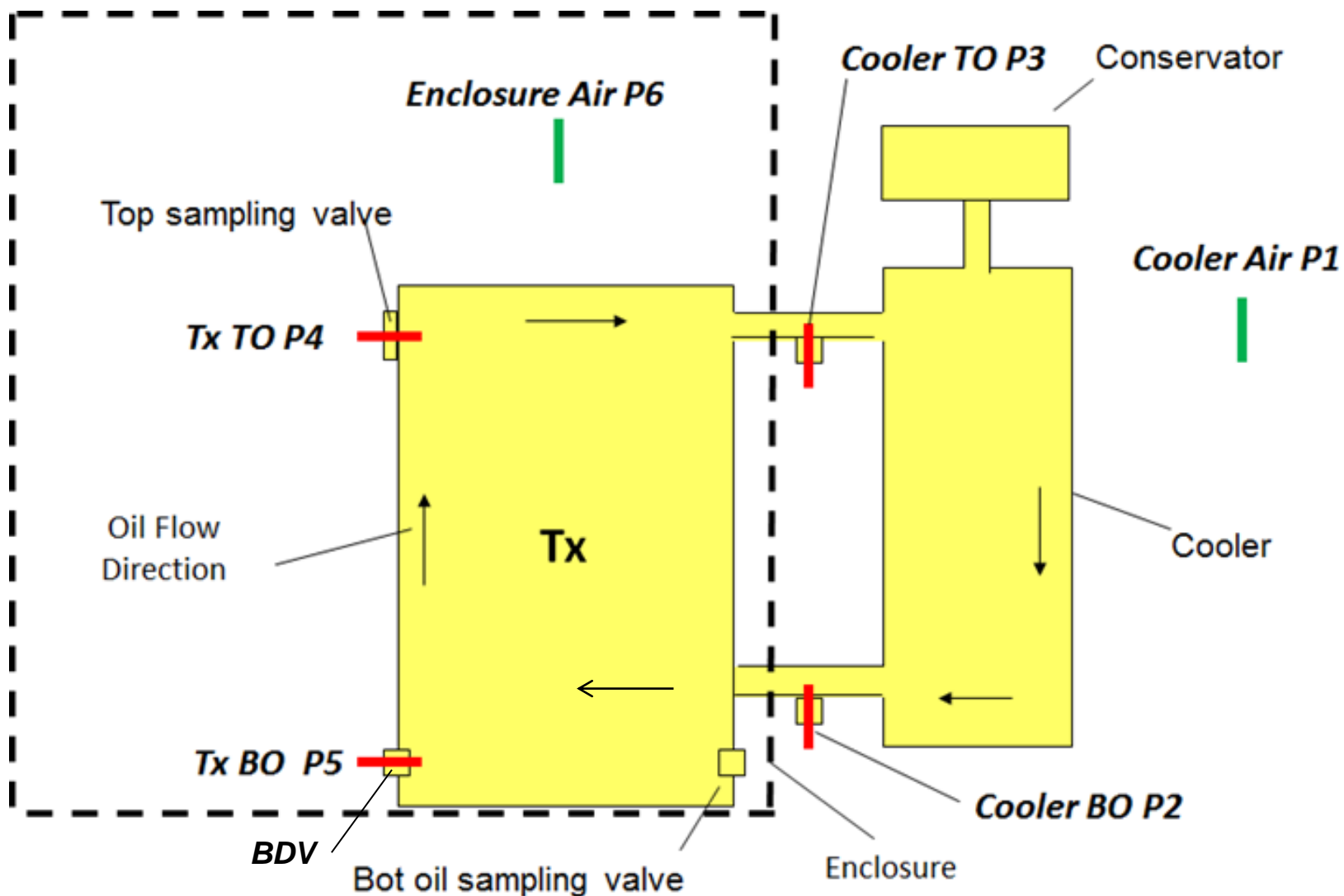
- It was suggested that the main cause of the failure was foggy (oversaturated) oil around the bottom windings
- Main reasons for the foggy oil formation:
  - Very wet insulation:
    - $WCP_{\text{inner max kf}} = 4.2\%$  (measured using Karl Fischer)
    - $WCP_{\text{surf}} > 5\%$  (estimated for the wettest portion of trf)
  - High amount of water in the oil during a few hot summer days
  - A sudden change of the ambient conditions due to a stormy weather one day before the failure:
    - Rapidly decreasing ambient air temperature, dropping from 36 to 9 °C within 12 hours
    - Heavy cold rain
  - Rapid cooling of oil inside the cooler resulting in the foggy oil

# Foggy (Oversaturated) Oil



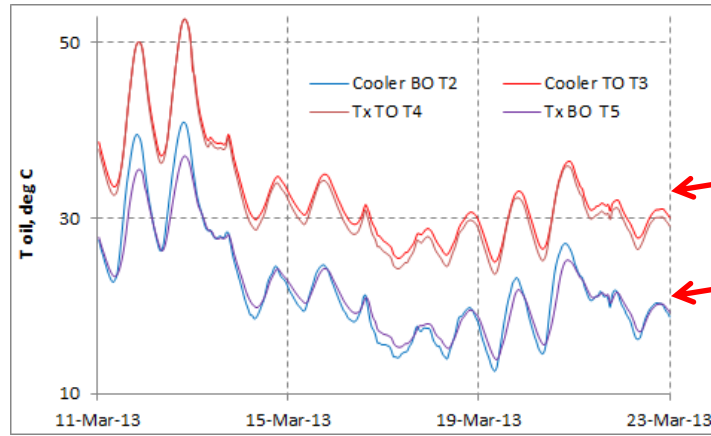
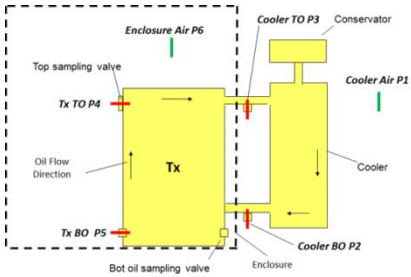


# Location of Moisture Probes (2007 - Present)



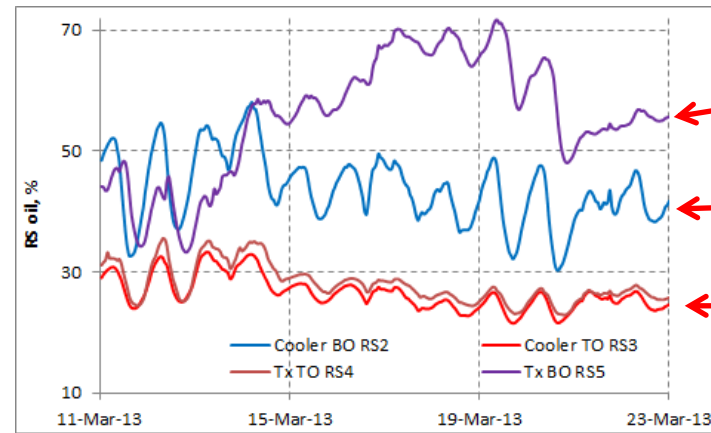
**Legend:** *P* – Probe, *TO* – Top Oil, *BO* – Bottom Oil

# E.g: Oil Temp, RS & WCO for 11-23 Mar 2013



$T_{TO}$ , two top probes

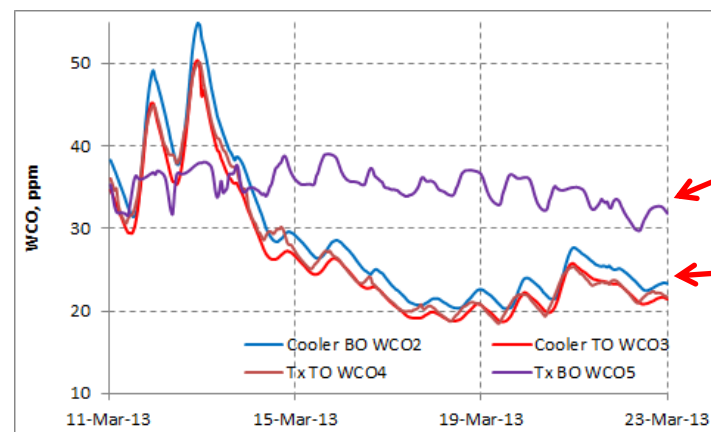
$T_{BO}$ , two bot probes



RS, bot trf (P5)

RS, bot cooler (P2)

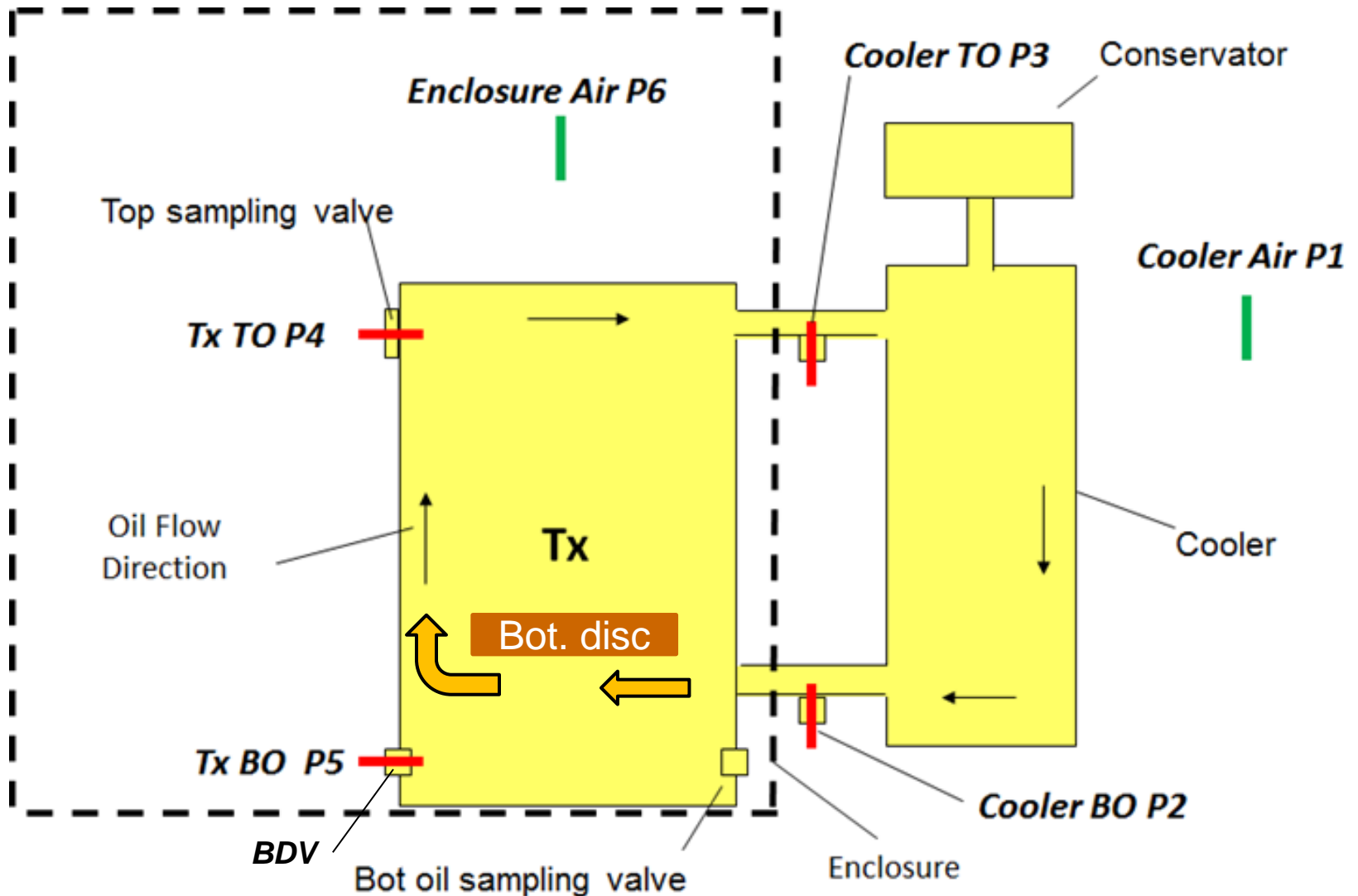
RS, two top probes



WCO, P5

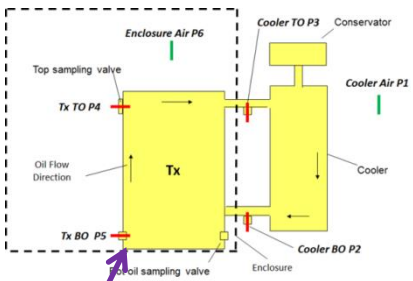
WCO, two top & P2

# Assumed Pattern of Main Oil Circulation

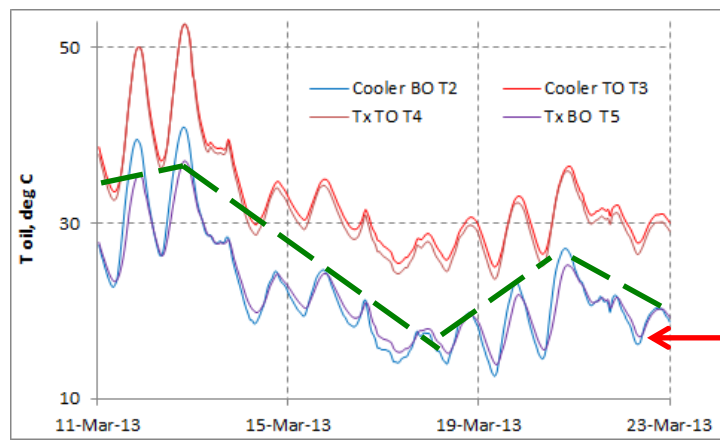


**Legend:** *P* – Probe, *TO* – Top Oil, *BO* – Bottom Oil

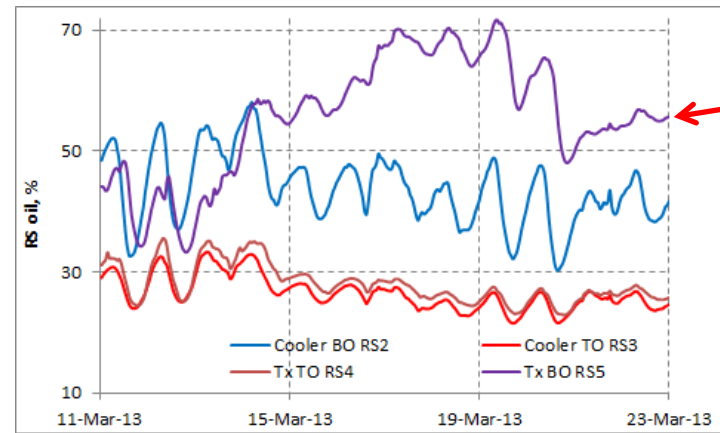
# Probe P5: Oil T, RS & WCO for 11-23 Mar 2013



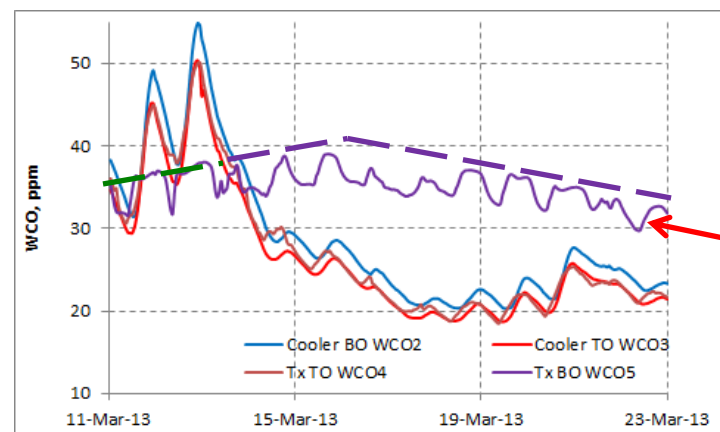
Probe P5



$T_{BO}, P5$

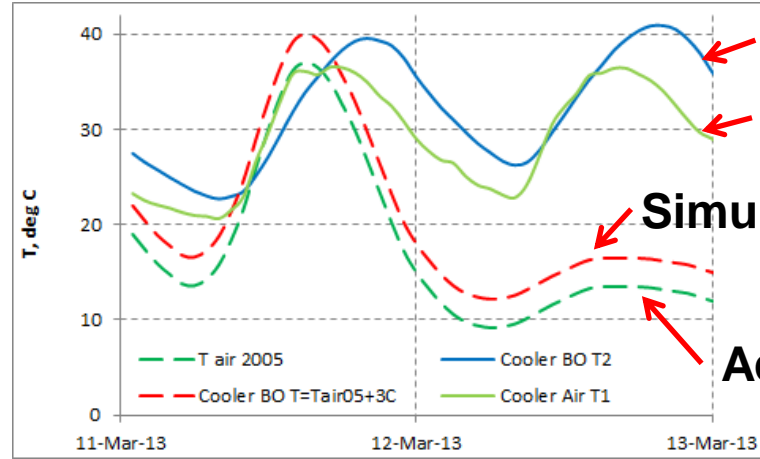
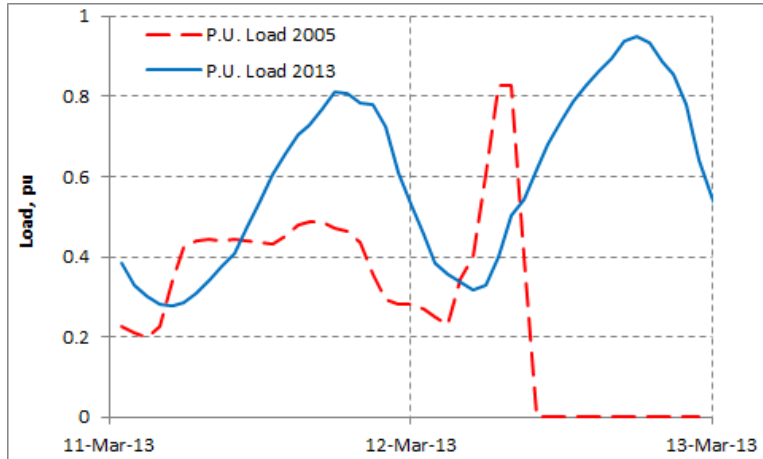


$RS_{BO}, P5$



$WCO_{BO}, P5$

# Actual and Simulated Data

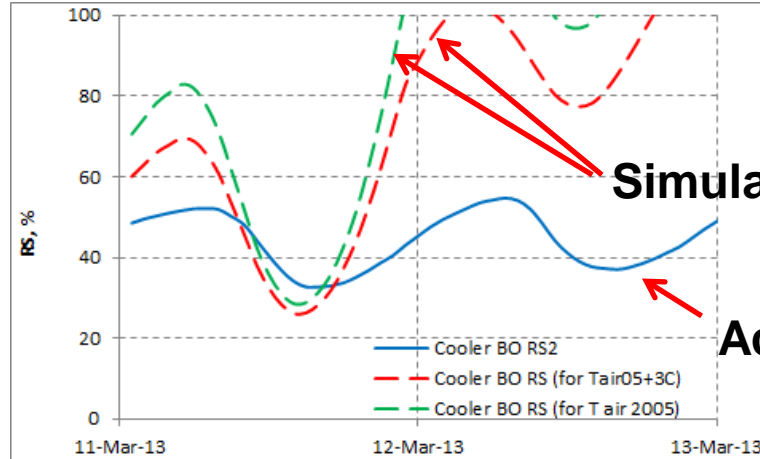
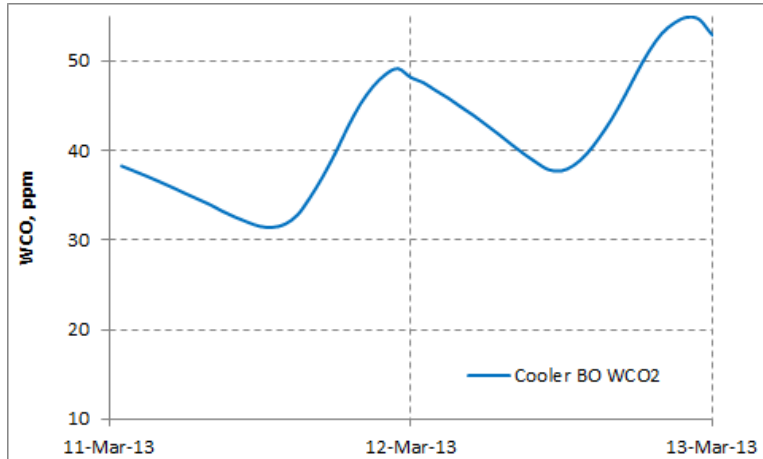


Actual  $T_{oil}$  2013

Actual  $T_{air}$  2013

Simulated  $T_{oil}$  2005

Actual  $T_{air}$  2005



Simulated  $RS_{2005}$

Actual  $RS_{2013}$

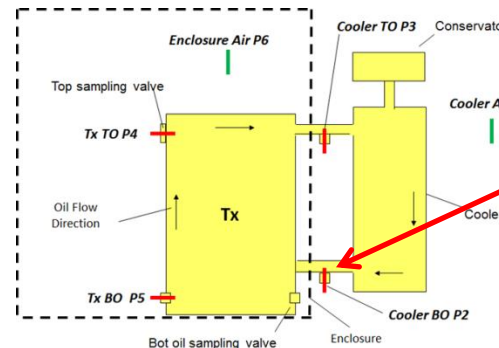
## Legend:

Actual Oil Data: 11-12 Mar 2013

Actual Load & Air Data: 2-3 Feb 2005

Simulated  $T_2$  &  $RS_2$  Data: 2-3 Feb 2005

[valery.davydov@ieee.org](mailto:valery.davydov@ieee.org)



Probe P2

ion into Transformer Failure  
In-Line Moisture Probes



# Established Mechanism of 2005 Failure

- **Condensation of water from oversaturated oil onto the insulation surface of bottom windings**
- **Inception of a corona discharge on the wet surface**
- **Escalation of the corona discharge into a disc-to-disc arcing discharge**

# Summary

- **The case study presented has demonstrated a transformer failure due to the relative saturation (RS) of oil reaching an extremely high level**
- **A very important observation has been made: moisture-in-oil PPM in the main oil circulation was significantly different to that at the bottom of the tank**
- **Nevertheless, it was possible inferring moisture-in-paper from moisture-in-oil data for each probe, including Probe P5**

**Thank you!**