Diagnostic Conference,
Siofok, Hungary, October 14th-16th 2009

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CORROSIVE SULFUR IN TRANSFORMER INSULATION

IVANKA ATANASOVA-HÖHLEIN

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What Happened ?

In the recent past failures on mostly young

TRANSFORMERS and REACTORS

due to formation of sulfide deposits on copper surfaces

During the last 15 years: 100 failures of large units?

All major transformer manufacturers affected

Several different oil suppliers

Many observations of copper sulphide
- but not always a cause of failures

WG A2-32 WAS SET UP TO DEAL WITH THE PROBLEM

Task Force 1
New test for detection of corrosive sulphur
(new standard IEC 62535)

Task Force 2
Metal passivator – analysis methods and stability

Task Force 3
Sulphur speciation

Task Force 4
Recommendations for users

All original tasks adressed, **Brochure No. 378 published**

Other related CIGRE and IEC working bodies active now:

Oil testing and specification	IEC TC10 MT21
Oil maintenance	IEC TC10 MT22
Sulphur speciation	IEC TC10 WG37

Copper sulphide - long term mitigation and risk assessment (starts in 2009)
CIGRE WG A2-40

Various dislocation of copper …

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inside

outside

… and deposits on paper

The OILS KNOWN TO HAVE CAUSED FAILURES

FULFILLED THE REQUIREMENTS

OF EXISTING STANDARDS

(both IEC and ASTM)

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REASONS:

OIL SPECIFICATIONS ARE CHANGING:

- THE SPECIFICATIONS FOR OXIDATION STABILITY WERE DRASTICALLY INCREASED

- OIL RAFFINATION TECHNIQUES HAVE BEEN MODIFIED

WHY DO OILS CONTAIN SULFUR COMPOUNDS?

SULFUR COMPOUNDS ARE GOOD NATURAL OXIDATION INHIBITORS, BECAUSE THEY REACT READILY WITH OXYGEN

HIGHLY REFINED OILS WILL NOT CONTAIN SULFUR,

BUT THEY WILL ALSO NOT EXHIBIT A SUFFICIENT

OXIDATION STABILITY

OXIDATION STABILITY IN SUCH OILS

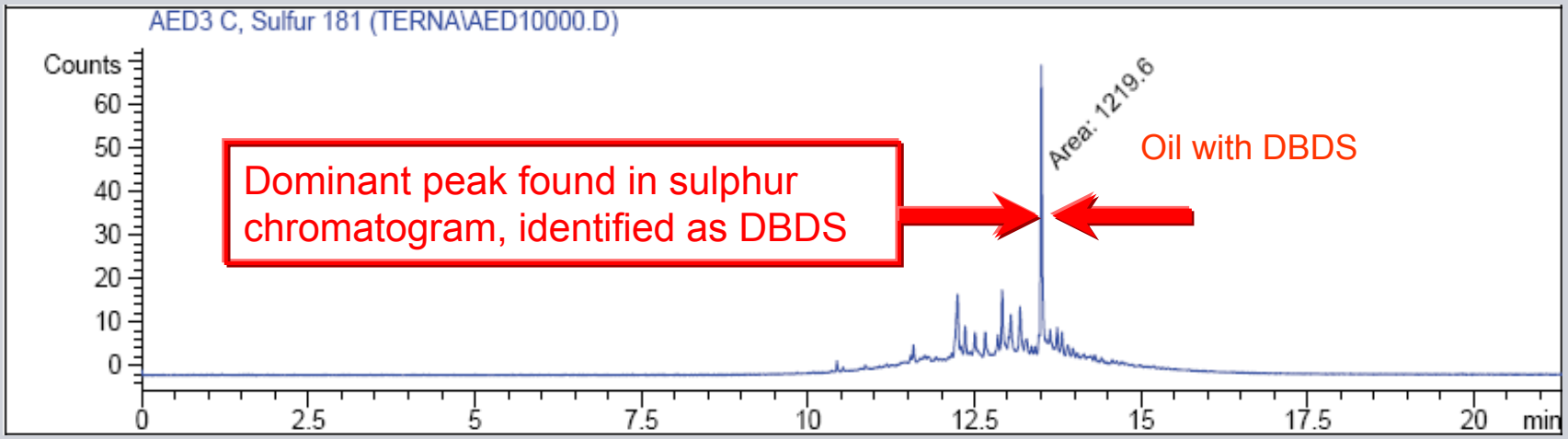
CAN ONLY BE ACHIEVED THROUGH THE ADDITION

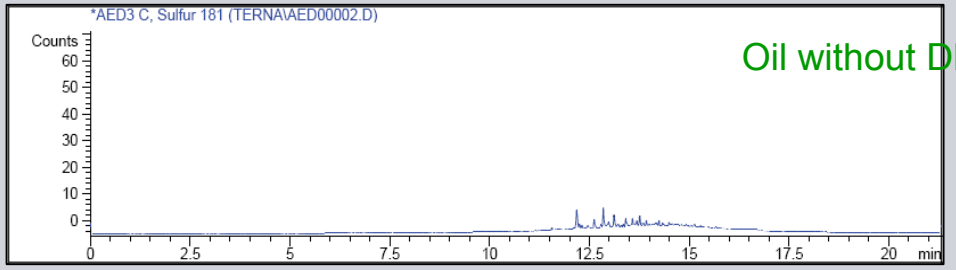
OF OXIDATION INHIBITORS, I. E. DBPC.

In some oils one dominant compound was identified.

This dominant compound was identified as dibenzyl-disulfide (DBDS)

DBDS has been shown to be a strong copper sulphide forming agent, present in most (but not all) oils involved


AED3 C, Sulfur 181 (TERNA\AED10000.D)
Counts
60
50
40
30
20
10
0
0
2.5
5
7.5
10
12.5
15
17.5
20
min
Area: 1219.6
Dominant peak found in sulphur chromatogram, identified as DBDS
Oil with DBDS


*AED3 C, Sulfur 181 (TERNA\AED00002.D)
Counts
60
50
40
30
20
10
0
0
2.5
5
7.5
10
12.5
15
17.5
20
min
Oil without DBDS

- Dibenzyl disulphide (DBDS)
  - GC-ECD
  - GC-MS
  - GC-AED

- Sum of disulphide and mercaptan sulphur
  - potentiometric titration with Ag/Ag_2S electrode

WHAT ARE THE CONSEQUENCES ?

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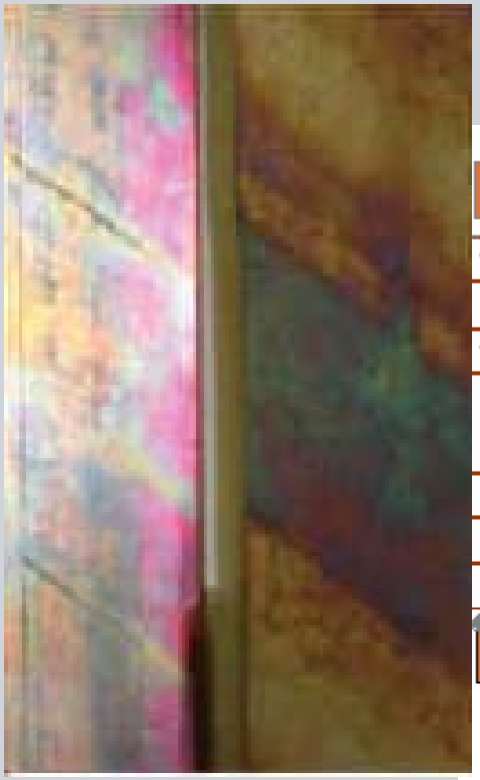

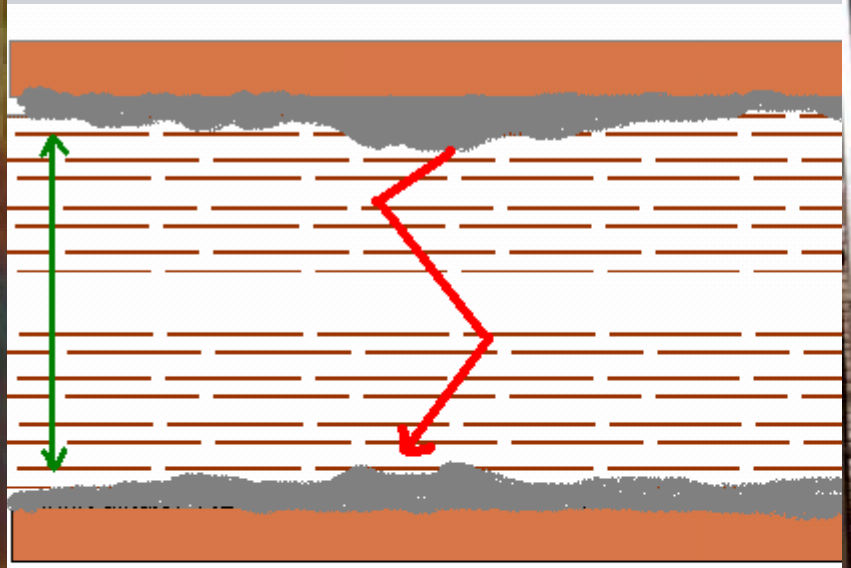

Dominating failure mechanism:

⇨ turn-to-turn failure of interleaved windings

5 QUESTIONS

1. How to detect oils with a potential ability to develop corrosive sulphur in new oils and oils in service in the future?

2. How to stop the action of the corrosive sulphur in transformers already in service?

3. What can we do to avoid this problem in the future?

4. How to detect the state of copper sulphide contamination of the winding insulation of operating equipment?

5. Which units are at risk?

1. **How to detect oils with a potential ability to develop corrosive sulphur**

   Testing methods should reflect the interaction between copper, paper and oil …

   and find a reasonable compromise between thermal oxidation and corrosion capability

Requirements on the Method of Testing

- ✓ Covers the existing failure modes
- ✓ Provides „reality relevant“ results in an accelerated mode

Defined conditions are important !

SIEMENS test method is accepted by Cigre A2.32 and proposed for standardization (CCD – Covered Conductor Deposition Test)

☞ now IEC 62535

15 ml oil, 5 ml air

3 cm copper conductor (8 mm x 2 mm) with 1 paper layer

72h 150°C

end concentration of oxygen: 6000 – 7000 ppm

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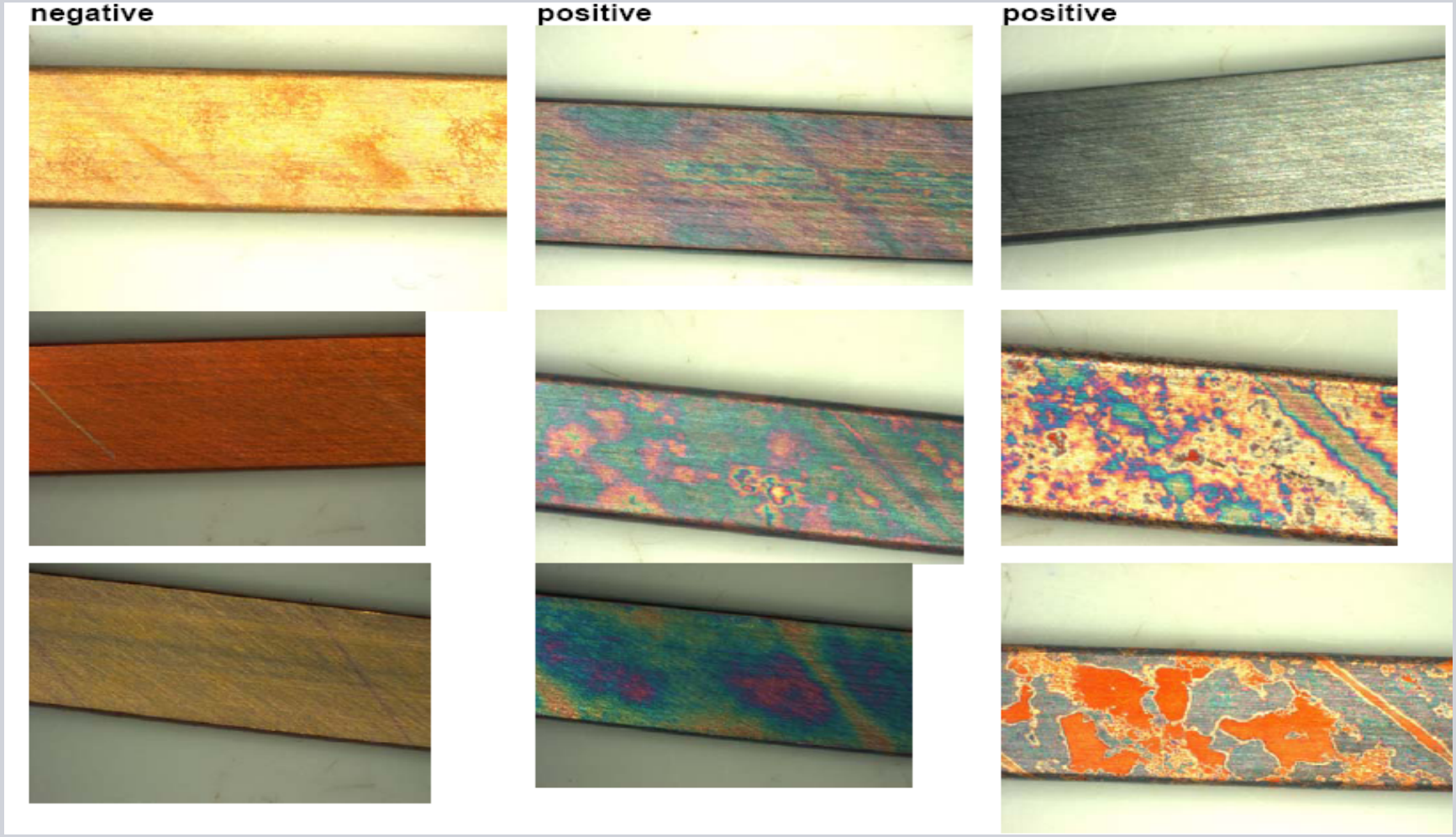

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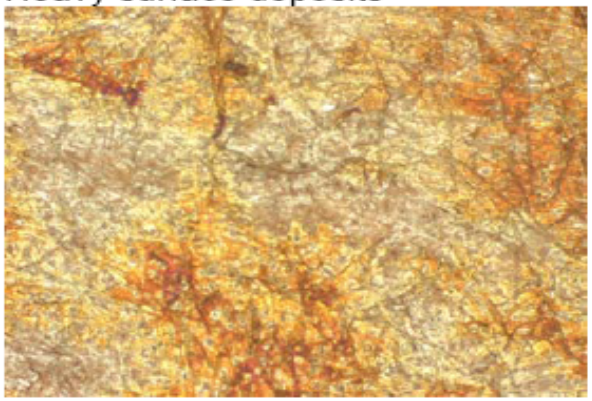
Evaluation of paper: Pay attention especially to deposits at edges and inside bends!

No deposits

Deposits on bends

Heavy surface deposits



Deposits at edges

Corrosive oil according to the Siemens Test,
now IEC 62535

2. How to stop the action of corrosive sulphur in transformers already in service?

- Passivation (e.g. Irgamet 39)
- Oil Change
- Reclaiming with fuller earth and special cartridges

REMARKS

Metal passivators stop the copper corrosion

Metal passivators do not negatively affect the oil characteristics

Metal passivators can only prevent corrosion on copper, but not recover corroded copper, nor recover paper contaminated with copper sulphide

Passivator is likely to be consumed with time, therefore monitoring should be applied.

Recommendation to treat transformers/reactors affected from corrosive sulphur :

↓

Add Metal passivator

↓

Proceed with regular oil supervision: Monitoring of DGA, Oil quality, Passivator effectiveness

3. What can we do to avoid this problem in the future?

CHANGE OF OIL SPECIFICATION

THROUGH

INTRODUCTION OF MORE STRINGENT METHODS

FOR CORROSIVITY

4. How to detect the stage of copper sulphide contamination of the winding insulation of operating equipment?

GENERALLY – NO CORRELATION TO DGA OR COPPER CONTENT IN OIL

IT IS, HOWEVER, HIGHLY RECOMMENDED TO CARRY OUT DGA AND OIL ANALYSIS ON A REGULAR BASIS, SINCE THIS ALLOWS THE RECOGNITION OF IRREGULARITIES EARLY ENOUGH. USUAL OIL CHARACTERISTICS LIKE COLOUR OR LOSSFACTOR CHANGE QUICKER THAN EXPECTED IN CASE OF HIGH TEMPERATURES.

ANY MAINTENANCE PROCEDURES (DEGASSING, RECLAIMING ETC) SHOULD BE RECORDED

5. Which units are at risk?

- ► corrosive oil
- ► windings with uncoated wire
- ► sealed oil preservation system
- ► high ambient temperature
- ► high winding to oil gradient
- ► high load

RISK

MEANS

COMBINATION OF TWO AND MORE FACTORS

POSSIBLE CONCLUSIONS FOR THE FUTURE

- CTC OR COATED FLAT WIRE
- WELL DESIGNED COOLING IS EXTREMELY IMPORTANT
- USE OF NOT CORROSIVE OILS – SPEC. IEC 62535
- APPLICATION ORIENTED INSTEAD OF GENERAL OIL SPECIFICATION

THANK YOU FOR YOUR ATTENTION!