Predictive maintenance of transformers through the determination of gassing characteristics and oil compatibility studies

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Powertech
Transformers

1. Summary

- Predictive maintenance of oil-filled transformers through the use of oil condition monitoring:
  - Essential for critical transformers located in remote areas.
  - A reliable and field tested methodology

- The advent of on-line monitors has brought awareness on:
  - Unusual gassing phenomenon at low temperatures (90°C-200°C), aka *Stray Gassing*

- Stray Gassing:
  - Is not associated with classic thermal and electrical faults
  - Has been linked mainly to the hydrogeneration processes employed in refining mineral oil, chemicals added to the oil for oxidation stability and the interaction of the oil with other transformer materials
  - Has been shown to be exacerbated by thermal stress

2. Challenges and objectives of the study

- Challenges associated with Stray Gassing:
  - No local or international guidelines on acceptable stray gassing gas concentrations and generation rates
  - Asset managers worry that stray gassing activity could mask gassing activity due to incipient or active classic faults; leading to insurance companies not covering the cost of replacing transformers with stray gassing oil

- Objectives of the study:
  - To analyse laboratory results of DGA and material compatibility tests performed on oil samples obtained from:
    - Virgin oils
    - Oils from transformers believed to have stray gassing activity
    - Transformers known to have classic faults
  - To determine how stray gassing activity has affected predictive maintenance of transformers

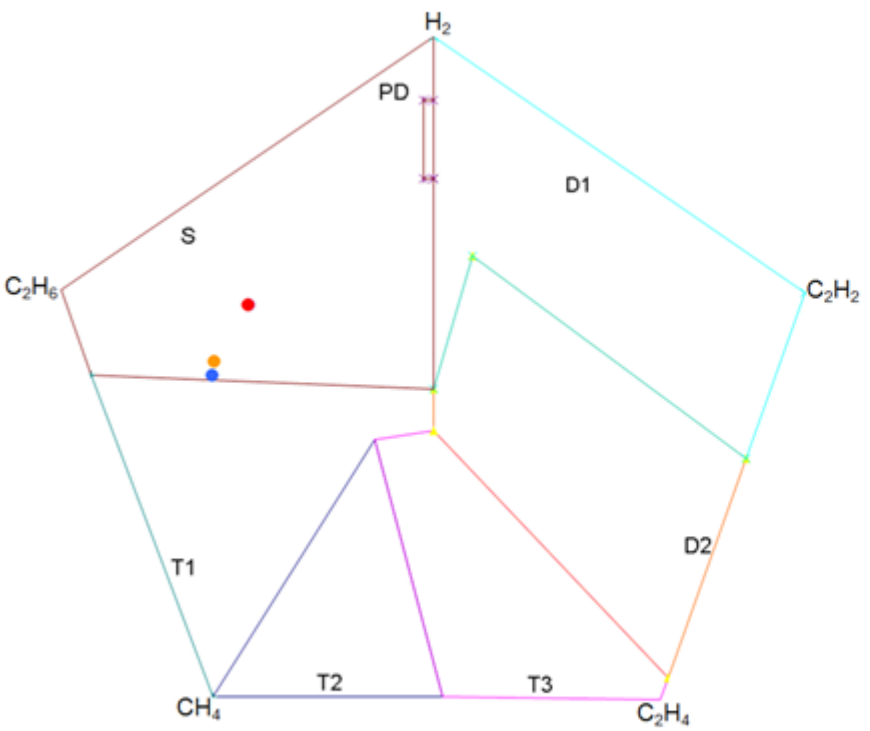
3. Standard condition monitoring results

Table 1: Results of the on-site diagnostic tests

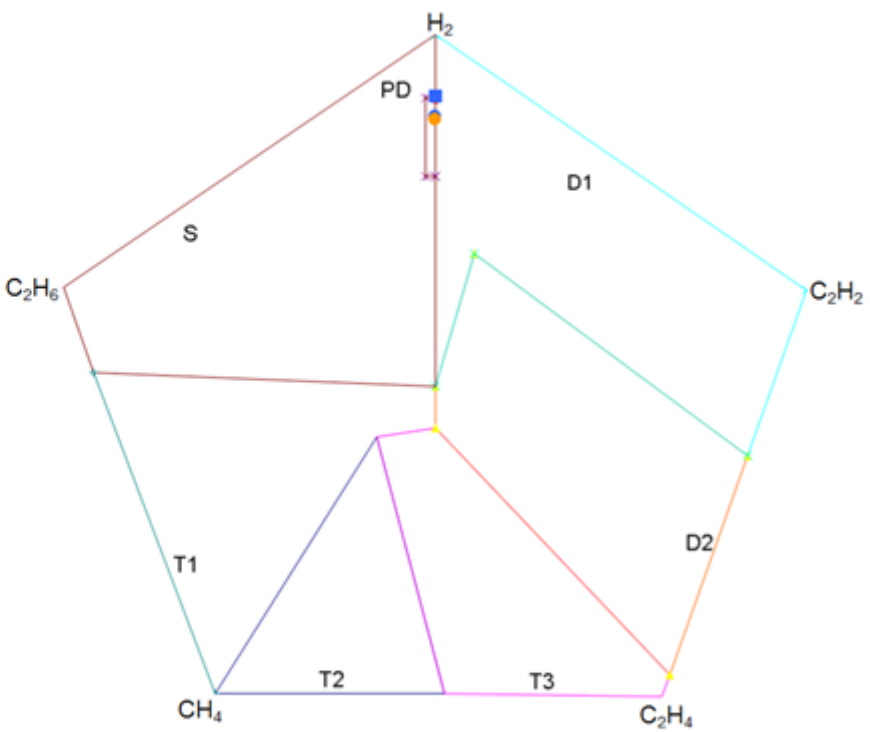
Gases	Transformer with Stray Gassing activity		Transformer with PD activity	
	Absolute value	*Production rate*	*Absolute value*	*Production rate*
H_2	111	15.36	192	9.76
O_2	6099	-	2470	-
N_2	88447	-	24133	-
CH_4	177	6.58	ND	-0.83
CO	189	14.81	214	-
CO_2	215	8.78	1127	-
C_2H_2	ND	-	ND	-
C_2H_4	15	8.23	ND	-
C_2H_6	534	82.30	ND	-
TCG	**1026**	**-**	**406**	**-**

3. Standard condition monitoring results

Duval Pentagon 1 analysis of multiple manual and on-line monitor oil samples



Transformer with Stray Gassing activity



Transformer with PD activity

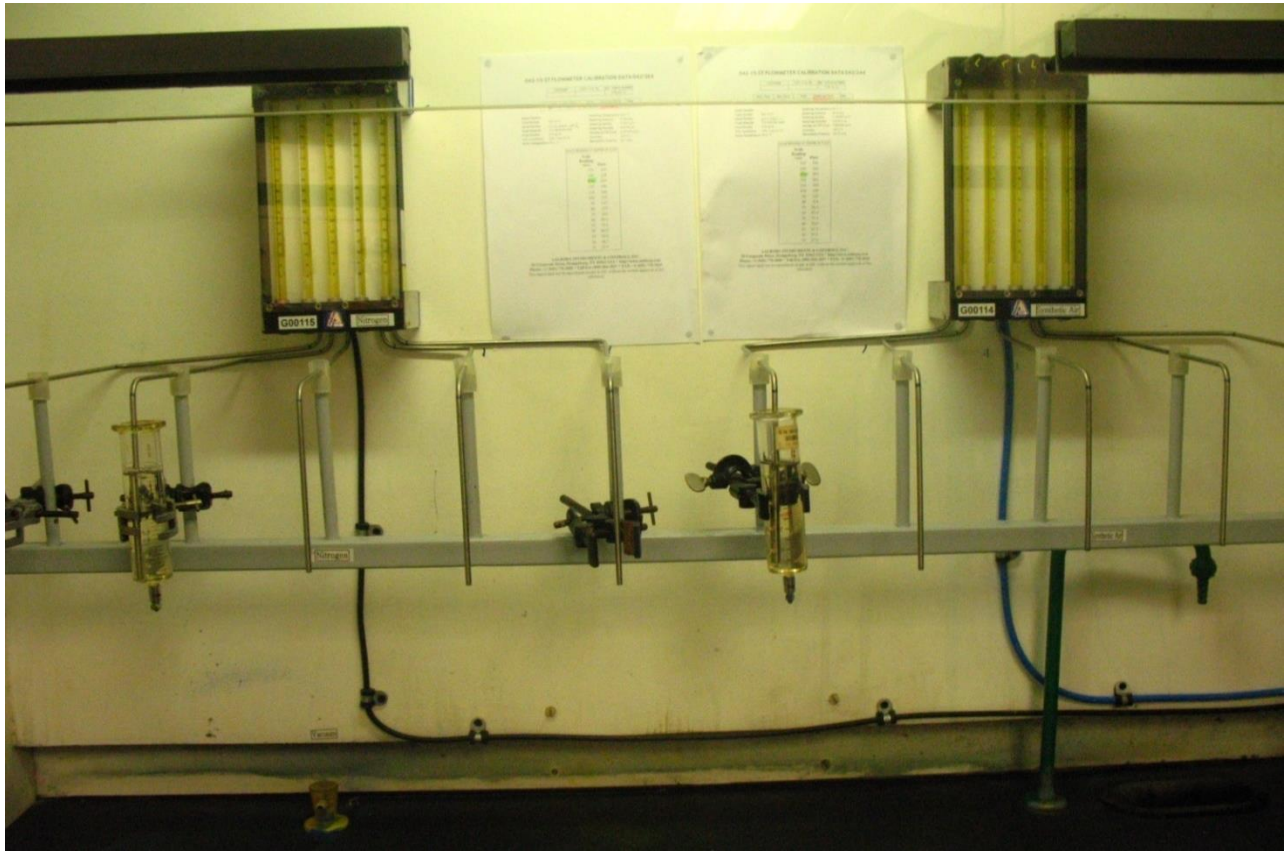
4. Diagnostic test results

Table 2: Results of the on-site diagnostic tests

Tests	Transformer with Stray Gassing activity	Transformer with PD activity
Electrical Tests	No issues	No issues
PD acoustic measurements	No PD activity detected	PD activity detected
Internal inspection	No evidence of fault activity	Evidence of PD activity found near detection region

5. Laboratory results – Stray Gassing

- Stray Gassing Test (ASTM D7150-13): Test configuration



6. Laboratory results – Stray Gassing

- The laboratory test:
  - New/ virgin oil or samples collected from in-service transformers
  - Filtered, degassed and then saturated with Nitrogen or Air Zero
  - For standard test, the samples are aged in an oven for 164hrs at 120°C

Table 3: Air purged samples

Gases	Transformer with Stray Gassing activity	Transformer with PD activity
H_2	1349	404
CH_4	220	19
CO	496	790
CO_2	1404	1637
C_2H_2	ND	ND
C_2H_4	4	11
C_2H_6	172	ND

7. Laboratory results – Compatibility

- DGA after aging, for compatibility studies
  - Oil samples aged with test samples for compatibility tests
  - Test material aged in oil, in an oven for 164hrs, at 100°C
  - At the end of aging, test material removed from oil
  - Oil then cooled to room temperature and DGA tests performed

Table 4: DGA after compatibility aging

Gases	Inhibited Oil		Uninhibited Oil
	Incompatible Material	*Compatible Material*	*Incompatible Material*
H_2	611	67	0
O_2	39494	21967	186904
N_2	362707	52709	566451
CH_4	139	2	0
CO	1184	111	22
CO_2	1768	858	592
C_2H_2	0	0	0
C_2H_4	6	0	0
C_2H_6	71	0	0
TCG	**2011**	**180**	**22**

8. Analysis of results and conclusions

- Stray gassing activity can be distinguished from classic fault activity in stray gassing oils and non-stray gassing oils
- A combination of normal DGA, field tests and stray gassing tests confirm or refute stray gassing activity
- There is no clear link between stray gassing activity and incompatible materials
- The gassing activity related to the introduction of other transformer materials into the oil is more dependent on the presence or absence of oxidation inhibitors
- Establishing a stray gassing baseline can assist in minimizing the risk of stray gassing activity masking classic fault activity
- Developing local limits for acceptable stray gassing levels is key to establishing common ground between OEM's, Asset Managers and Oil Suppliers

9. Selected References

[1] Recent Developments In DGA Interpretation- Joint Task Force D1.01/A2.11, CIGRE Brochure N° 296, 2006

[2] I. Höhlein, Unusual Cases of Gassing in Transformers in Service, IEEE Electrical Insulation Magazine, Vol. 22, Issue 1, February 2006

[3] ASTM D7150-13, Standard Test Method for the Determination of Gassing Characteristics of Insulating Liquids Under Thermal Stress

[4] M. Duval and L. Lamarre, The Duval Pentagon — A New Complementary Tool for the Interpretation of Dissolved Gas Analysis in Transformers, IEEE Electrical Insulation Magazine, Vol. 30, Issue 6, November/ December 2014, pp 9-12