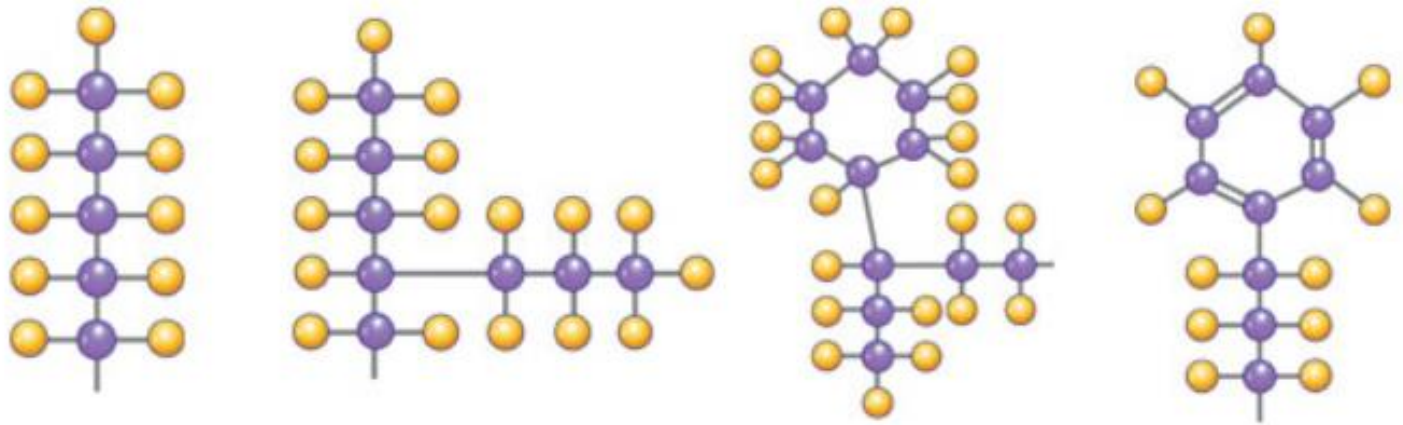
The importance of accuracy in DGA and different diagnostic tools.

Serge Gutieres P.eng.MBA
Sr. Business Development Manager OLMS
Asia,India,Australia

Mineral oil make up



Paraffin

C_nH_{2n+2}

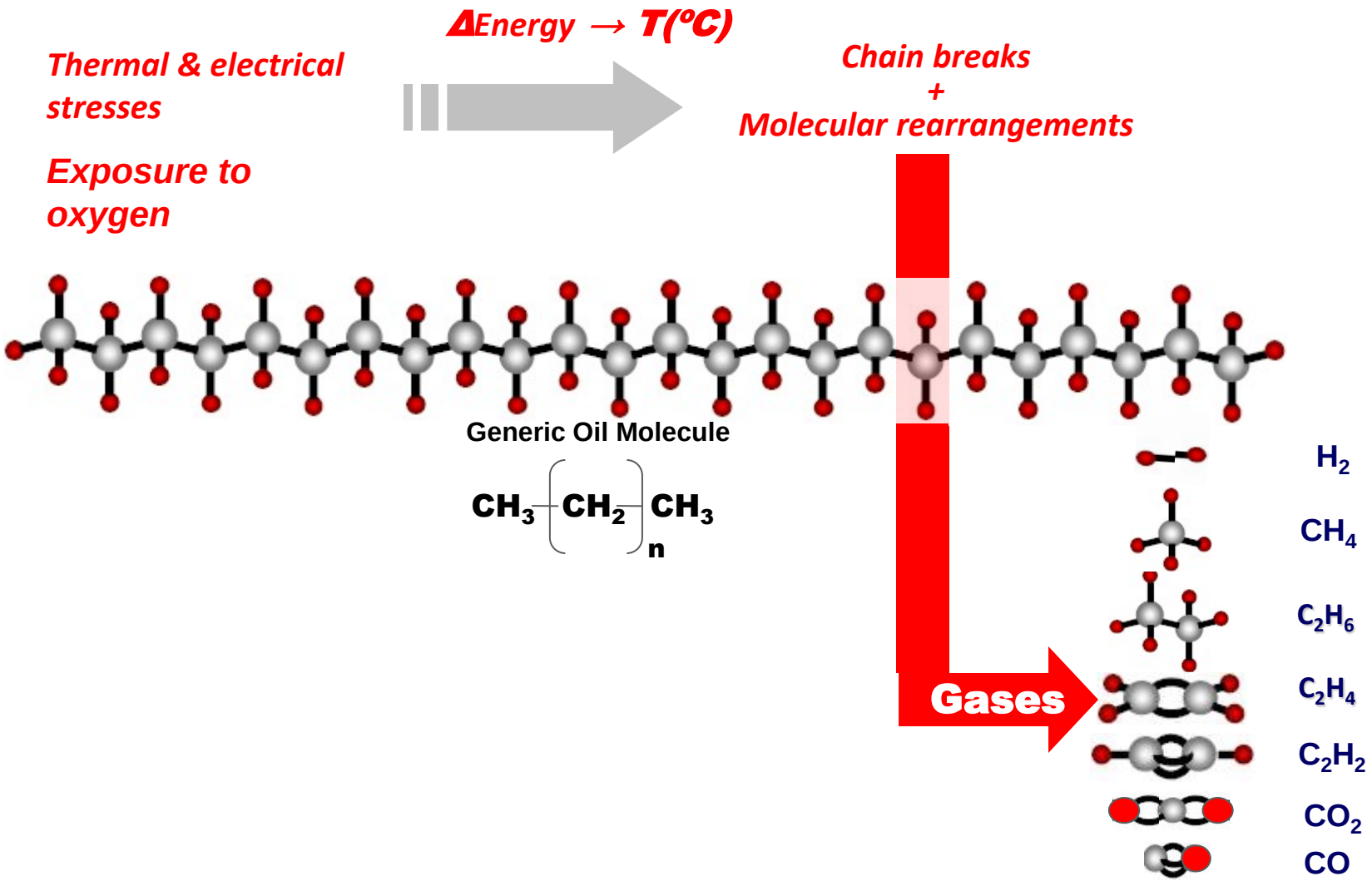
Branched Paraffin

Naphthene

C_nH_{2n}

Aromatic

How fault gases are generated



Dissolved fault gases

7 FAULT GASES

Carbon dioxide (CO_2)

Carbon monoxide (CO)

Indicates a hot spot

Burning the insulation paper

Hydrogen (H_2)

Methane (CH_4) 140 C

Ethane (C_2H_6) 250C

Ethylene (C_2H_4) 350C

Acetylene (C_2H_2) 500C+

Indicates developing faults

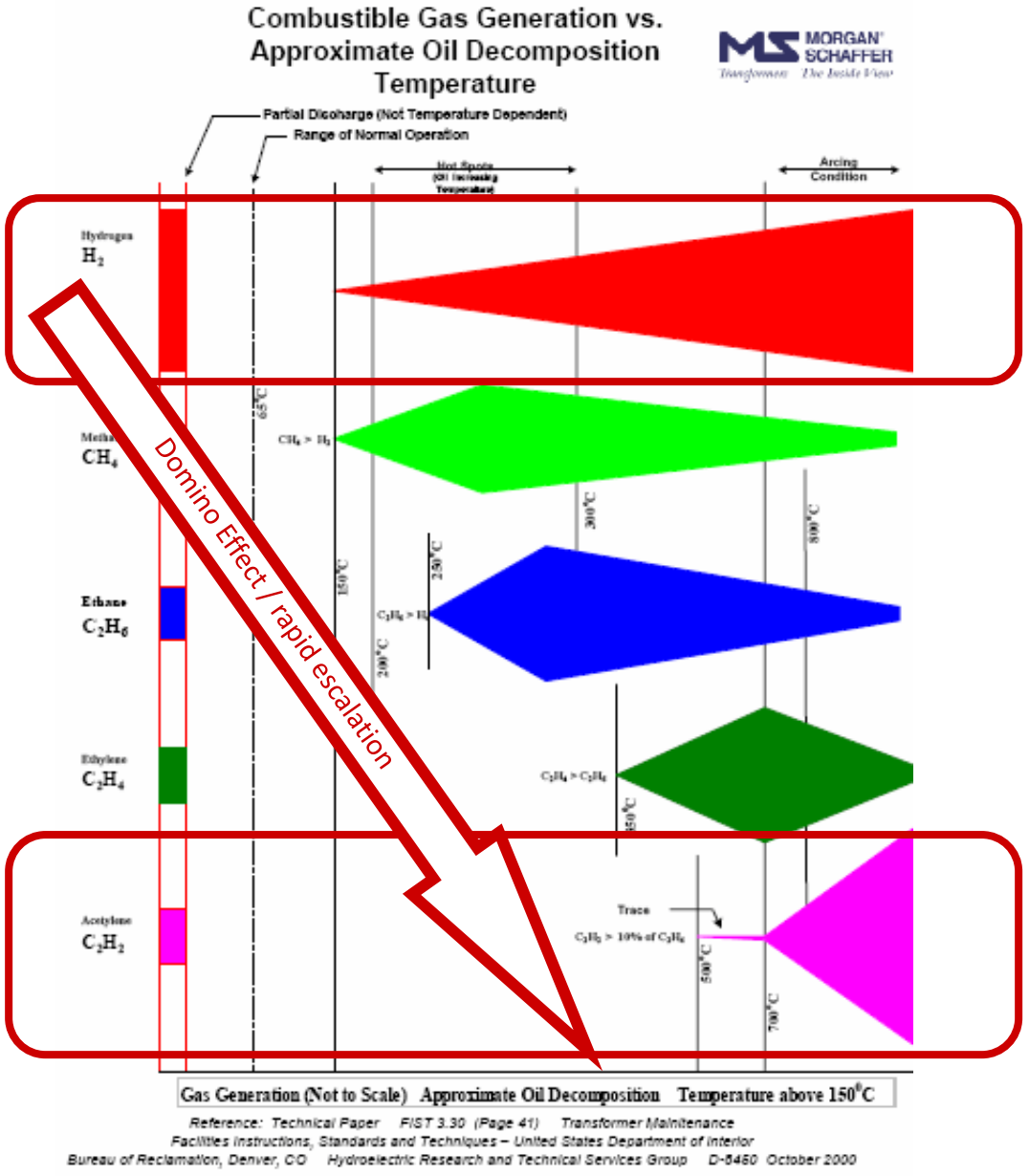
Gas formation from mineral oil

Temperature °C	Gases Formed	Symbol	Energy Required kJ/mole
~120 ↓ >700	Hydrogen	H_2	338
	Methane	CH_4	338
	Ethane	C_2H_6	607
	Ethylene	C_2H_4	720
	Acetylene	C_2H_2	960

Combustible gas generation rates

The only 2 gases that are constantly increasing are

H2 and C2H2



ALTANOVA
A DOBLE COMPANY

Importance of accuracy in DGA

Accuracy requirements for DGA

Accuracy Requirements for DGA

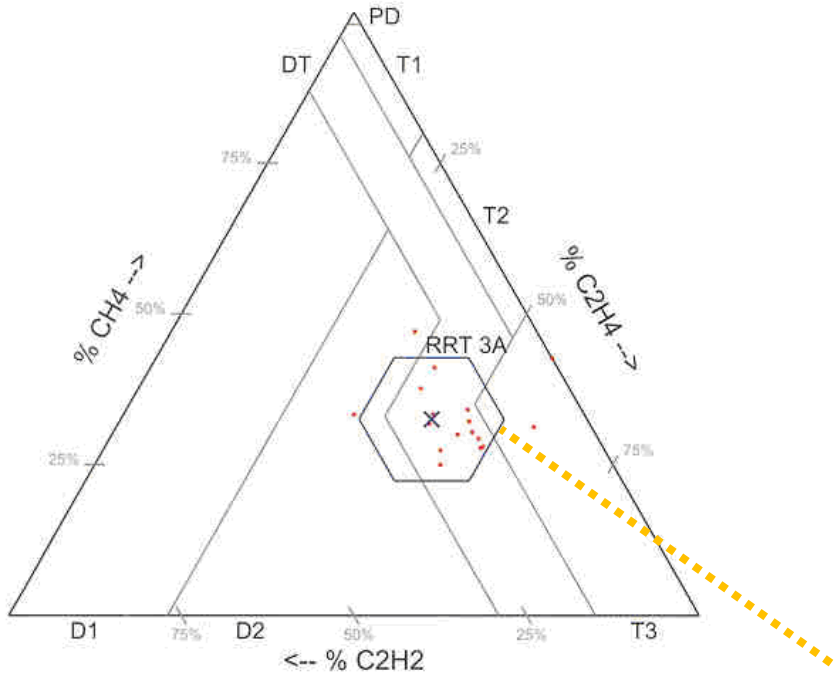
-an accuracy of 15% or better on gas concentrations is needed to obtain reliable DGA diagnosis. This is the accuracy specified by IEC 60567.

-15% of accuracy means that if the value measured by the laboratory is for example100 ppm, the actual value in the transformer may be anywhere between 85 ppm and 115 ppm.

- Accuracy short term and long term of the instrument is critical since all measuring instruments (lab & monitors) will drift with time and lose their accuracy. This is why an automatic calibration system is critical in monitors.

Your DGA results: accurate or not?

Diagnostic reliability is affected by the accuracy of the DGA measurement results



IEEE August 2005, M. Duval, J. Dukarm, Improving the reliability of transformer in gas-in-oil diagnosis

CIGRE result for Round Robin Test (RRT) at low concentration levels.

- *Results of individual laboratories*

x *prepared DGA standard value ()*

When an area of uncertainty crosses several fault zones , reliable diagnostic is not possible.

Fault severity is unclear.

+/- 15% variation limit of absolute values

Your DGA results: accurate or not?

Diagnostic reliability is affected by the accuracy of the DGA measurement results

Duval Triangle

Units: ppm %

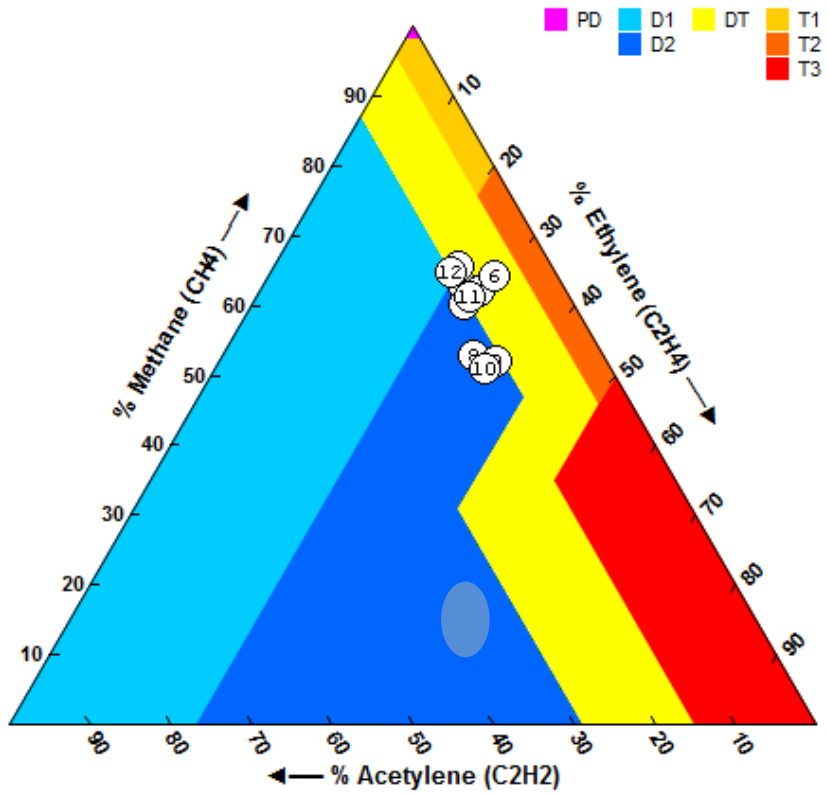
#	CH4	C2H4	C2H2
2	100	40	20
3	100	40	20
4	115	40	20
5	115	50	20
6	115	50	14
7	115	50	26
8	85	50	26
9	85	56	22
10	85	56	26
11	130	56	26
12	130	45	26

CH4: 130 ppm

C2H4: 45 ppm

C2H2: 26 ppm

Add



Real gas level CH4 100ppp,C2H4 50 ppm, C2H2 20 ppm with **accuracy +/- 30% range**

Your DGA results: accurate or not?

Diagnostic reliability is affected by the accuracy of the DGA measurement results

Duval Triangle

Units: ppm %

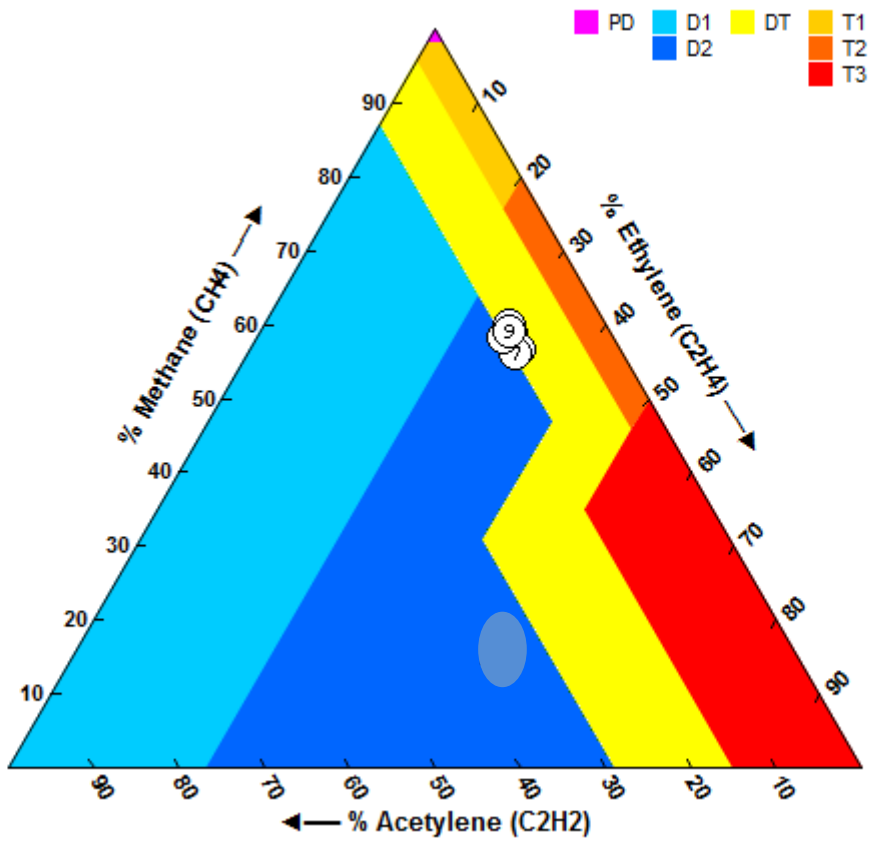
#	CH4	C2H4	C2H2
2	100	50	20
3	105	53	21
4	105	50	20
5	95	50	20
6	95	53	20
7	95	53	21
8	95	47	21
9	95	47	19

CH4: 95 ppm

C2H4: 47 ppm

C2H2: 19 ppm

Add



Real gas level CH4 100ppp,C2H4 50 ppm, C2H2 20 ppm with **accuracy +/- 5% range**

Your DGA results: accurate or not?

Diagnostic reliability is affected by the accuracy of the DGA

Duval Triangle

Units: ppm %

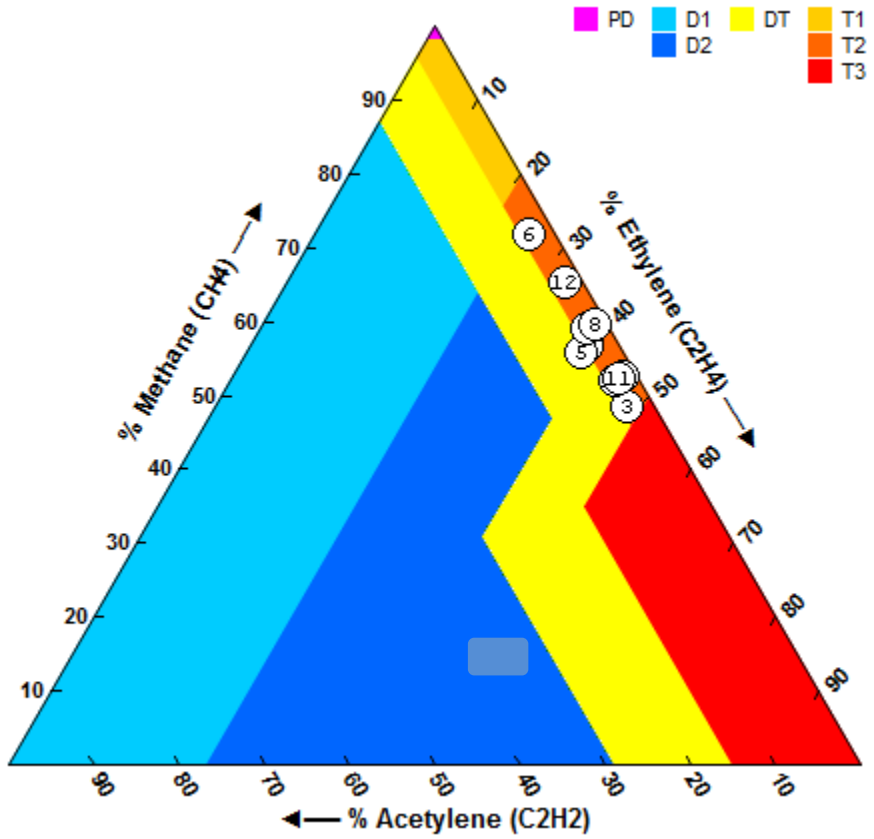
#	CH4	C2H4	C2H2
2	450	300	20
3	300	300	20
4	300	210	20
5	300	210	26
6	600	210	26
7	600	390	26
8	600	390	14
9	450	390	14
10	450	390	26
11	450	390	20
12	600	300	20

CH4: 600 ppm

C2H4: 300 ppm

C2H2: 20 ppm

Add



Real gas level CH4 100ppp,C2H4 50 ppm, C2H2 20 ppm with **accuracy +/- 30% range**

Your DGA results: accurate or not?

Diagnostic reliability is affected by the accuracy of the DGA measurement results

Duval Triangle

Units: ppm %

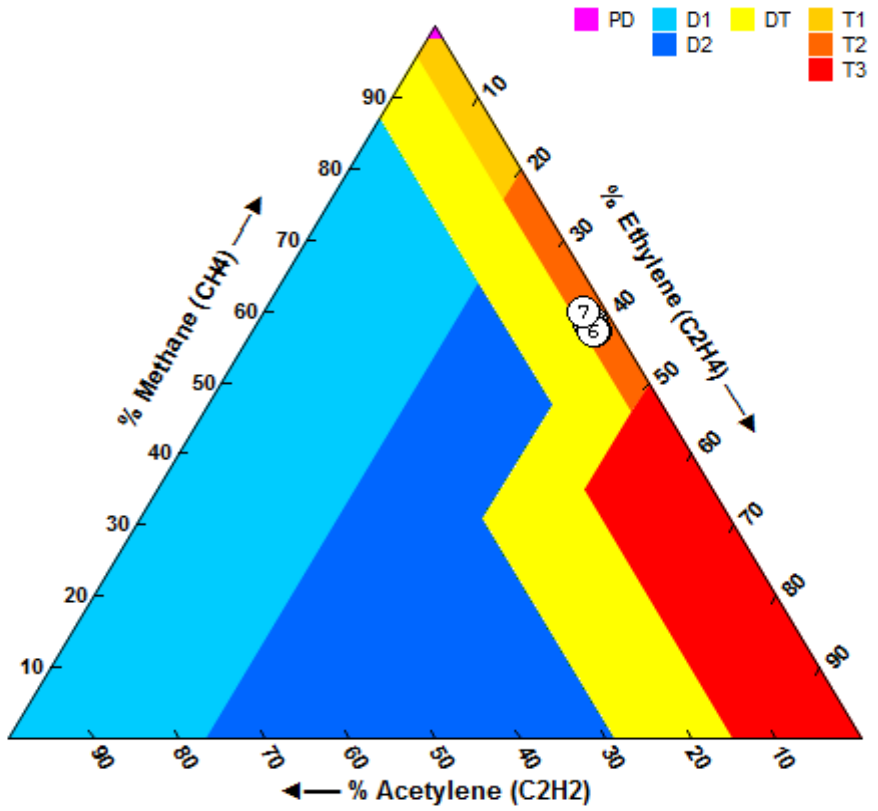
#	CH4	C2H4	C2H2
1	450	300	20
2	450	315	20
3	450	285	20
4	450	300	19
5	450	300	21
6	427	300	21
7	477	300	21

CH4: 477 ppm

C2H4: 300 ppm

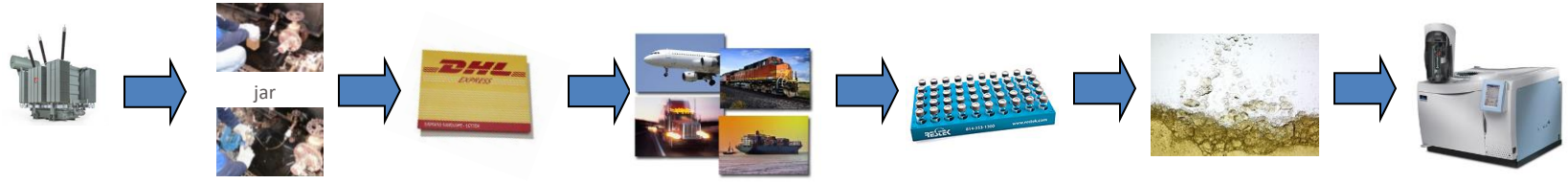
C2H2: 21 ppm

Add



Real gas level CH4 100ppp,C2H4 50 ppm, C2H2 20 ppm with **accuracy +/- 5% range**

DGA LAB – Ideal vs reality



	Sampling point	Sampling techniques & location	Packaging & handling	Transportation	Sample preparation	Gas extraction	Gas separation and measurement
Ideal situation	**100ppm**	100ppm	100ppm	100ppm	100ppm	100ppm	**100ppm**
			No loss / no variations				
Best case situation	**100ppm**	96ppm	94ppm	92ppm	90ppm	89ppm	**86pm**
			Little variations / controlled process				
Worst case situation	**100ppm**	90ppm	87ppm	85ppm	82ppm	72ppm	**70ppm**
			Process out-of-control / no accuracy				
			Issue with sample preparation / gas extraction / separation / measurement				

Even if a lab is very accurate, it only measures what it receives.

Your DGA results: accurate or not?

Every Laboratory should be able to demonstrate their precision and accuracy, if this is not possible or by any reason unknown, the below chart is recommended to use as a guide

Accuracy of IEC/CIGRE laboratories, from round-robin tests using DGA standards.		
	Medium gas concentrations	Low gas concentrations
Best lab	±3%	±22%
Average	±15%	±30%
Worst Lab	±65%	±64%

IEEE August 2005, M. Duval, J. Dukarm, Improving the reliability of transformer in gas-in-oil diagnosis

Accuracy

Oil standards are the best way to calibrate laboratory test procedures

- Accepted methods for performing Dissolved Gas Analysis (DGA) are outlined in **ASTM D3612** and **IEC 60567** standards.
- Both methods require proper **calibration of laboratory equipment** used to perform DGA prior to analyzing oil samples from the field.

MORGAN® SCHAFFER | Accuracy is Everything.

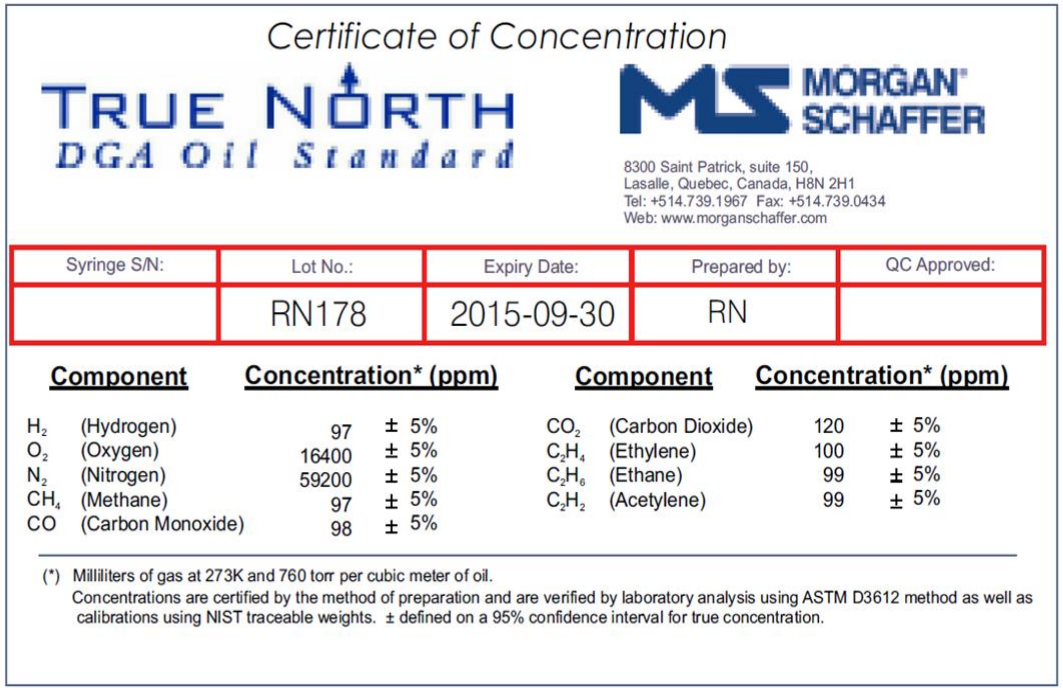
ALTANOVA
A DOBLE COMPANY

True North Gas-in-Oil Standard

Ensures proper calibration of gas extraction and chromatography

MORGAN® SCHAFFER | Accuracy is Everything.

Credibility



Certificate of Concentration

TRUE NORTH
DGA Oil Standard

MORGAN SCHAFFER

8300 Saint Patrick, suite 150,
Lasalle, Quebec, Canada, H8N 2H1
Tel: +514.739.1967 Fax: +514.739.0434
Web: www.morganschaffer.com

Syringe S/N:	Lot No.:	Expiry Date:	Prepared by:	QC Approved:
	RN178	2015-09-30	RN	

Component		Concentration* (ppm)		Component		Concentration* (ppm)	
H_2	(Hydrogen)	97	± 5%	CO_2	(Carbon Dioxide)	120	± 5%
O_2	(Oxygen)	16400	± 5%	C_2H_4	(Ethylene)	100	± 5%
N_2	(Nitrogen)	59200	± 5%	C_2H_6	(Ethane)	99	± 5%
CH_4	(Methane)	97	± 5%	C_2H_2	(Acetylene)	99	± 5%
CO	(Carbon Monoxide)	98	± 5%				

(*) Milliliters of gas at 273K and 760 torr per cubic meter of oil.
Concentrations are certified by the method of preparation and are verified by laboratory analysis using ASTM D3612 method as well as calibrations using NIST traceable weights. ± defined on a 95% confidence interval for true concentration.

- Traceability is key to credibility
- True North oil is produced using NIST traceable gas concentrations and NIST traceable calibrated balances
- Certificate of Concentration provided for each sample

MORGAN SCHAFFER | Accuracy is Everything.

Order Information

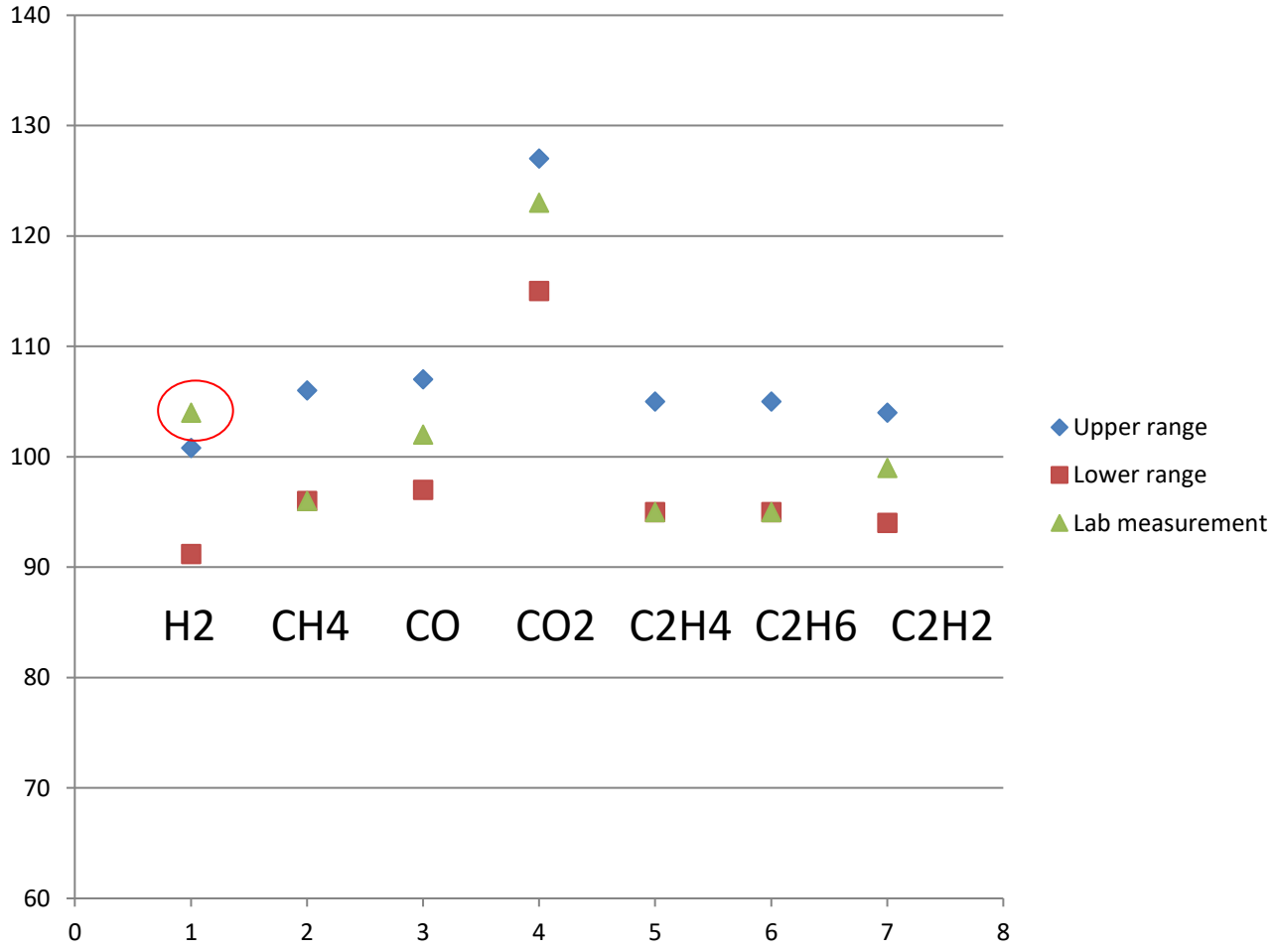
To order: **sales@morganschaffer.com**
or through your local Morgan Schaffer Authorized Representative

	True North	Atlantis
Syringe size	30 or 50 ml	30 or 50 ml
Concentration	10, 100 or 500 ppm	15 or 30 ppm
Guaranteed Shelf Life	True North: 30 days from syringe filling date True North Long Life: 60 days from syringe	30 days from syringe filling date
Warranty	True North: 30-days True North Long Life: 60-days	30 days

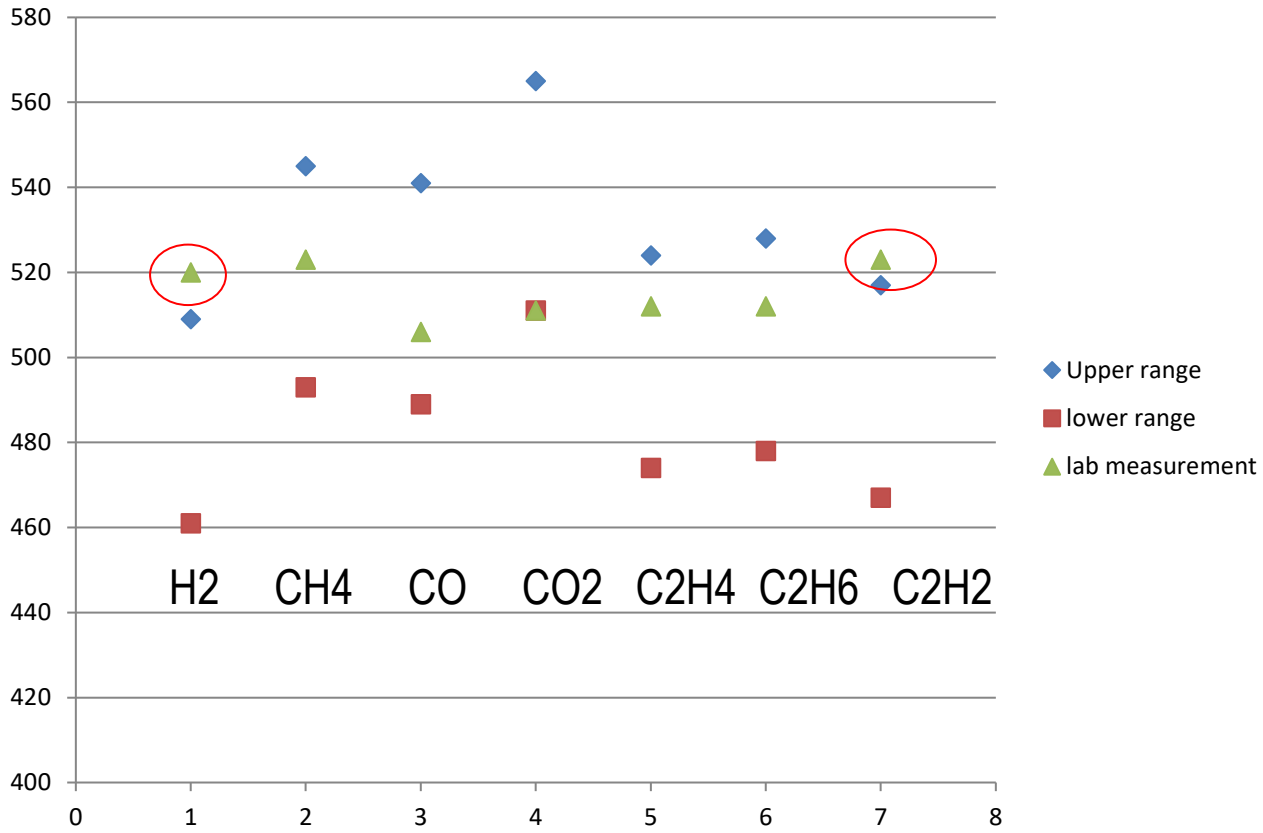
MORGAN® SCHAFFER | Accuracy is Everything.

Lab testing with gas in oil standard

100 PPM

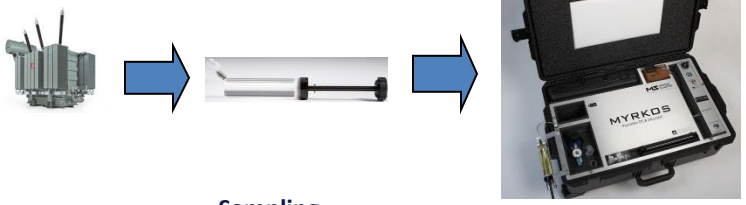


Lab testing with gas in oil standard 500 PPM



DGA – Portable vs lab

100ppm



Sampling point

Sampling techniques & location
Gas extraction

Gas separation and measurement

Best case situation **90ppm**

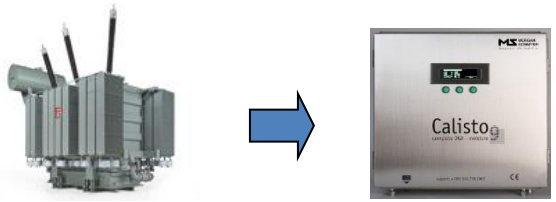
worst case situation **70ppm**

Portable accuracy depends on:

- Detector accuracy and LDL
- Regular calibration of the unit.
- Extraction and separation efficiency
- Time to analyze sample

DGA – OLM vs lab

100ppm



Gas extraction

Gas separation and measurement

Best case situation **95ppm**

worst case situation **70ppm**

OLM accuracy depends on:

- Oil circulation
- Detector accuracy and LDL
- Regular calibration of the system.
- Extraction and separation efficiency

Dissolved gas limits various sources

Criterion	H_2	CO	Methane	Ethane	Ethylene	Acetylene	CO2	TCG
DOBLE	100	250	100	60	100	5 (1)*	10,000 –core** 20,000-shell**	610
IEEE C57.104 (2008)	100 101-700 701-1800 >1800	350 351-570 571-1,400 >1,400	120 121-400 401-1,000 >1,000	65 66-100 101-150 >150	50 51-100 101-200 >200	1 2-9 10-35 >35	2500 2500-4000 4001-10000 >10,000	720 721-1920 1921-4630 >4630
IEC 60599 (ranges)	50-150	400-600	30-130	20-90	60-280	2-20 (No OLTC) 60-280 (Communicating OLTC)	3800-14,000	

Values based on statistical norms or consensus values

*Would consider 1 ppm or more of acetylene as abnormal for further evaluation

**Empirically based guidelines

Diagnosing transformer condition

IEEE Guide for Interpretation of Gasses C57.104-2008

Condition	TDCG (ppm)	TDCG Rate (ppm/day)	Sampling Interval	Operating Procedure
4	>4630	>30	daily	Consider removal from service. Advise manufacturer.
		10 - 30	daily	
		<10	weekly	Exercise extreme caution. Analyze for individual gases. Plan outage. Advise manufacturer.
3	1921 - 4630	>30	weekly	Exercise extreme caution. Analyze for individual gases. Plan outage. Advise manufacturer.
		10 - 30	weekly	
		<10	monthly	
2	721 - 1920	>30	monthly	Exercise caution. Analyze for individual gases. Determine load dependence.
		10 - 30	monthly	
		<10	quarterly	
1	<=720	>30	monthly	Exercise caution. Analyze for individual gases. Determine load dependence.
		10 - 30	quarterly	Continue normal operation.
		<10	annually	

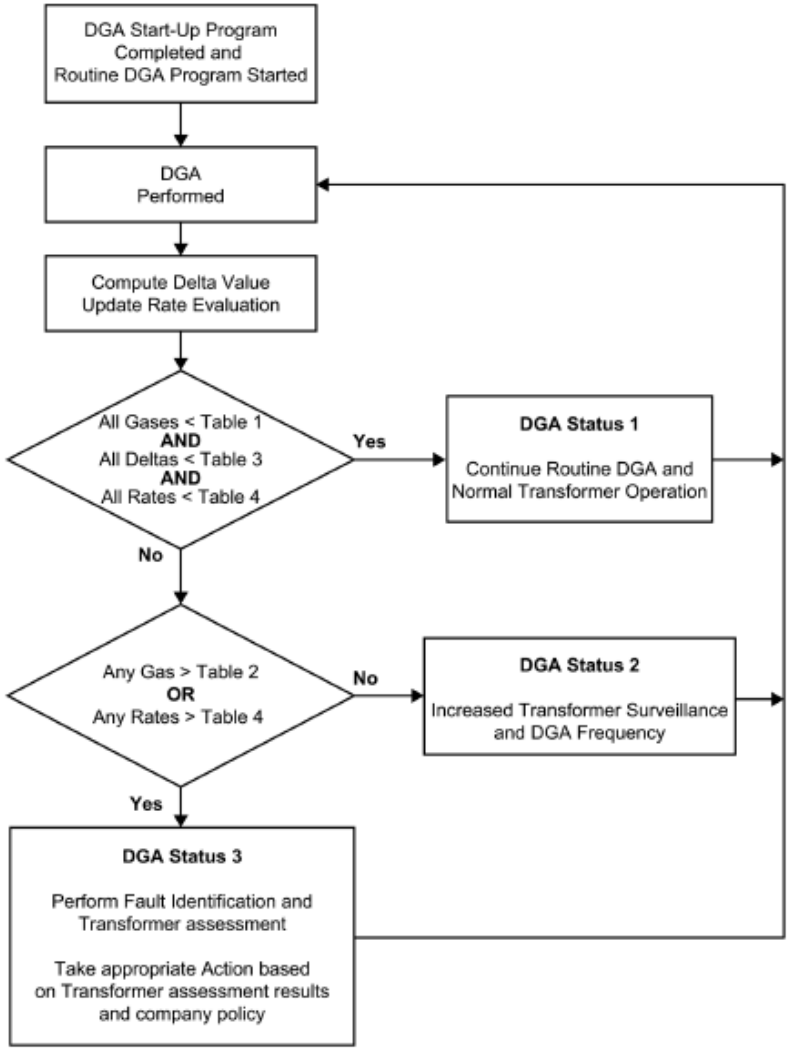
TDG (Total Dissolved Gases) expressed in % to 1.000.000ppm, i.e. in the picture TRN1 we see 7%, meaning there is a total of 70.000 ppm of gases (all the gases)

TDCG (Total Dissolved Combustible Gases) all the gases except N2, O2 and CO2, also in % to 1.000.000ppm, that's why we see 0% (less than 1ppm, as almost all the gases are N2, O2 and CO2)

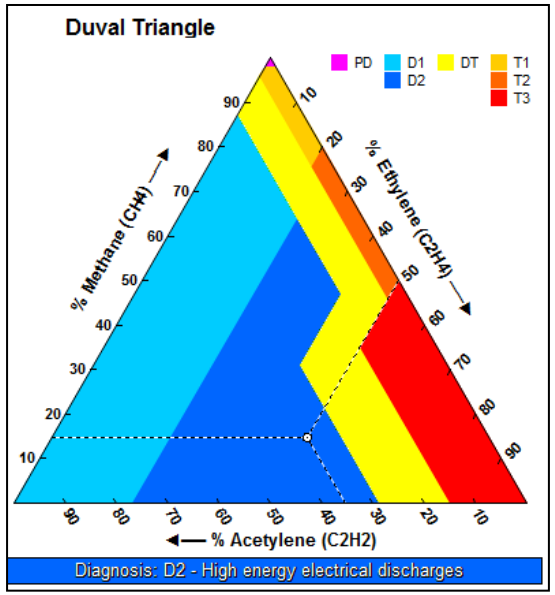
THCG (Total Headspace Combustible Gases) are the gases on the headspace at the transformers (especially in sealed transformers with N2 blanket) as the gases dissolved in the oil are in equilibrium with the headspace, we calculate, based on the Ostwald coefficient, each gas at the headspace level.

Accuracy

IEEE flowchart 57-104-2019



Diagnosing transformer condition



[1]

The Duval Triangle method, like any other DGA diagnostic method, should be applied only when there is some suspicion of a fault, based on an increase in combustible gas or some other suspicious symptom. The diagnostic method itself is not a means of fault detection.

Because of the relative inaccuracy of gas-in-oil concentration measurements at low concentrations, DGA diagnostic methods, including the Duval Triangle, should not be applied unless the gas concentrations are well above the detection limit.

If reasonably stable concentrations of the gases were present before the onset of the suspected fault, *it is advisable to subtract out the background concentrations,* provided that the differences are large enough for interpretation. The diagnosis should be based on recently-formed gas if possible, and including pre-fault gas in the diagnostic calculations can lead to misleading results[2].

Symbols	Faults	Examples
PD	Partial discharges	Discharges of the cold plasma (corona) type in gas bubbles or voids, with the possible formation of X-wax in paper
D1	Discharges of low energy	Partial discharges of the sparking type, inducing pinholes, carbonized punctures in paper Low energy arcing inducing carbonized perforation or surface tracking of paper or the formation of carbon particles in oil
D2	Discharges of high energy	Discharges in paper or oil, with power follow through, resulting in extensive damage to paper or large formation of carbon particles in oil, metal fusion, tripping of the equipment and gas alarms
DT	Thermal and electrical faults	Mixture of thermal and electrical faults
T1	Thermal fault, T<300°C	Evidenced by paper turning brownish (>200°C) or carbonized (>300°C)
T2	Thermal fault, 300<T<700°C	Carbonization of paper, formation of carbon particles in oil
T3	Thermal fault, T>700°C	Extensive formation of carbon particles in oil, metal coloration (800°C) or metal fusion (>1000°C)

[1] PPMreport, Morgan Schaffer Myrkos's operating system
[2] http://www.deltaxresearch.com/triangle.htm

Accuracy

Diagnosing transformer condition

Rogers Ratios	$\frac{\text{Acetylene } (C_2H_2)}{\text{Ethylene } (C_2H_4)}$	$\frac{\text{Methane } (CH_4)}{\text{Hydrogen } (H_2)}$	$\frac{\text{Ethylene } (C_2H_4)}{\text{Ethane } (C_2H_6)}$
Suggested Fault Diagnosis			
Normal	< 0.1	> 0.1 - < 1.0	< 1.0
Partial Discharge	< 0.1	< 0.1	< 1.0
Arcing	0.1 - 3.0	0.1 - 1.0	> 3.0
Slight Thermal Fault	< 0.1	> 0.1 - < 1.0	1.0 - 3.0
Thermal Fault <700C	< 0.1	> 1.0	1.0 - 3.0
Thermal Fault >700C	< 0.1	> 1.0	> 3.0

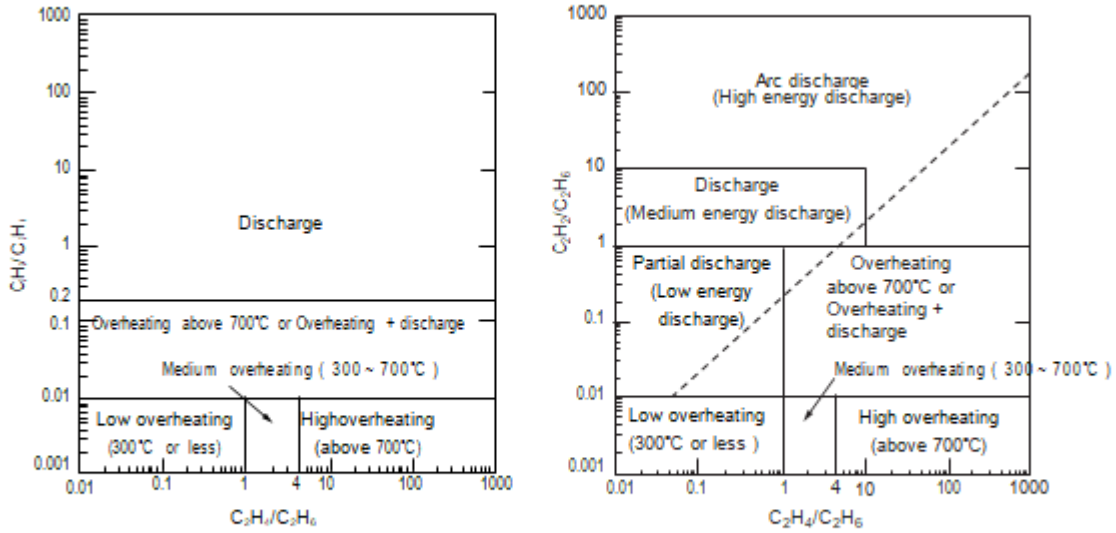
Rogers used these relationships and determined that if a certain ratio existed, then a specific temperature had been reached. By comparing a large number of transformers with similar gas ratios and data found when the transformers were examined, Rogers could then say that certain faults were present. Like the Key Gas Analysis above, this method is not a “sure thing” and is only an additional tool to use in analyzing transformer problems.

FIST 03-30, USA Bureau of reclamation

Doernenburg Ratios	$\frac{\text{Methane } (CH_4)}{\text{Hydrogen } (H_2)}$	$\frac{\text{Acetylene } (C_2H_2)}{\text{Ethylene } (C_2H_4)}$	$\frac{\text{Acetylene } (C_2H_2)}{\text{Methane } (CH_4)}$	$\frac{\text{Ethane } (C_2H_6)}{\text{Acetylene } (C_2H_2)}$
Suggested Fault Diagnosis				
Thermal Decomposition	> 1.0	< 0.75	< 0.3	> 0.4
Partial Discharge	< 0.1	Not Significant	< 0.3	> 0.4
Arcing	0.1 - 1.0	> 0.75	> 0.3	< 0.4

Accuracy

ETRA diagnostic



(a) Fault diagnosis chart A (b) Fault diagnosis chart B

Fig. 5-1-4 Fault diagnosis chart

- Tool used in Japan and Taiwan
- Easier to use than a triangle

Accuracy

OLTC DGA diagnostic duval triangle

Accuracy

OLTC DGA diagnostic

Ethylene / Acetylene	Arcing Type LTC's (Resistive & Reactive)*	
	<.5	Normal , continue annual sampling
	.5< X<1	Warning, sample more frequently, trend
	>1	Severe heating / coking probable, inspect,

* - Ethylene & Acetylene >50ppm

Total Combustible Gasses	Vacuum Type LTC's	
	< 10 ppm	Normal , continue annual sampling
	10< X<25 ppm	Warning, sample more frequently, trend
	>25 ppm	Heating / coking probable, Inspect

$$\frac{(CH_4)\ \text{Methane} + (C_2H_4)\ \text{Ethane} + (C_2H_6)\ \text{Ethylene}}{\text{Acetylene}^*\ (C_2H_2)}$$

* Acetylene >500 ppm

Ratio	Diagnosis	Recommended Sampling Frequency
< .5	Normal	Sample Annually
.5 to 1	Possible Heating	Sample every 3-6 months
1 to 3	Possible Heating	Sample every 1-3 months
3 to 5	Possible Heating	Sample weekly to monthly
> 5	Overheating Probable	Remove From Service & Inspect

Stenestam Ratios

Accuracy

New OLTC diagnostic tool

- Use Multigas monitor to generate DGA analysis
- Use OLTC Duval triangles to diagnose potential problems
- Will help go from a time maintenance base to a Condition base maintenance ….major $$$ saving

ALTANOVA
A DOBLE COMPANY

How to read an OLM spec sheet for LDL and accuracy

How to read accuracy spec sheet

The right way

Detector sensitivity

H_2 - 2 - 50,000 ppm
CO: 25 - 100,000 ppm

The wrong way

Measuring Quantities	Measuring range	Measuring accuracy H
Hydrogen H_2:	0 ppm ... 2.000 ppm	± 15 % of the measuring value ± 25 ppm
Carbon Monoxide CO:	0 ppm ... 2.000 ppm	± 20 % of the measuring value ± 25 ppm

H2 25 – 2,000 ppm
CO 25 – 2.000 ppm

Monitor accuracy - system vs detector

Performance										
	H_2	CO	CH_4	C_2H_2	C_2H_4	C_2H_6	CO_2	O_2	N_2	H_2O
Lower detection limit (LDL) [1]	ppm									2 ppm, or 2% RS
	0.5	10	0.2	0.2	0.2	0.2	15	500	2,000	
Range	ppm									Saturation, or 100% RS
	0 - 20,000	0 - 30,000	0 - 100,000	0 - 100,000	0 - 200,000	0 - 200,000	0 - 100,000	0 - 100,000	0 - 150,000	
Accuracy in factory[2]	Percent									
	2%	2%	2%	2%	2%	2%	2%	2%	2%	
Accuracy in service[3]	(LDL plus X% of reading) ppm									3 ppm, or 3% RS
	X=5	X=5	X=5	X=5	X=5	X=6	X=5	X=15	X=15	
Repeatability	(LDL plus Y% of reading) ppm									2 ppm, or 2% RS
	Y=3	Y=3	Y=3	Y=3	Y=3	Y=4	Y=3	Y=10	Y=10	
Resolution at LDL	ppm									1 ppm, or 1% RS
	0.5	2	0.2	0.2	0.2	0.2	5	100	1,000	
Measurement interval	User configurable: 80, 160 and 240 minutes. Conditional cycle on alarm.									6 seconds
Step response (typical)	In 80 minutes: 95% H_2; 90% CO, CH_4, CO_2, O_2, N_2; 80% C_2H_2, C_2H_4, C_2H_6									95% in 20 minutes

System Accuracy

extraction

separation

detection

Measuring Quantity	Accuracy of gas extraction	Accuracy of the gas measurement
Hydrogen H_2	≤ ± 8 % ± 4 ppm	≤ ± 10 % ± 20 ppm
Carbon Monoxide CO	≤ ± 8 % ± 30 ppm	≤ ± 10 % ± 5 ppm
Carbon Dioxide CO_2	≤ ± 8 % ± 30 ppm	≤ ± 10 % ± 5 ppm
Methane CH_4	≤ ± 8 % ± 4 ppm	≤ ± 10 % ± 5 ppm
Acetylene C_2H_2	≤ ± 8 % ± 4 ppm	≤ ± 10 % ± 5 ppm
Ethylene C_2H_4	≤ ± 8 % ± 4 ppm	≤ ± 10 % ± 5 ppm
Ethane C_2H_6	≤ ± 8 % ± 4 ppm	≤ ± 10 % ± 5 ppm
Propane C_3H_8	≤ ± 8 % ± 4 ppm	≤ ± 15 % ± 20 ppm
Oxygen O_2	≤ ± 8 % ± 500 ppm	≤ ± 10 % ± 500 ppm
Nitrogen N_2	≤ ± 8 % ± 1500 ppm	≤ ± 10 % ± 1500 ppm

Technical Specifications

MEASUREMENTS

Technology

Uses photo-acoustic spectroscopy (PAS) for field proven highly repeatable results

Eight target gases plus Total Dissolved Combustible Gas (TDCG) value. Estimation of Nitrogen content for free breathing transformers

Suitable for transformers using mineral insulating oil and also ester based oils (natural or synthetic)

Range (LDL - UDL)

Hydrogen (H_2)	5 - 5,000 ppm
Carbon Monoxide (CO)	2 - 50,000 ppm
Methane (CH_4)	2 - 50,000 ppm
Acetylene (C_2H_2)	0.5 - 50,000 ppm
Ethane (C_2H_6)	2 - 50,000 ppm
Ethylene (C_2H_4)	2 - 50,000 ppm
Oxygen (O_2)	100 - 50,000 ppm
Nitrogen (N_2) *	10,000 - 100,000 ppm
Moisture (H_2O)	0 - 100% RS (given in ppm)

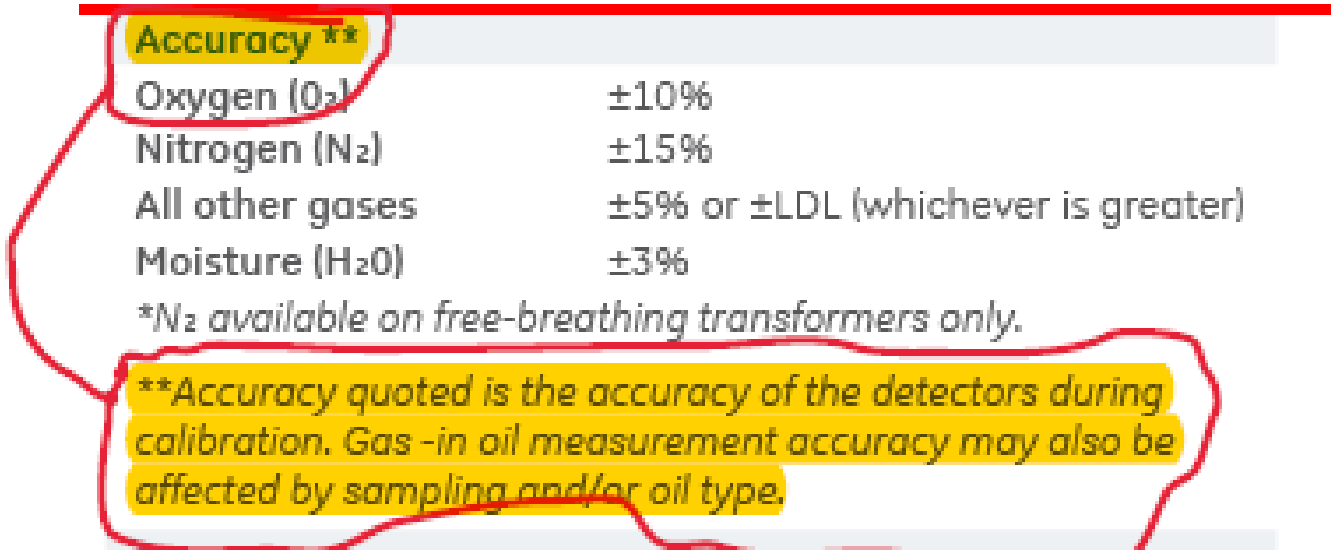
Accuracy **

Oxygen (O_2)	±10%
Nitrogen (N_2)	±15%
All other gases	±5% or ±LDL (whichever is greater)
Moisture (H_2O)	±3%

N_2 available on free-breathing transformers only.

***Accuracy quoted is the accuracy of the detectors during calibration. Gas -in oil measurement accuracy may also be affected by sampling and/or oil type.*

How to read accuracy spec sheet



Accuracy **	
Oxygen (O_2)	±10%
Nitrogen (N_2)	±15%
All other gases	±5% or ±LDL (whichever is greater)
Moisture (H_2O)	±3%

N_2 available on free-breathing transformers only.

***Accuracy quoted is the accuracy of the detectors during calibration. Gas -in oil measurement accuracy may also be affected by sampling and/or oil type.*

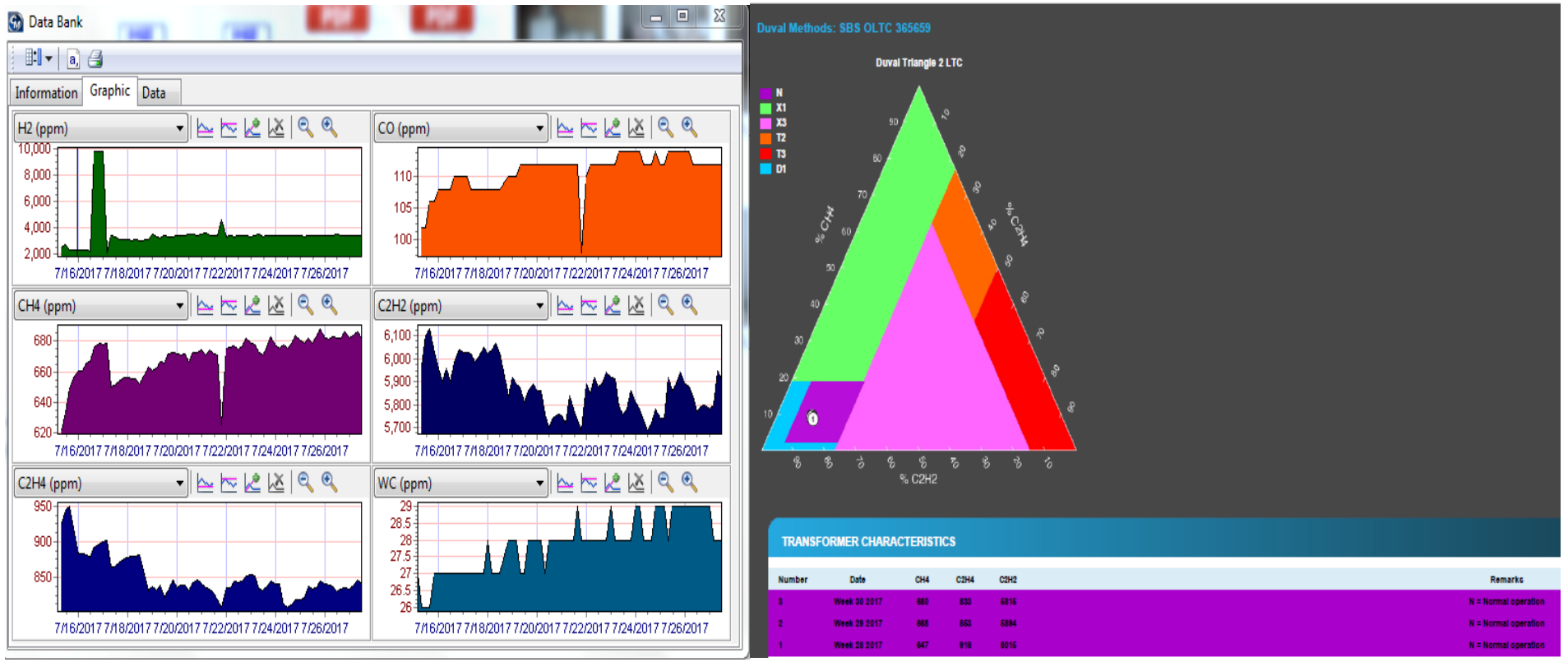
- Often accuracy stated is misleading . Accuracy shown is detector accuracy, not complete system accuracy (detector+extraction) and only during lab calibration , not long term accuracy…

OLTC / Main tank deployment with diagnostic tool

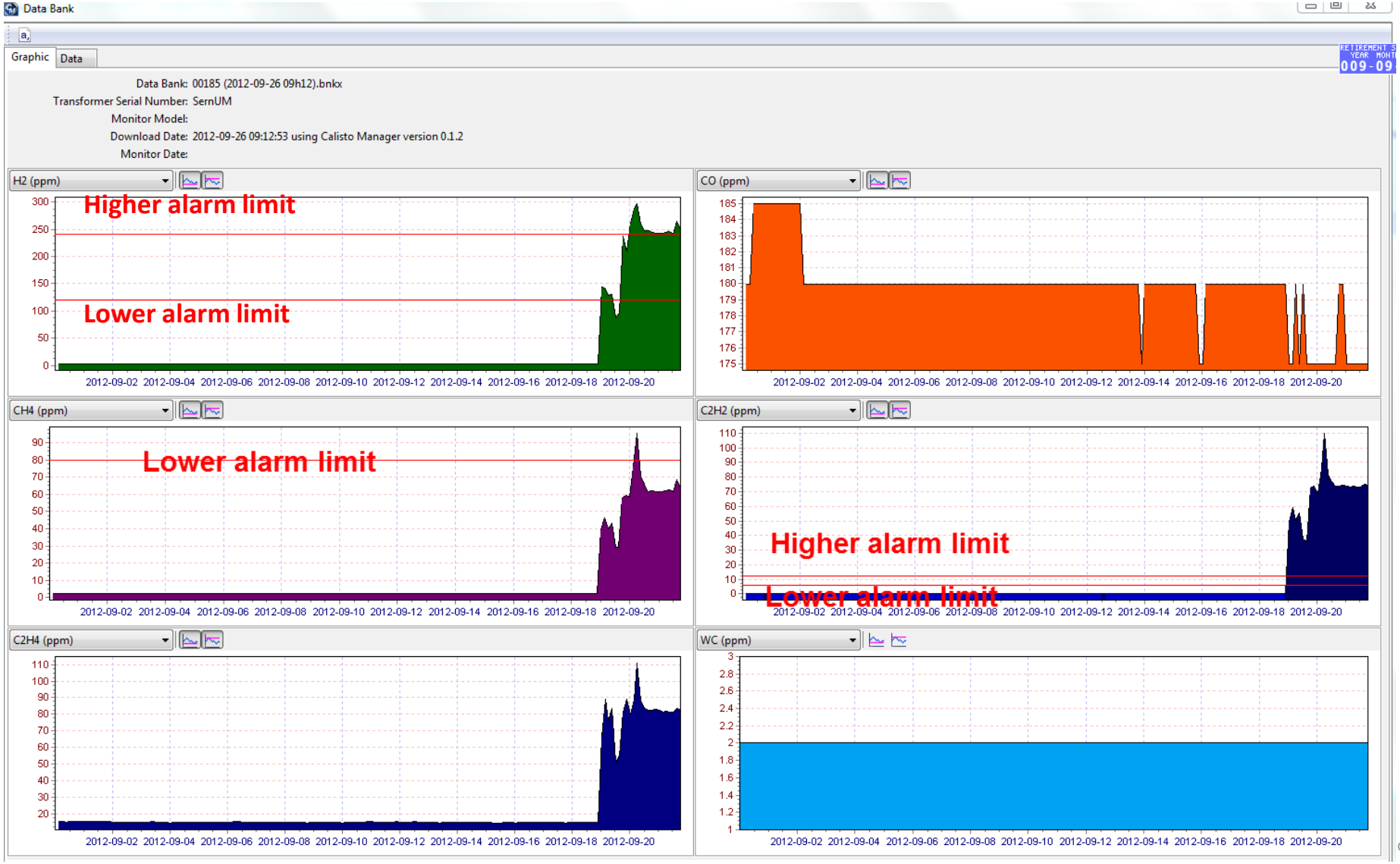
Asian Transit System
June 2017

Asian Transit System installation

OLTC analysis using IV 5.0



Nuclear Canadian Utility



ALTANOVA
A DOBLE COMPANY

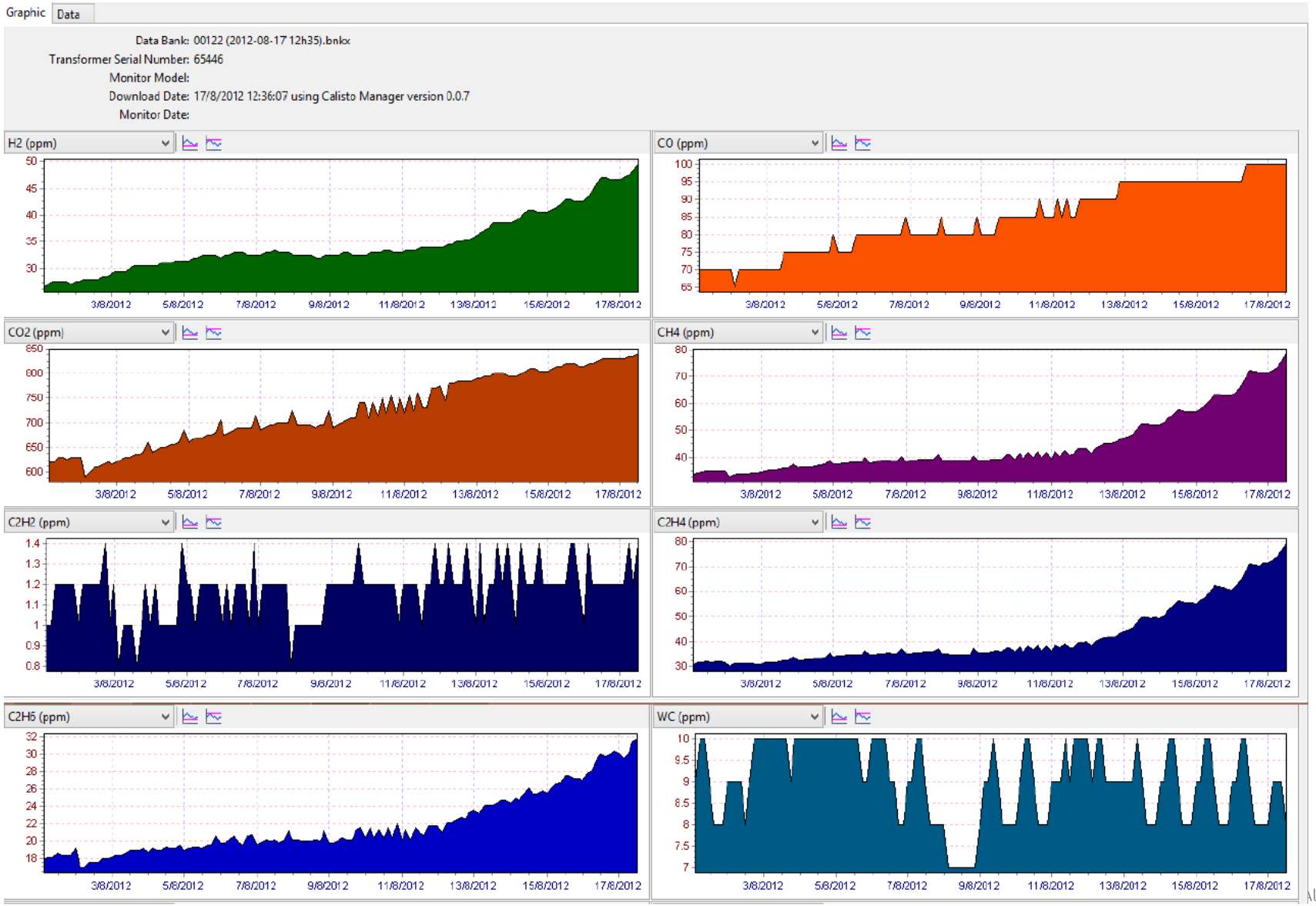
Case study: Steel Industry S.E. Asia

Steel Industry S.E. Asia

Main Tank Transformer Capacity 96 MVA, 22/1.1kv

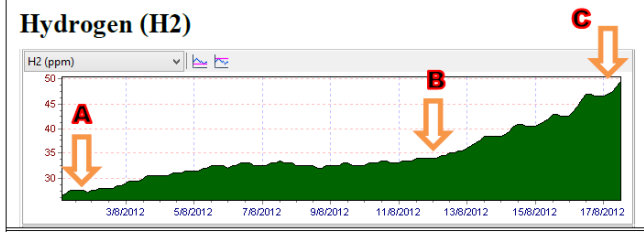
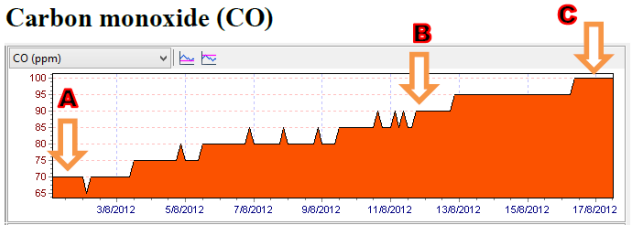
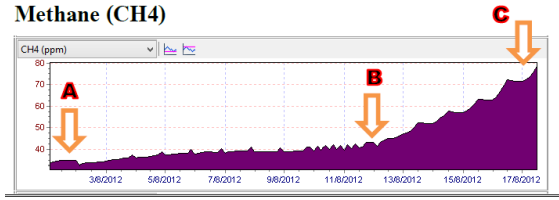
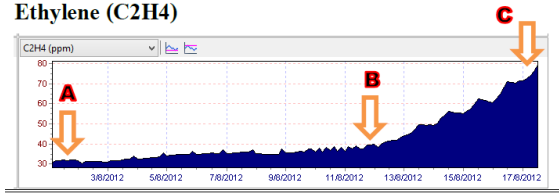
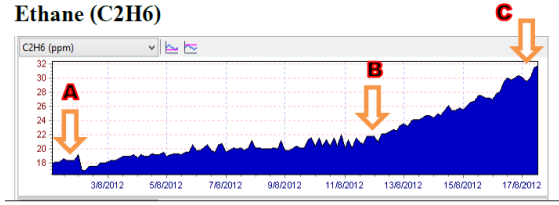
Manufacturers: TAMINI

Steel Industry S.E. Asia



Steel Industry S.E. Asia fault deteriorating

The DATA Bank It takes 12 days develop from A to B and 6 days form B to C

Hydrogen (H2) 	A to B 0.70 ppm/day B to C 2.25 ppm/day
Carbon monoxide (CO) 	A to B 1.66 ppm/day B to C 1.66 ppm/day
Methane (CH4) 	A to B 1.0 ppm/day B to C 6.16 ppm/day
Ethylene (C2H4) 	A to B 1.0 ppm/day B to C 6.83 ppm/day
Ethane (C2H6) 	A to B 0.3 ppm/day B to C 1.8 ppm/day

Steel Industry S.E. Asia Data vs IEC standard

ALARM SET: IEEE TRN MINERAL (V LESS OR EQUAL 69)

Name	H2	CH4	C2H6	C2H4	C2H2	O2	N2	CO2	CO
High Level 4	1801	1001	151	201	36			10001	1401
High Level 3	701	401	101	101	10			4001	571
High Level 2	101	121	66	51	2			2500	351
High Level 1	50	60	33	25	1			1800	175

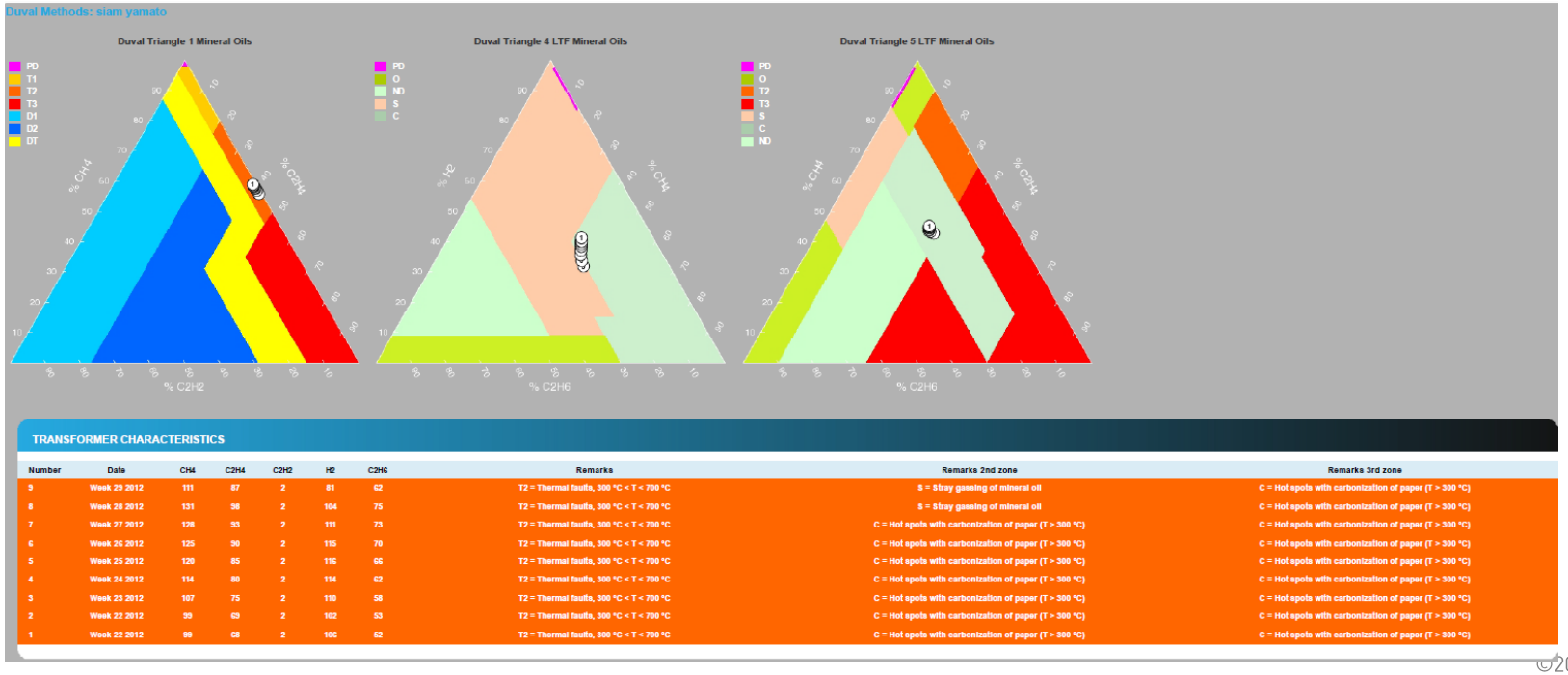
MEASUREMENTS (PPM)

Date	H2	CH4	C2H6	C2H4	C2H2	O2	N2	CO2	CO
Week 29 2012	80,8	110,5	61,9	86,7	1,5	21380,6	48527,8	2863,2	385,8
Week 28 2012	104,3	130,8	74,6	97,8	1,8	28119,6	61678,6	3656,6	498,8
Week 27 2012	110,7	127,5	72,7	92,7	1,9	27930,4	61946,4	3644,8	498,5
Week 26 2012	115,1	124,8	69,7	89,8	2	28025	61803,6	3585,9	486,7
Week 25 2012	116,4	120,3	66	85,2	2,2	28396,4	61571,4	3526,6	478,4
Week 24 2012	114,1	114,5	62,4	79,8	1,9	28641,1	61571,4	3458,4	464,8
Week 23 2012	109,5	106,6	57,7	74,7	2	28830,4	62392,9	3430,9	452
Week 22 2012	102	99,3	53,2	69,1	1,8	29931,3	63000	3439,4	446,9
Week 22 2012	105,9	98,6	52,3	67,7	1,6	31714,3	65285,7	3402,9	450,7

Steel Industry S.E. Asia diagnostic

DGA ANALYSIS

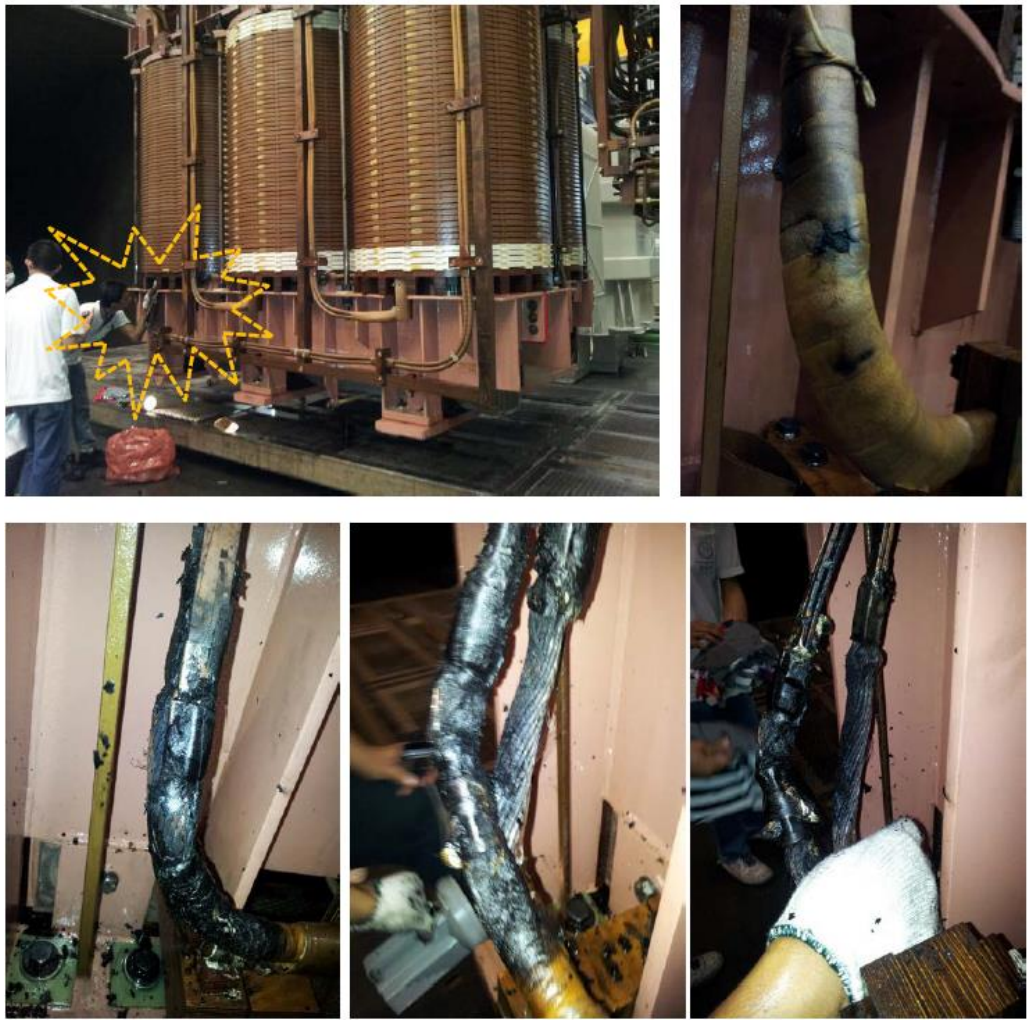
Date	Duval triangle	Rogers gas ratios	IEC 60599 gas ratios
Week 29 2012	T2 = Thermal faults, 300 °C < T < 700 °C	Thermal fault temp. range less than 700 °C	Thermal fault 300 °C < T < 700 °C
Week 28 2012	T2 = Thermal faults, 300 °C < T < 700 °C	Thermal fault temp. range less than 700 °C	Thermal fault 300 °C < T < 700 °C
Week 27 2012	T2 = Thermal faults, 300 °C < T < 700 °C	Thermal fault temp. range less than 700 °C	Thermal fault 300 °C < T < 700 °C
Week 26 2012	T2 = Thermal faults, 300 °C < T < 700 °C	Thermal fault temp. range less than 700 °C	Thermal fault 300 °C < T < 700 °C
Week 25 2012	T2 = Thermal faults, 300 °C < T < 700 °C	Thermal fault temp. range less than 700 °C	Thermal fault 300 °C < T < 700 °C
Week 24 2012	T2 = Thermal faults, 300 °C < T < 700 °C	Thermal fault temp. range less than 700 °C	Thermal fault 300 °C < T < 700 °C
Week 23 2012	T2 = Thermal faults, 300 °C < T < 700 °C	Low temp thermal fault	Unknown fault: partial or mixture of faults – mainly thermal faults
Week 22 2012	T2 = Thermal faults, 300 °C < T < 700 °C	Low temp thermal fault	Unknown fault: partial or mixture of faults – mainly thermal faults
Week 22 2012	T2 = Thermal faults, 300 °C < T < 700 °C	Low temp thermal fault	Unknown fault: partial or mixture of faults – mainly thermal faults



TRANSFORMER CHARACTERISTICS

Number	Date	CH4	C2H4	C2H2	H2	C2H6	Remarks	Remarks 2nd zone	Remarks 3rd zone
9	Week 29 2012	111	87	2	81	62	T2 = Thermal faults, 300 °C < T < 700 °C	S = Stray gassing of mineral oil	C = Hot spots with carbonization of paper (T > 300 °C)
8	Week 28 2012	131	98	2	104	75	T2 = Thermal faults, 300 °C < T < 700 °C	S = Stray gassing of mineral oil	C = Hot spots with carbonization of paper (T > 300 °C)
7	Week 27 2012	128	93	2	111	73	T2 = Thermal faults, 300 °C < T < 700 °C	C = Hot spots with carbonization of paper (T > 300 °C)	C = Hot spots with carbonization of paper (T > 300 °C)
6	Week 26 2012	125	90	2	115	70	T2 = Thermal faults, 300 °C < T < 700 °C	C = Hot spots with carbonization of paper (T > 300 °C)	C = Hot spots with carbonization of paper (T > 300 °C)
5	Week 25 2012	120	85	2	116	66	T2 = Thermal faults, 300 °C < T < 700 °C	C = Hot spots with carbonization of paper (T > 300 °C)	C = Hot spots with carbonization of paper (T > 300 °C)
4	Week 24 2012	114	80	2	114	62	T2 = Thermal faults, 300 °C < T < 700 °C	C = Hot spots with carbonization of paper (T > 300 °C)	C = Hot spots with carbonization of paper (T > 300 °C)
3	Week 23 2012	107	75	2	110	58	T2 = Thermal faults, 300 °C < T < 700 °C	C = Hot spots with carbonization of paper (T > 300 °C)	C = Hot spots with carbonization of paper (T > 300 °C)
2	Week 22 2012	99	69	2	102	53	T2 = Thermal faults, 300 °C < T < 700 °C	C = Hot spots with carbonization of paper (T > 300 °C)	C = Hot spots with carbonization of paper (T > 300 °C)
1	Week 22 2012	99	68	2	106	52	T2 = Thermal faults, 300 °C < T < 700 °C	C = Hot spots with carbonization of paper (T > 300 °C)	C = Hot spots with carbonization of paper (T > 300 °C)

Steel Industry S.E. Asia Internal investigation



Summary

- DGA is a very powerful tool for detecting and monitoring developing faults in oil-filled equipment
- The accuracy of the measurements can influence the conclusions drawn
  - Be sure to take a good oil sample
  - Always use an accredited laboratory
- Be aware of the claimed “accuracy” of online DGA monitors, read the small print!

ALTANOVA
A DOBLE COMPANY

THANK YOU

Serge Gutieres P.eng.MBA
sgutieres@doble.com