DGA - Method in the Past and for the Future

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Frei verwendbar

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THE METROPOLITAN-VICKERS GAZETTE

CONTENTS PAGE

The identity and significance of gases collected in Buchholz protectors

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1970	Doerenburg introduced the differentiation between electrical and thermal failure mode and introduced ratios for fault gases with similar solubility.
1973	Halstead developed the theoretical thermodynamic theory. The ratios are temperature dependent. With increasing the hotspot the amount of gases increases in the order: methane-ethane-ethylene.
1975	The evaluation scheme of the modern Gas-in-Oil Analysis is developed by Rogers, Mueller, Schliesing, Soldner (MSS).
1995	Development of In-Line Monitoring

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Different phenomena in oil take place like:

dielectric

thermal

dynamic

chemical

Change/Ageing

▶ Gas-in-Oil Analysis (DGA = Dissolved Gas Analysis)

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The measurement of dissolved gases allow the knowledge on

- **Type**
- **Complexity**
- **Seriousness**

of event

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Sampling

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Sampling Container

- ✓ **Perfectly cleaned & Dried**
- ✓ **Free from dust & moisture**
- ✓ **Airtight**
- ✓ **Glass or Metal cans, syringes**

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- ✓ **Protect sample from direct light**
- ✓ **Avoid moisture & dust contamination**
- ✓ **Use the sampling containers exclusively for transformer oil sampling**

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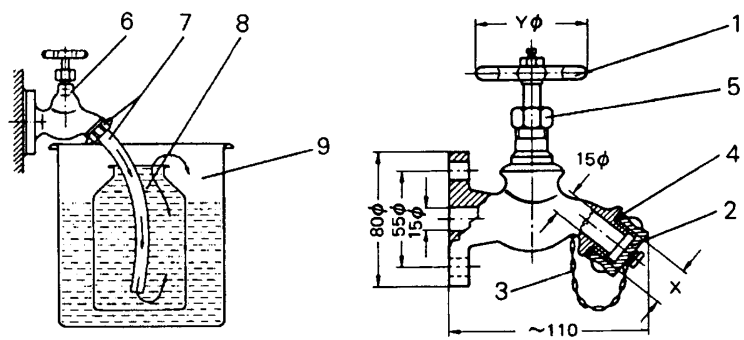

1 Handwheel
2 Sealing cap
3 Safety chain
4 Polyamid gasket
5 Nut
6 Drain valve
7 Hose and screw connector
8 Sampling bottle
9 Overflow vessel

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Required information concerning oil sample(example)

Requested analysis:

Colour	ISO 2049	☐
Appearance	IEC 60422	☐
Neutralisation value	IEC 62021-1	☐
Breakdown voltage	IEC 60156	☐
Water content	IEC 60814	☐
Loss factor at 50 Hz	IEC 60247	☐
Interfacial tension	ISO 6295	☐
PCB-content	EN 12766-2	☐
Furananalysis (DGA)	IEC 61198	☐
Gas-in-oil-analysis	IEC 60567	☐
		☐
		☐
		☐

Please fill in the following data:

Manufacturer:	FTNR (Manufacturing No.):
Customer:	WNR (Order No.):
Location:	Sample No.:
Year of manufacture:	Date sample taken.:
Type:	Type of oil
Power:	Quantity of oil:
Rating:	**Oil temperature in the sample taken:**

Sample taken from:	☐ Oil sample valve	☐ Oil drainage device A 22/31/40 DIN 42 551	☐ Others
Tank:	☐ Top	☐ Middle	☐ Bottom
conservator	☐ Transformer	☐ OLTC	☐ Bushing
OLTC	☐ OLTC tank	☐	☐
Bushing	☐	☐	☐
Others:	☐	☐	☐

Reason for sample taking:

- ☐ Date of operation fault:
- ☐ Date of repair :
- ☐ Date of oil treatment/reclaiming
- ☐ Routine checkup:
- ☐

Further informations and previous history:

Sample taker:

Date	Name in block letters	Company/ Department	Phone

Lab information:	**special features:**
Consecutive no.:	
Date sample received:	
Date sample analysed:	
Type of sample container:	

Extraction of Gases from the Oil

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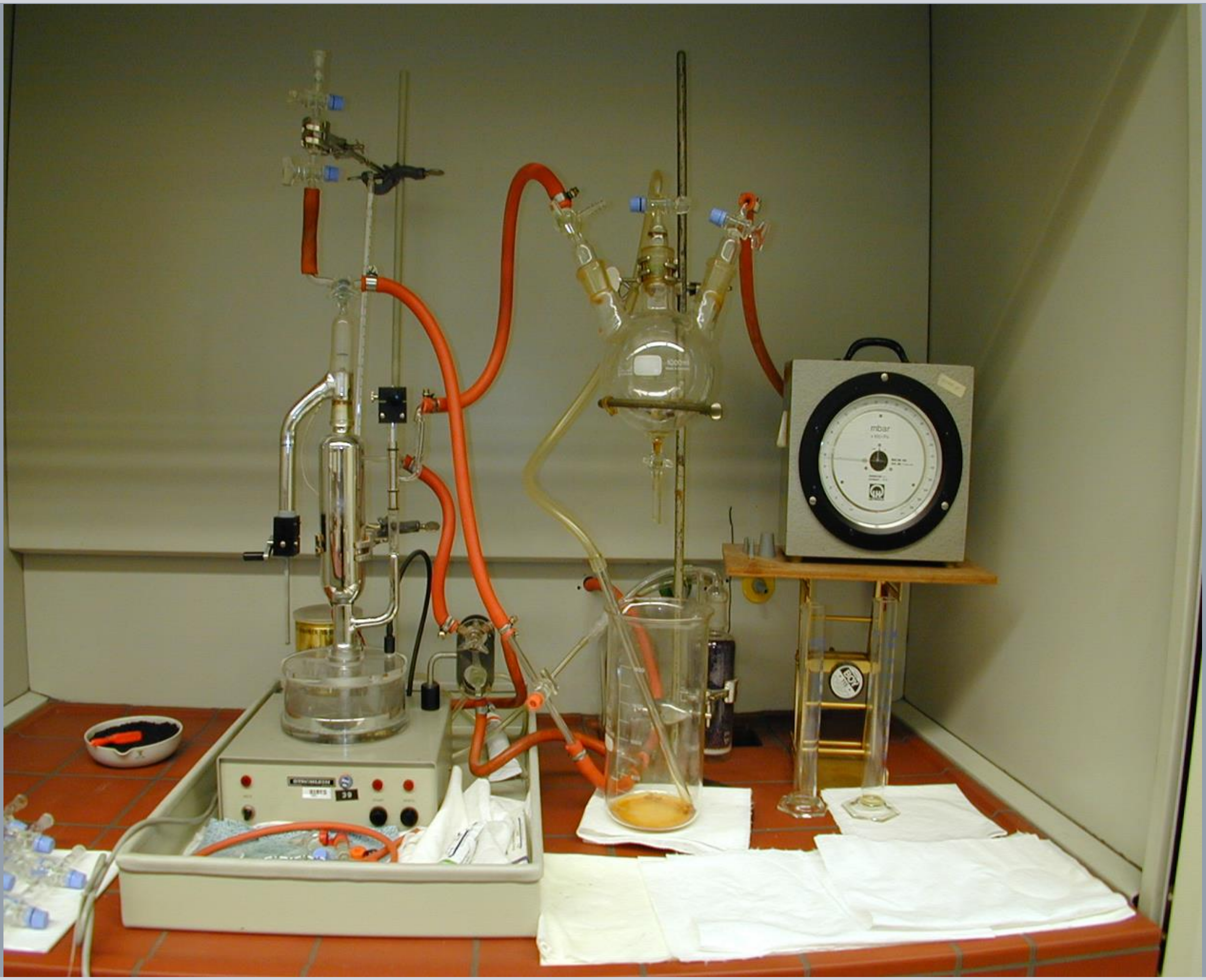
DGA. Toepler Pump



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DGA. Partial Degassing

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DGA. Headspace at Ambient Temperature

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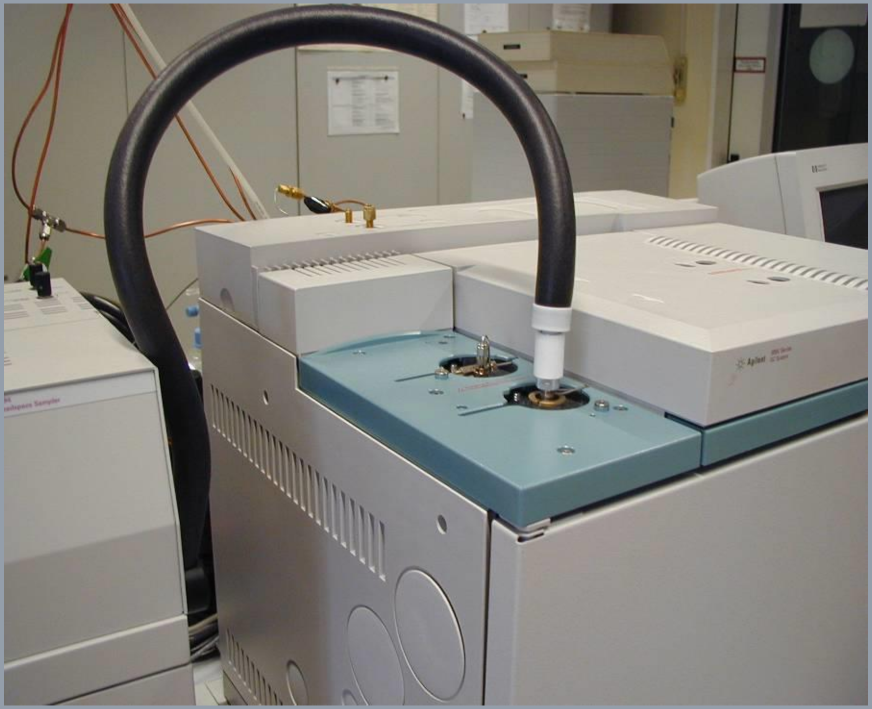
DGA. Headspace at 70°C



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Gaschromatographic Analysis

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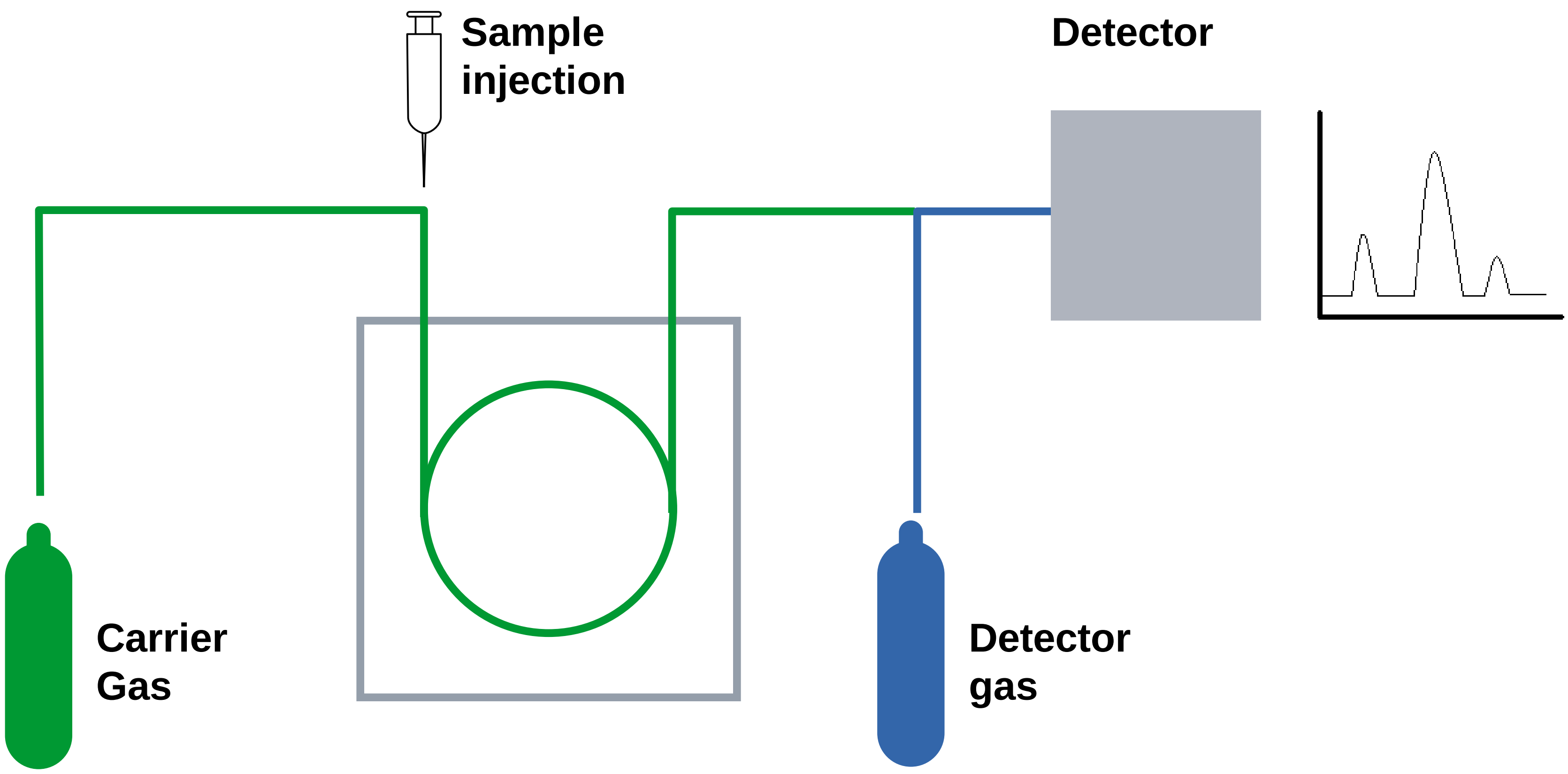
Gaschromatographic Analysis



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Failures which can be identified by DGA

- Partial discharges
- Electrical discharges
- Charcoal coating of contacts
- Accelerated cellulosic degradation
- Local overheating
- Untightness of OLTC tank
- Catalytic reactions of materials
- Additional information from BHR gas

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Failures which can not be identified by DGA

- **Incipient Failures**
- **Long lasting temperatures < 150 °C**

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Interpretation Schemes

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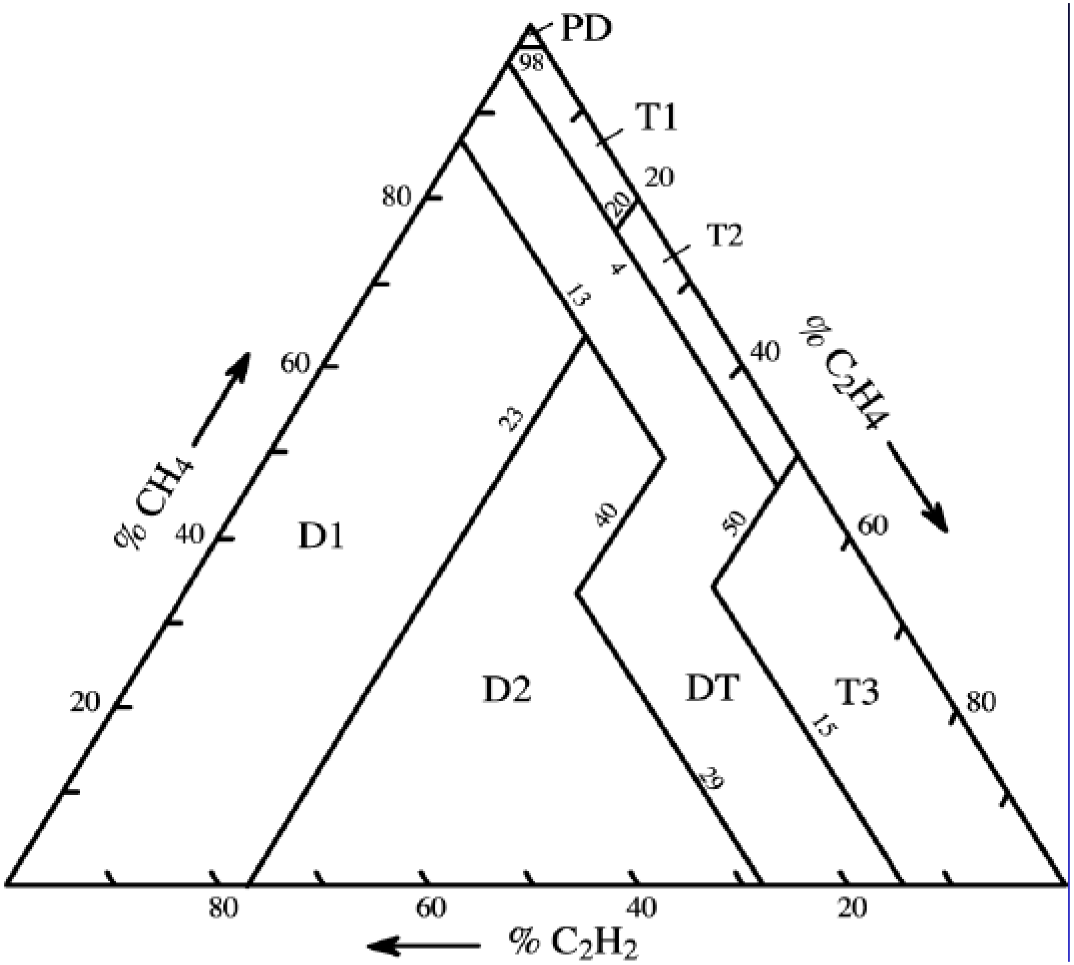
Duvals Triangle



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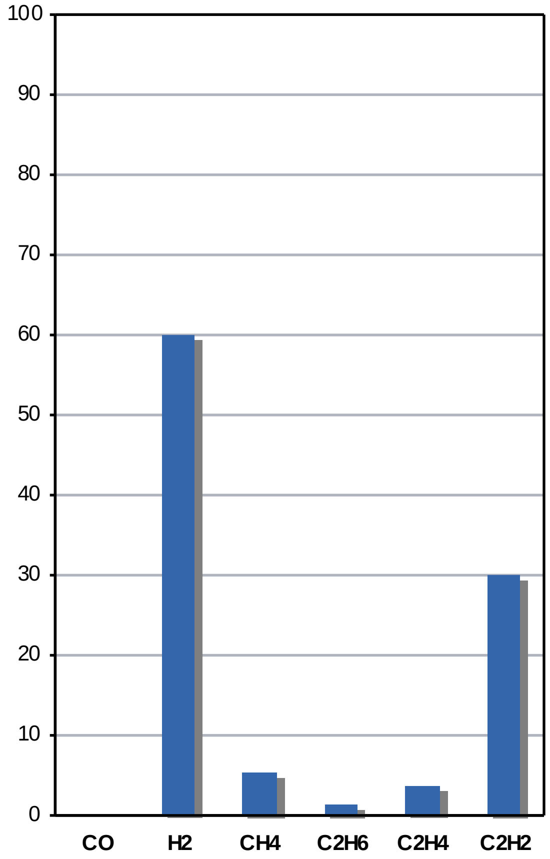
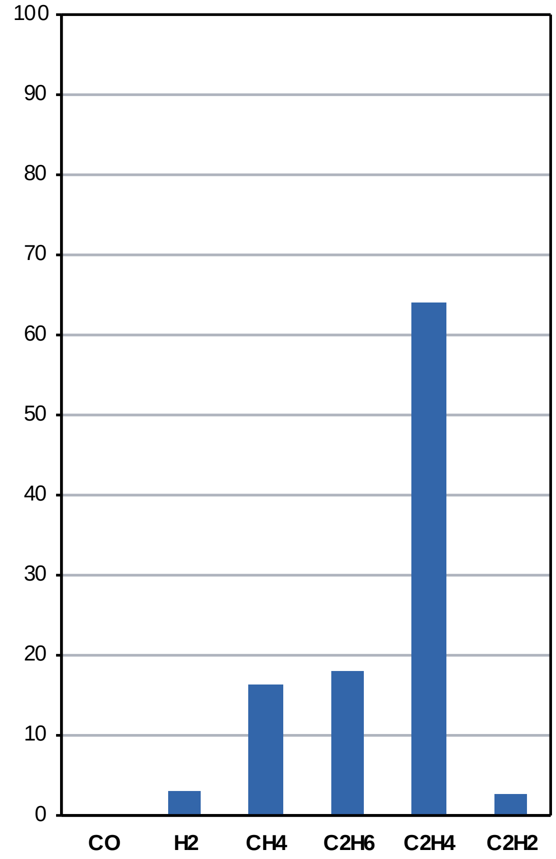
Patterns

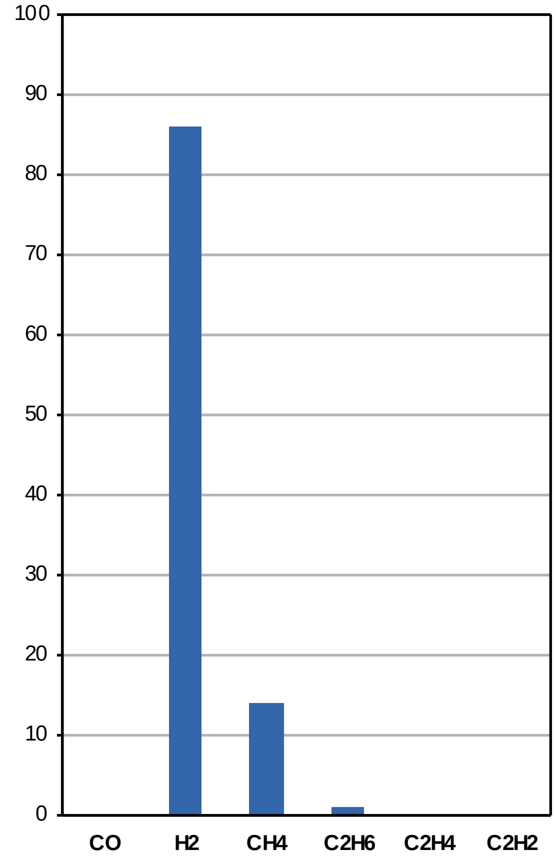
Electrical Discharges



Thermal Problem



Partial Discharges



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MSS Scheme

Ratio ranges	Ratio numbers				
	$\frac{[C_2H_2]}{[C_2H_6]}$	$\frac{[H_2]}{[CH_4]}$	$\frac{[C_2H_4]}{[C_2H_6]}$	$\frac{[C_2H_4]}{[C_3H_6]}$	$\frac{[CO_2]}{[CO]}$
<0.3	0	0	0	0	1
0.3 to < 1.0	1	0	0	1	1
1.0 to < 3.0	1	1	1	2	1
3.0 to < 10.0	2	2	1	3	0
≥ 10.0	2	3	1	3	2
Diagnosis	**Number sequences**				
Normal ageing of insultans	0	0	0	0	0
Discharge of high energy	2	1	1	2/3	1
Discharge of low energy	2	2	1	2/3	1
Partial discharge with high energy	1	3	0	n.i.	0
Partial discharge with low energy	1	3	0	n.i.	0
Local overheating up to 300 ºC	0	0	0	1	2
Local overheating from 300 ºC to 1000 ºC	0	0	1	2	2
Local overheating over 1000 ºC	1	0	1	2/3	2
Local overheating and discharge	1	1	1	2	2
Local overheating and partial discharge	0	3	1	2	2

n.i. = not indicative

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IEC Scheme

Case	Characteristic fault	$\frac{C_2H_2}{C_2H_4}$	$\frac{CH_4}{H_2}$	$\frac{C_2H_4}{C_2H_6}$
PD	Partial discharges (see notes 3 and 4)	NS[1)]	<0,1	<0,2
D1	Discharges of low energy	>1	0,1 – 0,5	>1
D2	Discharges of high energy	0,6 – 2,5	0,1 – 1	>2
T1	Thermal fault t < 300 °C	NS[1)]	>1 but NS[1)]	<1
T2	Thermal fault 300 °C < t < 700 °C	<0,1	>1	1 – 4
T3	Thermal fault t > 700 °C	<0,2[2)]	>1	>4

NOTE 1 In some countries, the ratio C_2H_2/C_2H_6 is used, rather than the ratio CH_4/H_2. Also in some countries, slightly different ratio limits are used.

NOTE 2 The above ratios are significant and should be calculated only if at least one of the gases is at a concentration and a rate of gas increase above typical values (see clause 9).

NOTE 3 CH_4/H_2 <0,2 for partial discharges in instrument transformers.

CH_4/H_2 <0,07 for partial discharges in bushings.

NOTE 4 Gas decomposition patterns similar to partial discharges have been reported as a result of the decomposition of thin oil film between overheated core laminates at temperatures of 140 °C and above (see 4.3 and [1] of annex C).

1) NS = Non-significant whatever the value.

2) An increasing value of the amount of C_2H_2 may indicate that the hot spot temperature is higher than 1 000 °C.

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In case of quotient information it must be clear, that quotients are only representative, if following values of the fault gases (in ppm) are exceeded:

C_2H_2	≥ 1
H_2	≥ 15
∑ [CXHY] x=1;2;3	≥ 50
CO	≥ 80
CO_2	≥ 200

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Example – thermal Problem

MSS-Code		00120
Fault gas		**ppm**
Hydrogen	H_2	1967
Methane	CH_4	8008
Ethane	C_2H_6	2013
Ethylene	C_2H_4	8323
Acetylene	C_2H_2	57
Propane	C_3H_8	401
Propylene	C_3H_6	4824
Carbon monoxide	CO	253
Carbon dioxide	CO_2	1903
Oxygen	O_2	18222
Nitrogen	N_2	61662

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MSS-Code		00120
Fault gas		**ppm**
Hydrogen	H_2	537
Methane	CH_4	1041
Ethane	C_2H_6	295
Ethylene	C_2H_4	1726
Acetylene	C_2H_2	25
Propane	C_3H_8	83
Propylene	C_3H_6	1012
Carbon monoxide	CO	1047
Carbon dioxide	CO_2	6158
Oxygen	O_2	11805
Nitrogen	N_2	58084

Manufacturing year 1970
360 MVA
Carbon deposits on PLTC Contacts

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Gas-in-Oil Analysis
Turn-to-Turn Failure

MSS-Code		21121
Fault gas		**ppm**
Hydrogen	H_2	4973
Methane	CH_4	1758
Ethane	C_2H_6	243
Ethylene	C_2H_4	2813
Acetylene	C_2H_2	8236
Propane	C_3H_8	58
Propylene	C_3H_6	1320
Carbon monoxide	CO	1196
Carbon dioxide	CO_2	2431
Oxygen	O_2	6743
Nitrogen	N_2	44120

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Thermal Problem with Partial Discharges

MSS-Code		00101
Fault gas		**ppm**
Hydrogen	H_2	1060
Methane	CH_4	2481
Ethane	C_2H_6	703
Ethylene	C_2H_4	2187
Acetylene	C_2H_2	4
Carbon monoxide	CO	450
Carbon dioxide	CO_2	995

Manufacturing year 1991
234 MVA, 330 kV
Defective welding joint

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Catalytical Effects

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MSS-Code		?3??0
Fault gas		**ppm**
Hydrogen	H_2	488
Methane	CH_4	1
Ethane	C_2H_6	< 1
Ethylene	C_2H_4	< 1
Acetylene	C_2H_2	< 1
Propane	C_3H_8	< 1
Propylene	C_3H_6	< 1
Carbon monoxide	CO	67
Carbon dioxide	CO_2	222
Oxygen	O_2	5180
Nitrogen	N_2	23700

Manufacturing year 1977
Closed type
Color 0,5 / Acidity 0,01

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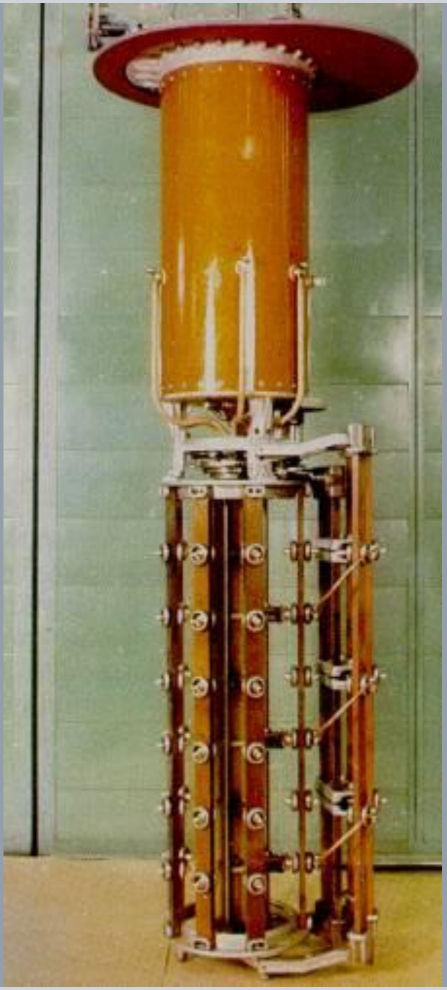
Untight OLTC

MSS-Code		22122
Fault gas		**ppm**
Hydrogen	H_2	128
Methane	CH_4	25
Ethane	C_2H_6	5
Ethylene	C_2H_4	81
Acetylene	C_2H_2	288
Propane	C_3H_8	5
Propylene	C_3H_6	50
Carbon monoxide	CO	143
Carbon dioxide	CO_2	1920
Oxygen	O_2	24600
Nitrogen	N_2	52000



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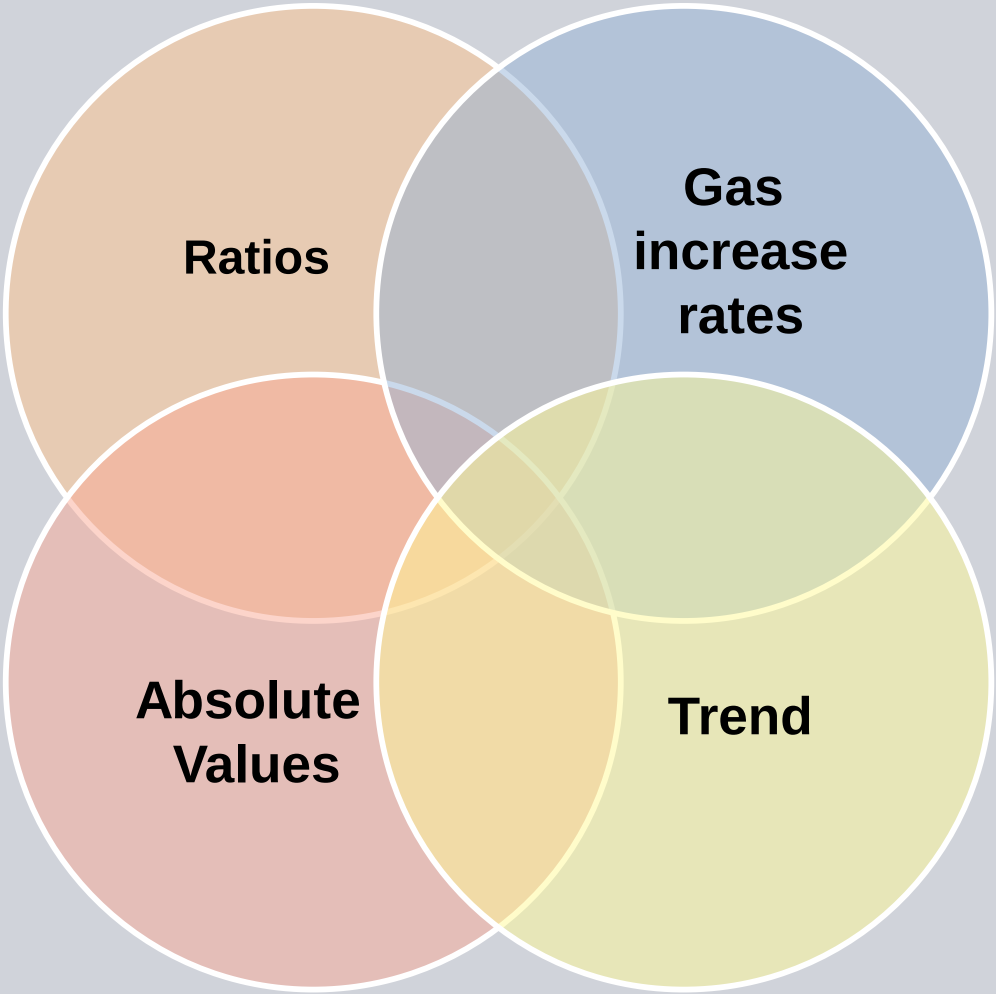
Diagnostic Importance in Service



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Absolute Values

IEC 60599 (VDE 0370-7)

	C_2H_2	H_2	CH_4	C_2H_4	C_2H_6	CO	CO_2
All transformers		50 ↓ 150	30 ↓ 130	60 ↓ 280	20 ↓ 90	400 ↓ 600	2800 ↓ 14000
No OLTC	2 ↓ 20						
Communicating OLTC	60 ↓ 280						

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Ratios

a) Eliminates the effect of the oil volume

b) Eliminates some effects of sampling

c) Especially interesting is the ratio formation for fault gases which exhibit similar solubilities, but their development is temperature dependent – e. g. the thermodynamic considerations of Halstead.

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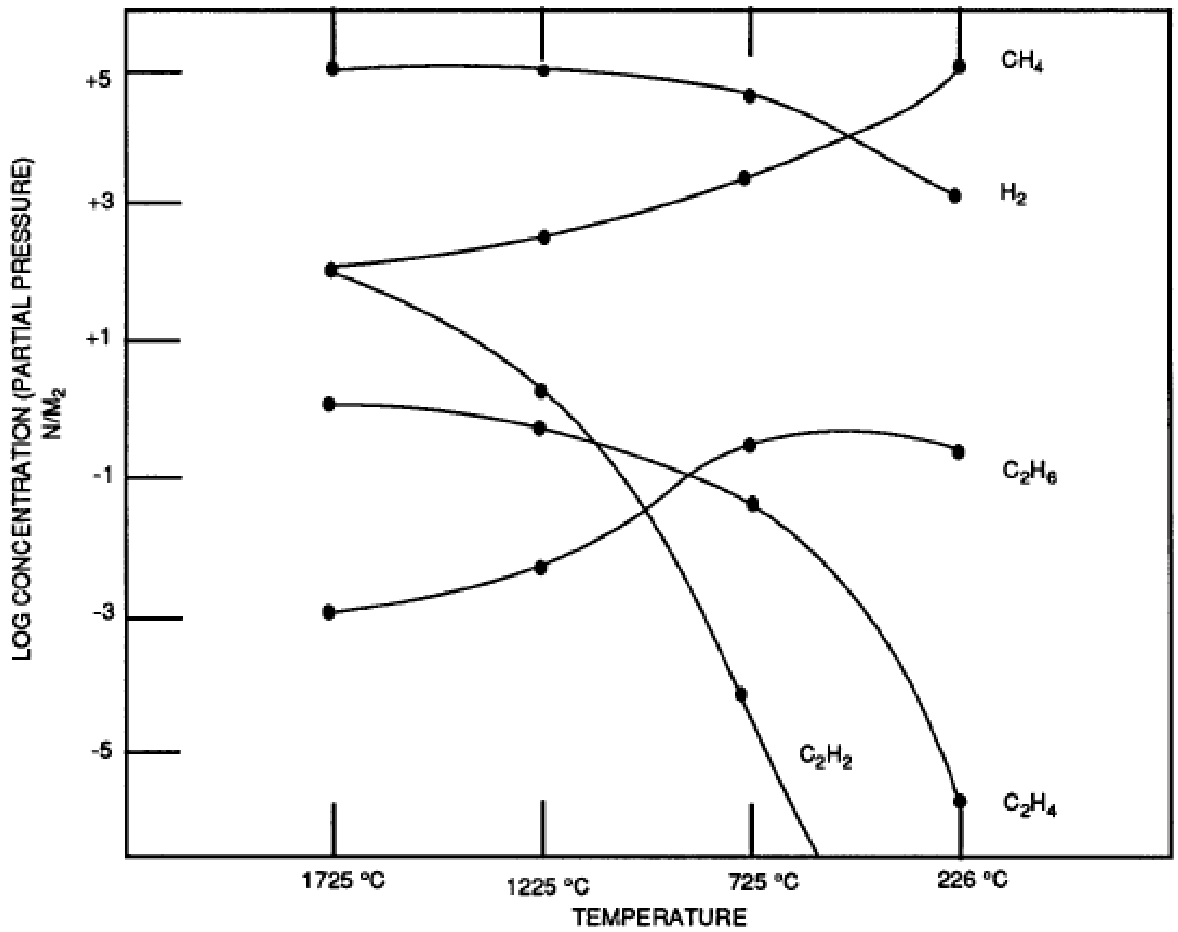
Thermodynamcal considerations of Halstead



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Gas Increase Rates – information on seriousness of failure

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	C_2H_2	H_2	CH_4	C_2H_4	C_2H_6	CO	CO_2
All transformers	0,01	0,36	0,33	0,40	0,25	2,9	27

▶ **90% gas increase source: Cigre TF11 in ppm/day**

Gas increase rates are temperature and volume dependent

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Trend Analysis

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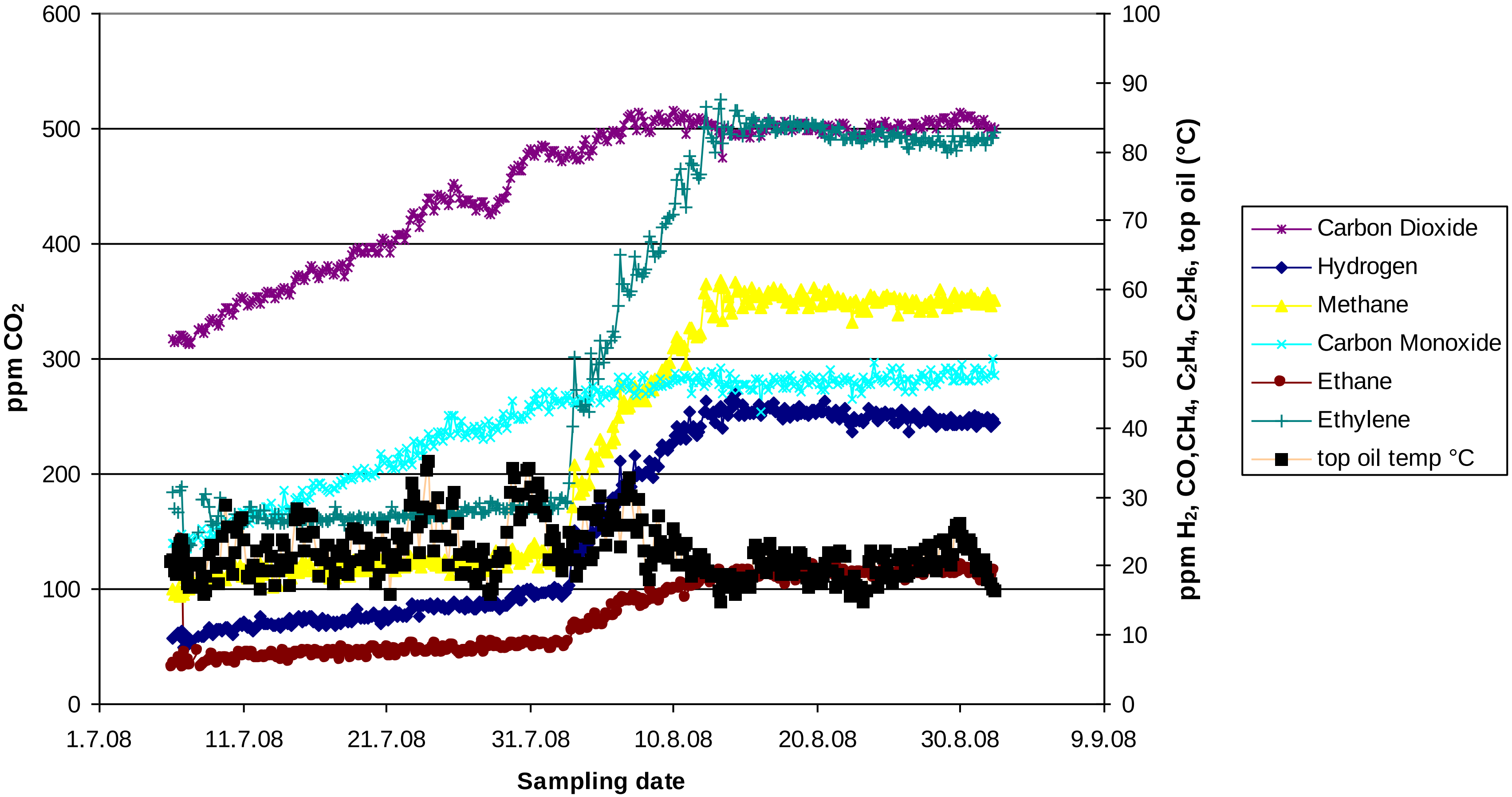
Development of the Fault Gases After Two Months of On-Line Monitoring



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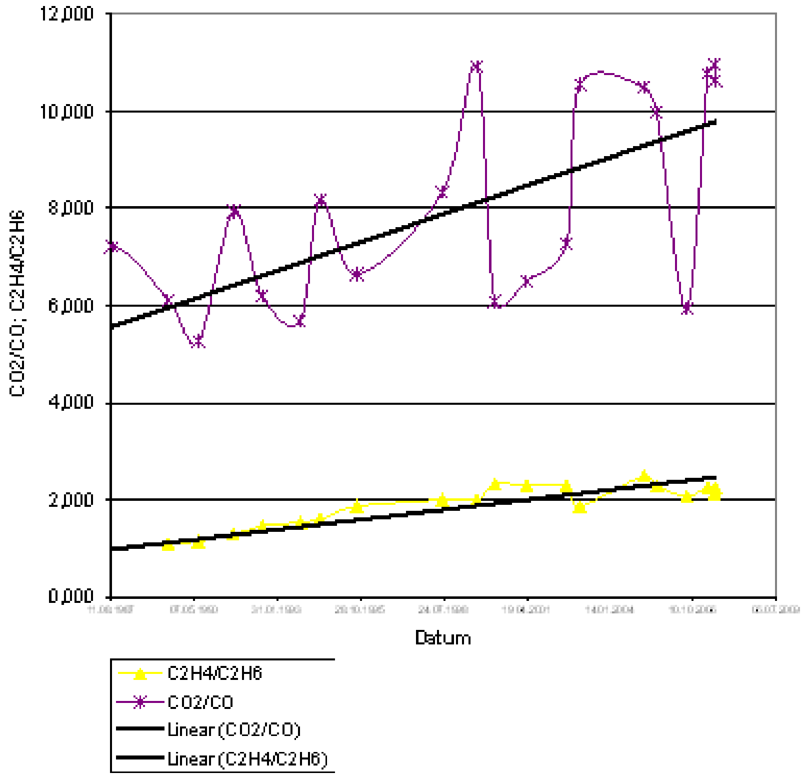
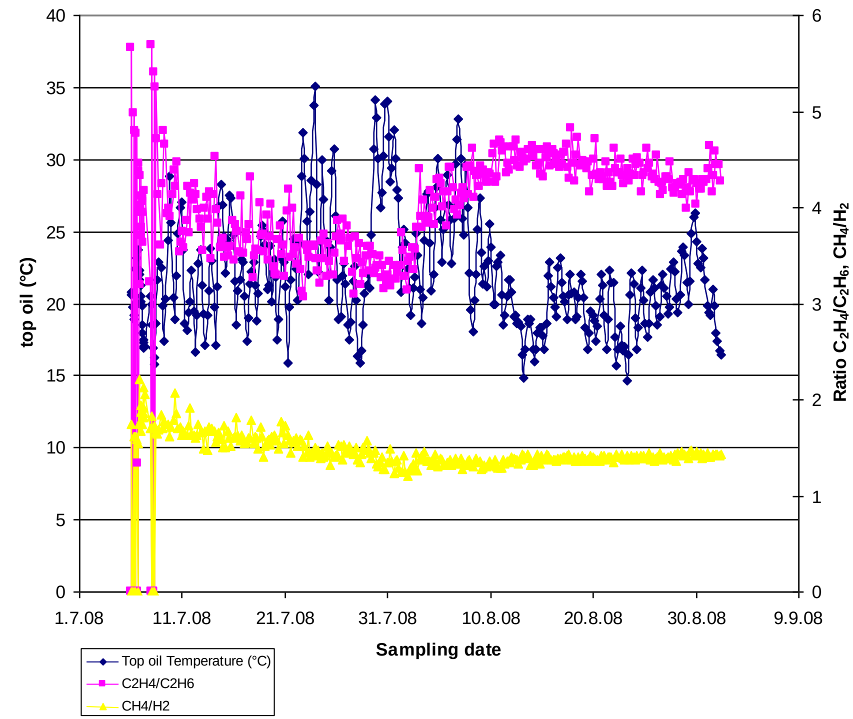
Trend Analysis





Trendanalysis is important not only with absolute values, but also with the ratios.

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On-Line Monitoring

- Early failure recognition
- Diagnosis is only possible with the sofisticated types – where IEC ratios can be built

Cigre TF 15 DGA did a comparison between On-Line monitoring systems and Off-Line analyses. The brochure is on the way.

Evaluated are:

- Precision
- Longterm stability
- Repeatability

In case of

- Routine concentrations, d.h. 5 * Detection Limit
- Low Concentrations, d. h. 2-5*Detection Limit

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Recommendation of Cigre A2.27 for On-LineMonitoring

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- Necessary in case a problem has been identified
- Often, however, difficult to maintain
- Interfaces can lead to problems
- Able to deliver important information in a short time
- Does not automatically lead to higher reliability

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What can be measured on-line:

- Temperature
- Current, Voltage
- OLTC
- Oil level
- Gas-in-Öl Analysis
- Humidity in oil
- Bushings
- Acoustic Signals
- Magnetic Circuit
- Coolers

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More Data does not mean automatically more Information

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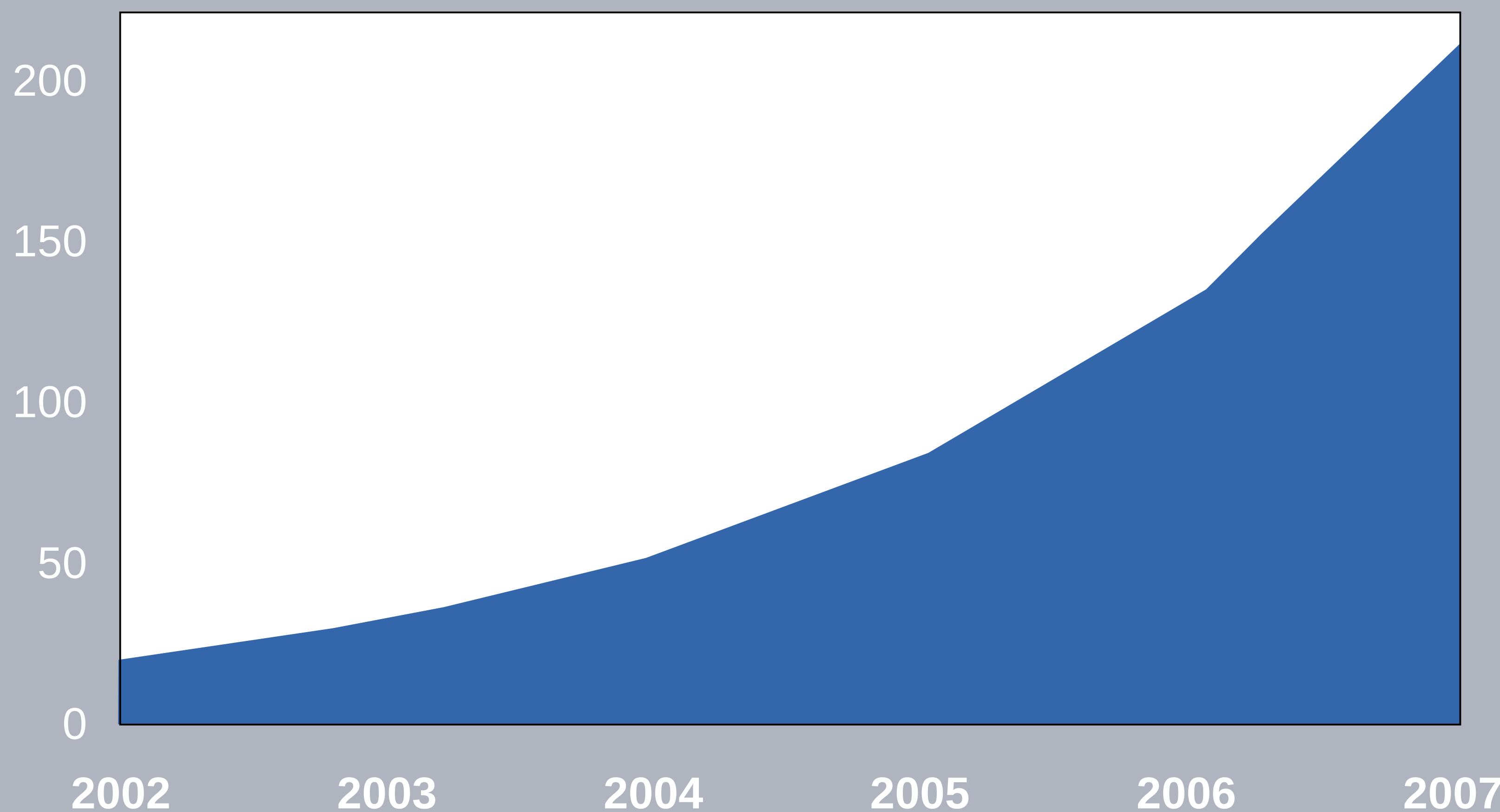
Data Explosion[1] (Total Exabytes)



1) Exa = 1016 = 10 Mil of Billions

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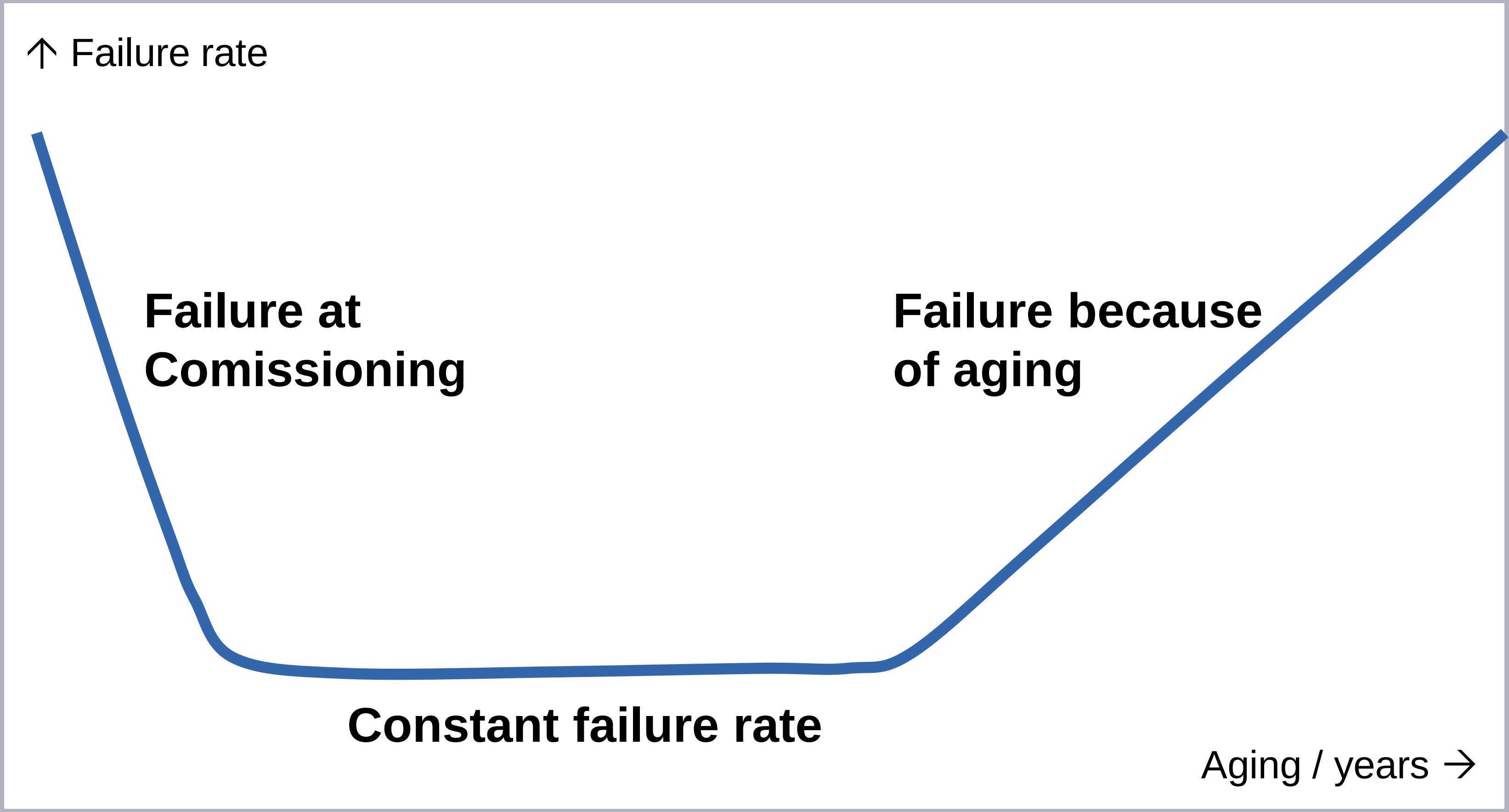
Transformer Failure Rate



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Future Developments

- Further development of the On-Line analysis with decision criteria
- Gas-in-oil analysis in OLTC
- Gas-in-oil analysis in alternative insulation fluids and high temperature insulating materials

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Thank you for your attention!

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