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

SIEMENS

DGA - Method in the Past and for the Future

IVANKA ATANASOVA-HÖHLEIN

SIEMENS

VOL. XXVII NO. 442 MAY 1956

THE METROPOLITAN-VICKERS GAZETTE

CONTENTS

PAGE

Frontispiece: Transformers for a C.E.A. power station
The identity and significance of gases collected in Buchholz protectors V. H. Howe, L. Massey & A. C. M. Wilson .. 139
A new signalling installation at Potters Bar (British Railways) H. C. Towers 149
The electrical equipment of a Scottish cotton mill J. W. Jackson 153
A polarity tester for high-power magnets J. W. Walley 157
The preparation of uniform plastic films B. S. M. Revell & A. W. Agar 159
Replica techniques in electron microscopy A. W. Agar & R. S. M. Revell 162
Design progress 7: Automatic power-factor correction equipment 166
Notes and news: Metrovick products on view at the British Industries Fair—More generating plant for Hong Kong—The Factory Equipment Exhibition—A miniature oscilloscope 167

The identity and significance of gases collected in Buchholz protectors

V. H. Howe A.M.I.E.E., Assoc.M.C.T. L. Massey M.Sc.Tech., A.R.I.C.

A. C. M. Wilson Assoc.M.C.T.

-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

Different phenomena in oil take place like:

dielectric
thermal
dynamic
chemical

Change/Ageing

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

The measurement of dissolved gases allow the knowledge on

Type
Complexity
Seriousness

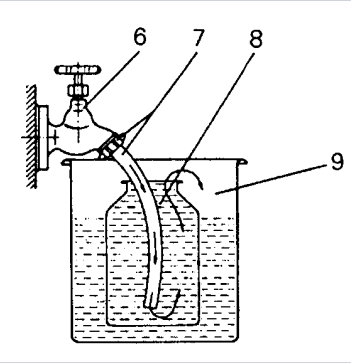
of event.

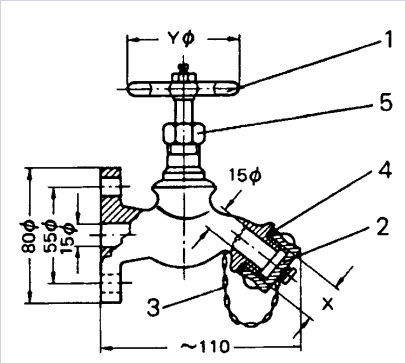
Sampling

SAMPLING CONTAINER

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

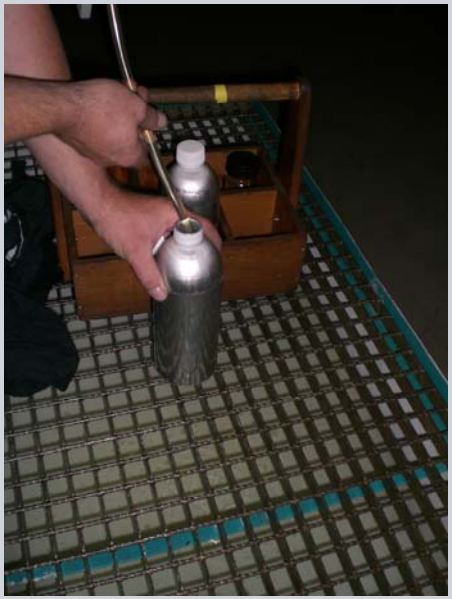
- ✓ **Protect sample from direct light**
- ✓ **Avoid moisture & dust contamination**
- ✓ **Use the sampling containers exclusively for transformer oil sampling**





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

SIEMENS



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

SIEMENS

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:**

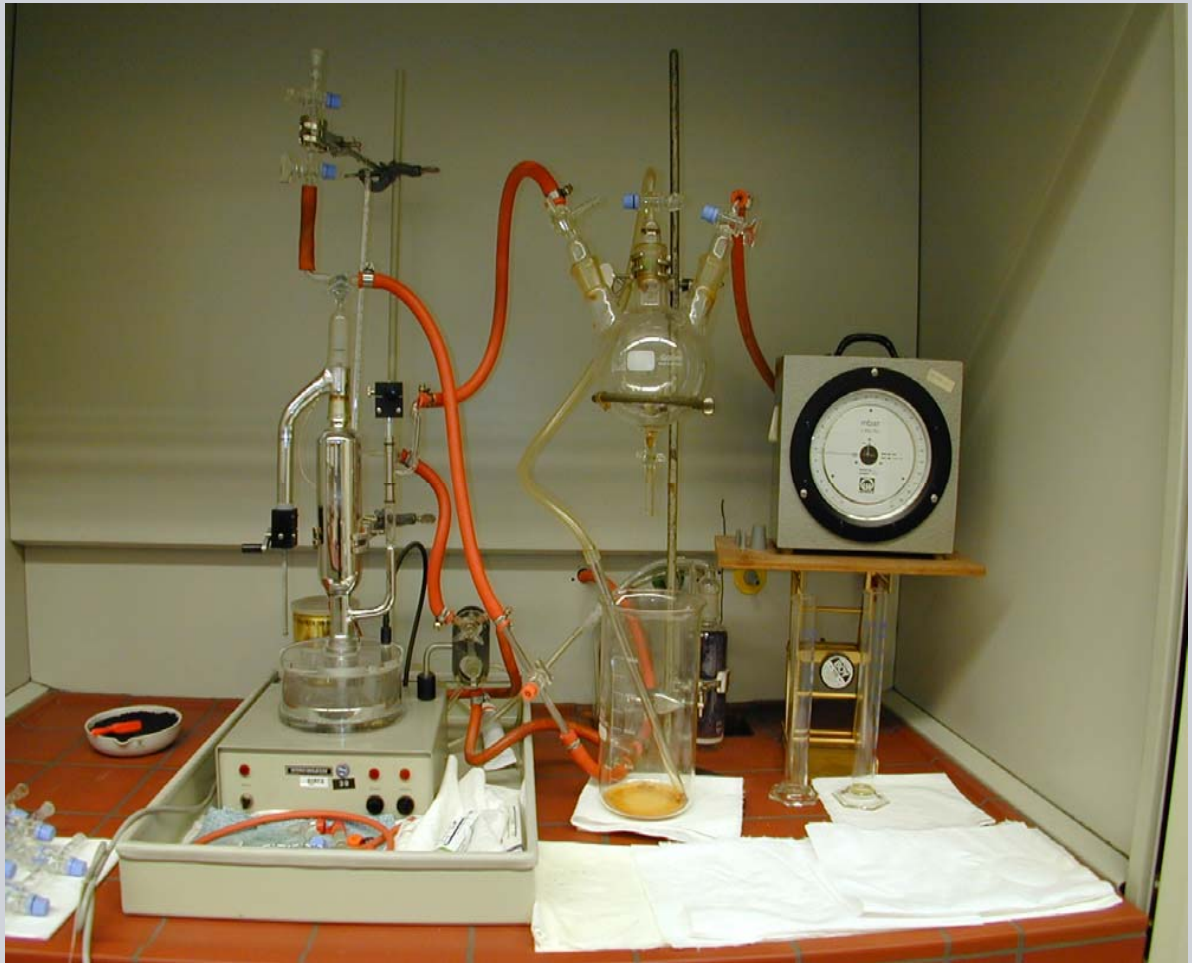
Sample taken from:	☐ Oil sample valve	☐ Oil drainage device A 22/31/40 DIN 42 551	☐ Others
Tank:	☐ Top	☐ Middle	☐ Bottom
conservator	☐ Transformer	☐ OLTC	☐ Bushing
OLTC	☐ OLTC tank	☐	☐
Bushing	☐	☐	☐
Others:	☐	☐	☐

SIEMENS

Extraction of Gases from the Oil

SIEMENS

DGA. Toepler Pump



SIEMENS

DGA. Partial Degassing

SIEMENS

DGA. Headspace at Ambient Temperature

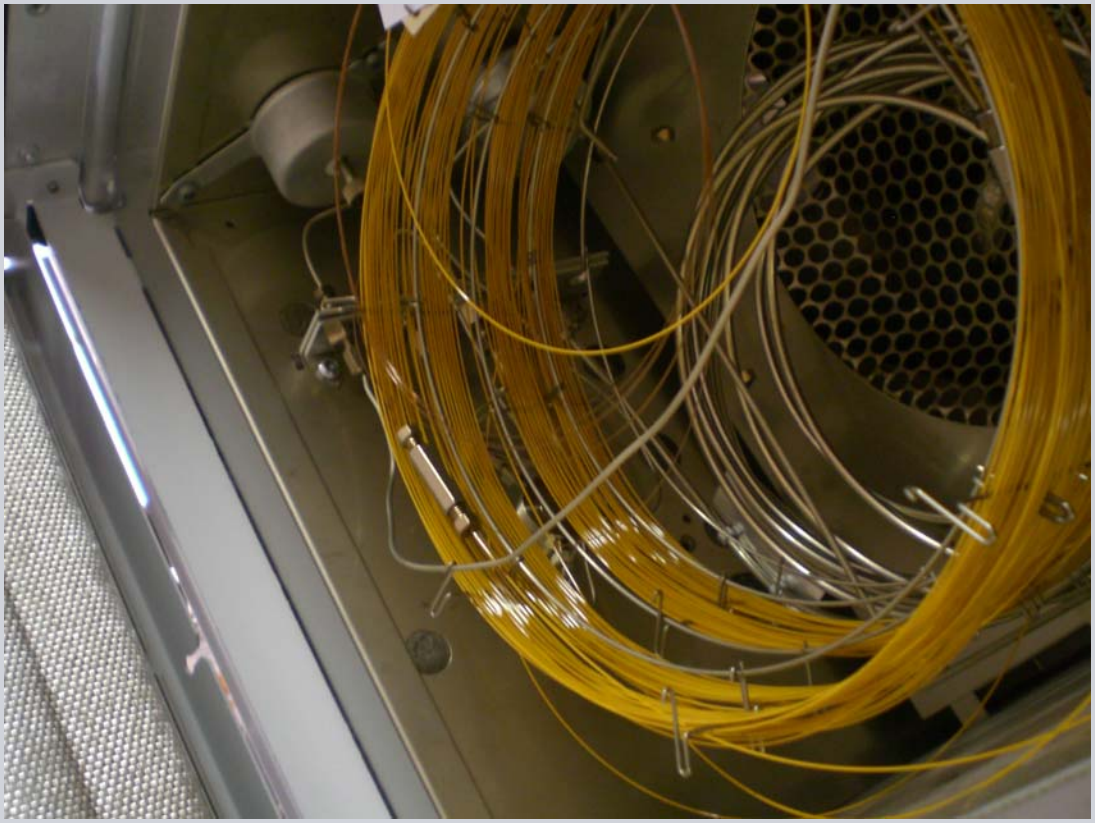
SIEMENS

DGA. Headspace at 70°C

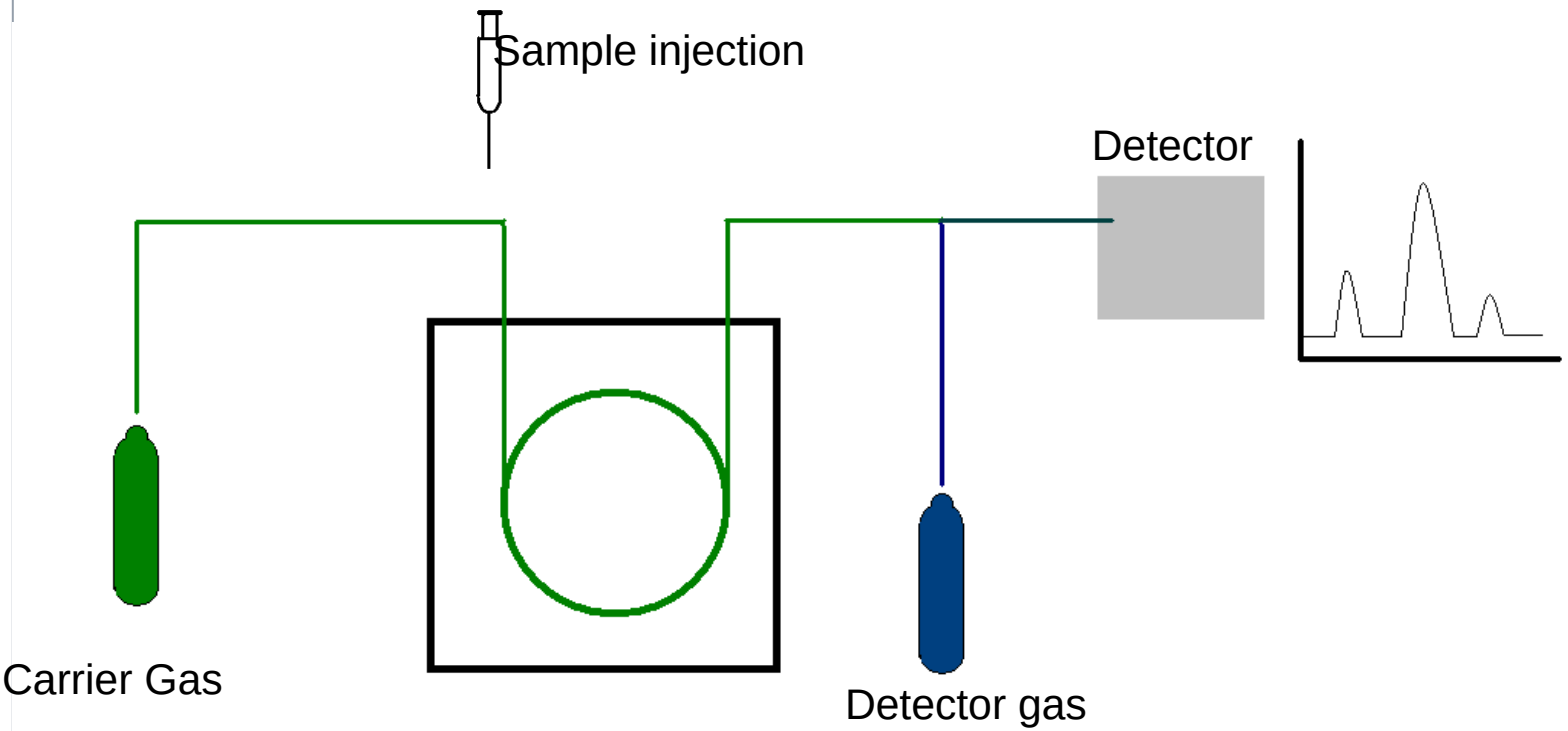
Diagnostic Conference,
Siofok, Hungary, October 14th-16th 2009

SIEMENS

Gaschromatographic Analysis



Gaschromatographic Analysis



- **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**

Failures which can be identified by DGA

SIEMENS

- **Incipient Failures**

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

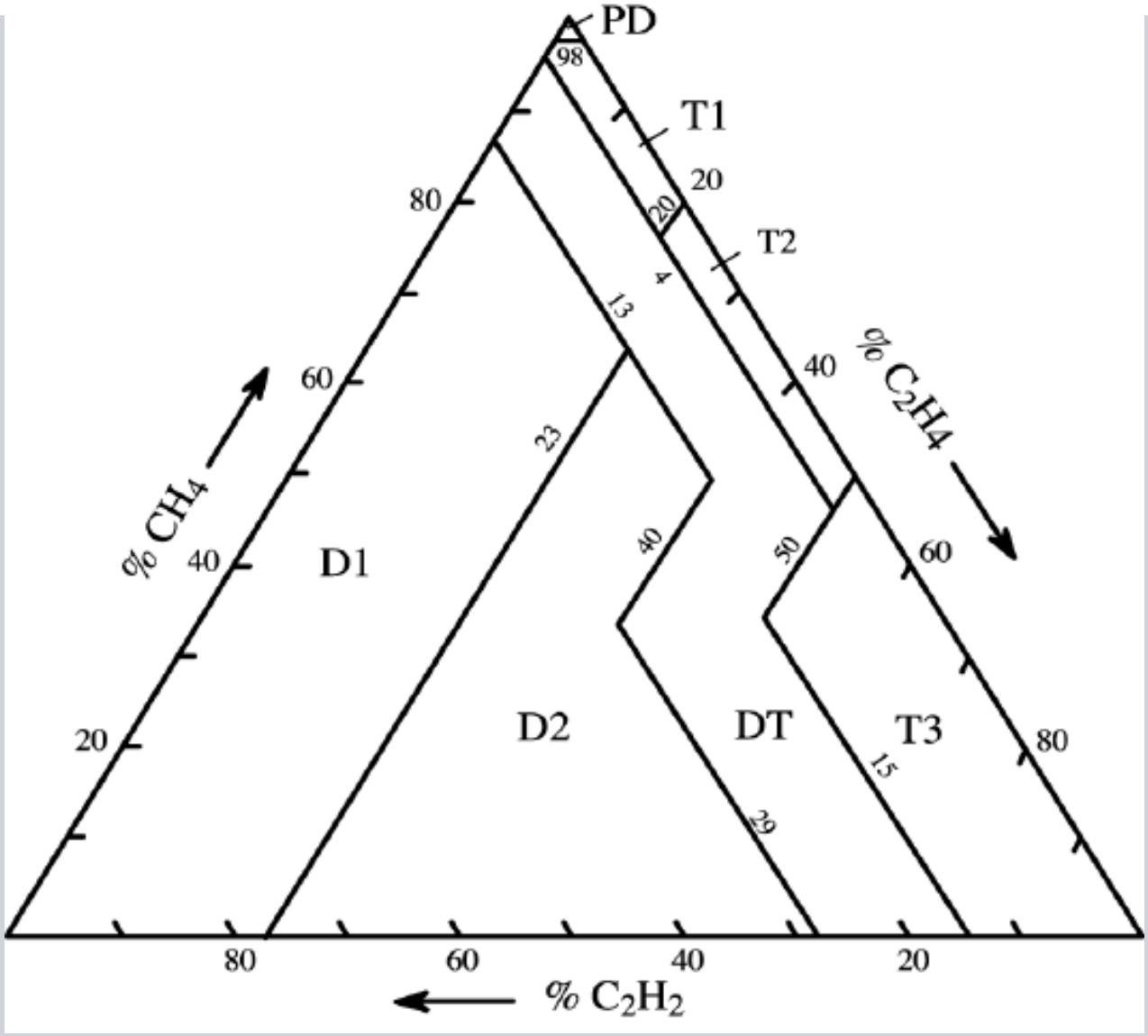
Failures which can not be identified by DGA

SIEMENS

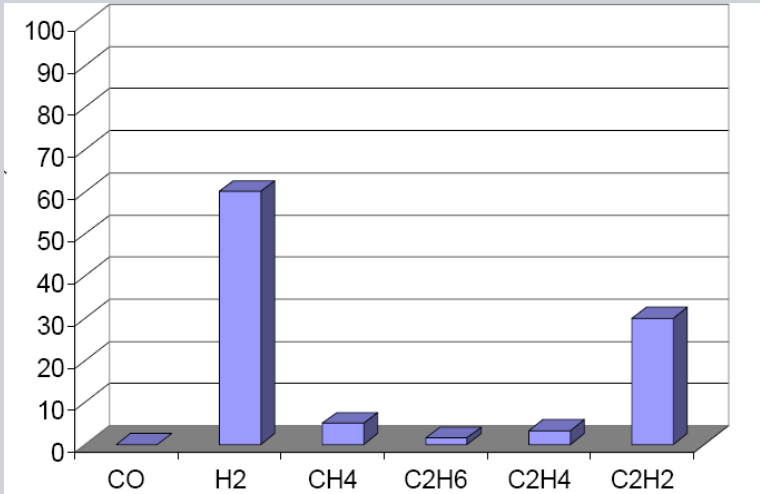
Interpretation Schemes

SIEMENS

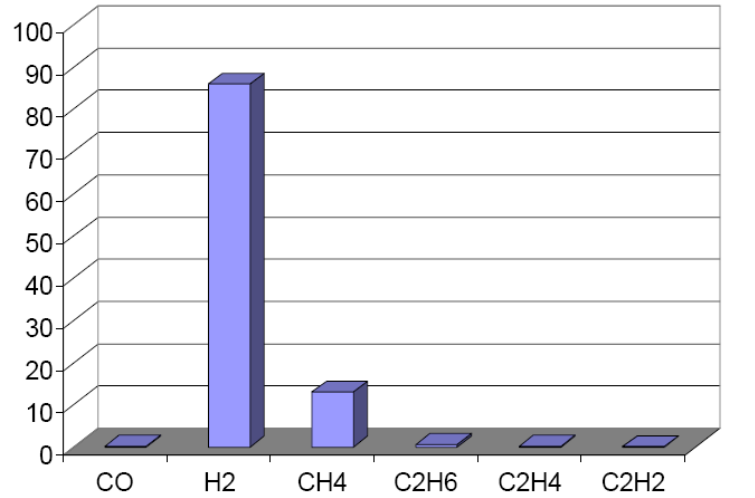
Duvals Triangle



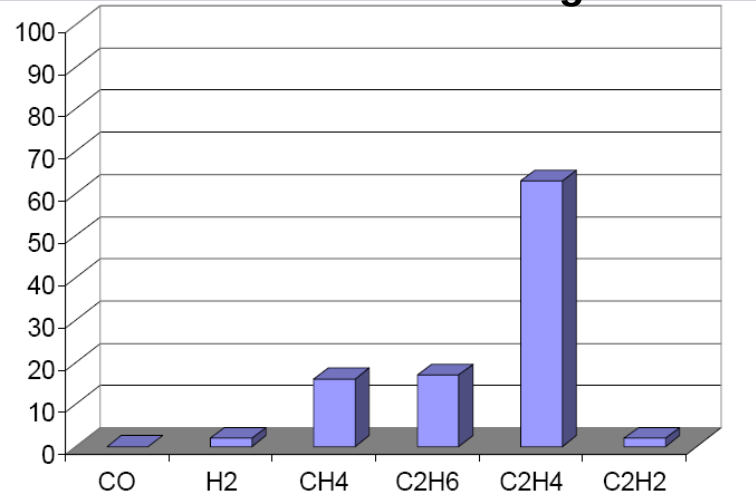
SIEMENS



Electrical Discharges



Partial Discharges



Thermal Problem

Patterns

SIEMENS

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 insulants	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	0	3	0	n.i.	0
Local overheating up to 300 °C	0	0	0	1	2
Local overheating from 300 to 1000 °C	0	0	1	2	2
Local overheating over 1000 °C	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

SIEMENS

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.

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

C2H2	≥ 1
H2	≥ 15
Σ [CXHY] x=1;2;3	≥ 50
CO	≥ 80
CO2	≥ 200

SIEMENS

DGA. Example – thermal Problem

MSS-Code 00120

Fault gas	ppm
Hydrogen	1967
Methane	8008
Ethane	2013
Ethylene	8323
Acetylene	57
Propane	401
Propylene	4824
Carbon monoxide	253
Carbon dioxide	1903
Oxygen	18222
Nitrogen	61662

360 MVA, Manufacturing year 1970
Carbon deposits on OLTC Contacts, **MSS Code 00120**

Fault gas	ppm
Hydrogen	537
Methane	1041
Ethane	295
Ethylene	1726
Acetylene	25
Propane	83
Propylene	1012
Carbon monoxide	1047
Carbon dioxide	6158
Oxygen	11805
Nitrogen	58084

Gas-in-Oil Analysis. Turn-to-Turn Fault

MSS Code 21121

	Fault gas	ppm
H_2	Hydrogen	4973
CH_4	Methane	1758
C_2H_6	Ethan	243
C_2H_4	Ethylene	2813
C_2H_2	Acetylene	8236
C_3H_8	Propane	58
C_3H_6	Propylene	1320
CO	Carbon Monoxide	1196
CO_2	Carbon Dioxide	2431
O_2	Oxygen	6743
N_2	Nitrogen	44120

SIEMENS

DGA. Thermal Problem with Partial Discharges

234 MVA, 330 kV, Manufacturing year 1991

Defective welding joint

MSS 00101

Hydrogen	1060
Methane	2481
Ethane	703
Ethylene	2187
Acetylene	4
Carbon monoxide	450
Carbon dioxide	995

SIEMENS

DGA. Catalytical Effects

Manufacturing year 1977, closed type, MSS Code ?3??0, color 0,5, acidity 0,01

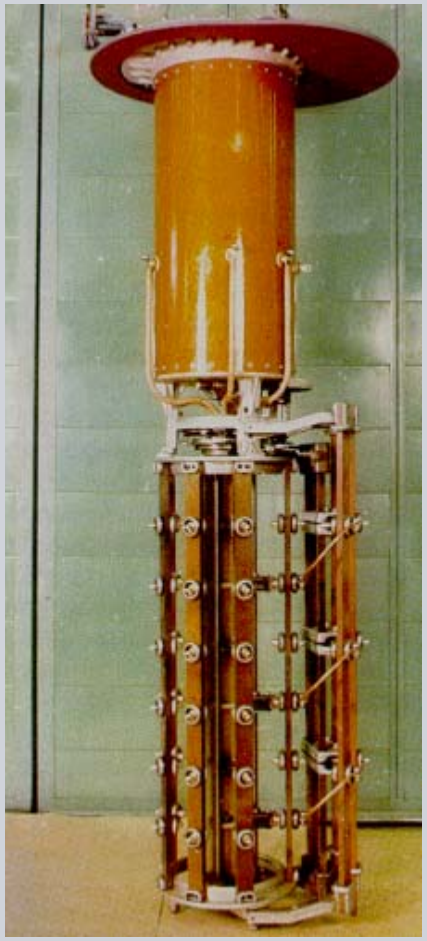
Hydrogen	488
Methane	1
Ethane	< 1
Ethylene	< 1
Acetylene	< 1
Propane	< 1
Propylene	< 1
Carbon monoxide	67
Carbon dioxide	222
Oxygen	5180
Nitrogen	23700

SIEMENS

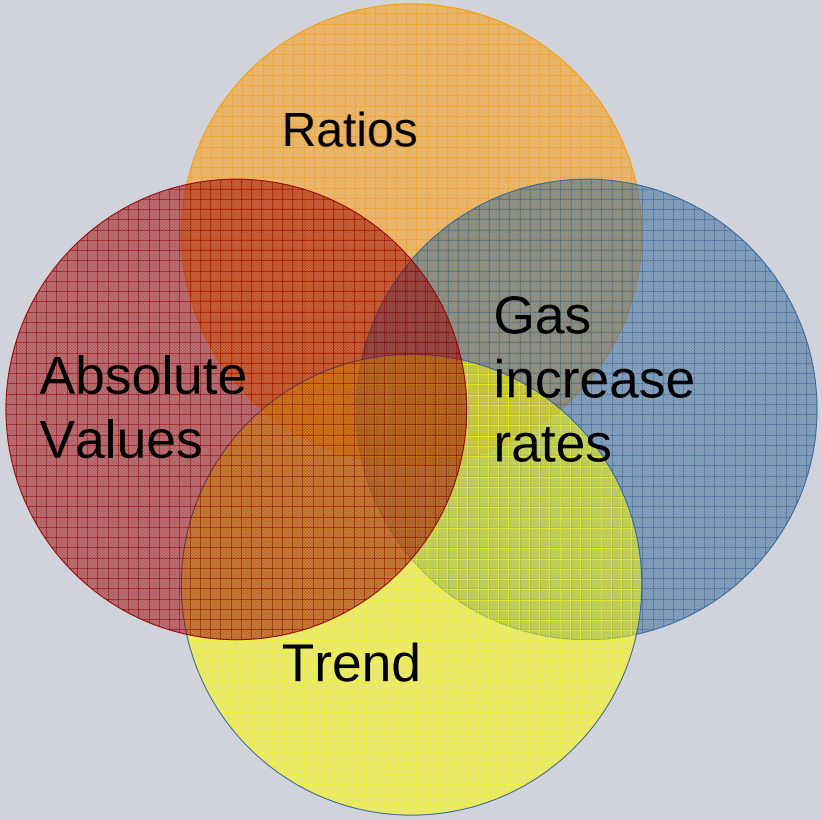
DGA. Untight OLTC

MSS 22122

Fault gas	ppm
Hydrogen	128
Methan	25
Ethane	5
Ethylene	81
Acetylene	288
Propane	5
Propylene	50
Carbon monoxide	143
Carbon dioxide	1920
Oxygen	24600
Nirogen	52000



Diagnostic Importance in Service. DGA



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	3 800 - 14 000
No OLTC	2 - 20						
Communicating OLTC	60 - 280						

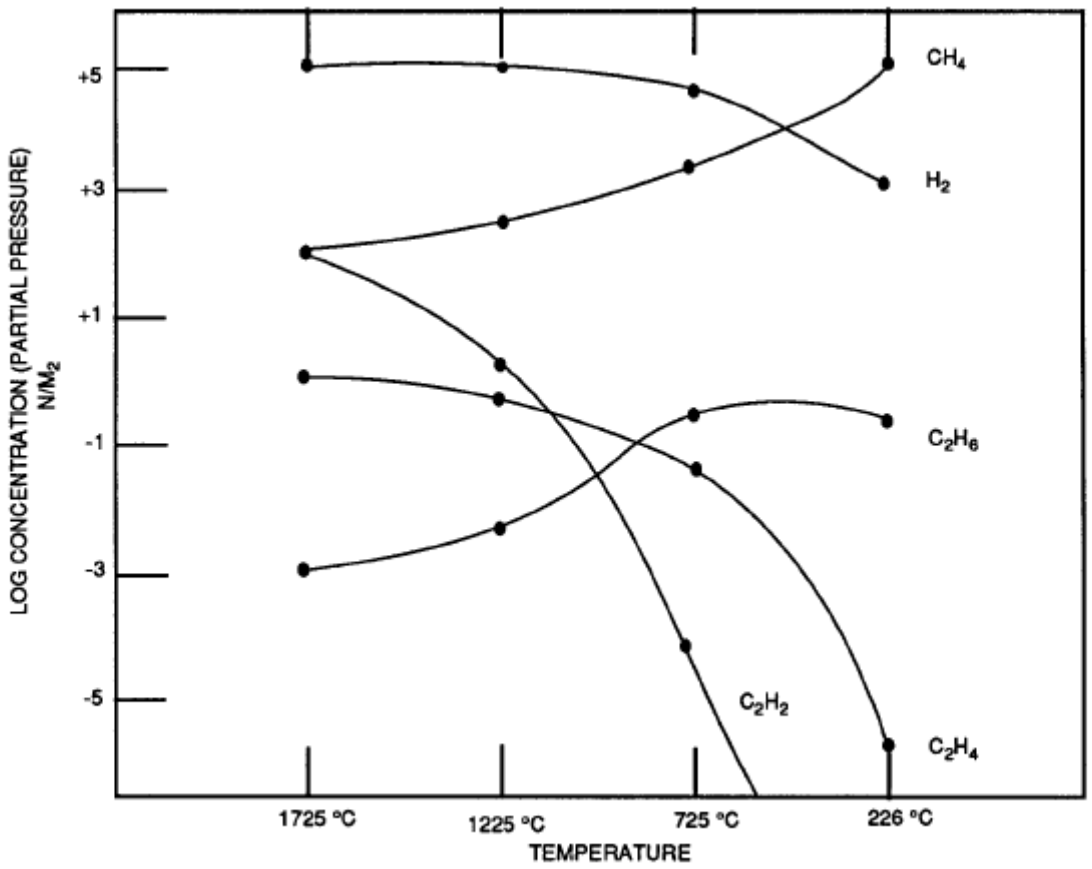
Ratios

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.

SIEMENS



Thermodynamcal considerations of Halstead

Gas Increase Rates – information on seriousness of failure

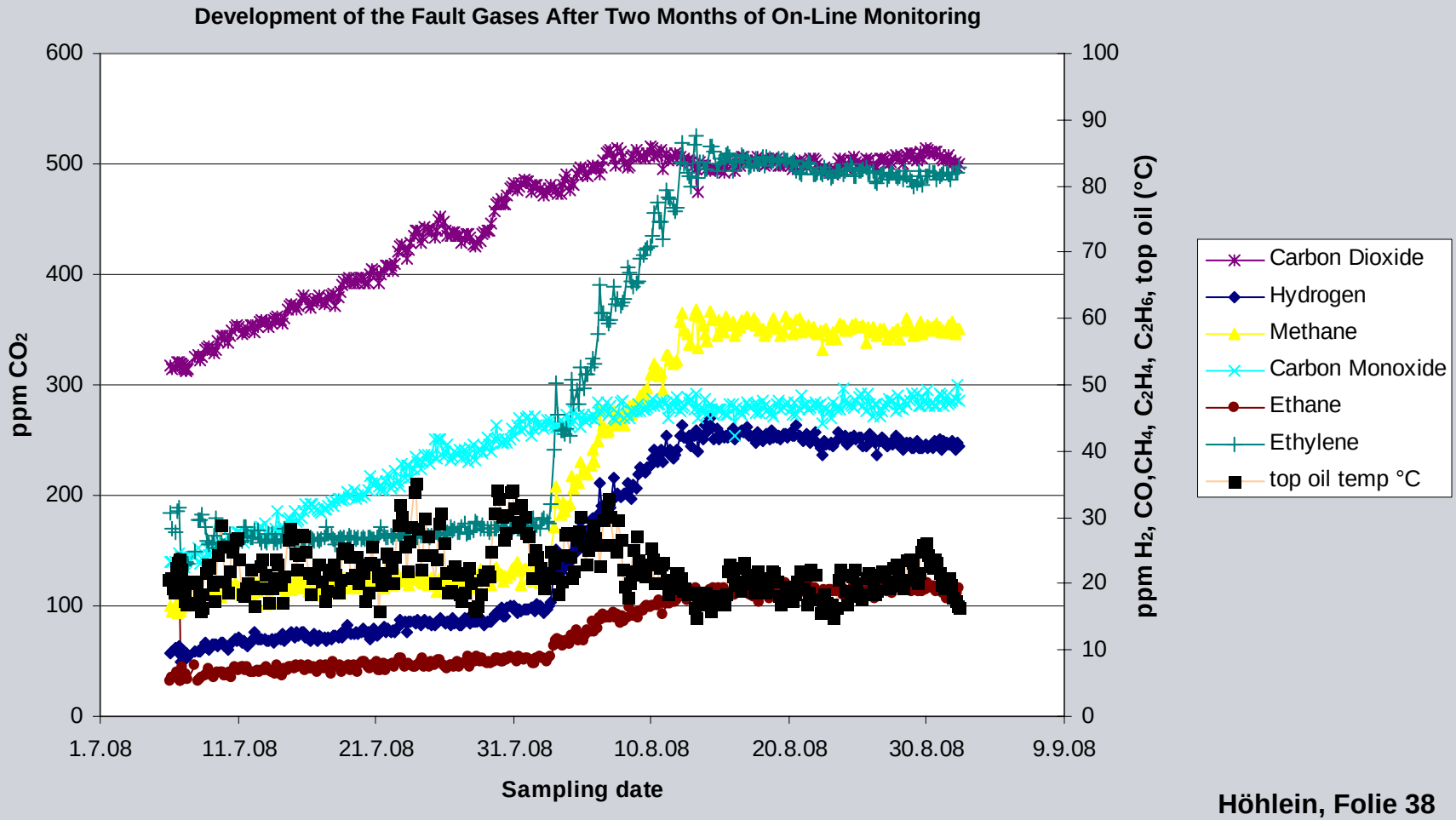
	C_2H_2	H_2	CH_4	C_2H_4	C_2H_6	CO	CO_2
All transformers	**0,01**	**0,36**	**0,33**	**0,40**	**0,25**	**2,9**	**27**

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

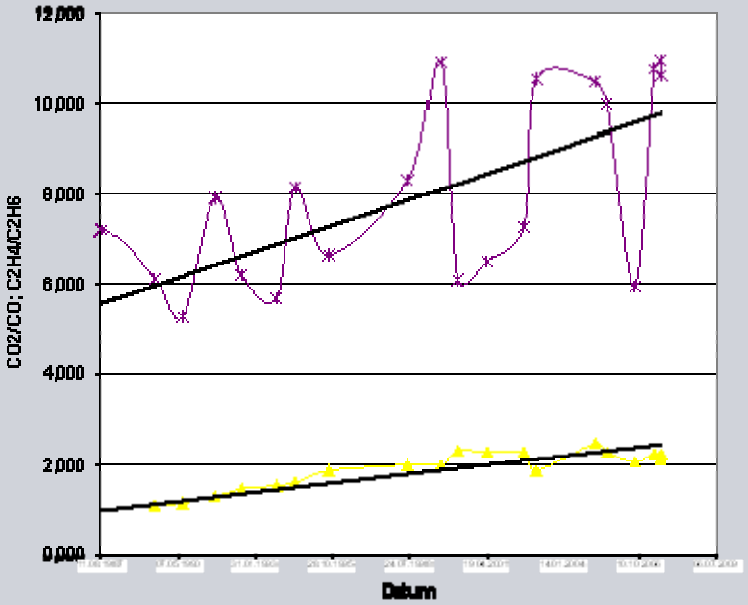
Gas increase rates are temperature- and volume dependent.

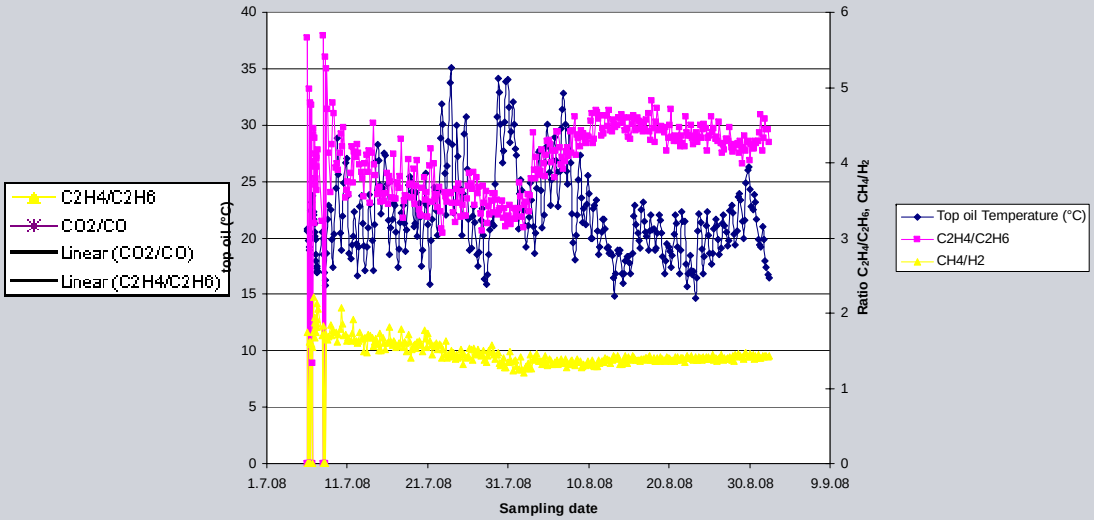
SIEMENS

TRENDANALYSIS



SIEMENS





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

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

RECOMMENDATION OF CIGRE A2.27 FOR ON-LINE MONITORING

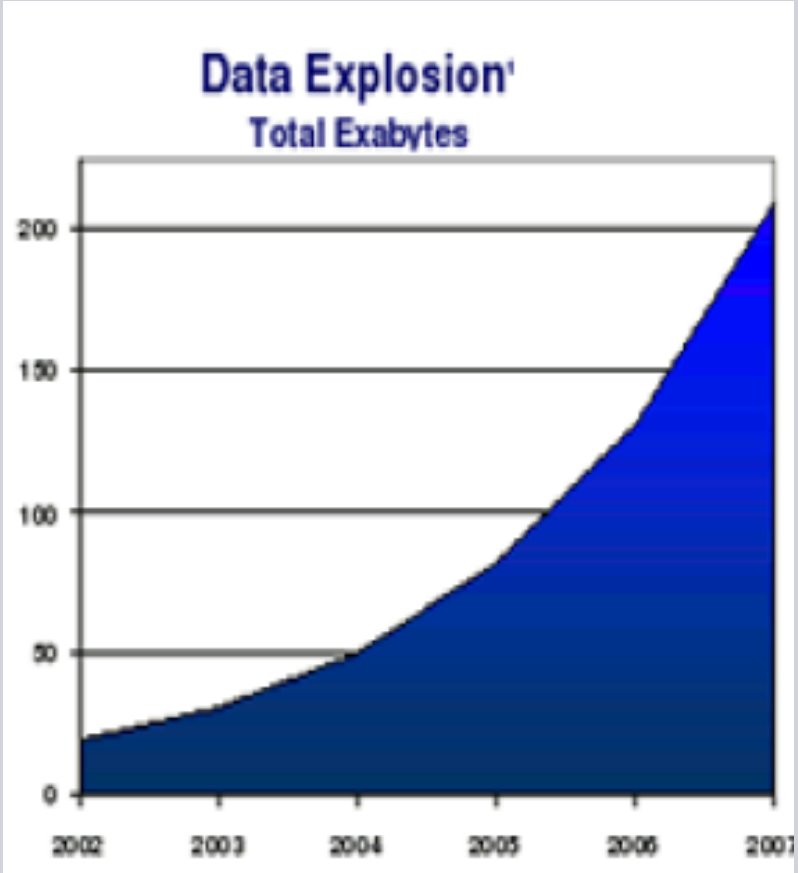
- Necessary in case a problem has been identified
- Often, however, difficult to maintain
- Interfaces can lead to problems
- Able to deliver important information in a short time
- Does not automatically lead to higher reliability

What can be measured on-line:

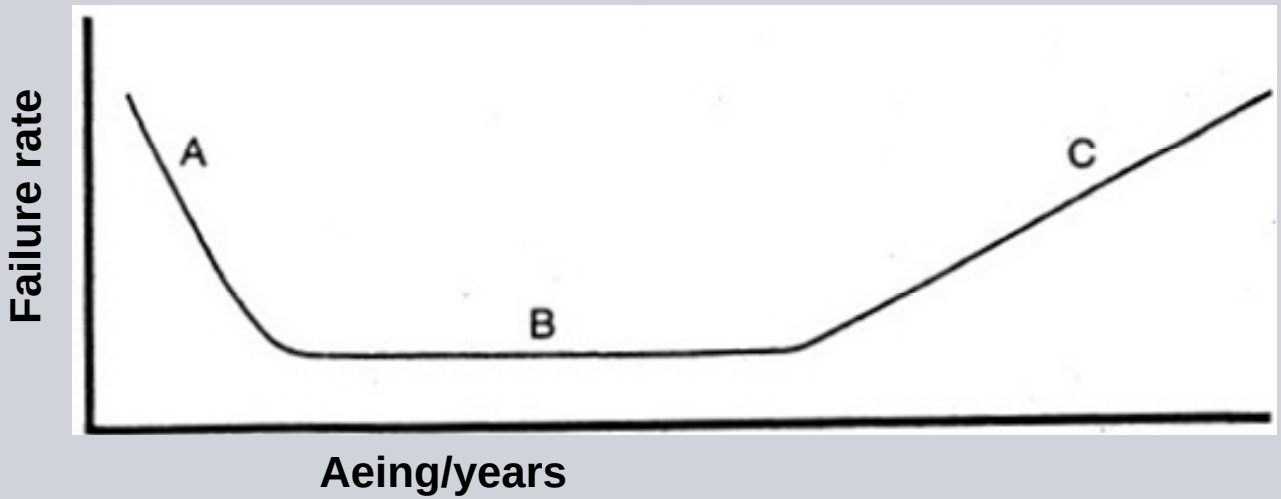
- Temperature
- Current, Voltage
- OLTC
- Oil level
- Gas-in-Öl Analysis
- Humidity in oil
- Bushings
- Acoustic Signals
- Magnetic Circuit
- Coolers

SIEMENS

MORE DATA DOES NOT MEAN AUTOMATICALLY MORE INFORMATION



1Exa = 10^{16} = 10 Mil of Billions



Transformer Failure Rate

A: Failure at commissioning; B: constant failure rate; C: failure because of ageing

DGA - Method in the Past and for the Future

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

THANK YOU FOR YOUR ATTENTION