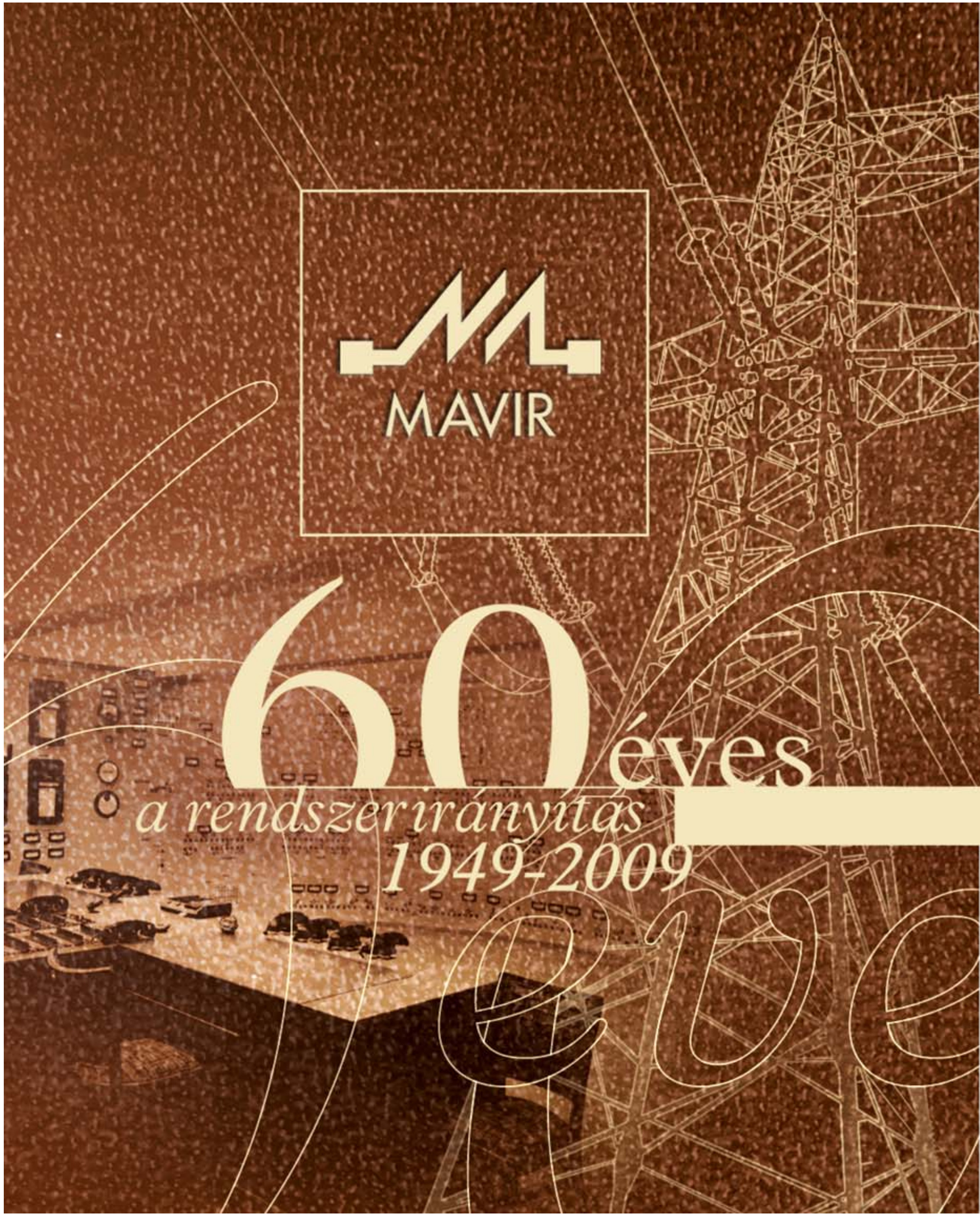


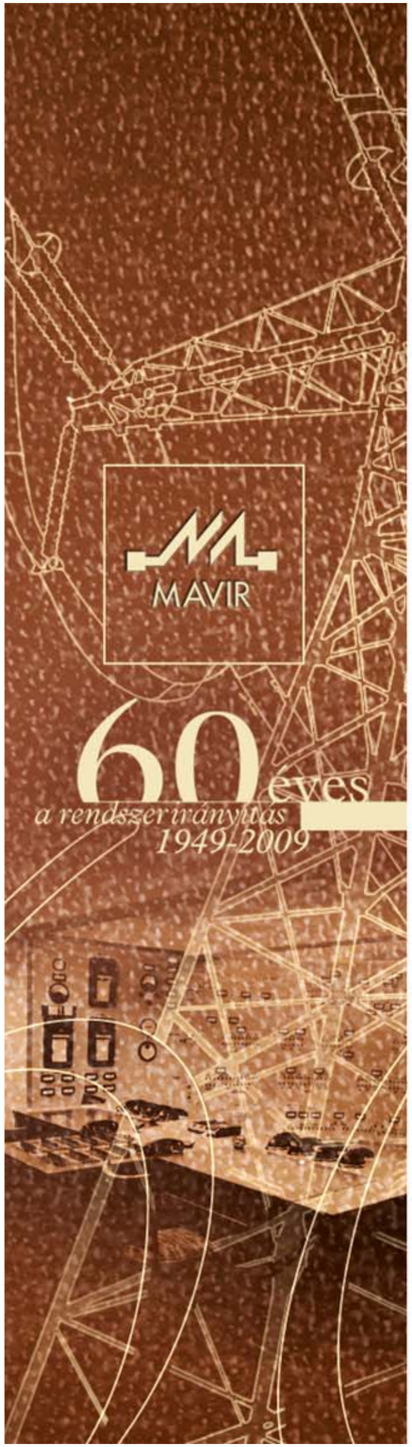
IX. Diagnosztikai Konferencia

CIGRE diagnosztika - 2009

SC A2 (transzformátorok)
és
SC D1 (anyagok és új technológiák)

Csépes Gusztáv
MAVIR ZRt.
Alállomás projekt munkatárs

IX. Szigeteléstechnikai Konferencia - 2009. október 14., Siófok



CIGRE szervezeti felépítése

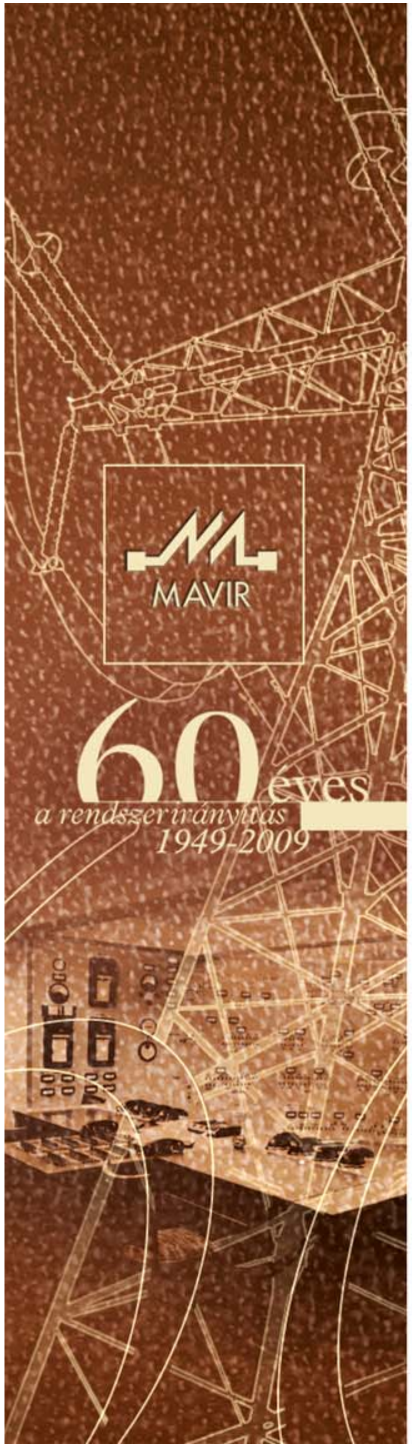
CIGRÉ =**C**onseil **I**nternational des **G**rands **R**éseaux **É**lectriques
CIGRÉ =International Council on Large Electric Systems
Székhely: Párizs, Franciország, **http.//www.cigre.org**

Szervezet tevékenységének célja:

Megkönnyíteni és elősegíteni a műszaki tudás és információ áramlást az államok között a villamos energia termelés és a nagyfeszültségű átvitel területén.

Munkavégzés helyei: SC, WG, TF
SC=Study Committee: Tanulmányi Bizottság
WG= Working Group= Munka Bizottság
TF= Task Force

CIGRE szervezeti felépítése



A1 ROTATING ELECTRICAL MACHINES

A2 TRANSFORMERS

A3 HIGH VOLTAGE EQUIPMENT

B1 INSULATED CABLES

B2 OVERHEAD LINES

B3 SUBSTATIONS

B4 HVDC & POWER ELECTRONICS

B5 PROTECTION & AUTOMATION

C1 SYSTEM DEVELOPMENT & ECONOMICS

C2 SYSTEM OPERATION & CONTROL

C3 SYSTEM ENVIRONMENTAL PERFORMANCE

C4 SYSTEM TECHNICAL PERFORMANCE

C5 ELECTRICITY MARKETS & REGULATIONC5

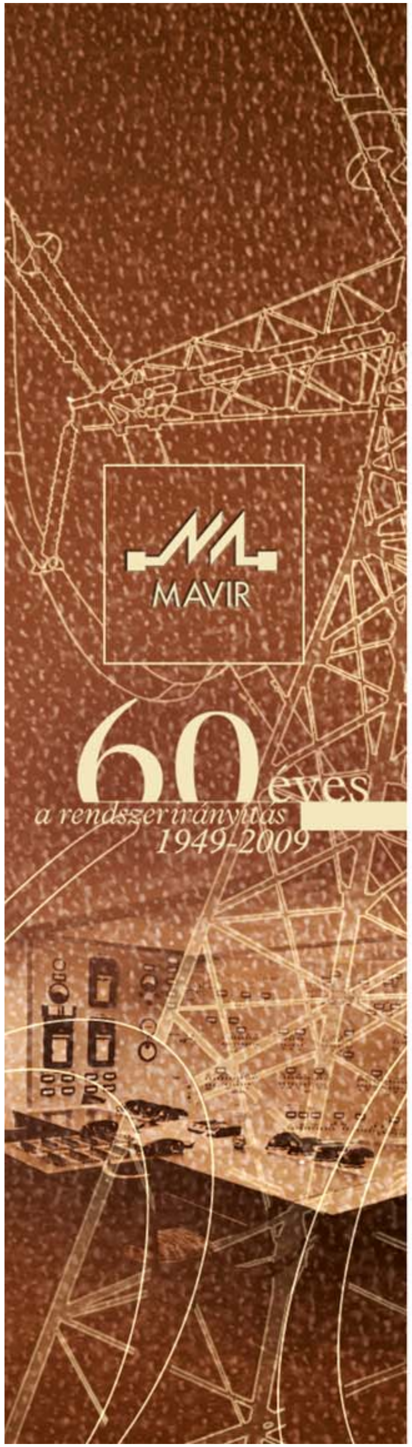
C6 DISTRIBUTION SYSTEMS & DISPERSED GENERATION

D1 MATERIALS & EMERGING TECHNOLOGIES

D2 INFORMATION SYSTEMS & TELECOMMUNICATIONS

A2: Transzformátorok

D1: Anyagok és kiemelkedő (új) technológiák

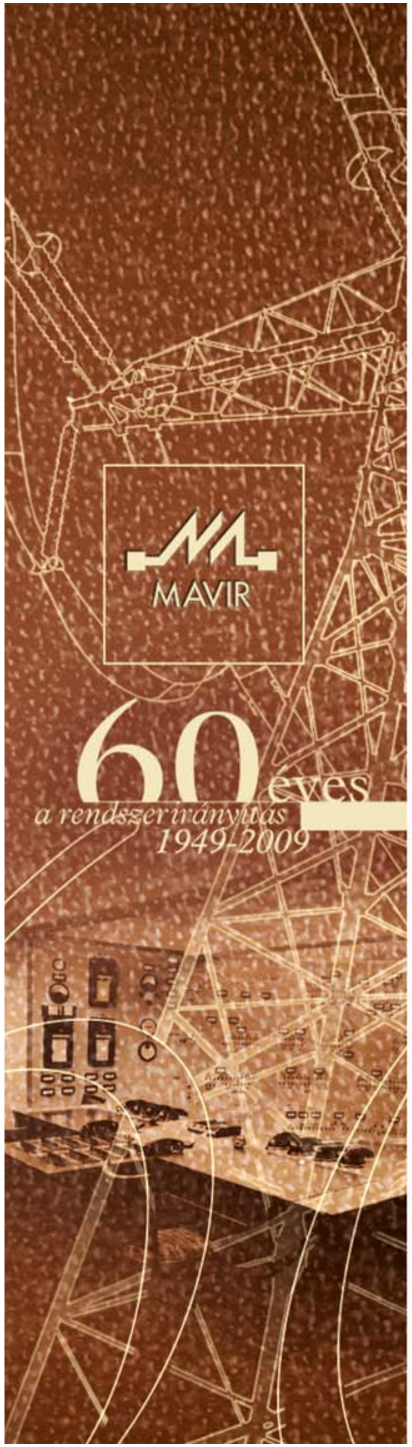


Az SC D1 célja:

-Megkönnyíteni ill. elősegíteni a műszaki fejlődést, a nemzetközi információcserét és tudást
-Az anyagok (szigetelő és nem szigetelő),
-A nagyfeszültségű és nagyáramú vizsgálati módszerek,
-A diagnosztikai rendszerek

területén

Módszer: a meglévő ismeretanyag feldolgozásával és az ajánlások továbbfejlesztésével további értékek létrehozása.



CIGRÉ SC D1 Magyarországon

A CIGRÉ Magyar Nemzeti Bizottsága meghívására a 2009. szeptember 20-25 között Budapesten rendezte páratlan években esedékes Kollokviumát ill. munkabizottsági üléseit.

Páros évek: **Párizs ülésszak az összes SC részére**

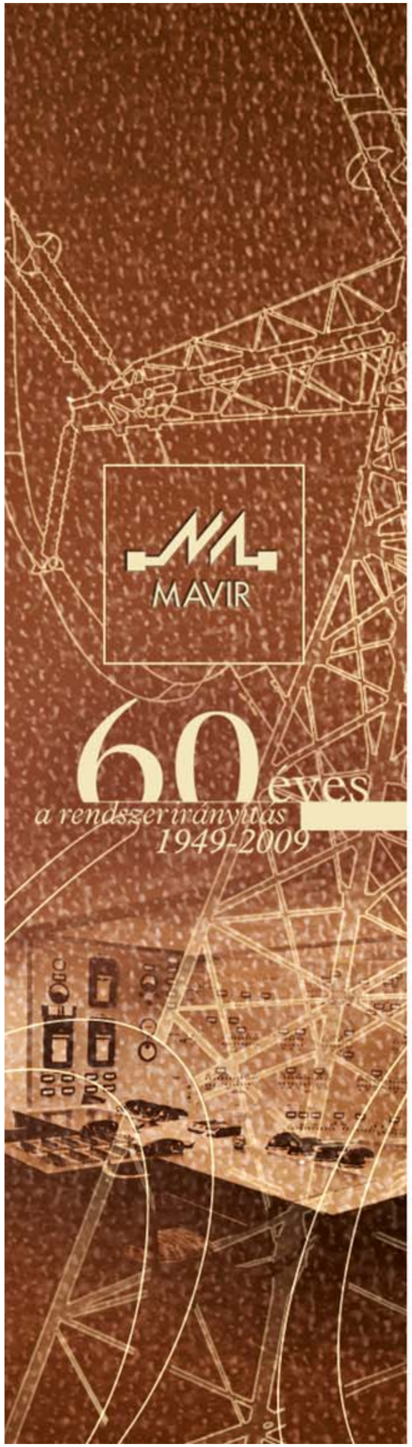
Páratlan évek: **SC ülés az aktív országokban**

Regular Member, Observer Member

Csépes Gusztáv: ***SC D1-ben 19 éves aktív tevékenységet, számos előadás és tanulmány, hat éven keresztül SC D1 magyar tagja (Regular Member).***

SC D1 főbb tevékenységi területe:

Villamos energiaiparban fontos anyagok ill. technológiák (szupravezetés, nano-technológai), transzformátor szigetelés és diagnosztikája, SF6 berendezések és diagnosztikája, általában villamos berendezések diagnosztikái, stb.).



-A budapesti rendezvény fő szponzora a fennállásnak 60. évfordulóját ünneplő MAVIR ZRt. volt.
-A lebonyolítását a MEE végezte,
-WG ülések és Kollokvium helyszíne a Kandó volt,
-Tudományos segítséget a BME nyújtotta,
-In memoriam Prof. Dr. Csernátony-Hoffer András

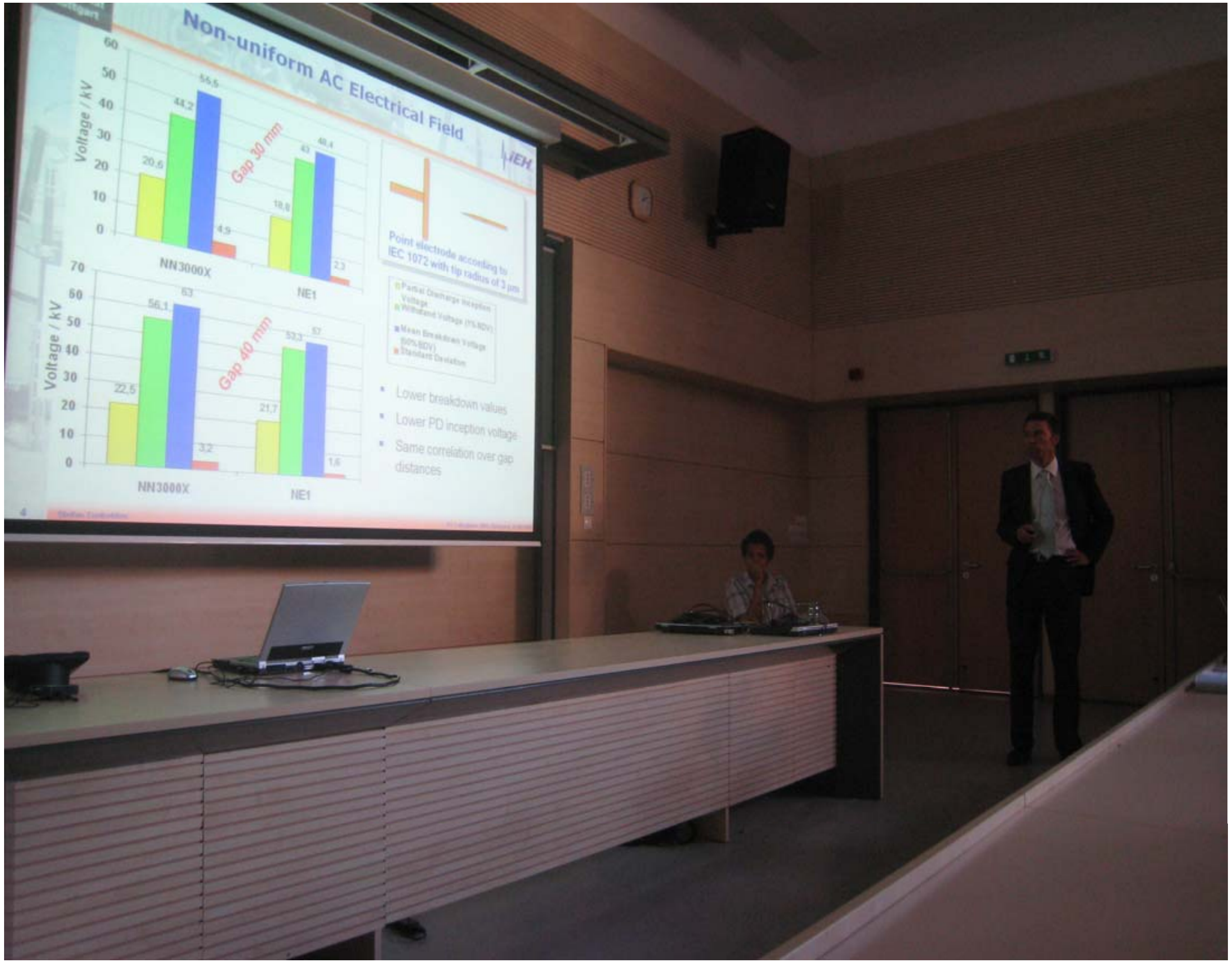
Kollokvium témakörei:

-PS1: New Insulation Materials for High Voltage Apparatus
Papers: 3
- PS2: Monitoring and diagnostics techniques, improved interpretation of measurements
Papers: 19
- PS3: Applications of High Temperature Superconducting Materials
Papers: 2

- Az SC D1 vezetőségi egy napos ülés (45 fő) az új MVM irodaház Jedlik termében,
- Látogatás a MAVIR új vezénylőjében.

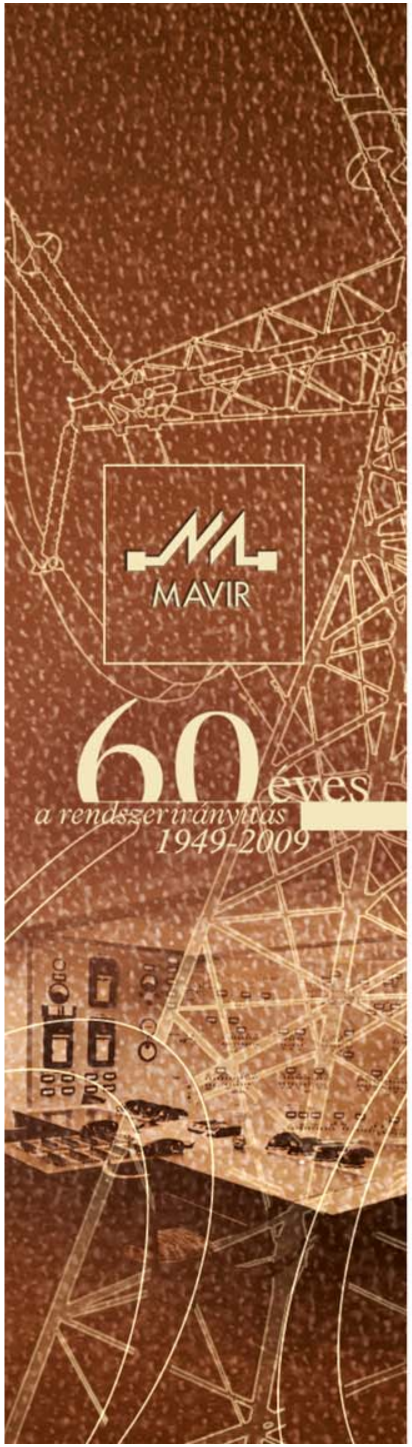
CIGRE Study Committee (SC) D1
Materials and Emerging Test Techniques

CIGRE Study Committee (SC) D1
Materials and Emerging Test Techniques



CIGRE Study Committee (SC) D1
Materials and Emerging Test Techniques

CIGRE Study Committee (SC) D1
Materials and Emerging Test Techniques



MAVIR

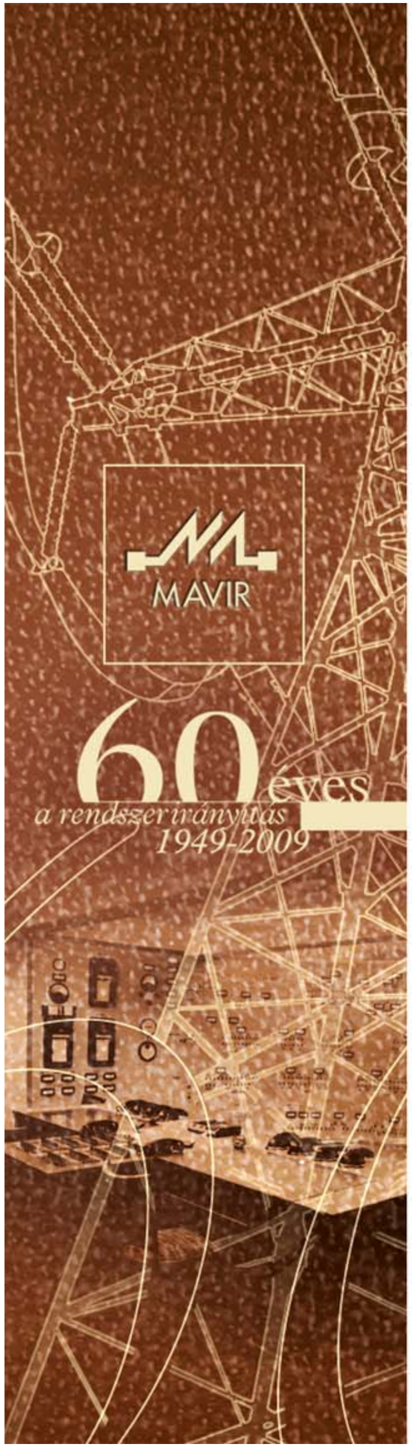
60 éves
a rendszerirányítás
1949-2009

CIGRE Study Committee (SC) D1
Materials and Emerging Test Techniques

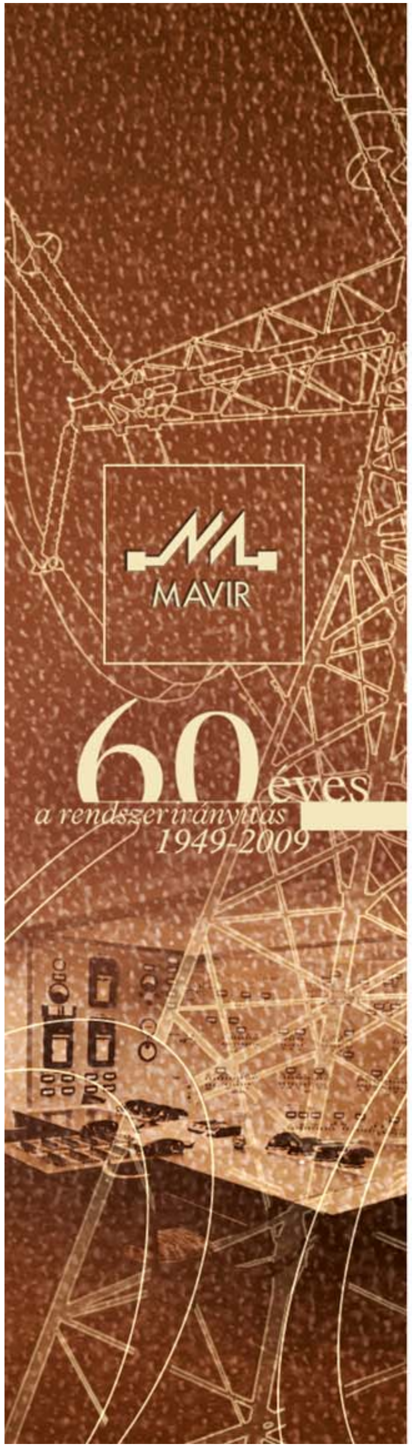
CIGRE Study Committee (SC) D1
Materials and Emerging Test Techniques

MAVIR

60 éves
a rendszerirányítás
1949-2009

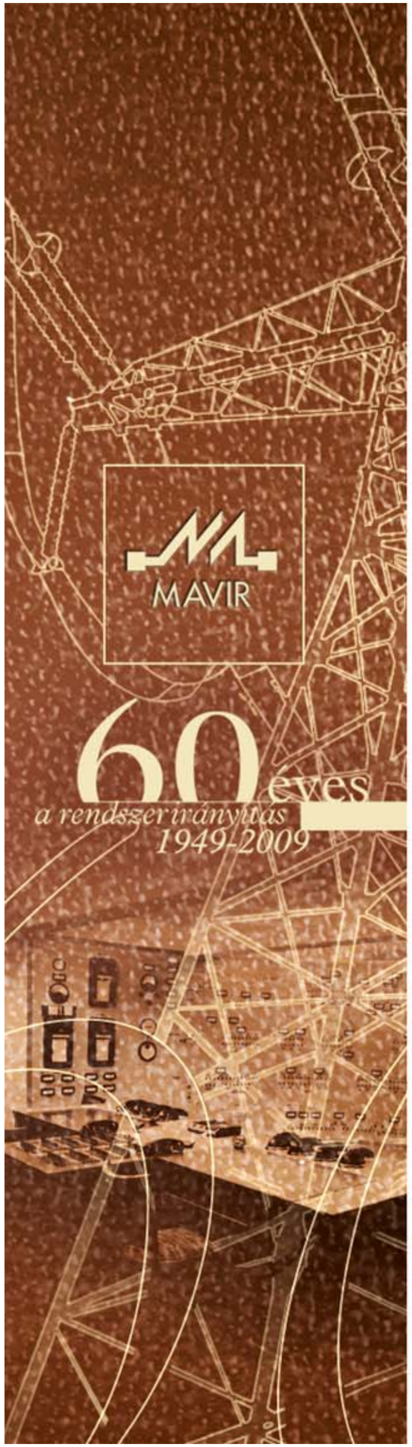


CIGRE Study Committee (SC) D1
Materials and Emerging Test Techniques



CIGRE Study Committee (SC) D1
Materials and Emerging Test Techniques

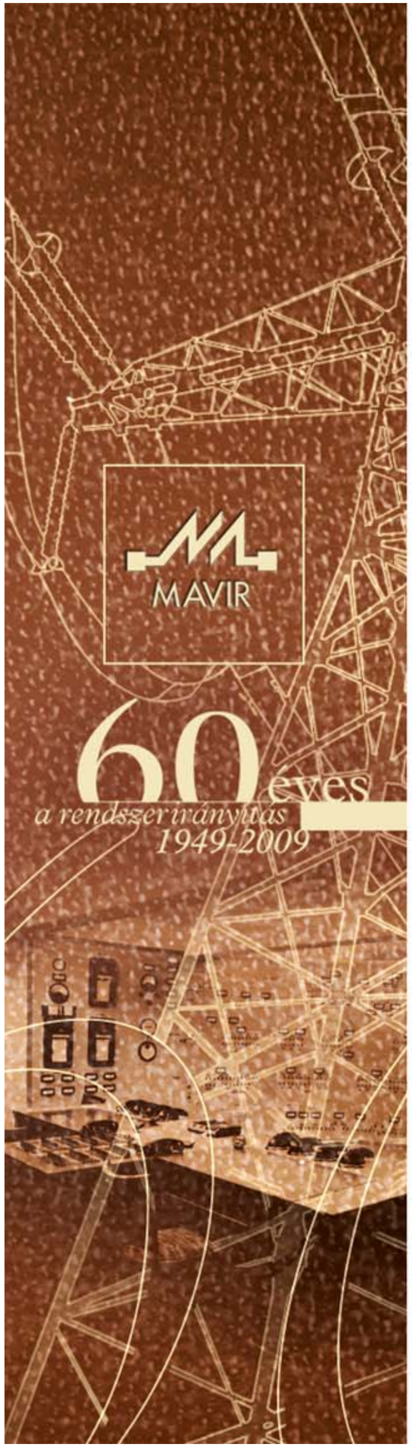
CIGRE Study Committee (SC) D1
Materials and Emerging Test Techniques



CIGRE Study Committee (SC) D1
Materials and Emerging Test Techniques

CIGRE Study Committee (SC) D1
Materials and Emerging Test Techniques

CIGRE Study Committee (SC) D1
Materials and Emerging Test Techniques



Röviden a kollokviumról

- Ritka lehetőség CIGRE kollokvium megrendezése,
- Sikeres lebonyolítás érdekében szponzori segítséget nyújtott MAVIR, Kandó, BME, OVIT ZRt., MVM ZRt., Paksi Atomerőmű ZRt., Ganz, magyar ABB és a Diagnostics Kft.
-Kollokviumon több magyar előadó ill. társszerző volt
-Dr. Vajda István, Dr. Berta István, Györe Attila, Kohári Zalán, Laboncz Szilvia, Németh Bálint, Tóth Sándor, Csecsődi Sándor, Dr Woynárovich Gábor, Schmidt János, Csépes Gusztáv
-Ezenkívül szép számmal voltak magyarok a hallgatóság között is.
- Az üléssorozat és műszaki kollokvium kitűnő lehetőséget nyújtott a szakértőknek az információcserére valamint a közelmúlt eredményeinek tapasztalatainak megosztására.

Working Groups

<u>*01 Liquid Impregnated Systems for Transformers*</u>

03 Insulating Gases

05 Insulation systems for capacitors

07 Solid Insulating Material for Rotating Machines

14 Material Properties for Non-Ceramic Outdoor Insulation

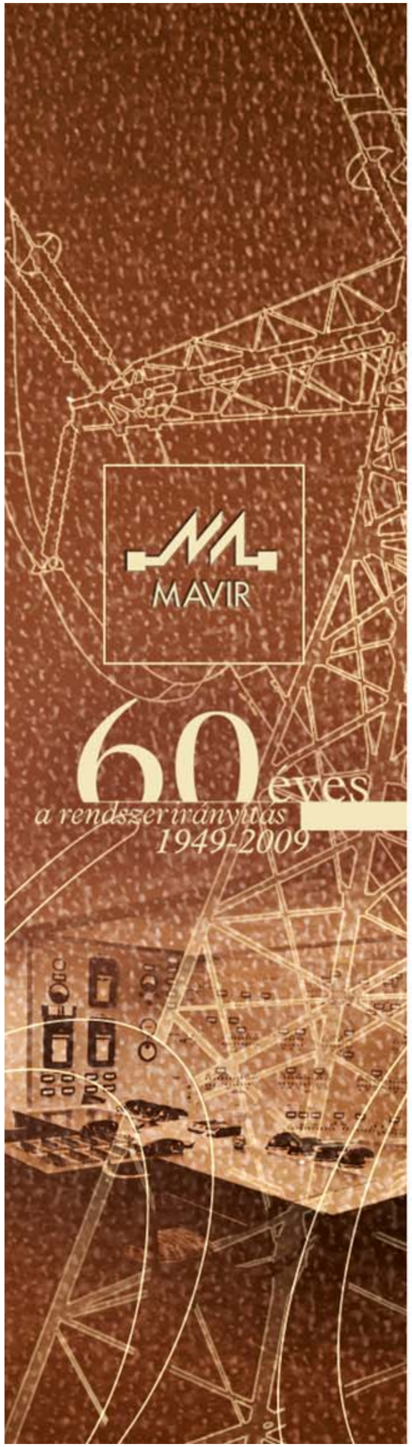
15 Superconducting and Insulating Materials for HTS Power Applications

16 High Field Phenomena in Solid Insulation and Interfaces

17 HV Asset Condition Assessment Tools, Data Quality - Expert Systems

19 Solid insulation endurance stressed by repetitive transient voltages caused by power electronics

20 Water Tree Detection in XLPE insulation



Working Groups

23 Diagnostics and Accelerated Life Endurance Testing of Polymeric Materials for HVDC Application

24 Potential of Polymer Nanocomposites as Electrical Insulation for Highly Stressed Insulation Material in AC and DC Application

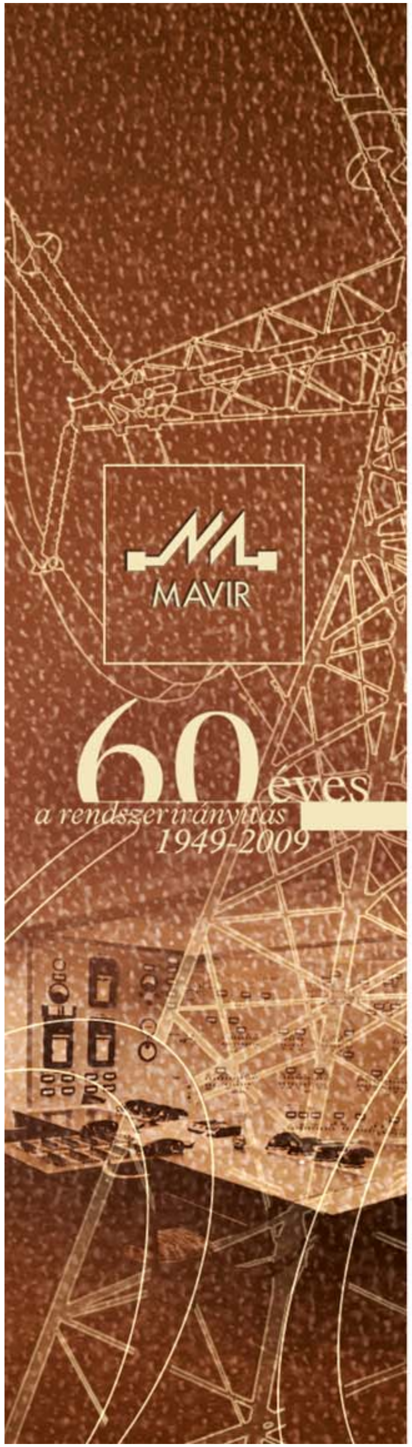
25 Application Guide for PD Detection in GIS using UHF or Acoustic Methods

26 Basic Principles to Determinate Methane Content of Cross-linked Solid Extruded Insulation of MV and HV Cables

27 Material Properties for New and Nonceramic Insulation

28 Optimized GIS by Dielectric Coated Electrodes and Functionally Graded Materials

29 PD recognition in liquid impregnated systems for transformers



Working Groups

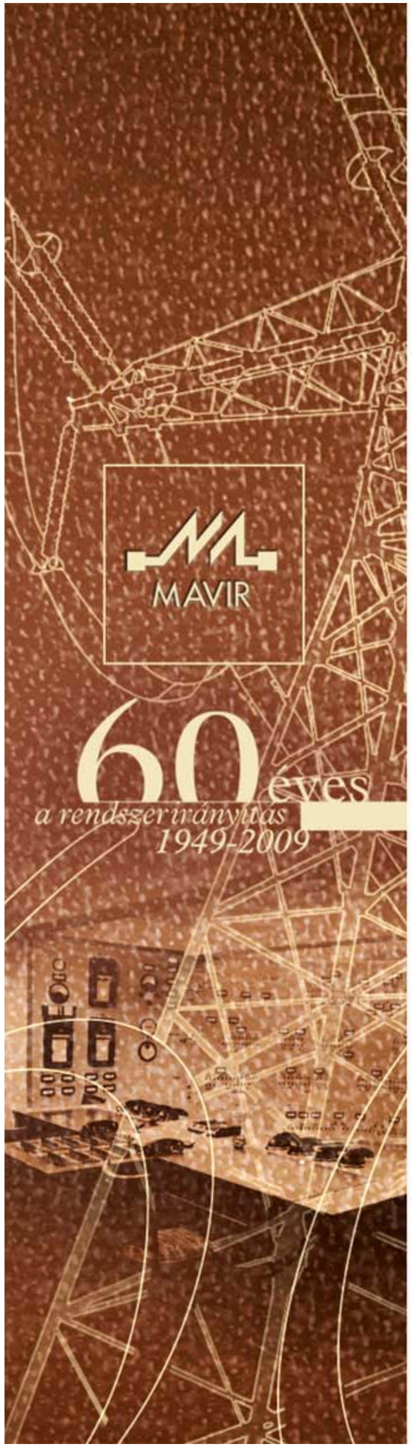
30 Oxidation stability of transformer liquids

31 Dielectric Performance of insulating liquids for transformers

32 New Application of DGA

33 High Voltage and Current Test Standard Recommendations

34 Condition assessment for Oil impregnated AC Cables

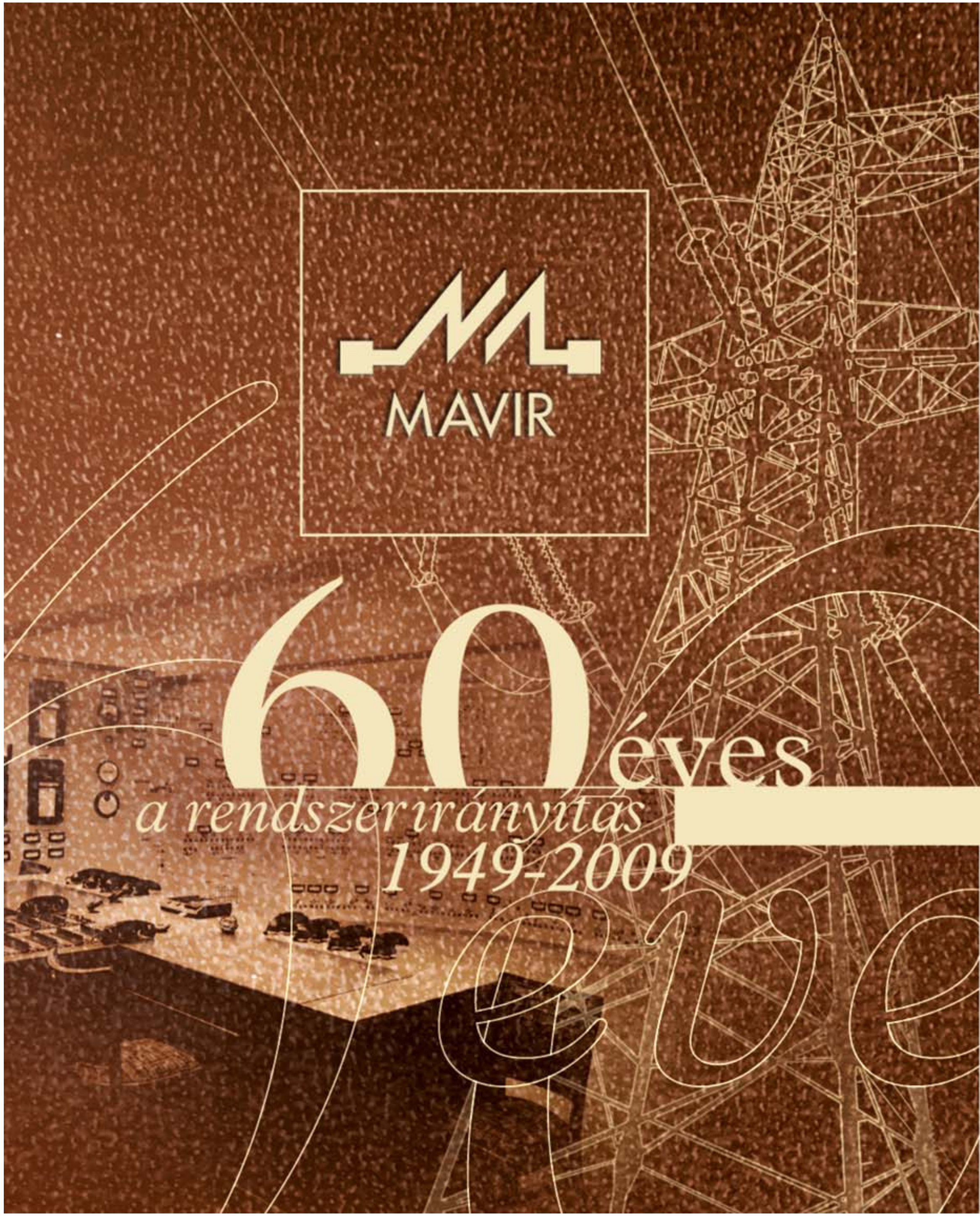


-Kollokvium Absract-ok megtekinthetők az interneten

http://www.mee.hu

Néhány fontosabb tanulmány kiemelése

-In Memoriam Csernátony-Hoffer András" jegyében került lebonyolításra



CIGRE SC D1Colloquium Budapest 2009

Dielectric Response Methods for Diagnostics of Power Transformers:

Hungarian Research Work in the mid-1970s

In memoriam Prof. András CSERNATONY-HOFFER

Gusztáv CSÉPES/MAVIR
CIGRE SC D1 Colloquium - Budapest 2009
Dr Gábor Woynárovich/MAVIR
János Schmidt/Ganz

-1970-es években növekvő számú trafó meghibásodás
- Intenzív munka új diagnosztikai módszerek keresésében
- Probléma: olaj-papír szigetelés elnedvesedése és öregedése
- Ismerni kell hogyan hatnak a fentiek a villamos paraméterekre
- Dr. Csernátony-Hoffer András a NIM-OMFB-MVMT megbízásból egy nagy kutatómunkát indított az un. dielektromos válasz módszerek használhatóságára: visszatérő feszültség, tg delta/C frekvencia függése, töltő/kisütő áram mérése
- **Új nevek: RVM, FDS (**Frequency Domain Spectroscopy**), PDC**
-Dr. Csernátony-Hoffer András hirtelen meghalt, mielőtt teljesen befejezte volna a munkát
-Tagja volt a CIGRE SC 15, D1 elődjének (magyar Regular Member)
- Ez a tanulmány csak a legfontosabb görbéket mutatta be

- **To investigate the influence of aging of the oil** three different aged oils **were used for impregnation:**
- new (Pt:lp/01**: tgδ =0,01% or 10^4 tgδ =100 at 90°C)**,
- moderately aged (Pt:lp/02: **tgδ=0,1% or 10 tgδ =1000 at 90°C), and**
- heavily aged (Pt:lp/03: **0.5%≤tan(δ)≤0.7% or 10^4tgδ =5000-7000 at 90°C).**
- **In the figures, the marking of samples with oil ducts was** Pt:lp+pp (soft paper with spacer), **and without oil gap (only layered soft paper, without oil duct), the marking of samples was** Pt:lp.

-The temperature **with** 6 equally spaced values **between** 25°C and 90°C **(25, 38, 51, 64, 77 and 90°C),**

-The moisture content **of the cellulose with** 5 values **between** 0.5% and 4% **(0,5, 1, 2, 3 and 4 %),**

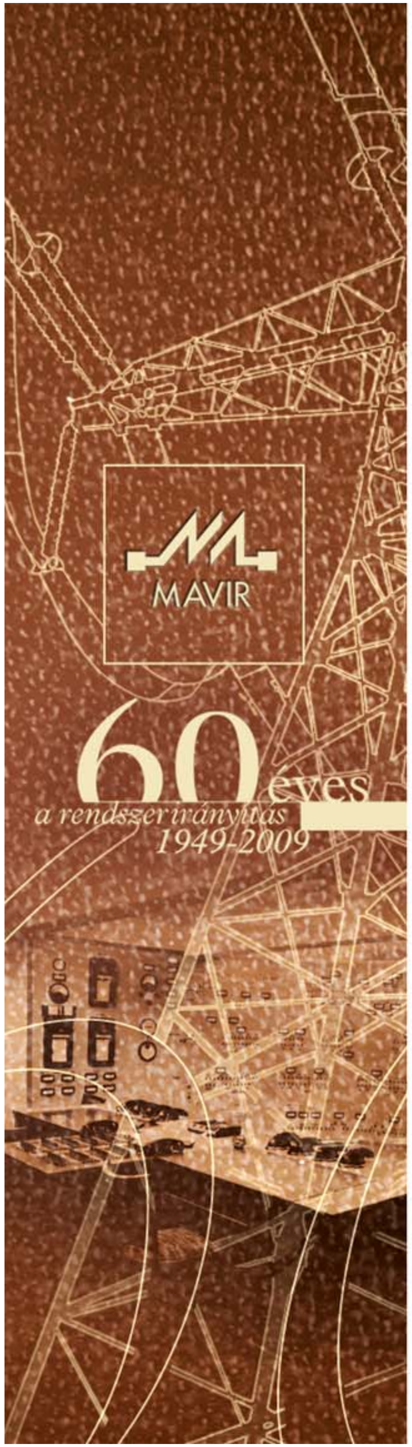
-served as parameters in all of these measurements.

-Where frequency **was a variable parameter (tg/C or FDS), 8 measurements were taken between** 0.05Hz and 50 Hz.

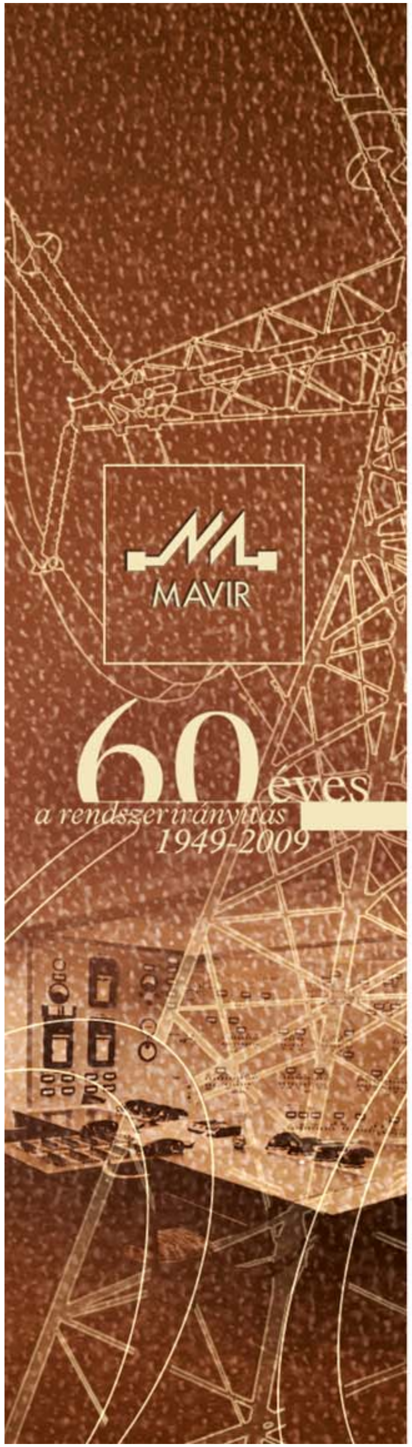
-Where voltage **was a variable parameter,**

- **8 measurements between** 6V and 1400V **at 50 Hz were taken for** AC tests **and**
- **8 measurements at values from** 5V to 1000V **were taken for** DC tests.

-**Recovery Meas (RVM) were taken at charge and discharge times between** 0.02s/0.01s and 1000s/500s **(following the series 2; 5; 10).**

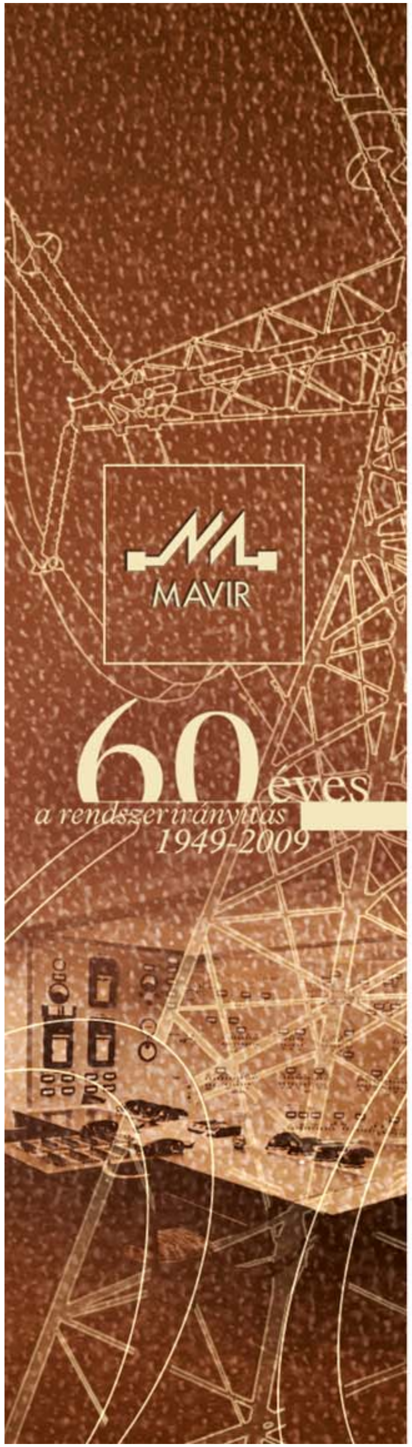


- **In the scope of this research work - among other things – the** following parameters **have been investigated:**
- **R10:** virtual 10 minutes resistance (U/I), **R10(U;T;X) means "ten-minute resistance" was measured** in function of voltage (U), temperature (T) and moisture content in the paper (X).
- **tg**δ50Hz:Dielectric dissipation factor measured at 50 Hz, **104tgδ(U;T;X) means "loss factor, was measured** in function of voltage (U), temperature (T) and moisture content in the paper (X).



- tgδ: Dielectric dissipation factor **measured at constant voltage, tgδ(f;T;X) means "loss factor" , was measured** in function of frequency (f), temperature (T) and moisture content in the paper (X) **(presently called "dielectric** Frequency Domain Spectroscopy (FDS),

- C: Capacitance **at constant voltage, C(f;T;X), means the capacitance, was measured in** function of frequency (f), temperature (T) and moisture content in the paper (X).



- Two parameters of Return Voltage were measured:
  - **was measured** in function of
- **- charge/discharge times ((t_C/t_D),**
- **- temperature (T) and**
- **moisture content in the paper (X).**

- **The peak of the recovery voltage: $U_R max(t_C/t_D;T;X;T;X)$**
  - **and**
- **The Initial slope of recovery voltage: $S_R(t_C/t_D;T;X)$**

- **Return voltage measurements (RVM), sometimes also called Recovery Voltage,**

Local maximum inflection point tgδ(f) curves move toward higher frequencies with increasing moisture content and temperature.

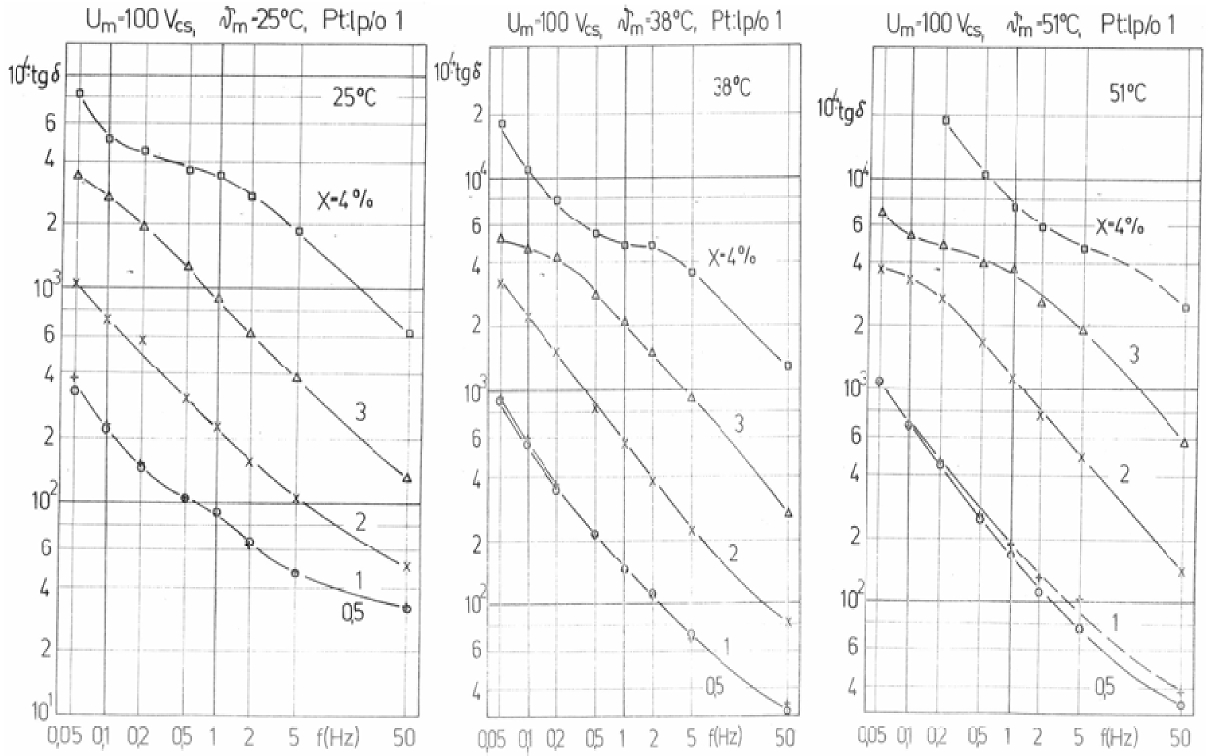
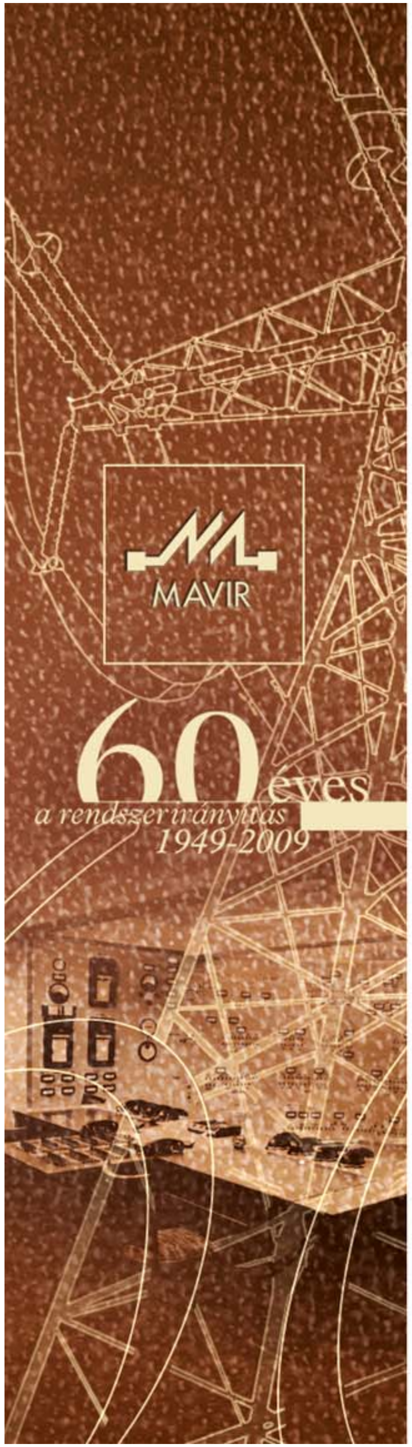


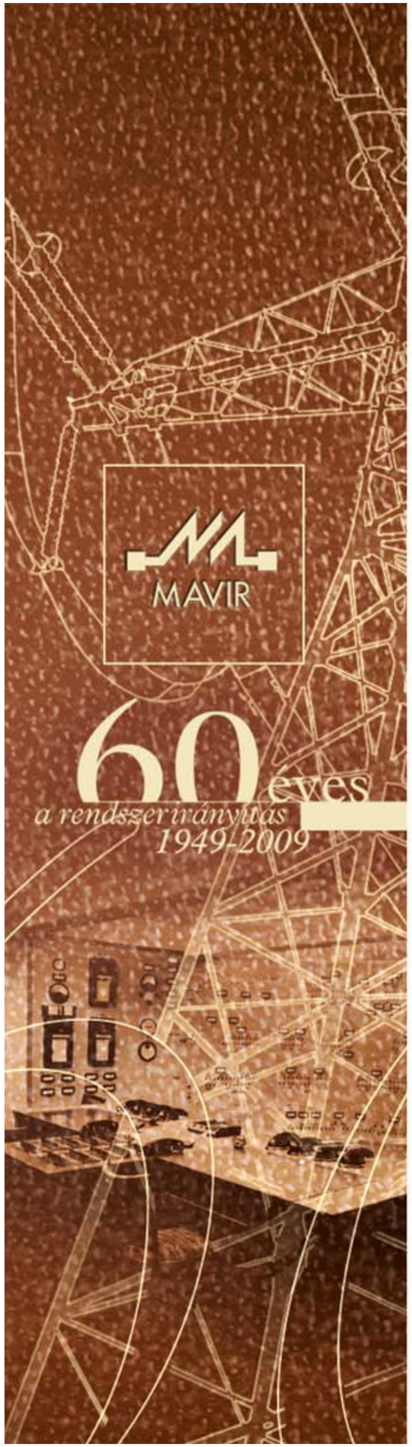
Fig 4: tg δ(f;T;X): dissipation factor measured at constant voltage, in function of frequency (f), moisture content (X) as parameter at temperature (T) of 25°C, 38°C and 51°C.



- Insulating liquids for future transformers
- Paper D1-102

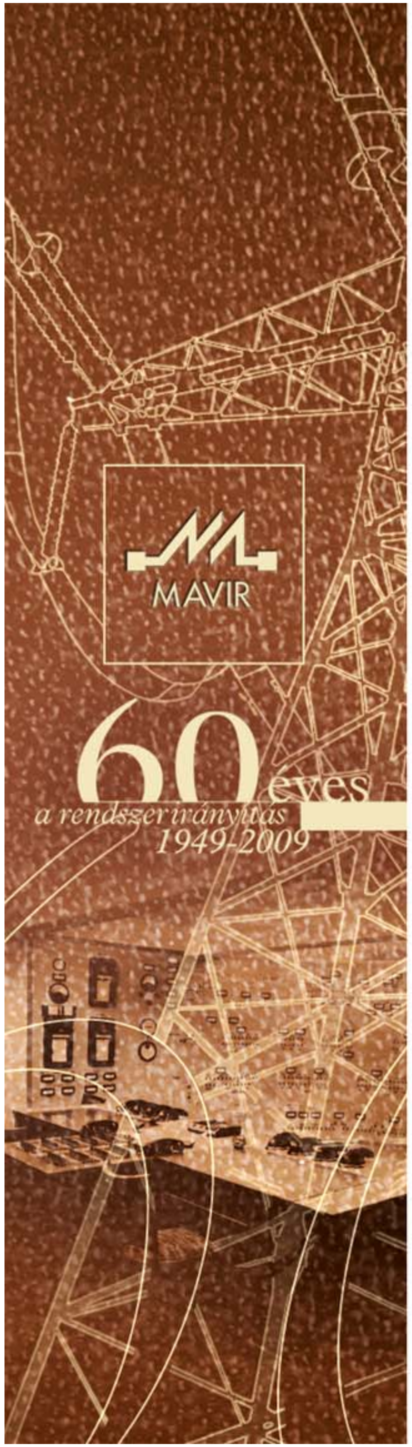
- H. Borsi, E. Gockenbach

Leibniz Universität Hannover



Insulation systems for transformers are mainly based on solid-liquid insulation

- Power transformers have up to 100 % oil (liquid)-solid insulation
- Distribution transformers are to a certain extent dry-type transformers, but the rest have also solid-liquid insulation
- high electric strength
- high heat conductivity
- low viscosity
- good ageing performance
- high permittivity
- compatibility with solid material
- high temperature
- high flash point
- high ignition temperature
- low dielectric losses
- high water solubility
- good gassing behaviour



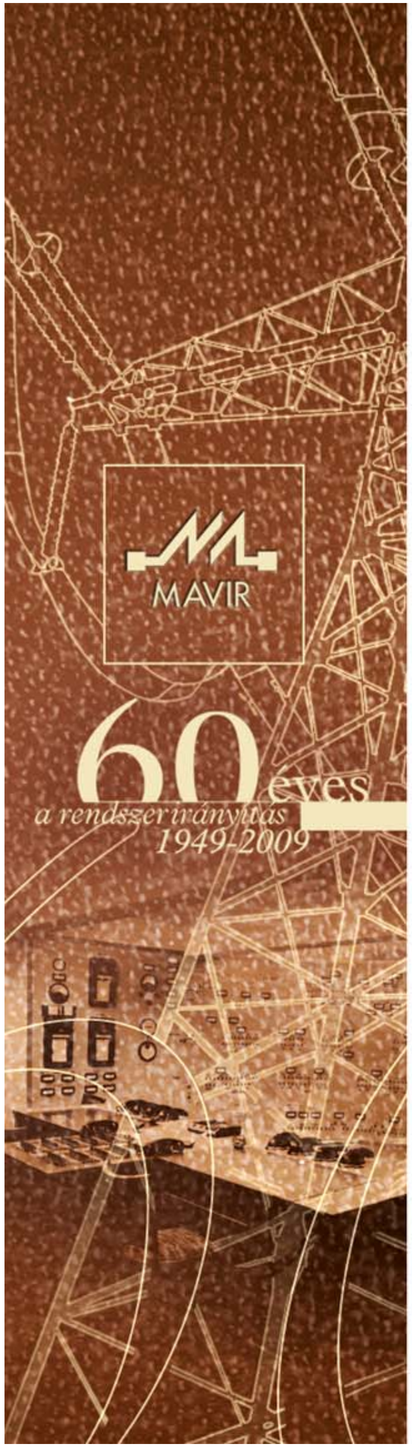
Type of insulation liquids

According to the requirements different liquids may be used

- **Liquids based on mineral oil**
- **Silicone**
- **natural and synthetic esters**
- **mixtures**

Characteristic values

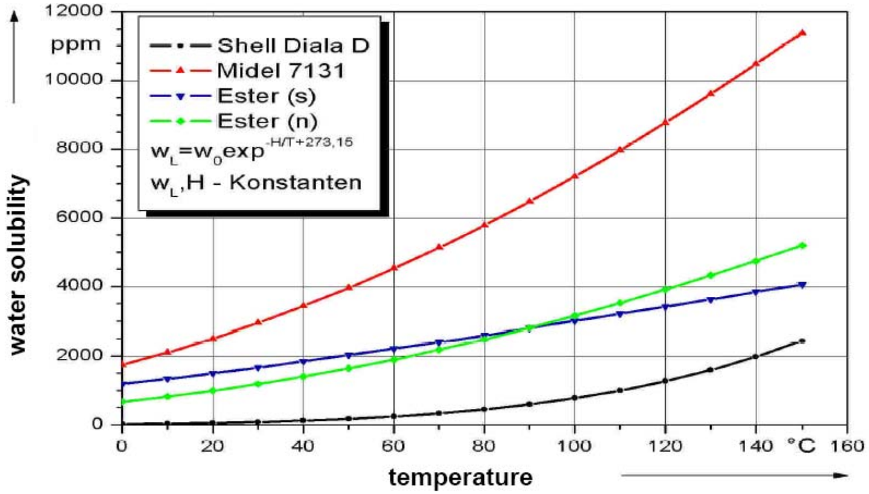
Electrical performance	Ester	Silikone	Mineral oil	PCB
loss factor 25° C	10	0.9	< 10	30
permittivity ε at 23 ° C, 50 Hz	3,3	2,7	2,2	4,4
breakdown voltage IEC (kV)	55	50	60	50
flash point (° C) (ASTM D 92)	310	>335	150-175	-
flame point (° C) (ASTM D 92)	257	>300	135-145	200
combustion heat (kJ/kgx10 ³)	36,8	32,2		12,6



Characteristic values

	Ester	Silicone	Mineral oil	PCB
heat conductivity (W/m K)	0,156	0,151		0,105
cinematic viscosity at 25° C (mm^2/s)	56	50	20	12
Pourpoint (° C)	-50	-53	-40	-40
toxicity LD50/LC50	passed	passed	passed	not passed
spec. weight at 25 ° C (kg/m^3)	960	960	900	1390

Water solubility

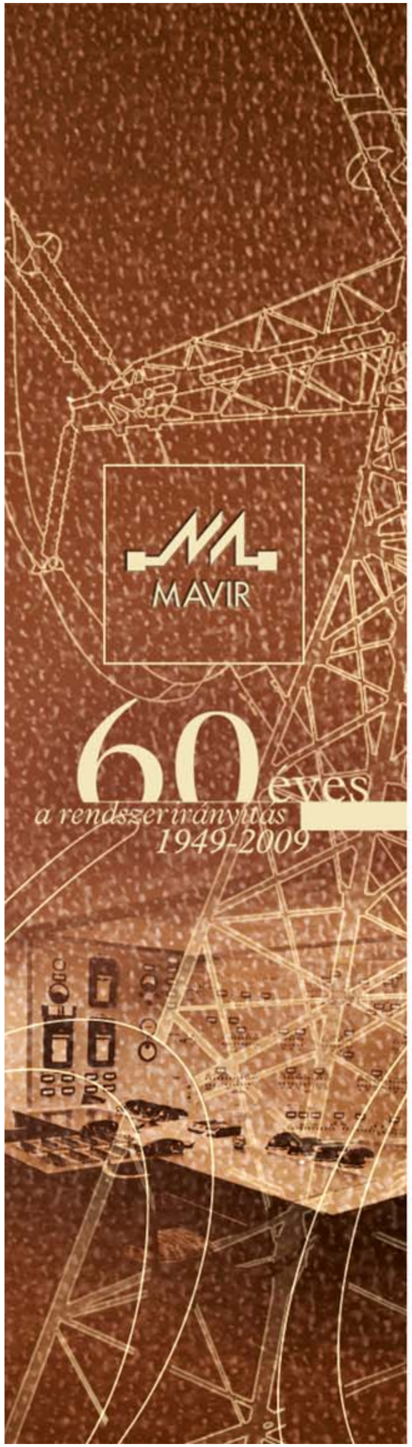


-Az észter és szilikon olajok jó villamos, dielektromos, termikus és öregedési paraméterekkel rendelkeznek,

- Alacsonyabb a lobbanáspont és kisebb a tűzveszély,

- A nedvességtartalom kevésbé fontos a dielektromos tulajdonságok között

- Az öregedési viselkedést a legfontosabb, amit még meg kell vizsgálni



AREVA

Suitability of Thermoplastic Polymer Used as Insulator for HV Apparatuses

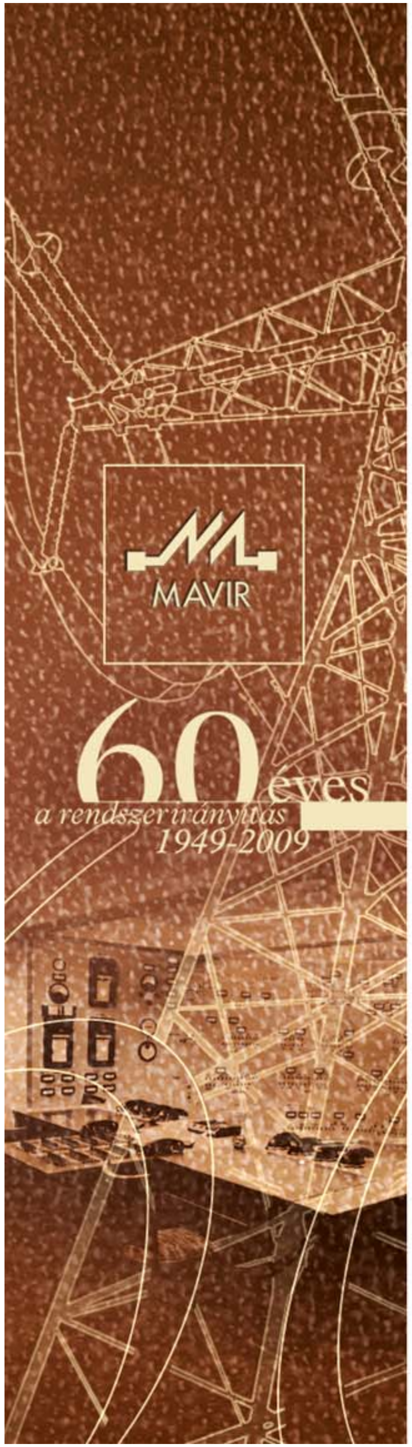
Y. KIEFFEL, A. GIRODET, K. POHLINK

Yannick KIEFFEL

H.V. Switchgear Research Centre
Villeurbanne/France

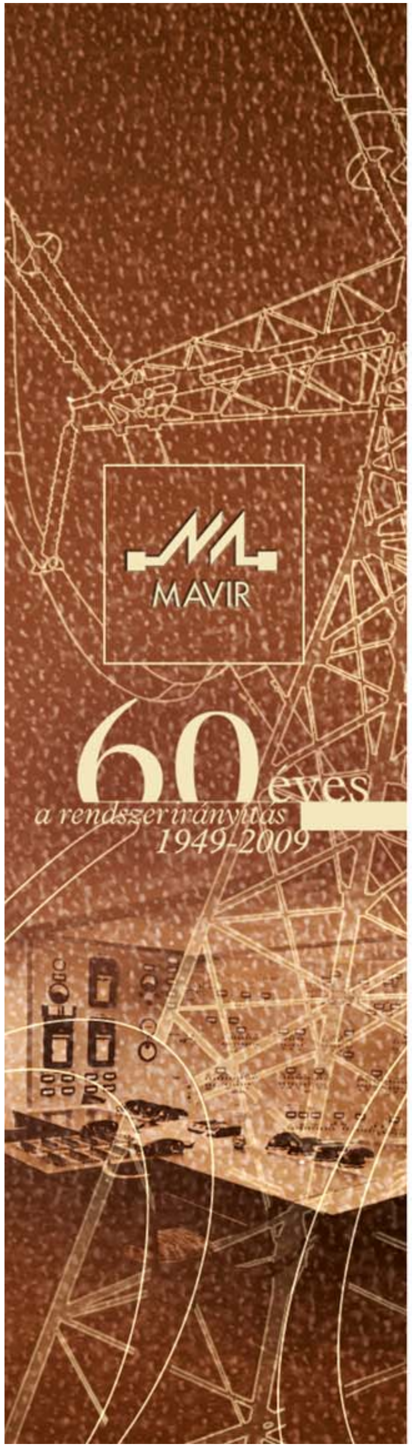
CIGRE SCD1 Colloquium in Hungary, Sept 2009

AREVA T&D



Gassing and Oxidation Behaviour of Insulating Fluids under Thermal Stress

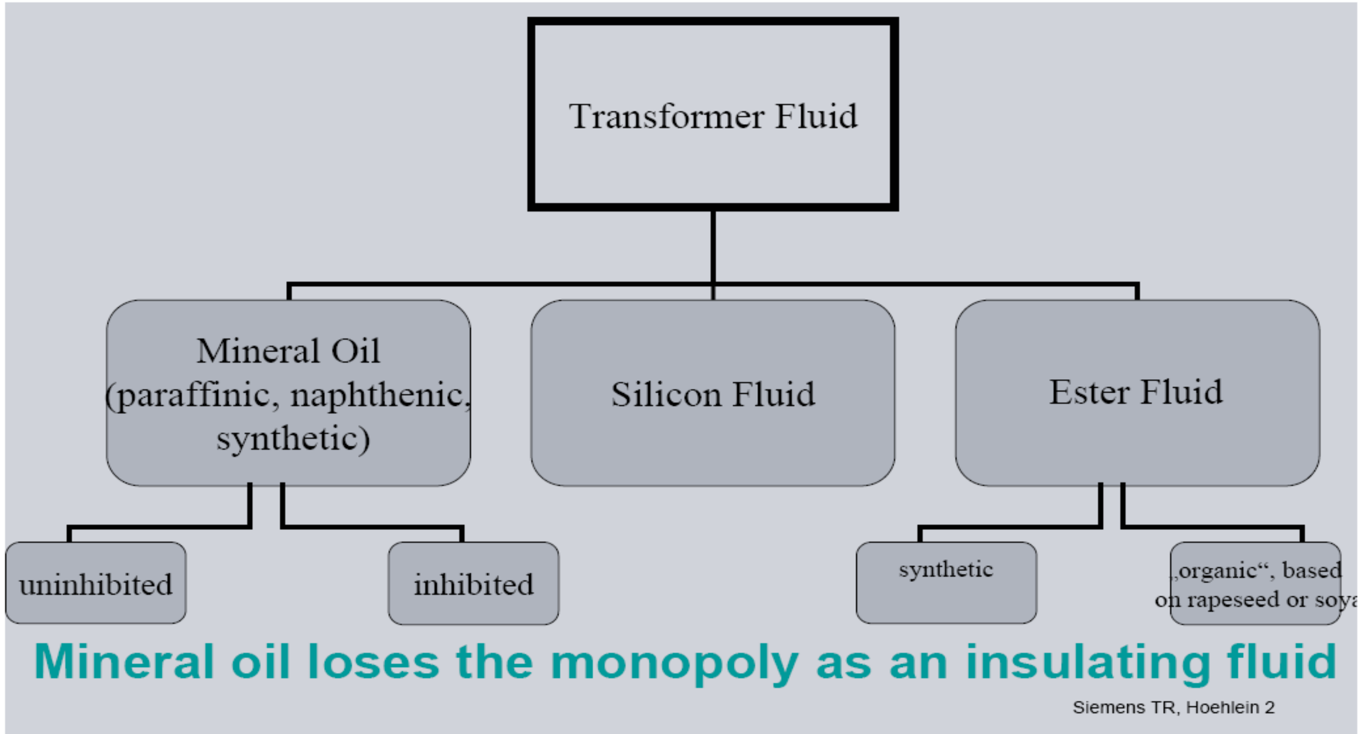
IVANKA ATANASOVA-HÖHLEIN

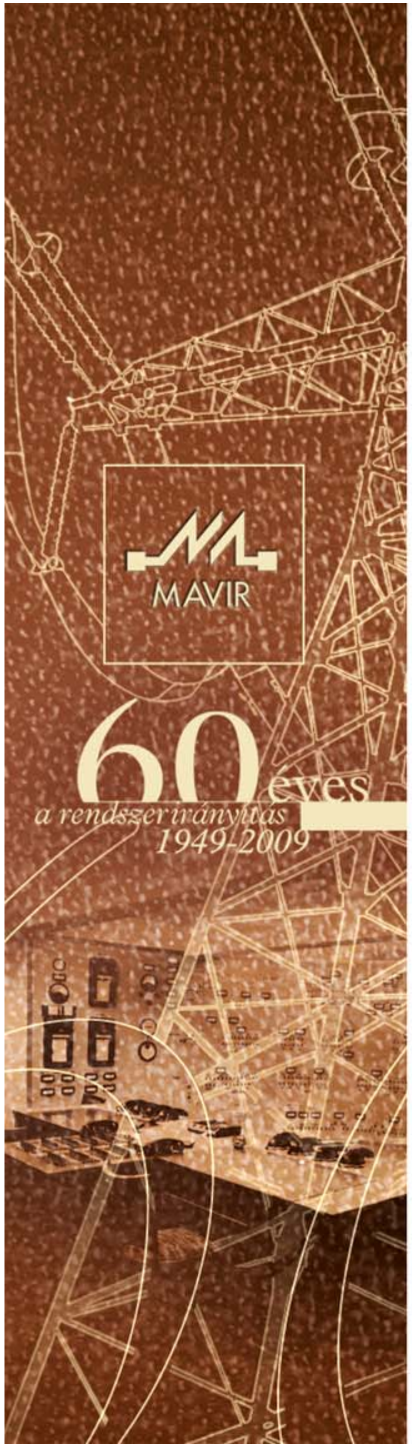


CIGRE SC D1 Colloquium in Budapest, Septemer 23rd 2009

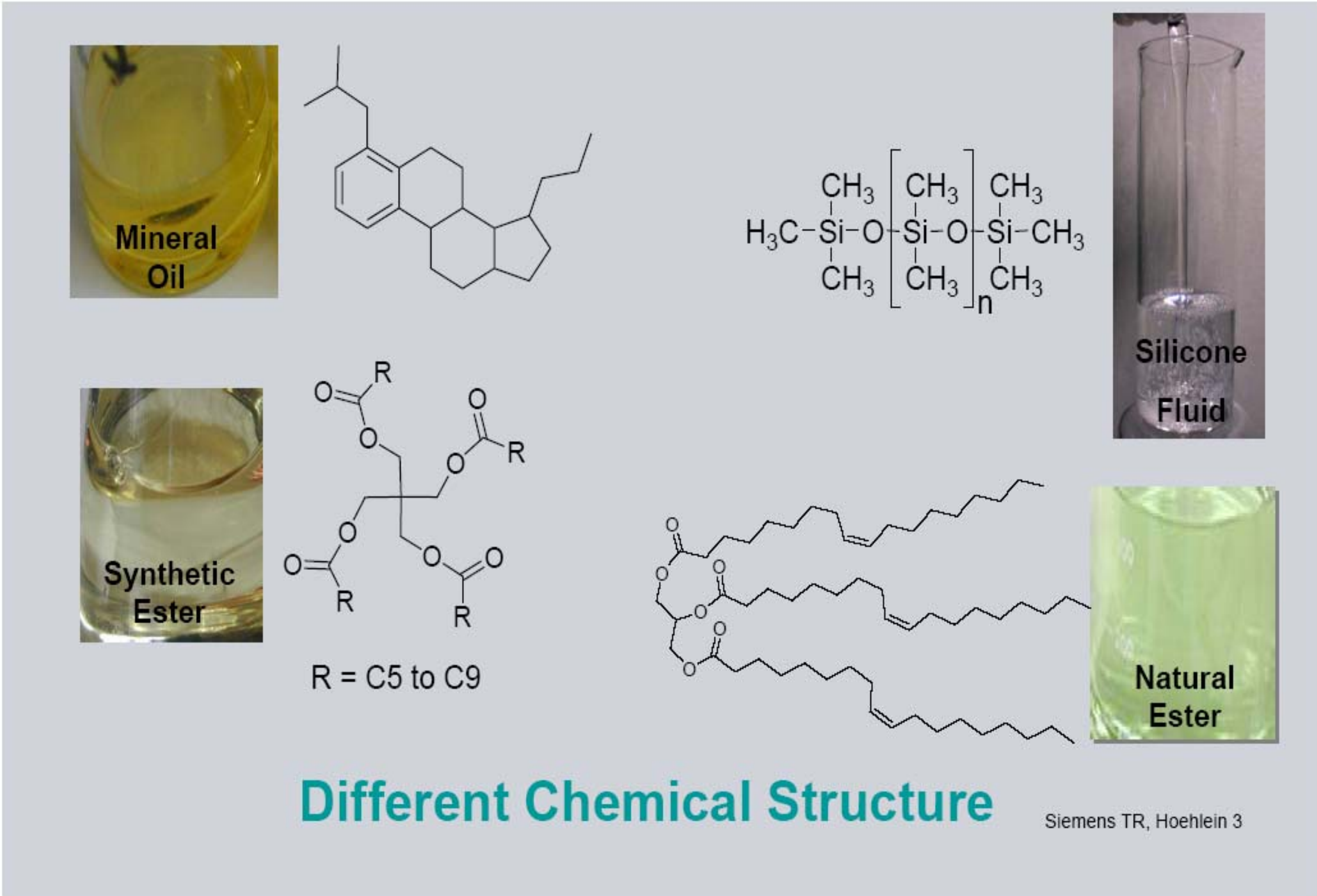
CIGRE SC D1 Colloquium in Budapest, September 23rd 2009

SIEMENS





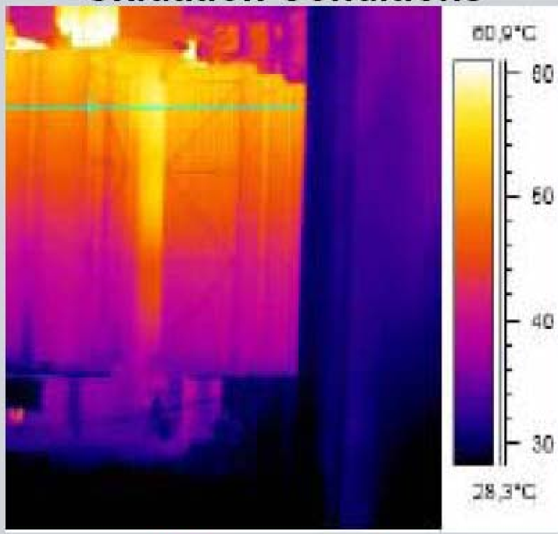
MAVIR
60 éves
a rendszerirányítás
1949-2009



Mineral Oil
Silicone Fluid
$H_3C-Si(CH_3)_2-O-[Si(CH_3)_2-O]_n-Si(CH_3)_2-CH_3$
Synthetic Ester
R = C5 to C9
Natural Ester
Different Chemical Structure
Siemens TR, Hoehlein 3

This gassing is dependant on:

- Nature of the fluid
- Operating Temperature
- Oxidation Conditions



Moderate Thermal Stress Causes Gassing

Siemens TR, Hoehlein 4

Markers of Gassing at Medium Thermal Stress

Carbon Oxides and their Ratios – What are they telling us?

CO_2/CO Ratios

IEC 60599
Mineral oil-impregnated electrical equipment in service –
Guide to the interpretation of dissolved and free gases analysis

5.4 CO_2/CO ratio

The formation of CO_2 and CO from oil-impregnated paper insulation increases rapidly with temperature. Incremental (corrected) CO_2/CO ratios less than 3 are generally considered as an indication of probable paper involvement in a fault, with some degree of carbonization.

Uninhibited oil | Inhibited oil | Vegetable fluid

After ageing at 150° C for 164h in a headspace vial

first vial oil without copper

second vial – with copper strip

third vial – with copper and paper

Siemens TR, Hoehlein 5

Systematic Study of Gassing under Thermal Stress

$K = C_i Oil / C_i gas$

At 20°C

CO		CO_2
1		1
0,1		0,93

Solubility CO (Carbon Monoxide) – 0,1

Solubility CO_2 (Carbon Dioxide) – 0,930

-In closed type transformers ratios CO2/CO < 3 can be quite normal.

- Temperatures up to 150°C lead to a moderate decomposition of transformer oil.

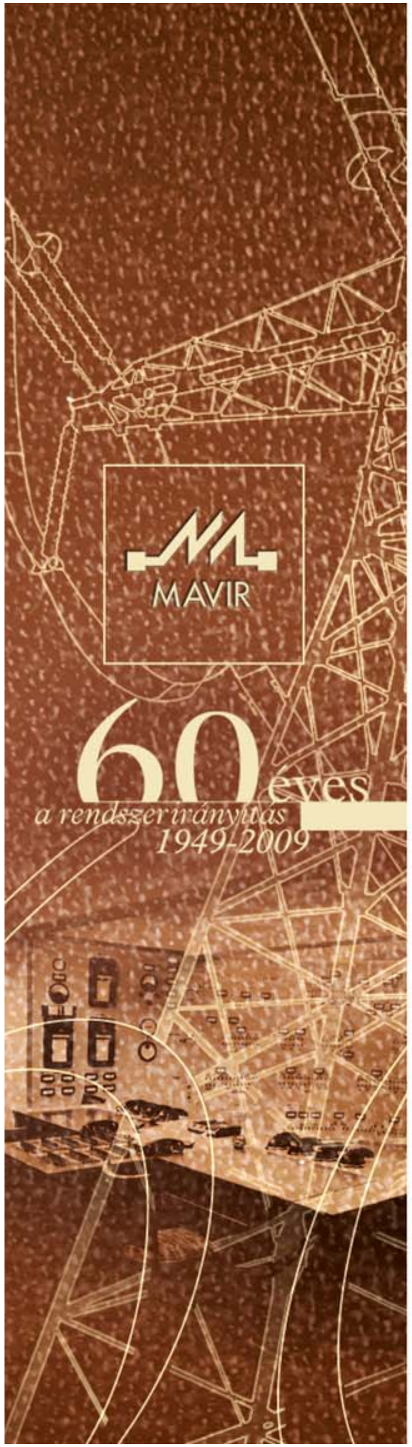
- As expected methane, ethane and ethylene accompanying CO are the most representative for this range.

- Higher values are usually typical for non-inhibited oils, as encountered in service. Often this phenomenon is referred to as stray gassing.

- The distribution of hydrocarbon gases in different fluids is quite different, e. g. methane is produced mainly in mineral oils, while ethane is indicative for natural esters.

Conclusions

- The experiments of gassing of insulating fluids under normal thermal stress (up to 150°C) correlate to field results and show that:
- the usual evaluation scheme concerning ratios of CO to CO2 in closed type transformers needs to be revised, since a significant amount of CO comes from oil and not from paper, as considered up to now.
- The development of CO2 in case of natural and synthetic esters is much more pronounced than in case of mineral oils, both for the fluid itself or in combination with copper and paper.
- The most important DGA marker for thermal and oxidative stress in natural ester fluids is ethane, independent of the origin of the fluid. This effect is to be considered as a kind of stray gassing. Even new or less used fluids develop some ethane level, which reflects normal service conditions.
- Peroxides in case of all insulating fluids, and viscosity in case of „vegetable oils“ are very good markers for the oxidation behaviour of these fluids.
- In case of mixed fluid insulation care should be taken of the changed diagnostic criteria in case of gassing.



Budapest University of Technology and Economics

Fuzzy logic based power transformer fault diagnostics

B. Németh*, Sz. Laboncz**, I. Kiss*, G. Csépes**

* Budapest University of Technology and Economics, Hungary
** OVIT ZRt. (National Power Line Company Inc.), Hungary
*** MAVIR Ltd. (Hungarian Transmission System Operator Company Ltd.)

mvm ovit

Dielectric loss diagnosis of service aged HV power cables

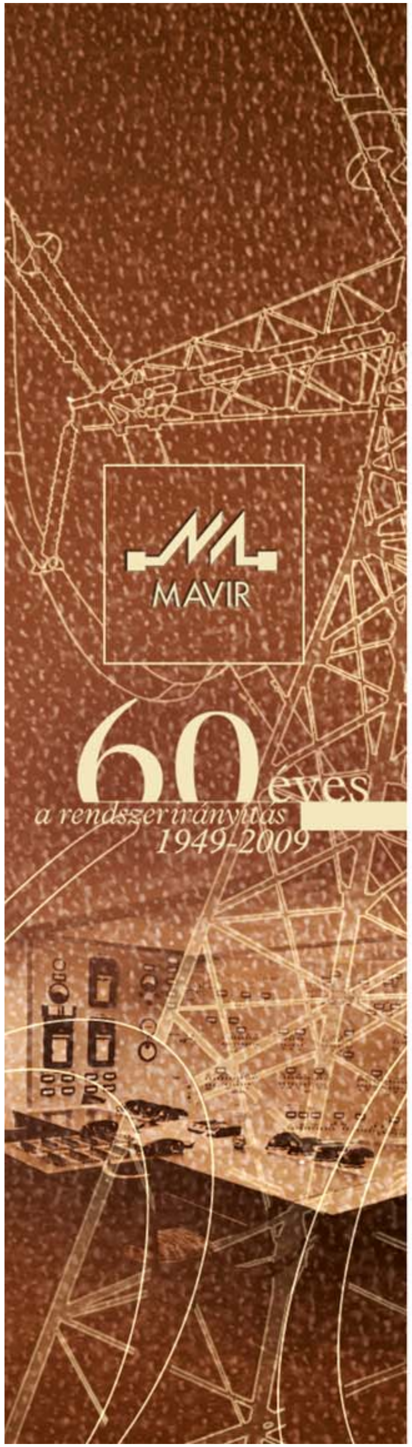
Edward Gulski, Piotr Cichecki, Johan J. Smit
Delft University of Technology, The Netherlands

Frank de Vries
Alliander, The Netherlands

Riccardo Bodega, Theo Hermans
Prysmain Cables and Systems, The Netherlands

Paul P. Seitz
Seitz Instruments AG, Switzerland

CIGRE SC D1 – COLLOQUIUM IN HUNGARY BUDAPEST 2009



General consideration

condition assessment

1. Condition assessment of oil-impregnated HV power cables is important:

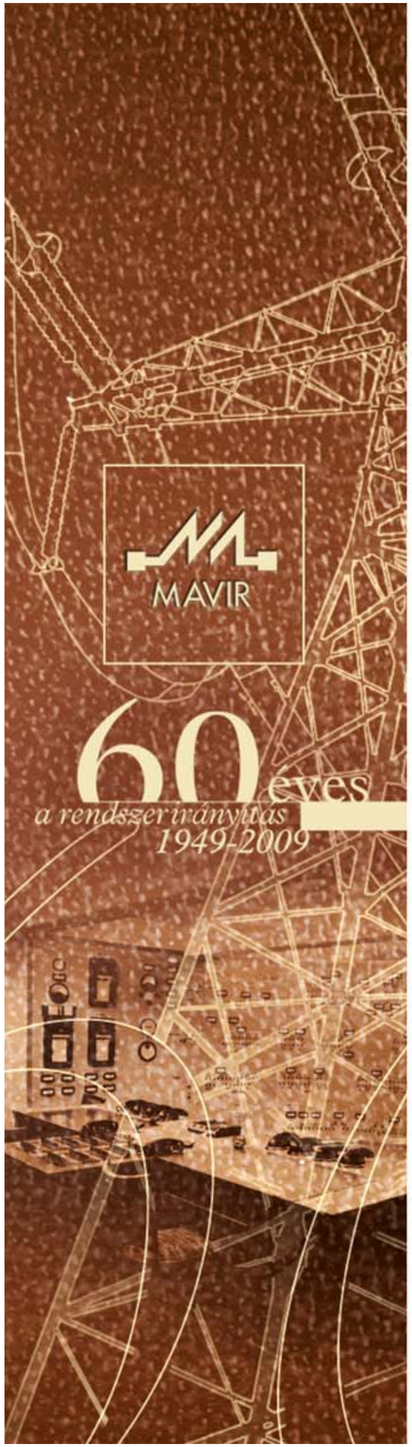
.

   a) to evaluate overall status of individual HV cable circuits,

   b) to be able to estimate the reliability and availability,

   c) to set up maintenance/replacement schedule.

2. By providing reference values of diagnostic tools (voltage testing including partial discharges and dielectric loss) future inspections.



General consideration

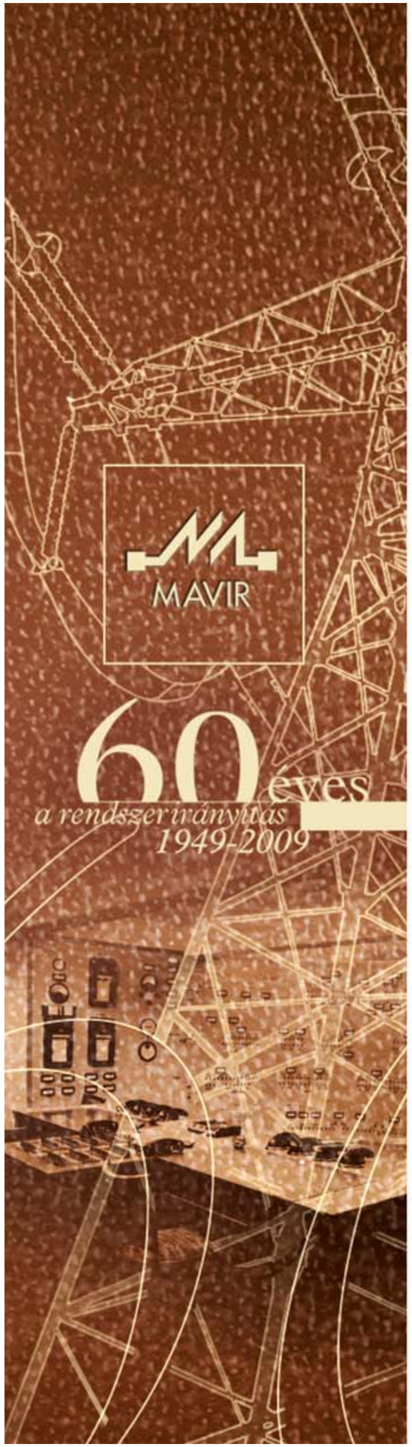
insulation degradation

1. The thermal effects of past and future operation conditions (e.g. short term over-loading) are of importance on the life expectancy of oil-filled cables.

2. Thermal and mechanical degradation are major aging mechanisms of oil-impregnated insulation (partial discharges may accelerate this process).

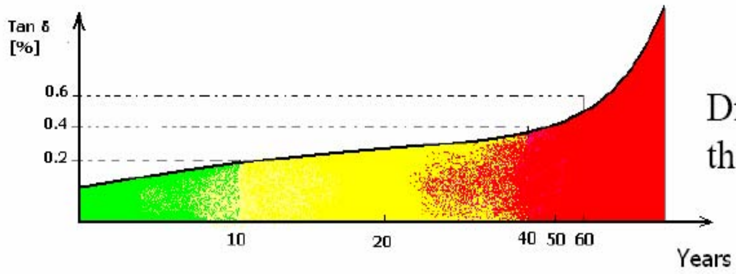
3. Electric stresses e.g. switching surges or lightings may result in physical erosion through the paper structure.

4. Deterioration effects like increase of paper porosity, moisture presence, dissolved gasses may increase of the conduction in the oil-impregnated paper insulation.

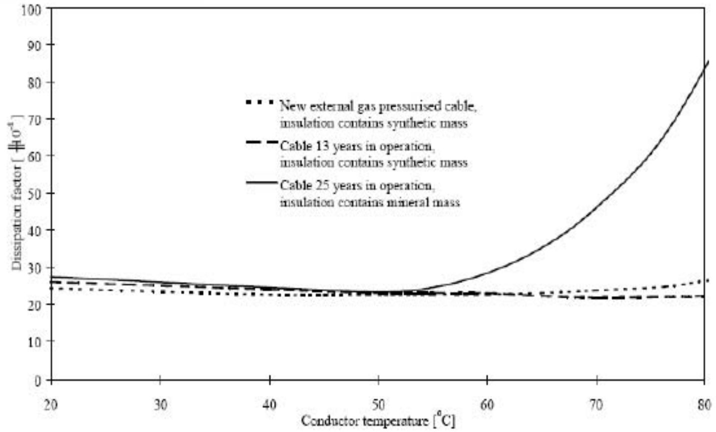


Dielectric loss diagnosis of service aged HV power cables

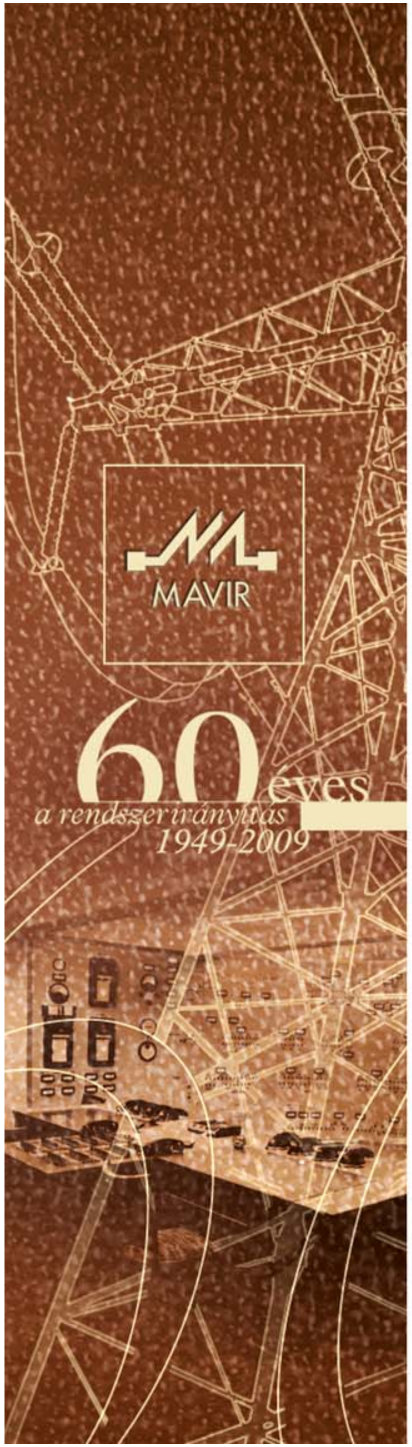
General consideration
dielectric loss



Dielectric loss increases with the service age



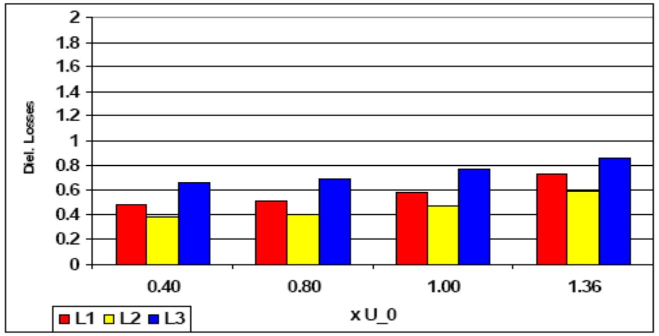
Thermal stability depends on dielectric loss



Dielectric loss diagnosis of service aged HV power cables

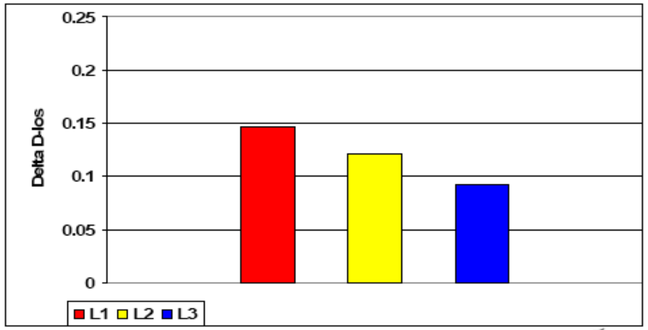
Practical consideration

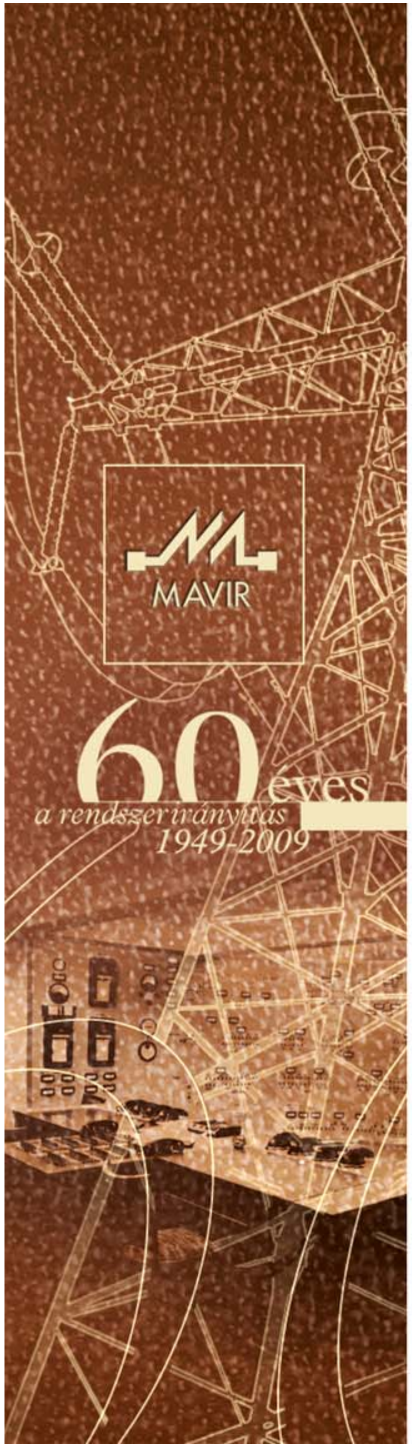
example: on-site dielectric loss diagnosis service aged 230 kV power cable



Installation year:	1976
Insulation type:	Oil-filled
Cable length:	13.314 m
Voltage ratting:	Uo = 133 kV_{rms}
Cable capacitance:	4 µF

On-site testing using damped ac voltages: (20 Hz) up to 1.36 Uo

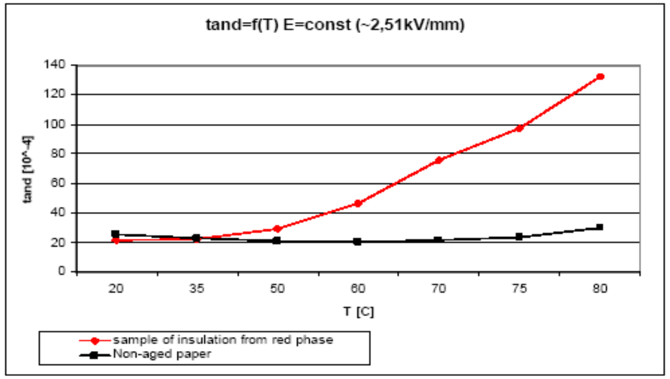




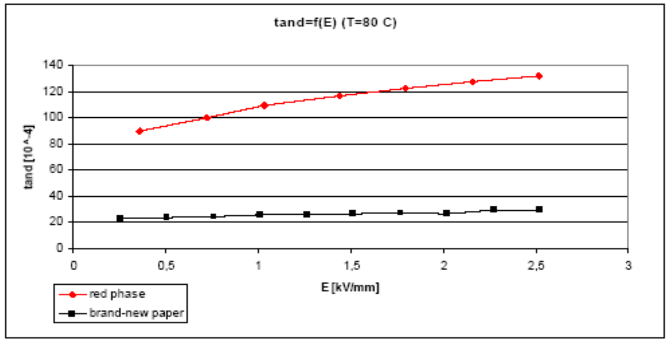
Dielectric loss diagnosis of service aged HV power cables

Practical consideration

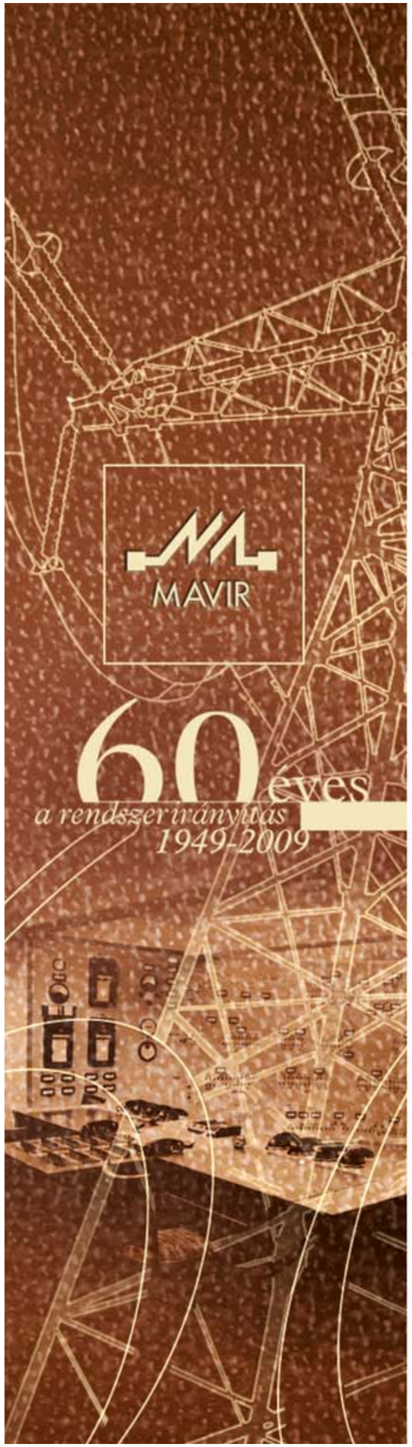
example: material investigation on samples of an aged cable



- Dielectric loss of strongly aged insulation increases with temperature
- At higher temperature the value of dielectric loss is higher than for non aged insulation



- Dielectric loss of strongly aged insulation is significantly higher than of non aged
- Dielectric loss of strongly aged material increases with the electric field



Dielectric loss diagnosis of service aged HV power cables

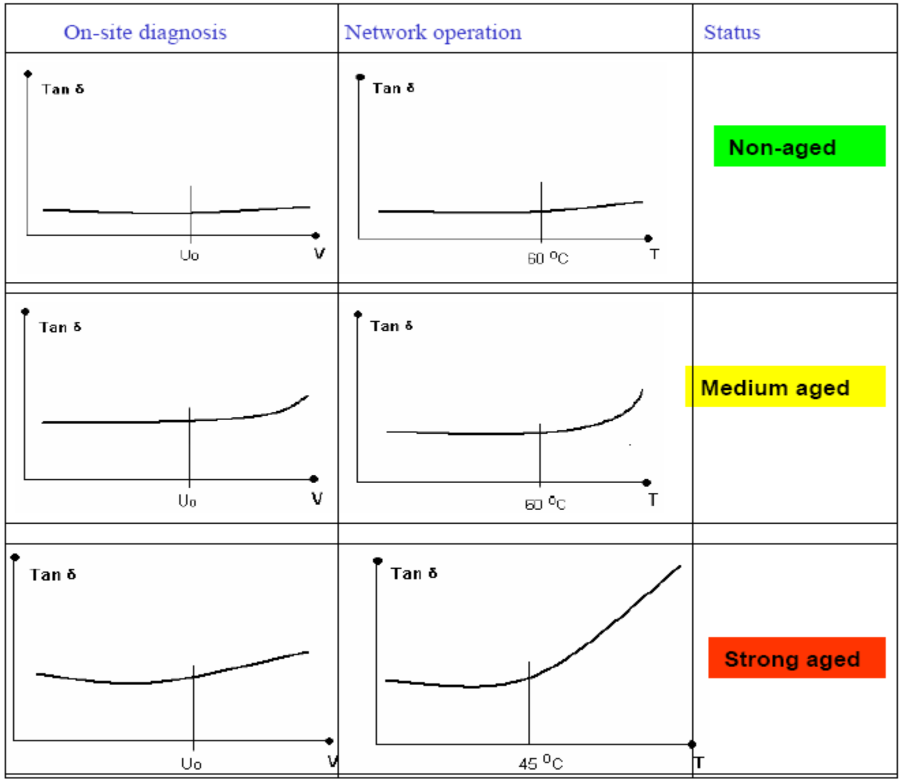
Knowledge rules development

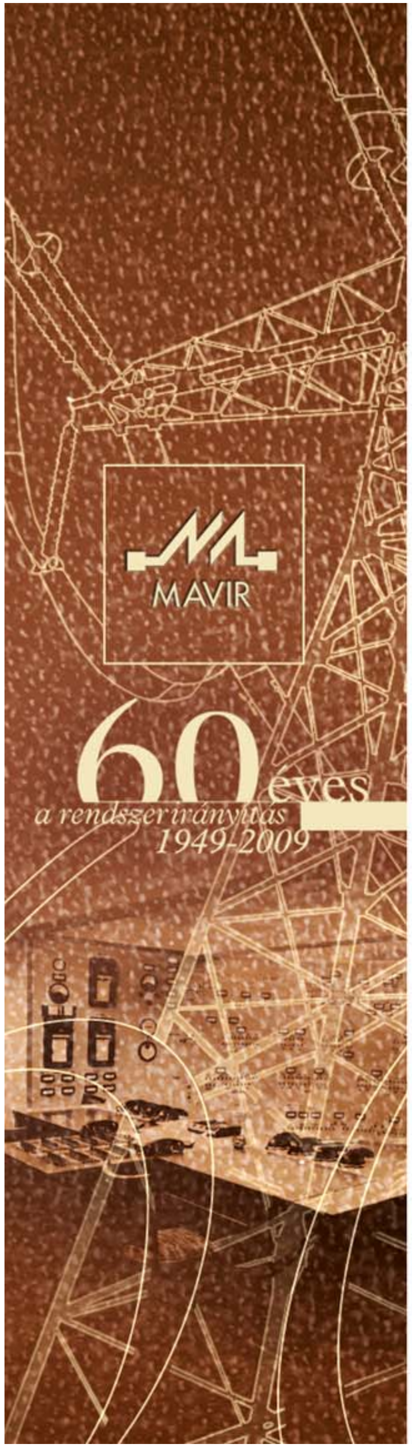
Network operation:

- constant E-field, 1xUo
- due to changing load variable temperature

On-site diagnosis:

- constant temperature,
- variable E-field e.g. up to 1.7Uo





Dielectric loss diagnosis of service aged HV power cables

Experimental work

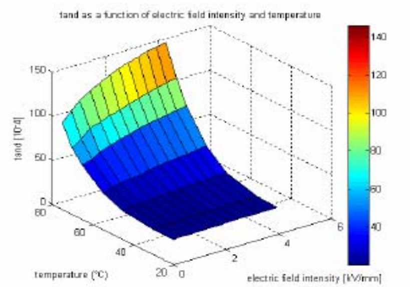
accelerated aging of oil-impregnated paper samples

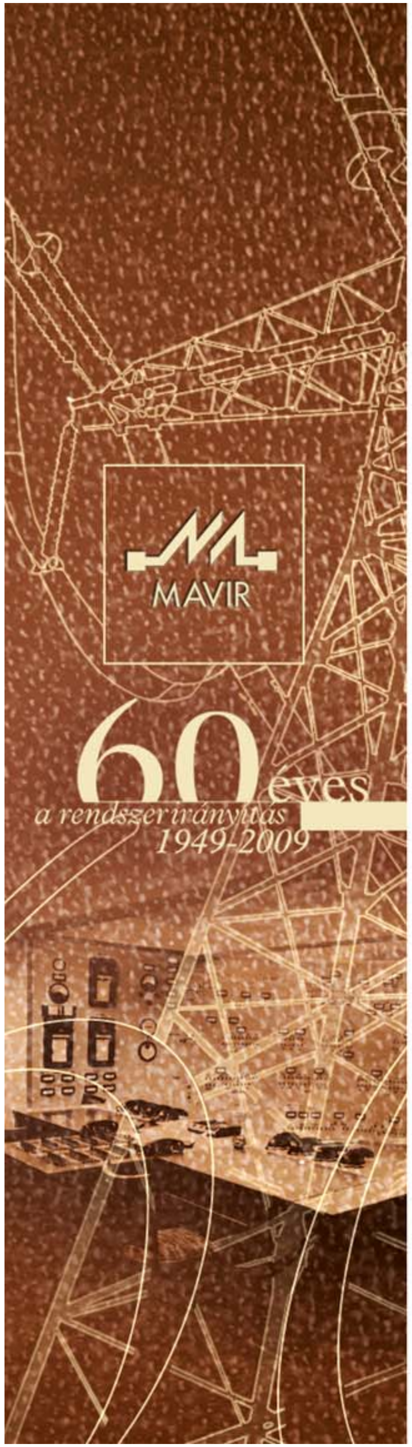
Non aged samples → Aging f(T) → Breakdown

Aging f(T) ↓

Degradation ⟶ increase of tanδ

↓ Δtanδ=f(T) ↓ Δtanδ=f(E)





Budapest University of Technology and Economics

CABLE DIAGNOSTICS BY VOLTAGE RESPONSE MEASUREMENT

Zoltán Ádám TAMUS

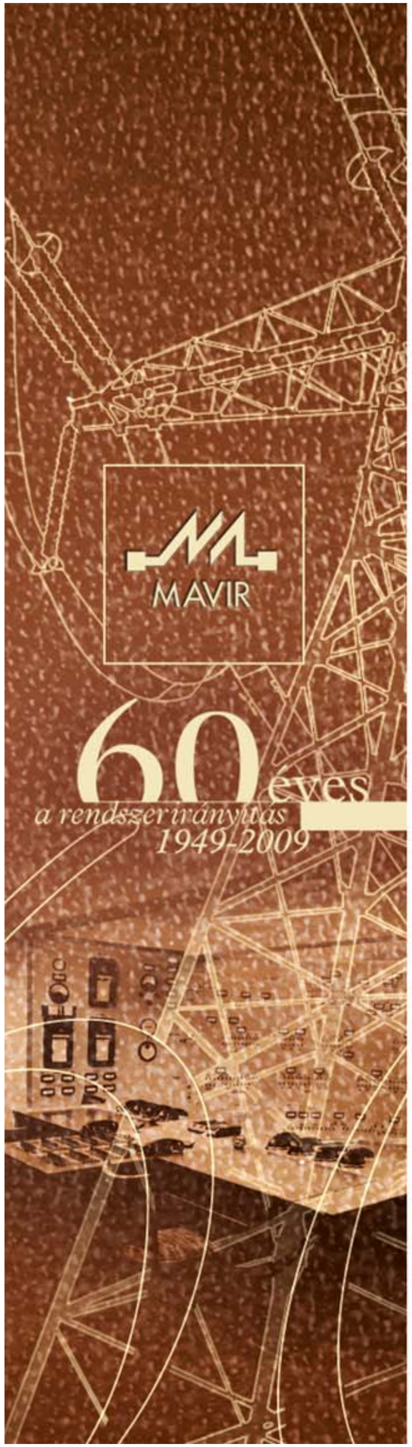
e-mail: tamus.adam@vet.bme.hu

BME Department of Electric Power Engineering
Group of High Voltage Engineering and Equipment

Performance of Oil and Paper in Transformers based on IEC61620 and Dielectric Response Techniques

- **S. Bhumiwat (NZ),** S. Lowe (NZ), J. Perera (Australia), . Wickramasuriya (Australia), P. Nething (New Caledonia) P. Kuansatit (Thailand

- **Classification of Problems in Transformer Insulation**
- Conduction (contaminants, leakage)
- Moisture (in the form of dissolved water, free water), carbon dust, conducting particles or deposits, etc.
- Polarization (deterioration):
- Polar molecules in oil (polar aromatics, polar compounds, etc)
- Oxidation-by-products (acid and non-acid type)
- Sludge at oil-paper Interface
- By-products of Partial discharges
- Thermal deterioration products in paper
- Moisture in the molecular level



- **PERFORMANCE COMPARISON OF ON-LINE TRANSFORMER MONITORING INDICATORS WITH CONVENTIONAL TRANSFORMER OIL TESTS**

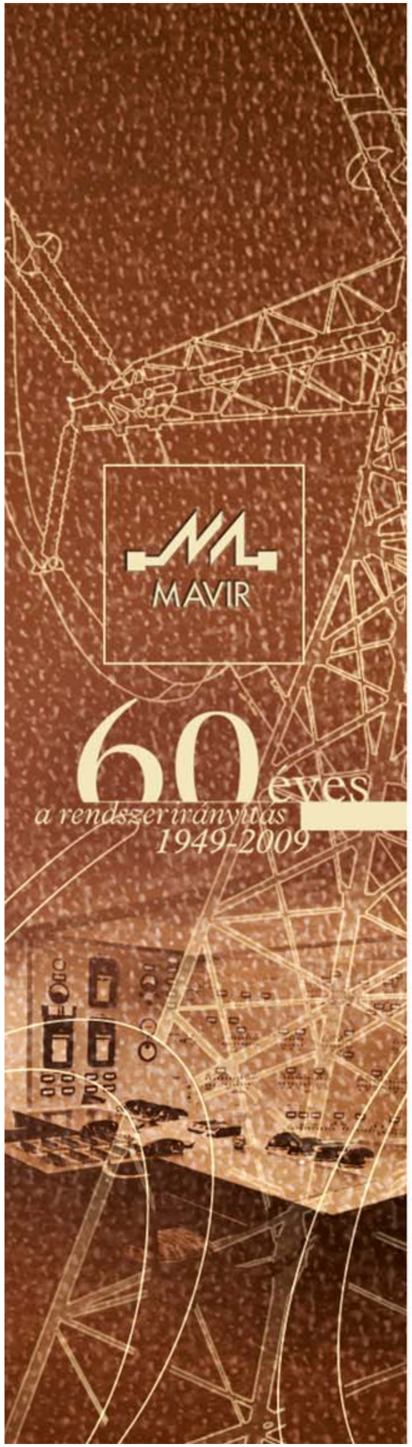
- **T. GRADNIK, M.KONČAN-GRADNIK**

Milan Vidmar Electric Power Research Institute, Slovenia

- **M. PEZDIRC, A. POLAJNER**

ELES, Slovenia

- **Case study: comparison of transfomer on-line monitoring results to laboratory test results on oil samples of a new transformer**
- **On-line monitoring sensors:**
  - **- gases in oil sensor (Hydran 201Ti)**
  - **- water in oil sensor (Vaisala MMT318)**
  - **- estimation of water in paper isolation**
- **Accredited laboratory comparative oil tests**
- **Findings & Conclusions**



Gases in oil sensor

Fuel-cell based detector for incipient fault gases in transformer.

Sensor signals: ppm readout =

100% H_2+ 18% CO + 8% C_2H_2 + 1.5% C_2H_4

Sensor signals and operating parameters (temperatures, load, tap changer pos.) gathered by monitoring system.

Meas. accuracy: ±10 % + 25 ppm

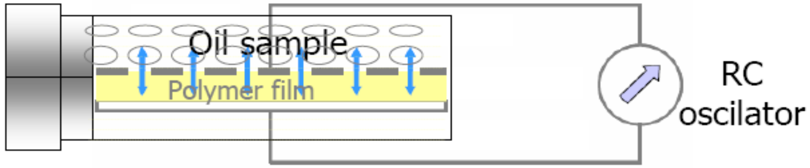
AREVA MS2000 Monitoring system

Hydran 201Ti

Water in oil sensor:

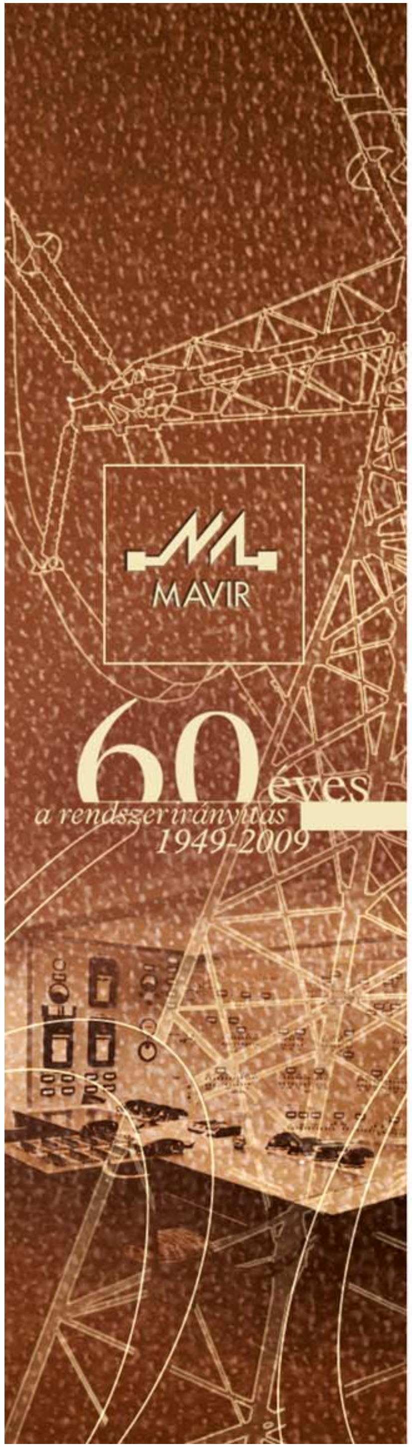
(Vaisala MMT318)

Water from the oil sample penetrates into/from the thin-foil polymer film capacitor, until relative humidity equilibrium is reached.



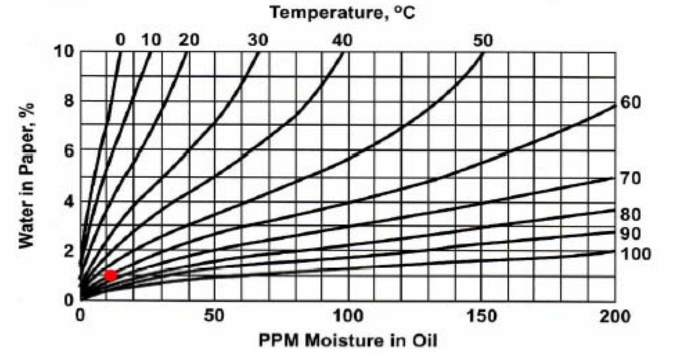
Capacitance of the thin-foil capacitor is proportional to the relative water-in-oil saturation of the oil sample

- The sensor measures relative water-in-oil saturation
- The sensor calculates the absolute content of water in oil (in ppm) by application of water solubility corelation curves
- Water solubility of oil sample depends on sensor temperature and chemical properties of the oil.
- The sensor measures the oil sample (bottom oil) temperature, solubility properties are pre-determined

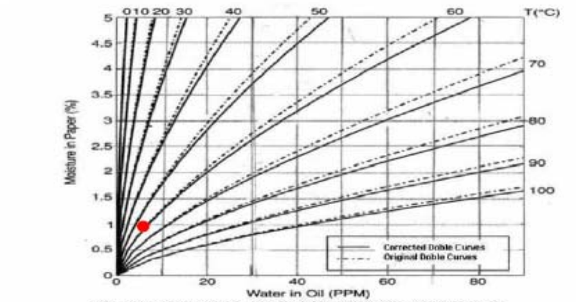


Water in paper estimation

Four paper humidity correlation curves: 5 ppm @ 60°C

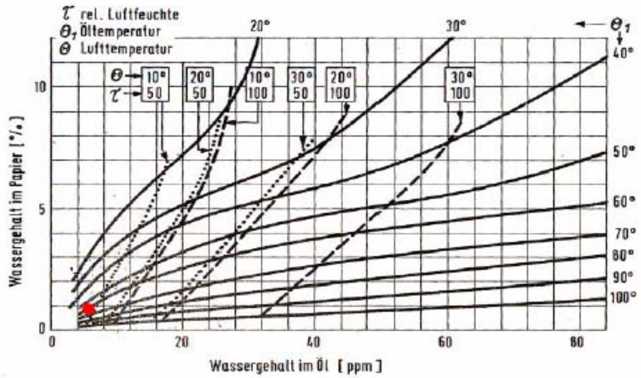


T. V. Oommen (1983)

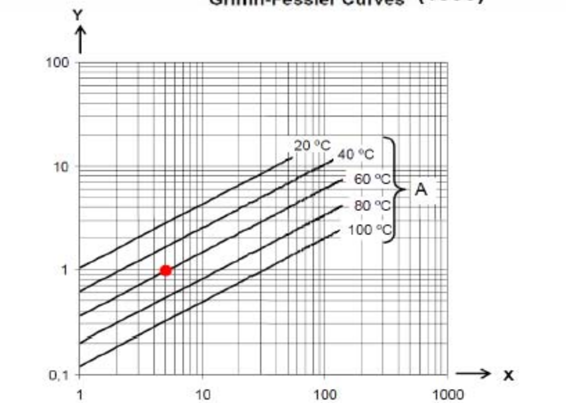


Ref. MIT Paper El Mag Jan/Feb 1999; Doble 98 paper Griffin et. al

Griffin-Fessler Curves (1990)



Fabre J., Pichon (1960)



Key
X axis — Water in oil (mg/kg)
Y axis — Water in paper (%)
A — Mean oil temperature

Norwegian standard NEK 240-1 (2001)

The Role of On-site HV Testing in Australia

- Barry Finlay & Joe Tusek
- 23 September 2009

- Introduction:
- On-site HV testing has been performed in the eastern states of Australia for over 50 years
- Over this time considerable benefits have been realised
- Despite this, pressures increase to reduce the amount of testing performed on site
- This presentation outlines the benefits onsite testing has provided over the past 10 years

- **Major issues identified by on-site HV testing:**

  -Damage during transportation to site
  -Faulty manufacture
  -Poor installation practices
  -Poor on-site repair
  -Poor storage practices
  -Plant ageing mechanisms

- **Vibration Diagnostic System of Power Transformers**
  Project leader: Dr.Veszprémi Károly: *Participants:* Dr. Schmidt István, Dr.Erdélyi István, Janka Sándor, Györe Attila (BME) Tóth György (E.ON), Diagnostics Kft.
- Motivation
- The power transformers are the major parts of power systems, thus their condition is a significant information about the operational reliability
- Previous work
- 2005: Diagnostics of transformers. Selecting the vibration diagnostics as the part of our competence.
- 2006: Vibration diagnostics on two operating transformers.
- Aims
- Early recognition of faults. As a result decreasing the number of unexpected breakdowns.
- Operation fitted to the condition of the transformer, providing optimal life-time.
- Decision about the necessary measures (repair, renewal, etc.)

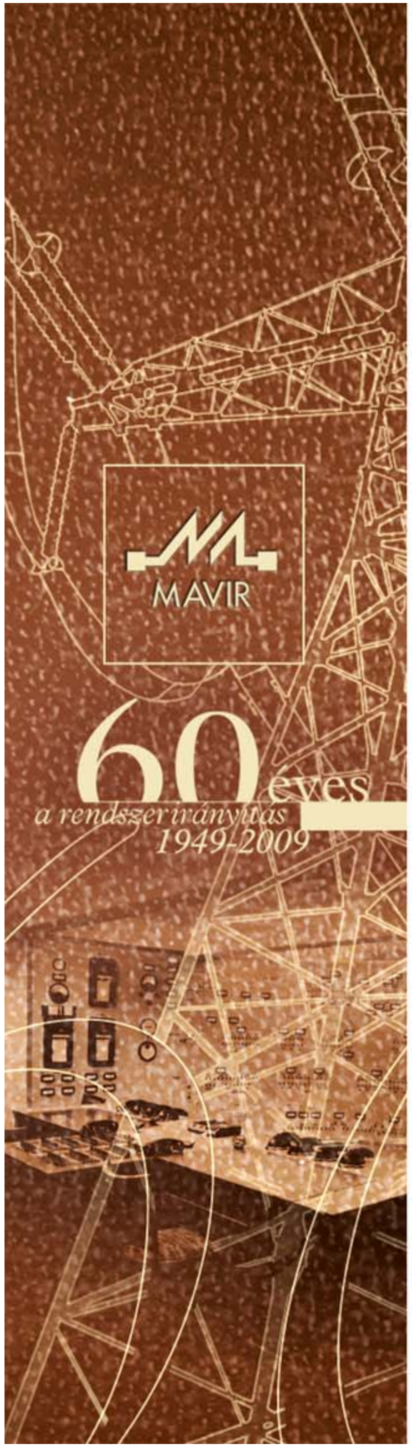
CIGRE Study Committee (SC) D1
Materials and Emerging Test Techniques

For fun

They do not ask us to diagnose their „transformer".

Nevertheless it works, but how long?

A utility must pursue higher reliability! That is why our investigations are necessary…

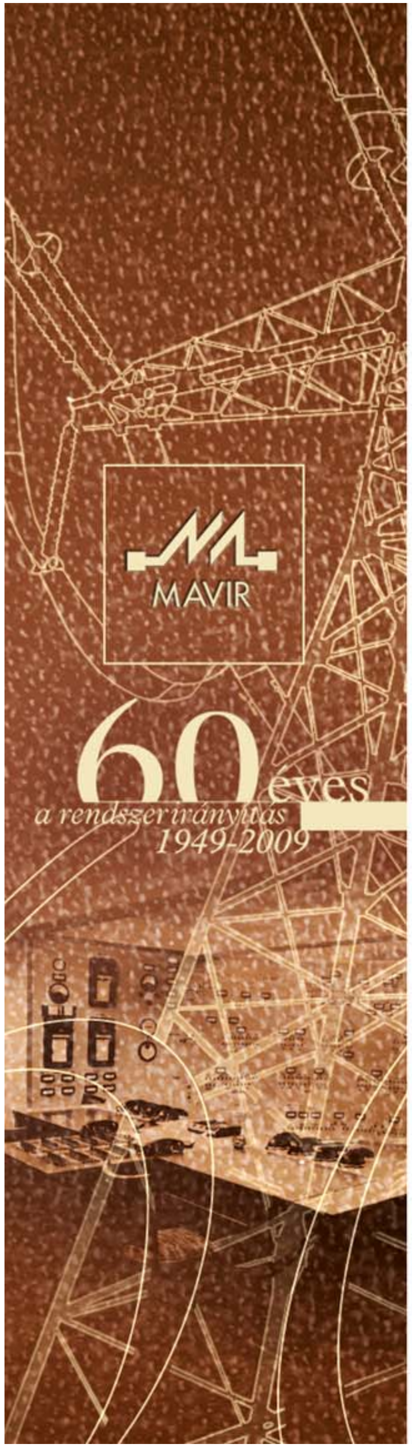


CIGRE SC Organization

A1 Rotating electrical machines	B1 Insulated cables	C1 System development and economics
A2 Transformer	B2 Overhead lines	C2 System operation and control
A3 High voltage equipment	B3 Substations	C3 System environ-mental performance
	B4 HVDC and power electronics	C4 System technical performance
	B5 Protection and automation	C5 Electricity markets and regulations
		C6 Distribution systems and dispersed generation

D 1 Materials and test techniques

D 2 Information systems and telecommunication



SC A2 – Colloquium – 2009
Somerset West, Western Cape, South Africa
17th - 21st August 2009

Key themes

End of Life Asset Management

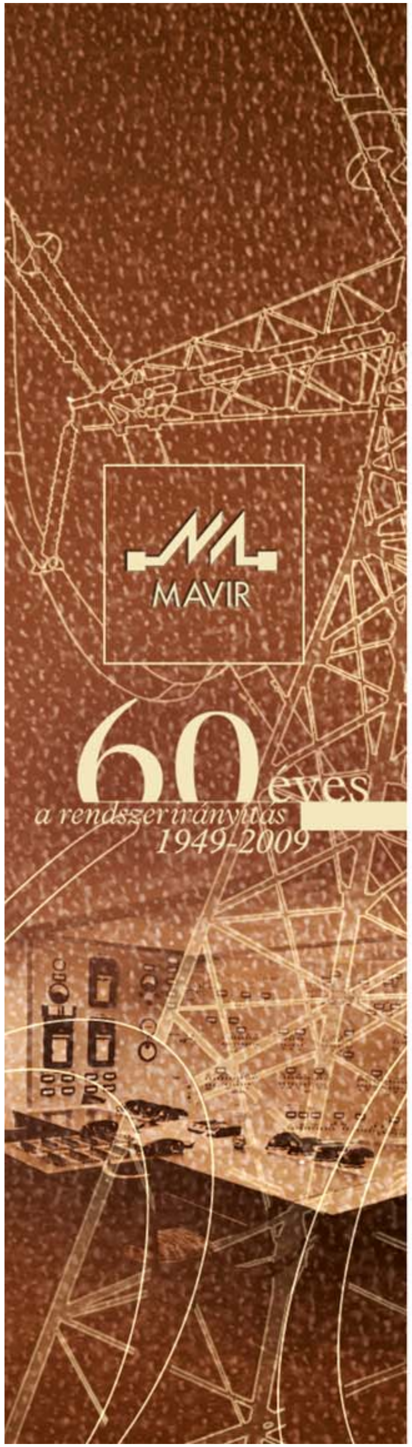
- *Strategies for reinvestment*
- *Residual life assessment*
- *Timely & efficient replacement/refurbishment*
- *Spare strategies & equipment re-use*
- *Transportation*

Maintenance of Equipment for Maximized Reliability

- *Different strategies and type of maintenance*
- *Maintenance activities: solutions and benefits*
- *Condition monitoring and maintenance regimes*
- *Low/easy maintenance equipment*

Recent CIGRE BROCHURES

Scope	*Ref*	*Year*
Thermal aspects	96	1995
Static electrification	170	2000
Effect of particles	157	2000
Customer specifications	156	2000
Design reviews	204	2002
Short circuit performance	209	2002
Life management of transformers	227	2003
Economics of Transformer Management	248	2004
Transformer Lifetime Data Management	298	2006



Recent CIGRE BROCHURES (cont.)

Scope	*Ref*	*Year*
Mechanical Condition Assessment of Transformer Windings	342	2008
Recommendations for Condition Monitoring and Condition Assessment Facilities for Transformers	343	2008
Moisture Equilibrium and Moisture Migration within Transformer Insulation Systems	349	2008

see also brochures issued by SC D1, resp. WG D1-01

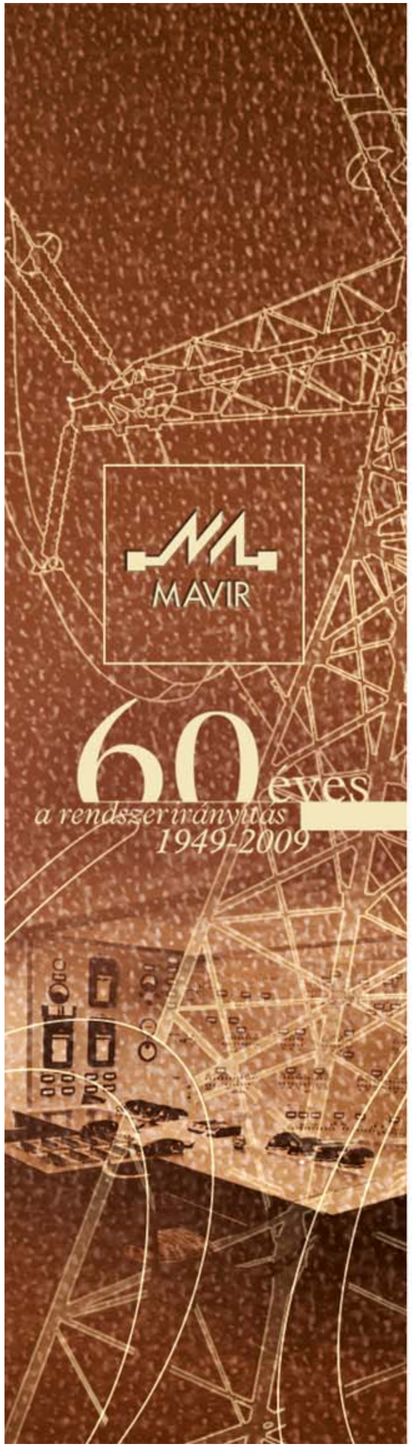
The Transformer Committee (A2)

Scope : Design, construction, manufacture and operation for all kinds of power transformers, including industrial , DC converters and phase-shift transformers and for all types of reactors and transformer components (bushing, tap-changer…)

In the past *(known as SC12)* activities were focused on design problems related to the rapid increase of rated voltage and power

Today, the two Strategic Directions for A2 future activities are :

- **Services to Customers** (Reliability, Life management, Economics, Tutorials, ...)
- **Technology Issues** (Safety, New technologies and New concepts, Electrical environment, Pre-standardization work, ...)



Present A2 Activities

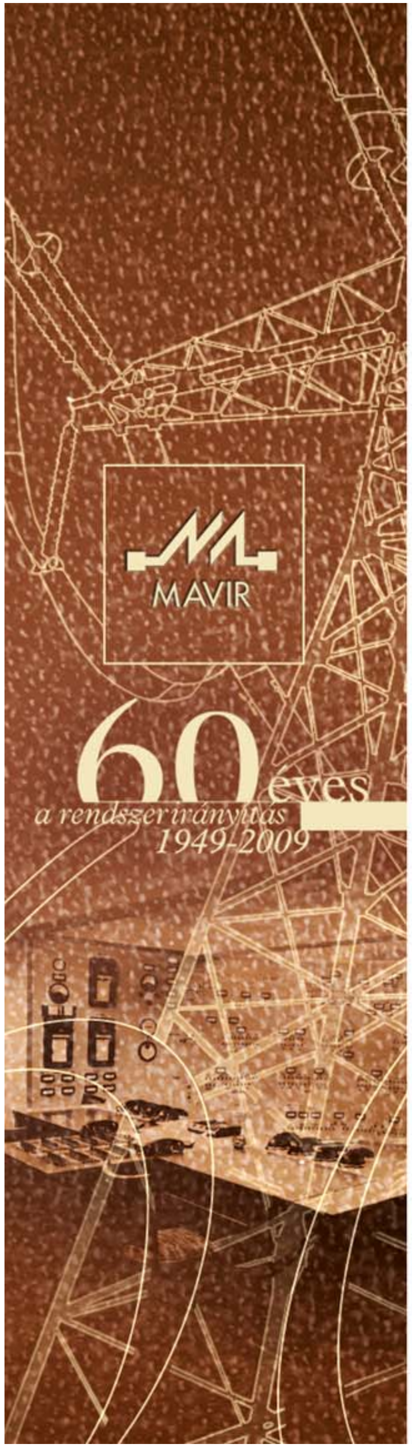
WG finishing editorial :

WG A2.24 Thermal performances	Declercq (BE)
WG A2.28 HVDC Converter Transformer	Saravolac (FR)
WG A2.32 Copper sulfide in power transformer insulation	Dahlund (SE)

WG underway :

WG A2.33 Aspects related to Fire Safety	Petersen (AU)
WG A2.34 Guide on maintenance	Rajotte (CA)
WG A2.35 Experiences with new liquids	Martin (UK)
WG A2.36 Guide for Transformer Procurement Process	Breckenridge (UK)
WG A2.37 Transformer Reliability Survey	Tenbohlen (DE)
WG A2.38 Temperature Modelling	Lapworth (UK)
JWG A2/C4.39 Electrical Transient Interaction between Transformer and the Power System	Rocha (BR)

New Working bodies in preparation :
- Reactor
- Transformer transportation
- Requirement for transformer tank
- Contingency of transformer practices, standardization
- Short circuit capability in the context of transformer ageing
- ...

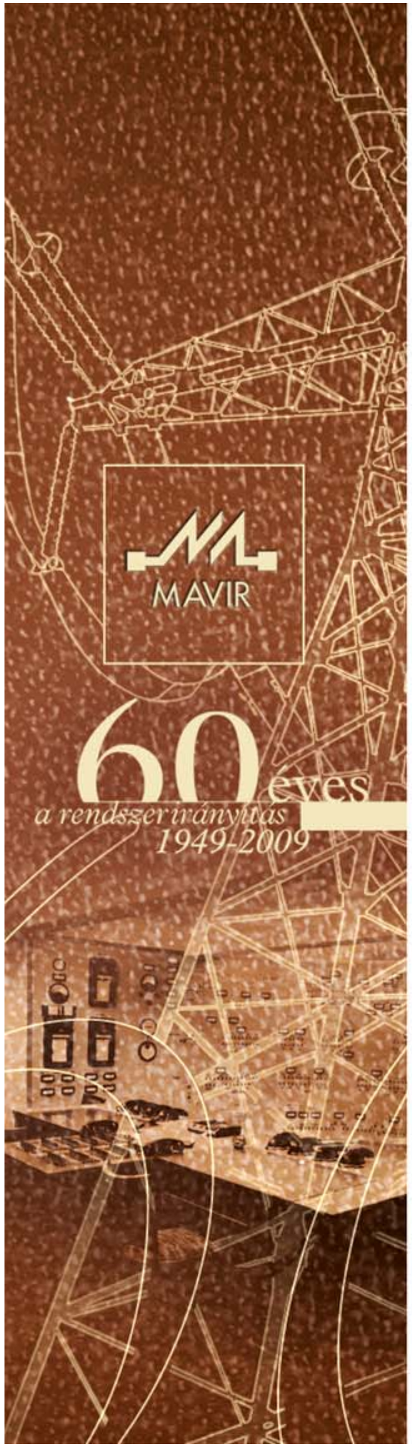


CIGRE Study Committee (SC) A2 Transformers

P501	Twelve years test experience with short-circuit withstand capability of large power transformers	R Smeets
P502	Predicting transmission transformer condition status using DGA signatures	A Singh
P503	Interpretation of frequency response analysis (FRA) Results for diagnosing transformer winding deformation	A Darwin
P504	Aspects of the practical application of sweep frequency response analysis (SFRA) on power transformers	A Kraetge
P505	Determining of pole-zero representation of FRA measurement data for interpretation of power transformer transfer function deviations	M Heindl
P506	Protection of oil-filled transformer against explosion	G Périgaud
P507	Quality assurance of insulating oil for use in new transformers	A Lombard
P509	Comparing various moisture determination methods for power transformers	M Koch
P510	Environmental friendly insulating liquids - a challenge for power transformers	G Pukel

CIGRE Study Committee (SC) A2 Transformers

C101	Short-circuit resistant power transformers - prerequisite for reliable supply of electrical energy	C Krause
C102	Addressing the requirements of an ageing fleet of transmission transformers on the Eskom transmission network	S Mtetwa
C103	Eskom Transmission experience in procuring system transformers outside South Africa	N Buthelezi
C104	Different approaches for the acquisition and evaluation of transformer failure data	J Jagers
C105	End-of-life modeling for power transformers and reliability of aged power system networks	Z. Wang
C106	Evaluating and managing transformer factory acceptance test statistics as performance criteria	J Koen
C107	Gassing and oxidation behaviour of insulating fluids under thermal stress	I Atanasova-Hoehlein
C108	Managing a large and aging transformer fleet	E Figueroa
C109	Effects of on-line reclaiming on the corrosive sulphur content of transformer oil	M Dahlund
C110	A path-way to cope with the dilemma of aging assets, limited capital expenditure, reduced budgets for maintenance and the remaining need to supply electricity at unchanged quality	B Schmitz
C111	Development of methods of evaluation of power transformer insulation aging taking into account random exploitation factors	V Vasin



PREDICTING TRANSMISSION TRANSFORMER CONDITION STATUS USING DGA SIGNATURES

A. SINGH
Eskom Holdings Limited
(South Africa)

L. MOODLEY
Doble Engineering Africa
(South Africa)

K. GOVENDER
Doble Engineering Africa
(South Africa)

Y. CHINABOO
Doble Engineering Africa
(South Africa)

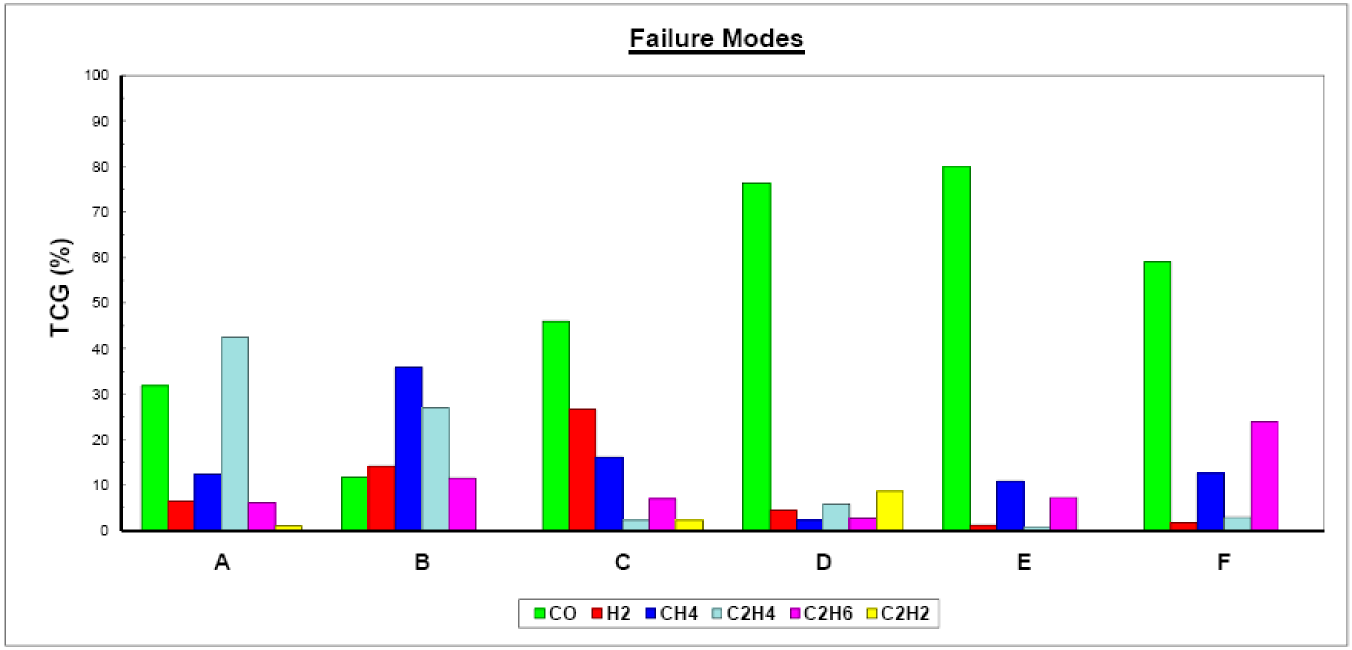
S. GOVENDER
Trans Africa Projects
(South Africa)

SUMMARY

This paper presents the results from a DGA study into failed Eskom transformers to identify typical failure signature patterns. Historical DGA data of failed transformer units was analysed to identify typical signature patterns of the failures.

From the results it is evident that careful analysis of DGA patterns can predict dielectric, thermal and overloading problems. The methodology was developed by analyzing the DGA signatures and comparing the failure causes obtained after tear downs of the failed units.

For the cases that were analyzed the failure modes predicted using DGA signatures verified the findings after the tear downs. It is important to note that the DGA signatures gave clear indication of a fault in its early stages of development. The trends of the DGA signatures, over time, have proved to be a key component in the detection of faults.



Thermal Failure Mode (A and B)

It can be seen that the dominant gases (Most prominent, as in position in relation to other gases), is typically ethylene and methane.

1. Thermal Fault - Circulating Current

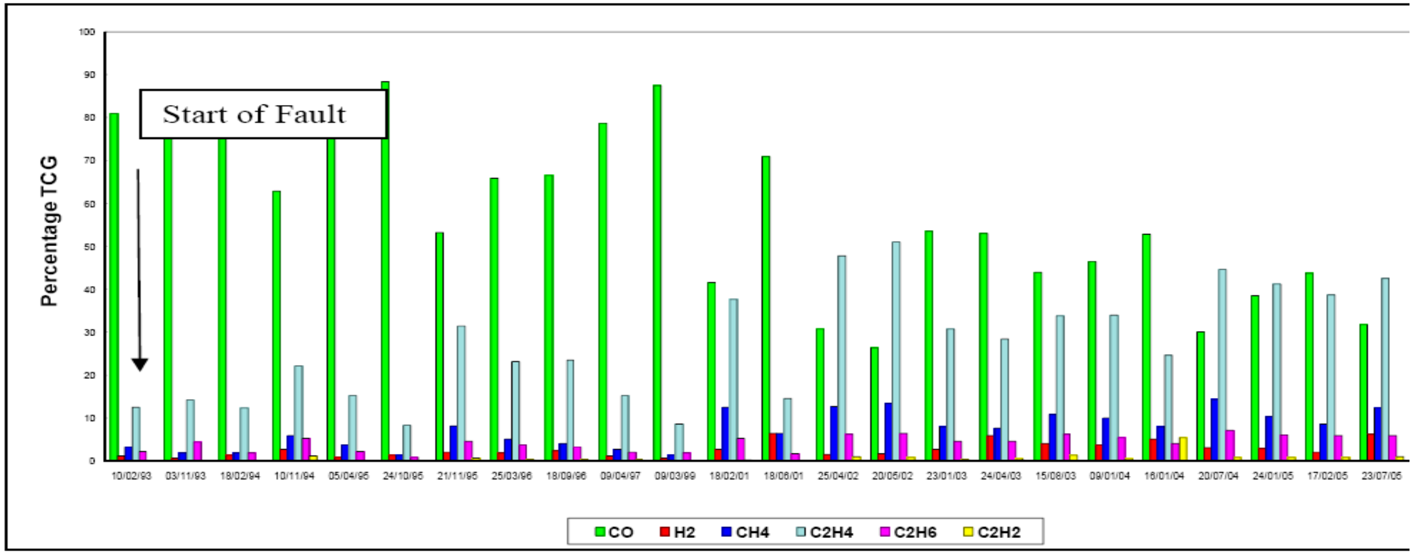


Figure 1: Historical DGA trend for transformer

Figure 1 gives the historical DGA signature. The failure mechanism was a core circulating current whose characteristic trend is high levels of ethylene followed by significant levels of methane and ethane. The DGA signature does not show a significant change over the history of the fault. The sample on the 10/02/93 (start of fault) was identified as a thermal failure mode. Intervention on this date may have prevented failure of the transformer. The severity of the fault is defined by increasing levels of hydrogen and acetylene. The failure sample is indicative of a dielectric type fault. This can be very misleading if the if the DGA signature is not analysed to identify the root cause of the fault.

2. **Thermal Fault- Winding Tracking Fault**

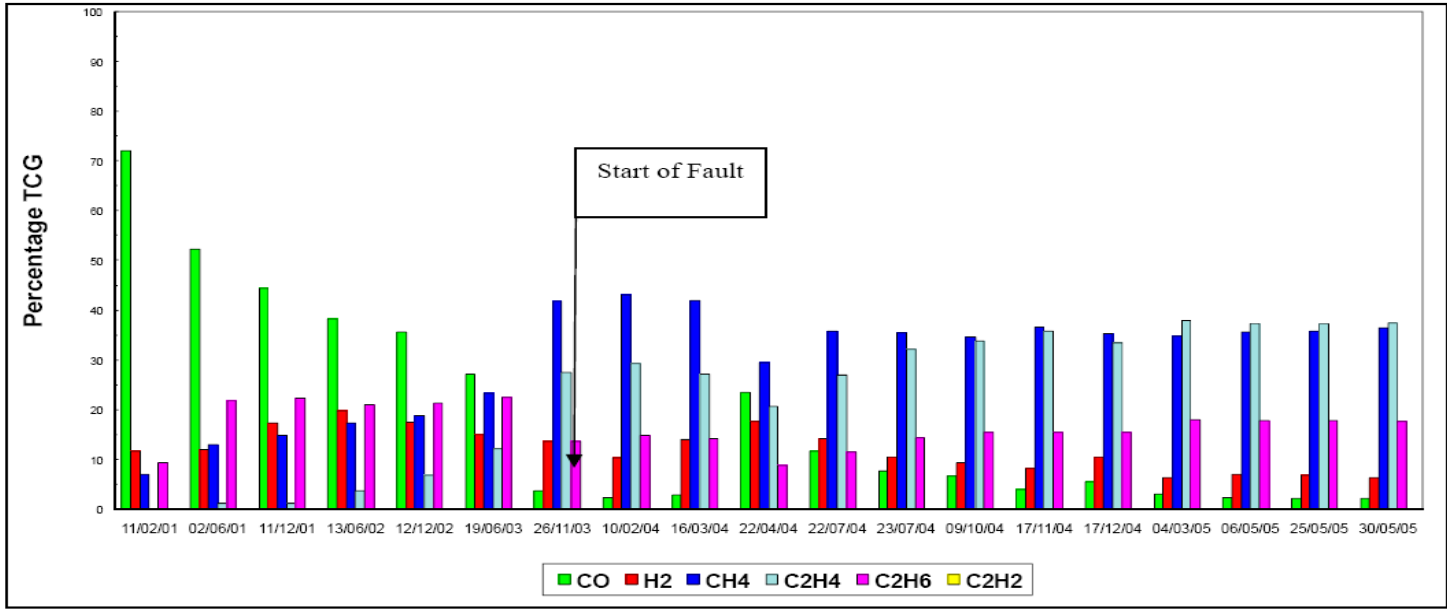


Figure 2: Historical DGA trend for transformer

Figure 2 gives the historical DGA signatures. The root cause for the failure was a thermal fault of the winding tracking type, which began on the 26/11/03, whose characteristic trend is ethylene and methane being the dominant gases. They are at similar levels and significantly high. A good indication of the severity of the fault is given by a decrease in carbon monoxide and an increase in ethylene and methane.

3. Dielectric Fault - Discharge

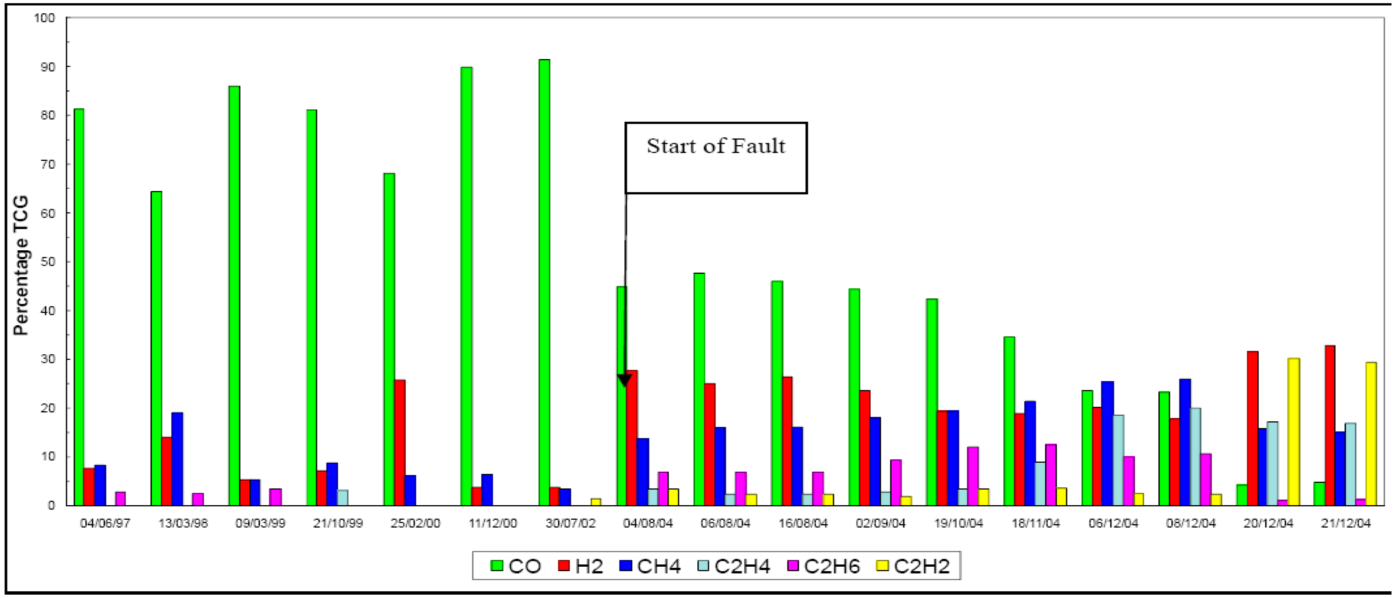


Figure 3: Historical DGA trend for transformer

Figure 3 gives the historical DGA signatures. The root cause for the failure was a discharge type fault. The fault began on the 04/08/04. The failure report indicated that it "failed due to tracking, causing a flashover to earth and damaging the windings of the C-phase". The characteristic trend is high levels of hydrogen followed by significant levels of methane. The severity of the fault is defined by increasing levels of methane. The fault sample is indicative of a dielectric type fault.

4. **Overheating Fault - Severe**

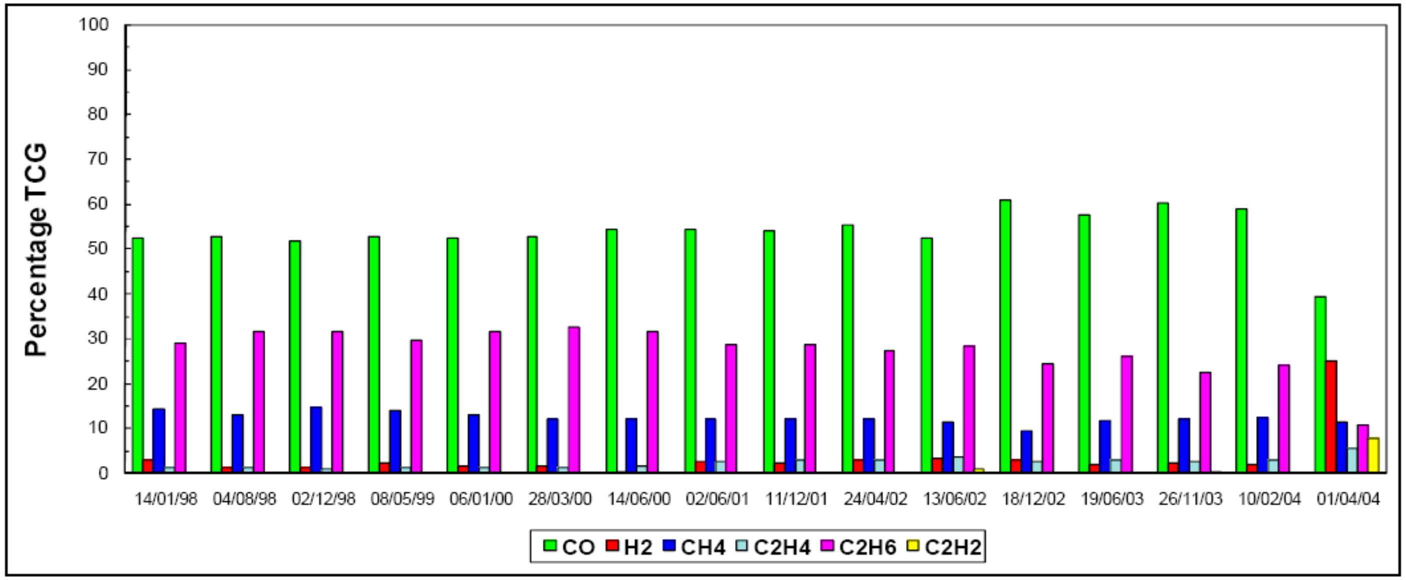


Figure 4: Historical DGA trend for transformer

Figure 4 gives the historical DGA signatures. The DGA signature does not show a significant change over the history of the fault. The root cause of the problem was an overheating/overloading fault, which existed throughout the DGA history. It was concluded that ethane leading methane is of a more severe problem than vice versa. This trend often leads to transformer failure. The total combustible gasses did give some indication of a fault.

5. Stray Gassing (Normal Condition)

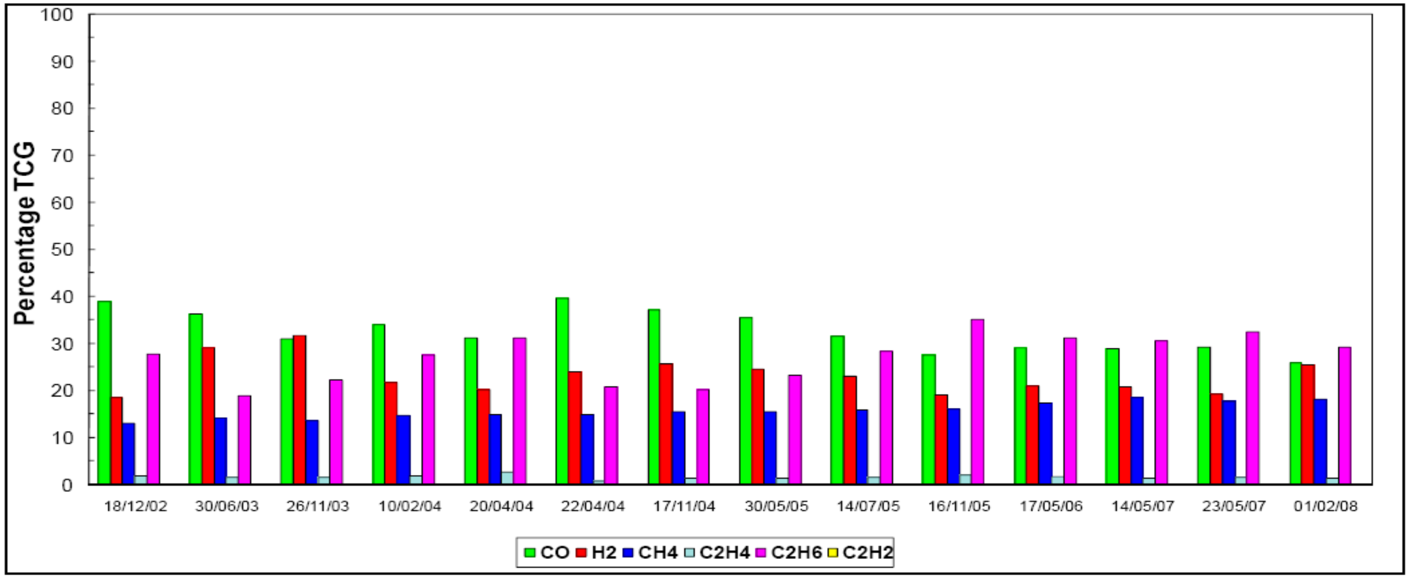
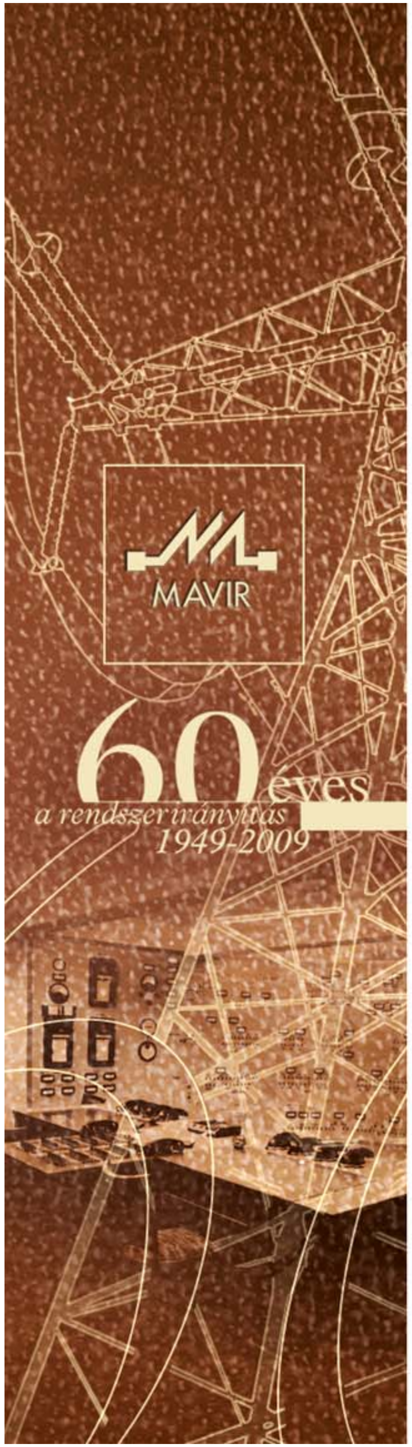


Figure 5: Historical DGA trend for transformer

Depending on the type of oil used, stray gassing may be mistaken as a discharge, overheating, and/or catalytic gassing on metal surfaces type of fault. It is therefore important to identify such gassing patterns and avoid misinterpreting stray gassing for a fault.

Figure 5 gives the historical DGA signatures. Stray gassing has a similar signature to that of an Overheating/Overloading DGA trend. The difference is the abnormal levels of hydrogen. The levels of hydrogen, methane and ethane are seen to fluctuate throughout the DGA history.



INTERPRETATION OF FREQUENCY RESPONSE ANALYSIS (FRA) RESULTS FOR DIAGNOSING TRANSFORMER WINDING DEFORMATION

A.W. DARWIN*
AREVA T&D
(United Kingdom)

D. SOFIAN
AREVA T&D
(United Kingdom)

Z.D. WANG
University of Manchester
(United Kingdom)

P.N. JARMAN
National Grid
(United Kingdom)

SUMMARY

The short circuit currents caused by a fault in power system networks are experienced by other apparatus operating on the faulty system, and could impact on the integrity of this apparatus, particularly if it is in an aged condition. Power transformers in particular are designed to accept and limit short circuit currents, but these currents can cause extreme electromagnetic forces within the windings and this can cause mechanical deformation of the windings if the design is poor or if the mechanical strength of the transformer has been reduced by ageing processes. It is obviously important that the asset manager knows whether the involved transformer has suffered damage that could limit its life expectancy.

To be able to diagnose such winding deformation without intrusive inspections requires advanced detection techniques such as frequency response analysis (FRA) together with correct interpretation of the FRA measurement results. CIGRE A2 has published a technical brochure which details the effectiveness of this diagnostic measurement method. The main challenge for this effective technique is how to accurately interpret the FRA measurement results to ensure correct diagnosis, especially when the difference between the measured result and the reference fingerprint is ambiguous.

Using a manufacturer's expertise and knowledge of the transformer structure, coupled with the expertise of mathematically modelling transformers, FRA fingerprints have been generated for different winding deformation scenarios, as well as for various winding structures and lead connections. These results have been compared with FRA traces of existing National Grid transformers. This has lead towards the development of some general FRA interpretation rules as well as a better understanding. The uniqueness of this paper is that it is based on the synergy of twenty years of National Grid's FRA measurement experience, a transformer manufacturer's knowledge and experience, and a university's modelling skills. This synergy has provided valuable interpretation experience for winding deformation diagnosis using the FRA technique.

5. WINDING DEFORMATIONS

The main purpose of comparing FRA traces is to identify the possibility of winding movement.

Fig. 4 shows the FRA measurement results before and after a serious fault that occurred on the tap winding of a transformer, together with a photos showing the corresponding damage, where it is clear that the tap winding has collapsed partially axially and has local inter-turn damage. The FRA measurement result after the fault had occurred is clearly different from the FRA measurement result taken in the factory.

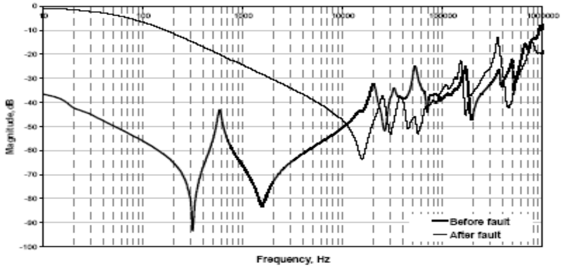
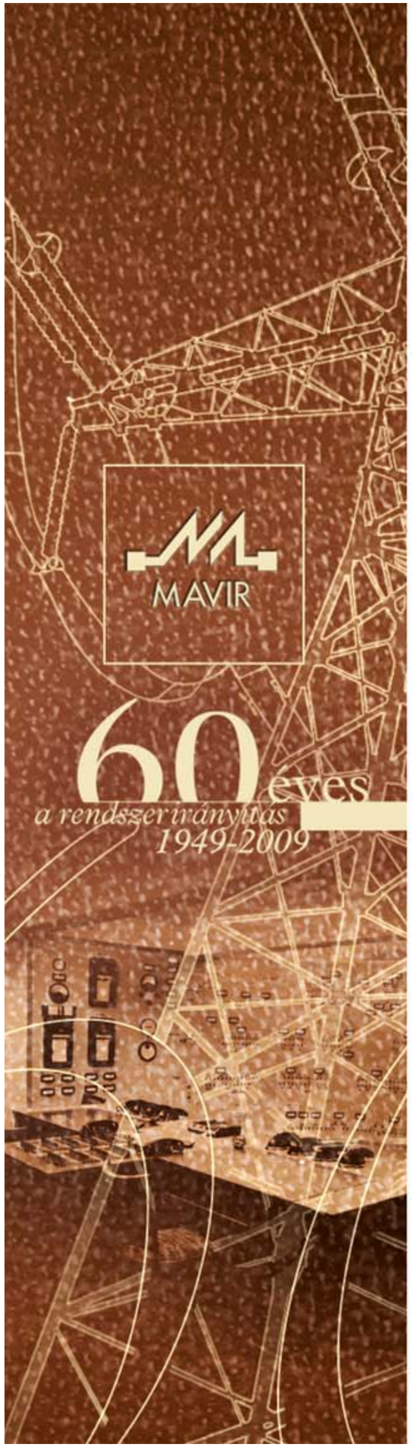


Fig. 4. FRA measurement results for transformer with fault in tap winding and photo of corresponding damage.

This shows an extreme example of FRA change, but clearly identified that the transformer had a major fault. If faults could be detected during the incipient stage, then mitigation actions could be taken and a transformer possibly prevented from failing. In this respect, FRA could be used to check for the "suspicious" condition of transformers. It is therefore very useful to be able to identify the differences that could be anticipated in particular regions or features of the FRA response for various types of transformer faults. Although many studies have been carried out to identify such relationships, the findings cannot be generalised for a large population of transformers that are often different. Some faults or problems, which may have caused the differences in certain frequency regions or features for a particular transformer, may be detected in different frequency regions or features for transformers with different designs and/or constructions. Clearly, catalogues of fault identifications successfully detected by FRA would be extremely useful. Such a catalogue or database would need to include reports and pictures produced during the dismantling of failed transformers together with details of their design and constructional features. The involvement of technical committees such as CIGRE in this work would be beneficial in establishing such a set of "standard" FRA fingerprints for various kinds of transformer faults and/or transformer designs and construction.



ASPECTS OF THE PRACTICAL APPLICATION OF SWEEP FREQUENCY RESPONSE ANALYSIS (SFRA) ON POWER TRANSFORMERS

A. KRAETGE
OMICRON Electronics GmbH (Austria)

M. KRÜGER
OMICRON Electronics GmbH (Austria)

J.L. VELÁSQUEZ
OMICRON Electronics GmbH (Austria)

H. VILJOEN
Alectrix (Pty) Ltd
(South Africa)

A. DIERKS
Alectrix (Pty) Ltd
(South Africa)

SUMMARY

Sweep Frequency Response Analysis (SFRA) has turned out to be a powerful and sensitive method to evaluate the mechanical integrity of core, windings and clamping structures within power transformers by measuring their electrical transfer functions over a wide frequency range. The contribution summarizes various aspects of the practical application of SFRA. After a short introduction of SFRA basics a survey of existing standards and guides on FRA is given. The different sources of reference data and their significance are discussed using examples. Uncertainties are shown and tips for dealing with them are presented. The choice of test types is discussed for measurements without existing reference data. Information about the handling of test data is mentioned. A summary of guidelines derived from a large number of successful measurements is given to put the reader in a position to achieve a good degree of repeatability, too. Finally the application of SFRA for the evaluation of transportation is described and an example for the successful detection of shipment damage is given.

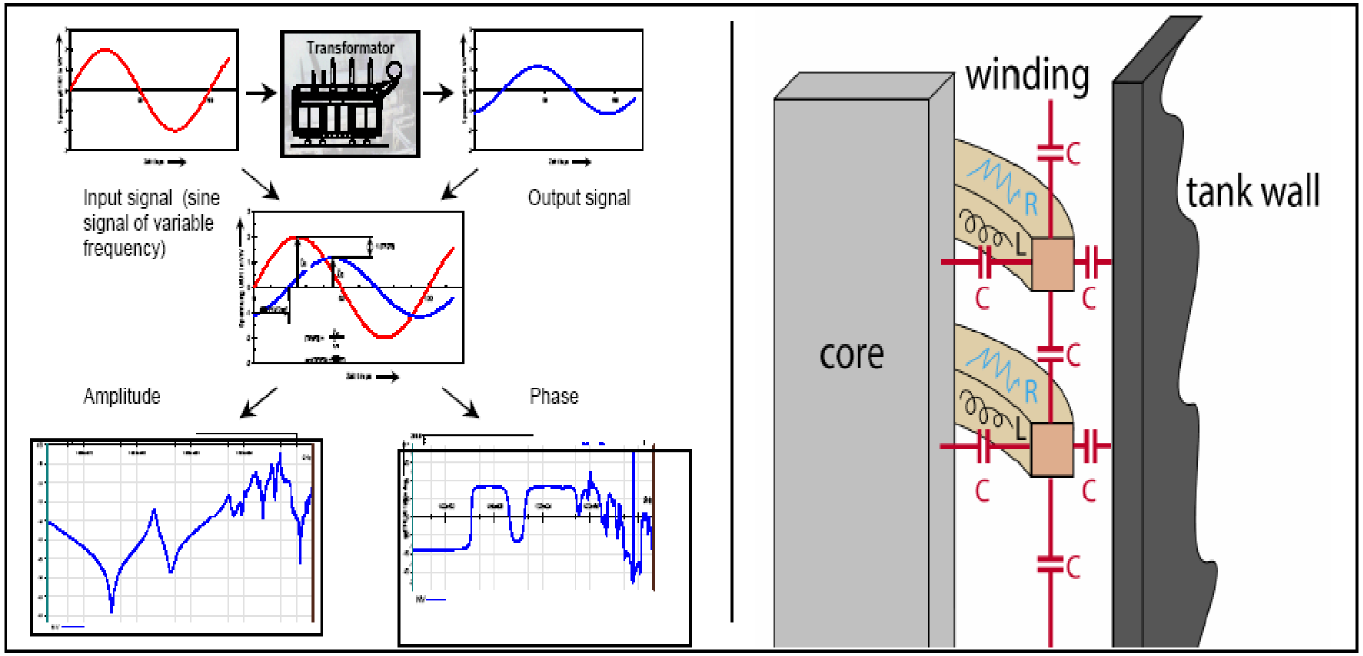


Figure 1: Principle operation of SFRA (left) and simplified network behavior of a transformer's active part (right)

CIGRE Study Committee (SC) A2
Transformers

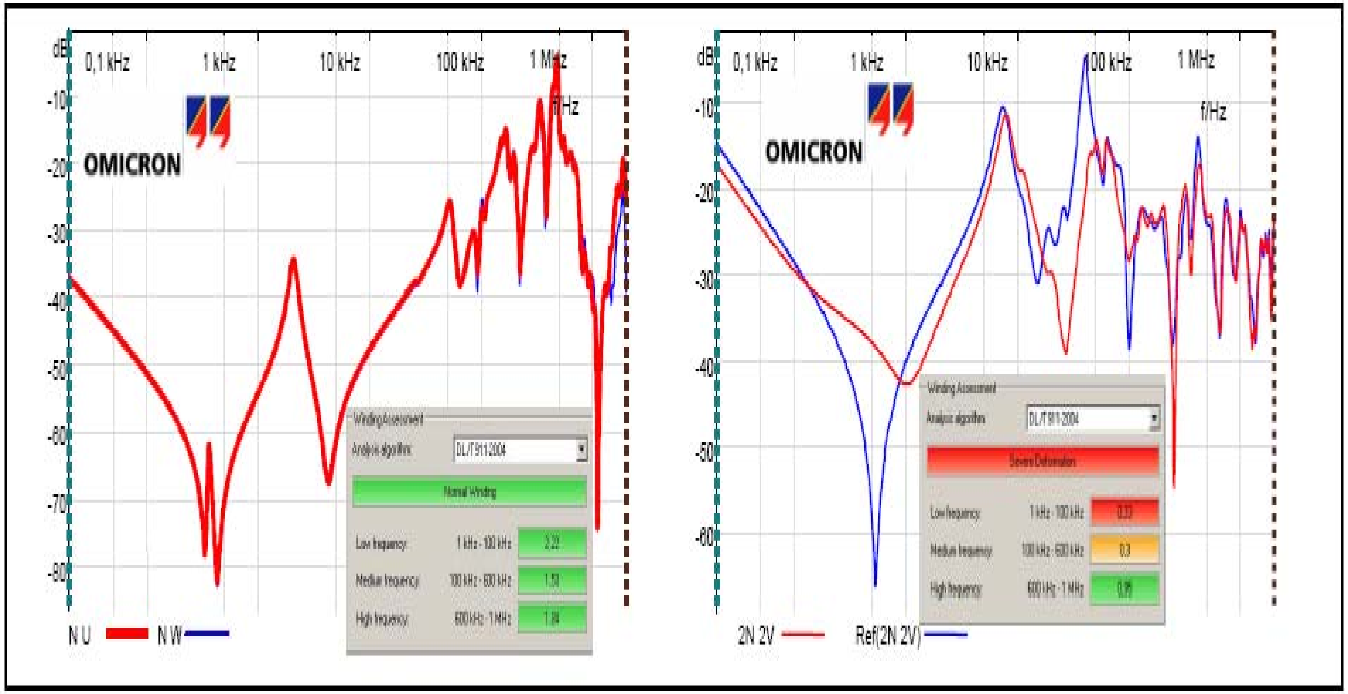
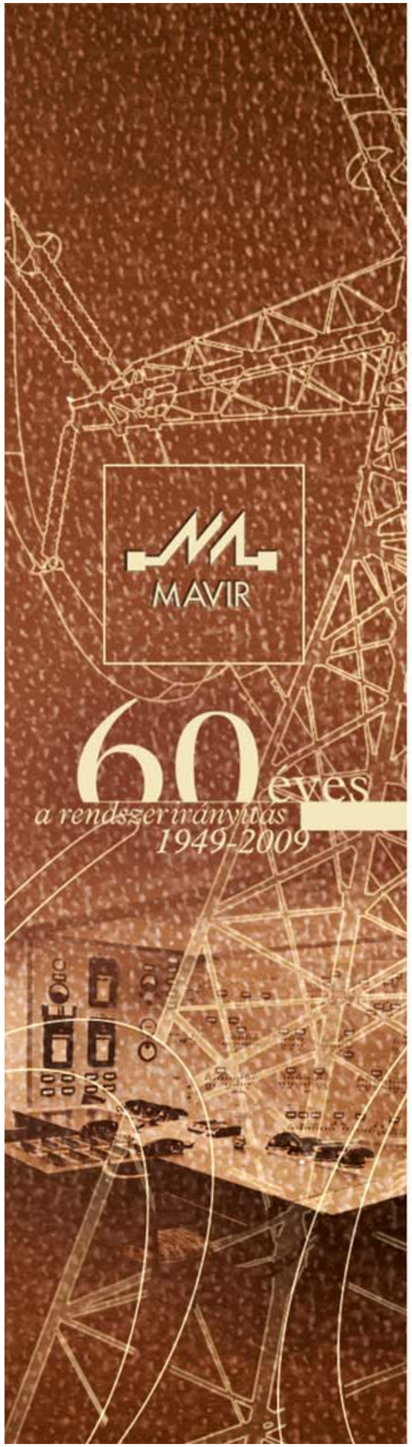


Figure 2: Assessment tool confirms healthy condition(left) ; Failure clearly identified by the assessment tool (right)



COMPARING VARIOUS MOISTURE DETERMINATION METHODS FOR POWER TRANSFORMERS

M. KOCH*
Omicron Energy
(Austria)

M. KRÜGER

S. TENBOHLEN

SUMMARY

This paper discusses and compares various methods of assessing moisture in the liquid and solid insulation of power transformers. Water in oil-paper-insulations causes three damaging effects: it decreases the dielectric withstand strength, accelerates cellulose aging and causes the emission of gaseous bubbles at high temperatures. Therefore knowledge about the moisture concentration in a transformer is of great importance for safe operation and for further maintenance actions.

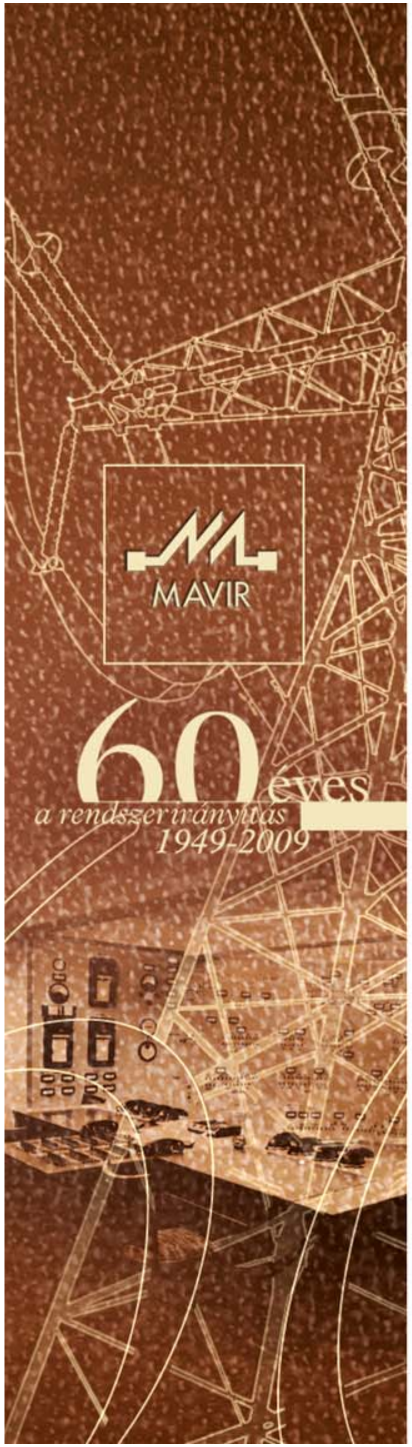
On-line, on-site and off-site moisture determination methods have been compared: Karl Fischer titration applied to oil and paper samples, capacitive probes, equilibrium diagrams and dielectric response methods (Recovery Voltage Method RVM, Polarisation and Depolarisation Currents PDC, Frequency Domain Spectroscopy FDS).

The traditional method of moisture evaluation, oil sampling with subsequent Karl Fischer titration and application of an equilibrium diagram, suffers from severe errors resulting into a poor accuracy. Therefore a new type of equilibrium diagrams based on moisture saturation in the oil (relative humidity) was developed.

For dielectric response methods, the recovery voltage method is now outdated since its interpretation scheme appeared to be unable for compensating the interfacial polarisation effect and oil conductivity. In contrast to this, the new methods polarisation and depolarisation currents and frequency domain spectroscopy feature scientifically founded interpretation schemes and are thus able to reliably calculate water in the solid insulation. In this article a new approach is applied, which combines measurements in time and frequency domain for shortening the time duration. Its software also compensates for conductive aging by-products.

The methods were applied to several transformers for on-site moisture evaluation comparing conventional to new approaches. For new transformers, the analysis of the dielectric response suits best since moisture equilibrium cannot be expected directly after the manufacturing process. However, due to the dry condition particularly the measurement of the low frequencies is of importance (e.g. down to 100 µHz). The study case on oil processing impressively illustrates that most of the moisture is in the solid insulation and for drying purposes the cellulose needs to be treated. Another transformer was dried using on-line oil circulation for 1.5 years, resulting in a decrease of moisture content by about 1.2 % and therefore a longer life expectation. Moisture determination for a heavily aged transformer indicates that the methods and algorithms not taking into account the aging state will overestimate the moisture content. This may lead to wrong maintenance decisions.

Equilibrium diagrams based on moisture saturation in oil delivered credible results in contrast to the conventional use of moisture content (ppm). Within this work the developed dielectric analysis software proved its capability to compensate for conductive aging by-products and provide dependable results for moisture assessment of power transformers.



2 MOISTURE DETERMINATION METHODS

2.1 Karl Fischer Titration

Karl Fischer titration is a method in analytical chemistry that determines trace amounts of water in a sample using volumetric or coulometric titration. Titration basically means to add a reagent of known concentration (titre) to an unknown substance until the concentrations are balanced.

To evaluate the moisture content in the liquid and solid insulation the titration according to Karl Fischer is not only widely used, but also serves as a benchmark for other methods such as dielectric response methods.

However, it is affected by several influences: There is always moisture ingress from the atmosphere during sampling, transportation and sample preparation. Cellulose binds water with chemical bonds of different strengths. It is uncertain whether the thermal energy releases all the water, therefore heating temperature and time certainly changes the released water. Individual laboratories treat differently constraints that are not covered by standards, such as the solvent for oil extraction. Sometimes direct injection and heating method lead to different results for moisture in oil.

For these reasons round robin tests revealed an unsatisfactory comparability of different laboratories [1]. Conclusively, whenever Karl Fischer titration is used to evaluate other methods, their inherent inaccuracy needs to be considered. This particularly applies if paper samples taken from a transformer are used to judge the results of new approaches like dielectric response or equilibrium diagrams, or when comparing between new methods.

2.2 Capacitive Probes

Capacitive probes have been in use since the mid-nineties and indicate moisture relative to saturation. They consist of two electrodes with a hydroscopic dielectric, e.g. a polymer, see Fig. 1. Water molecules penetrate into the polymer and change the capacitance depending on the relative saturation of the ambient material. This change of capacitance correlates with the surrounding relative humidity. Advantages of capacitive probes are very easy application even on-site and on-line, continuous measurements and high accuracy compared to sampling and transportation to laboratory with subsequent Karl Fischer Titration.

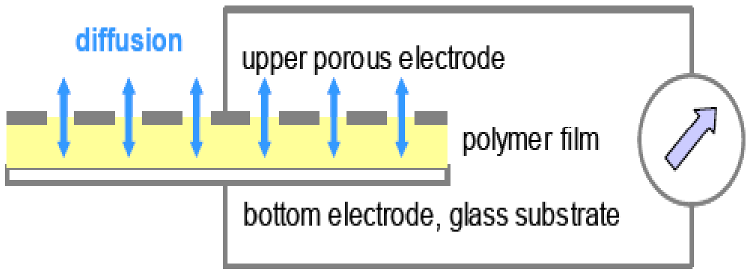


Fig. 1: Polymer thin film probe

In the last years discussions frequently flared up about the reliability of Karl Fischer titration in comparison with capacitive probes. Some transformer operators listed significant differences between the moisture by weight (ppm) results from Karl Fischer titration and capacitive probes or other instruments based on moisture equilibrium. However, due to the different measurement principles (chemical reaction vs. moisture deposition) a comparison is impossible without calibrating one method to the other.

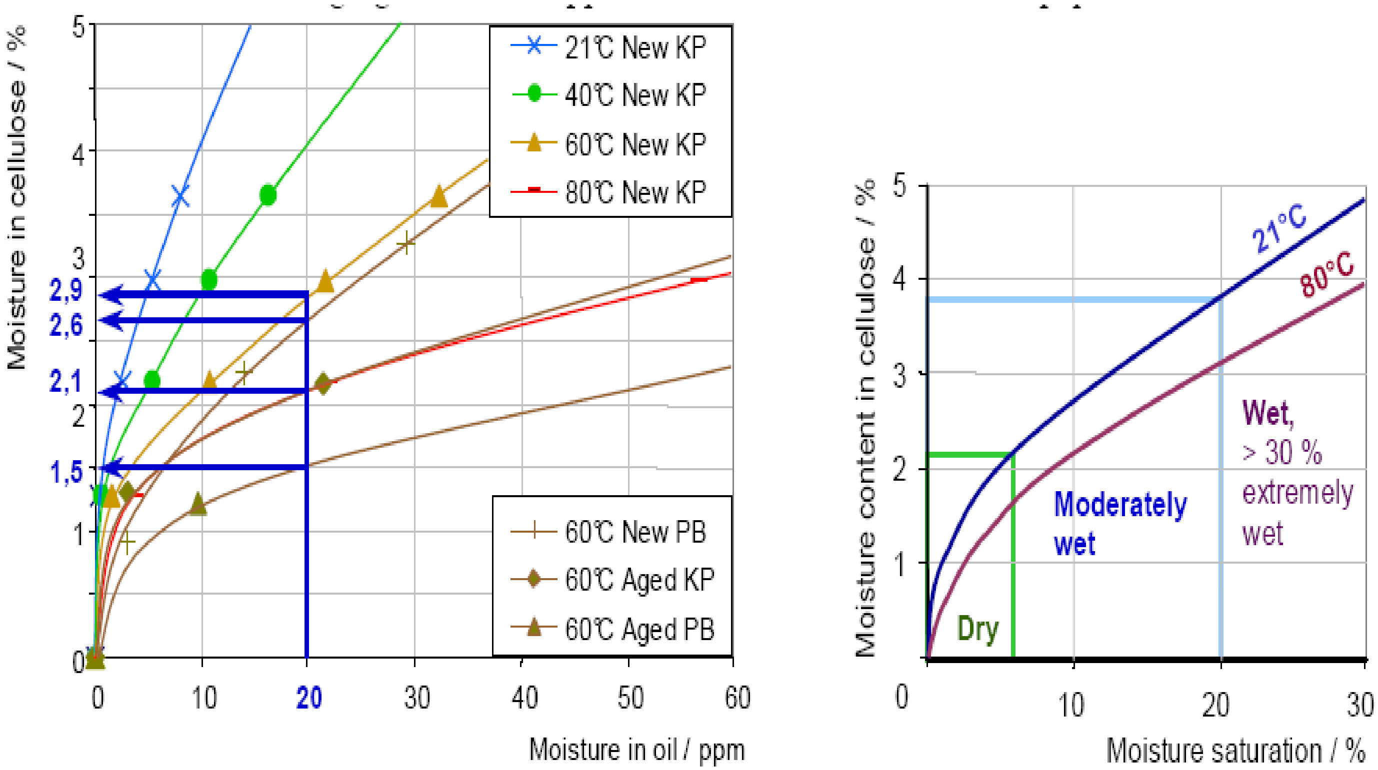


Fig. 2: Left: Equilibrium diagram for moisture in Kraft paper KP and oil with additional graphs for new pressboard PB and thermally degraded Kraft paper and aged pressboard
Right: Equilibrium diagram based on relative saturation in oil with limits of IEC60422

3.3 On-Line Drying of a Power Transformer

A three winding transformer with 150 MVA was dried on-line by continuous oil circulation for a period of 1.5 years and the moisture assessed before and after drying. Three moisture measurement methods were applied before drying: Dielectric response measurement, an equilibrium diagram based on moisture content in oil [2] and an equilibrium diagram based on relative saturation in oil [3]. Fig. 6 depicts the moisture content in the solid insulation as obtained by the various methods before and after drying. The dielectric response method came to a result of 2.5 % for the main insulation.

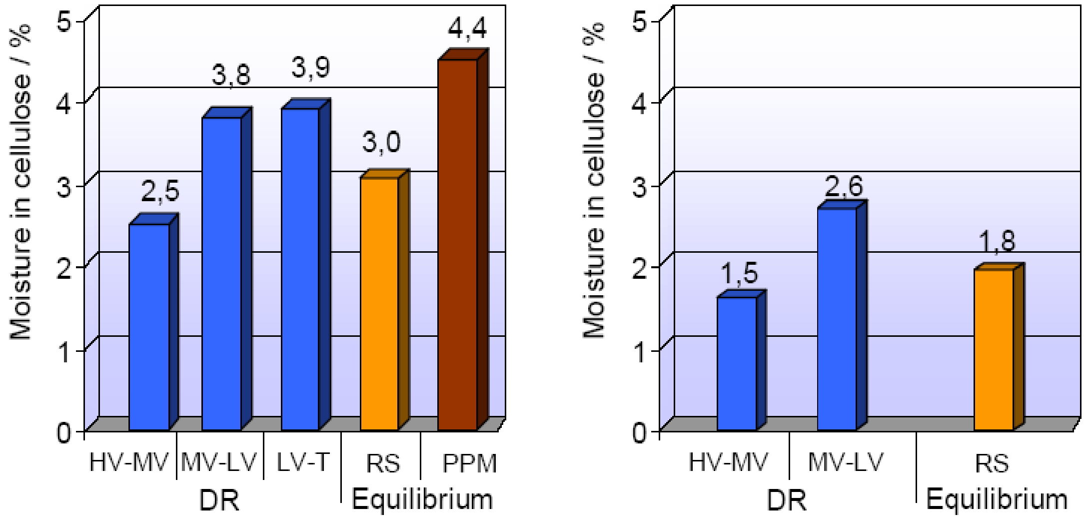
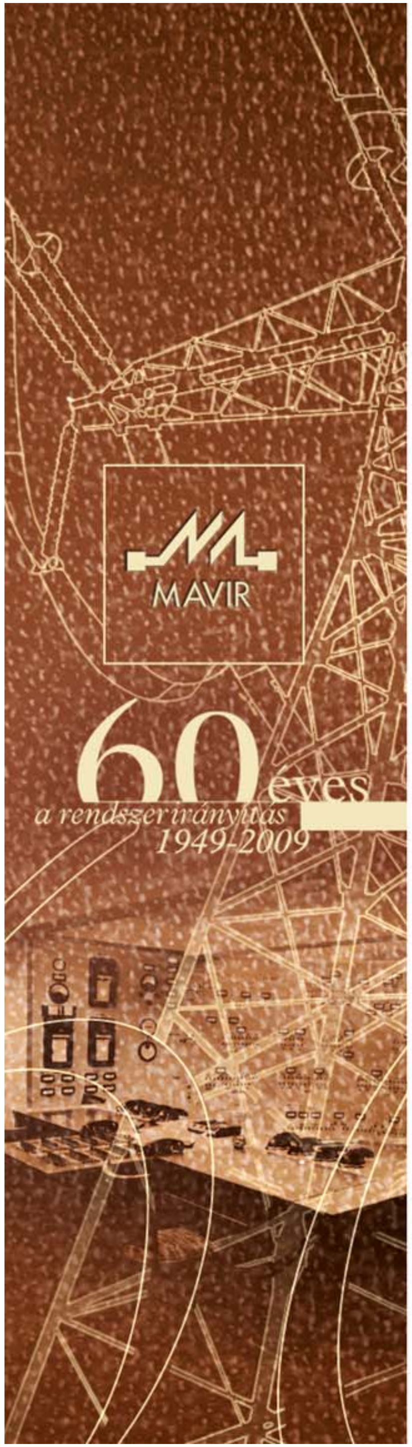


Fig. 6: Moisture content in the solid insulation before drying (left) and thereafter (right), as obtained from dielectric response analysis (DR) and via equilibrium diagrams from the relative saturation of oil (RS) and from moisture content in oil (PPM)

- 2009. augusztus 17-én Szibériában, a Jenyiszej folyón épült Sajono Szuszenszkaja vízerőműben robbanás történt.
- A jelentések szerint egy erős, bombaszerű lökés lerombolta a gépterem falát és mennyezetét
- Az első jelentések szerint a 2-es turbina ill. generátor csoport karbantartás ill. javítása alatti transzformátor robbanása volt a kiinduló ok.
- 10 gépcsoportból kettő tönkrement, egy harmadik megsérült.
- A szóban forgó egység egy olajszigetelésű, generátor transzformátor (GSU, Generation Step Up) volt.



KHAKASSIA- Jenyiszej vízerőmű üzemzavar robbanás oka ?

- Az erőmű 1978 óta üzemel Dél-Szibériában, 6.400 MW-al Oroszország legnagyobb vízerőműje, a világ harmadik legtöbb energiát termelő erőműje.
- Várhatóan több, mint 1 Milliárd USD az újjáépítési kár. Hat bánya és nagy ipari létesítmény (főleg alumínium és acélmű) ellátására épült, így jelentős lesz az energiakesésből adódó kár is.
- A jelentések szerint 437 dolgozóból 100 volt szolgálatban, 17 ember meghalt, 72 eltűnt.
- 2009. augusztus 20-i CIGRE A2 ülésen egy orosz delegált bejelentette, hogy nem a trafó volt az első ok, hanem turbina oldalon történt vízátömlés, ami elárasztotta a trafót és az azután robban fel.

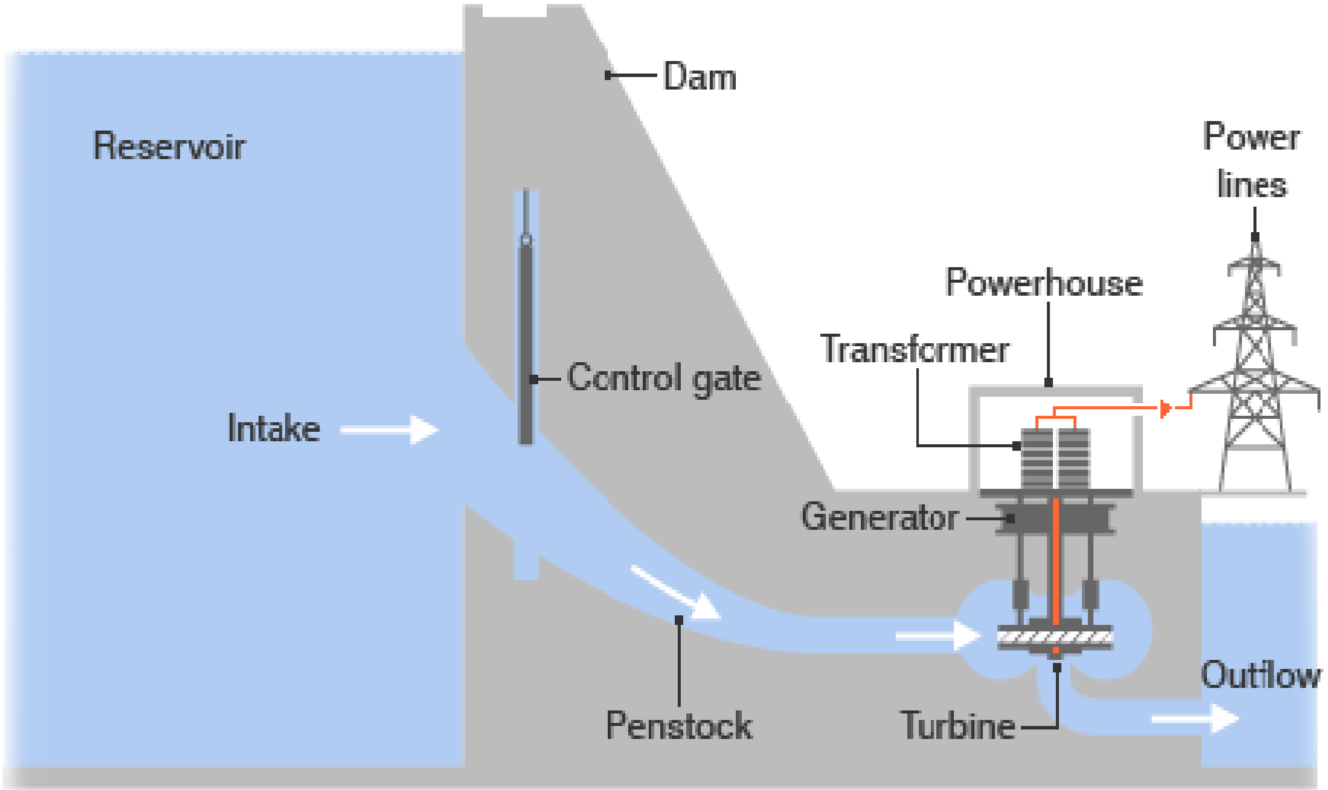
KHAKASSIA- Jenyiszej vízerőmű üzemzavar robbanás oka ?

KHAKASSIA- Jenyiszej vízerőmű üzemzavar robbanás oka ?

MAVIR
60 éves
a rendszerirányítás
1949-2009

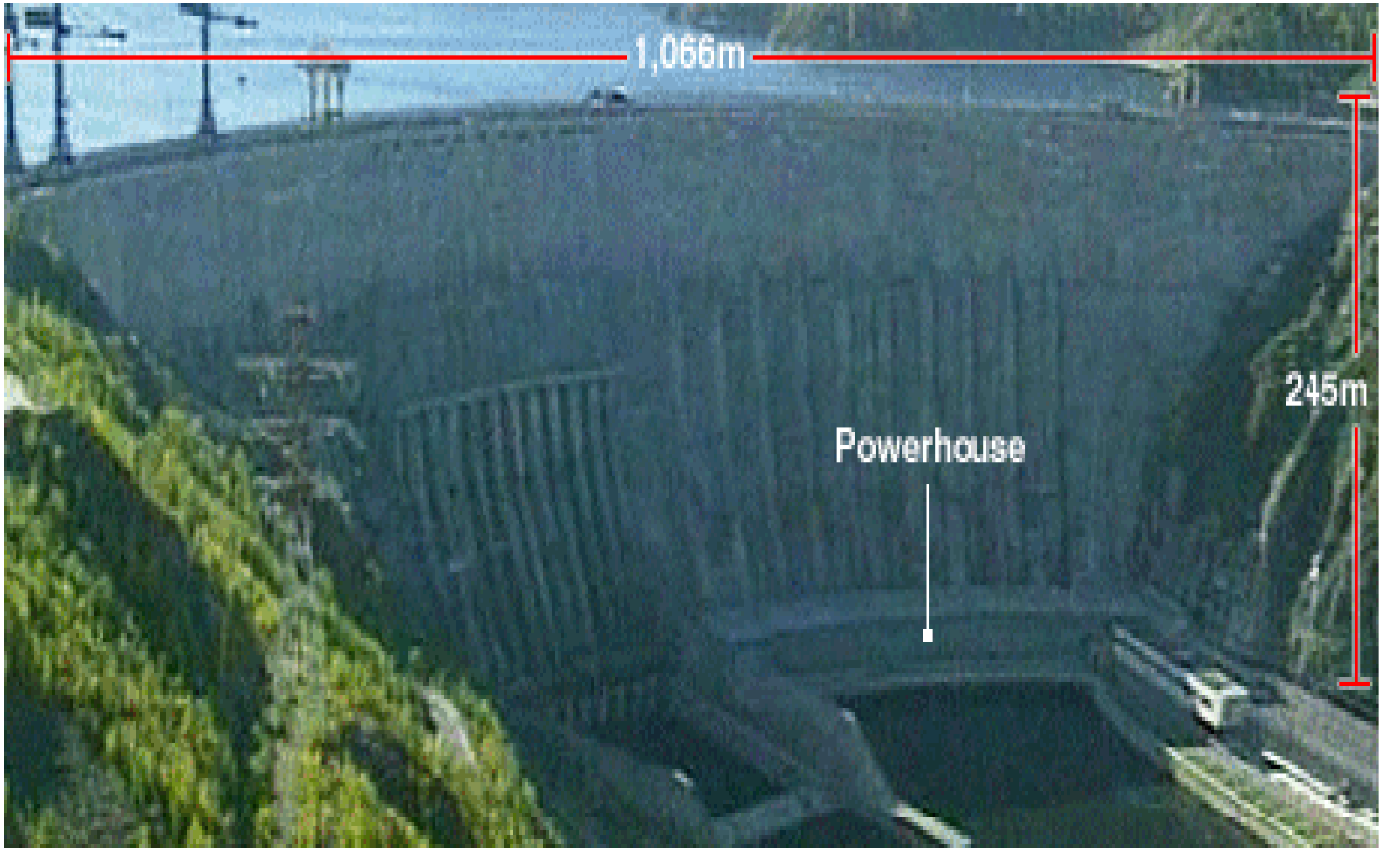
KHAKASSIA- Jenyiszej vízerőmű üzemzavar robbanás oka ?

Cross-section of typical hydroelectric power plant



KHAKASSIA- Jenyiszej vízerőmű üzemzavar robbanás oka ?

KHAKASSIA- Jenyiszej vízerőmű üzemzavar robbanás oka ?

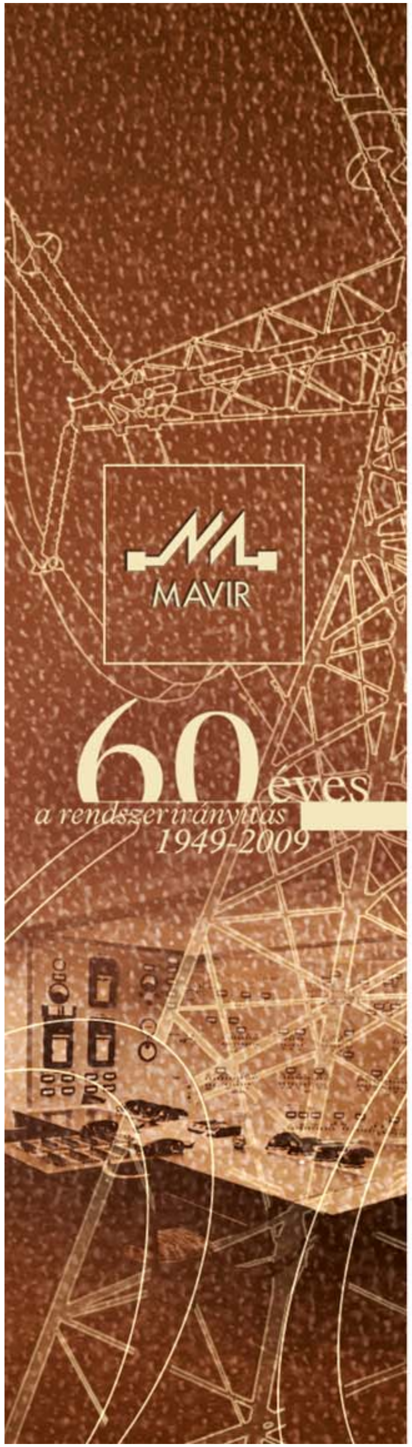


KHAKASSIA- Jenyiszej vízerőmű üzemzavar robbanás oka ?

KHAKASSIA- Jenyiszej vízerőmű üzemzavar robbanás oka ?

KHAKASSIA- Jenyiszej vízerőmű üzemzavar robbanás oka ?

KHAKASSIA- Jenyiszej vízerőmű üzemzavar robbanás oka ?



Working Groups

23 Diagnostics and Accelerated Life Endurance Testing of Polymeric Materials for HVDC Application

24 Potential of Polymer Nanocomposites as Electrical Insulation for Highly Stressed Insulation Material in AC and DC Application

25 Application Guide for PD Detection in GIS using UHF or Acoustic Methods

26 Basic Principles to Determinate Methane Content of Cross-linked Solid Extruded Insulation of MV and HV Cables

27 Material Properties for New and Nonceramic Insulation

28 Optimized GIS by Dielectric Coated Electrodes and Functionally Graded Materials

29 PD recognition in liquid impregnated systems for transformers

Köszönöm a megtisztelő figyelmet!