Sümeg, 20 X 2016, Michał Lasota

XVI. Szigetelésdiagnosztikai Konferencia

Transformer Service ABB Poland
LFH transformer drying

LFH transformer drying
Transformer aging and failure rate

1. Introduction

2. Problem of water in transformers

3. Moisture related phenomena

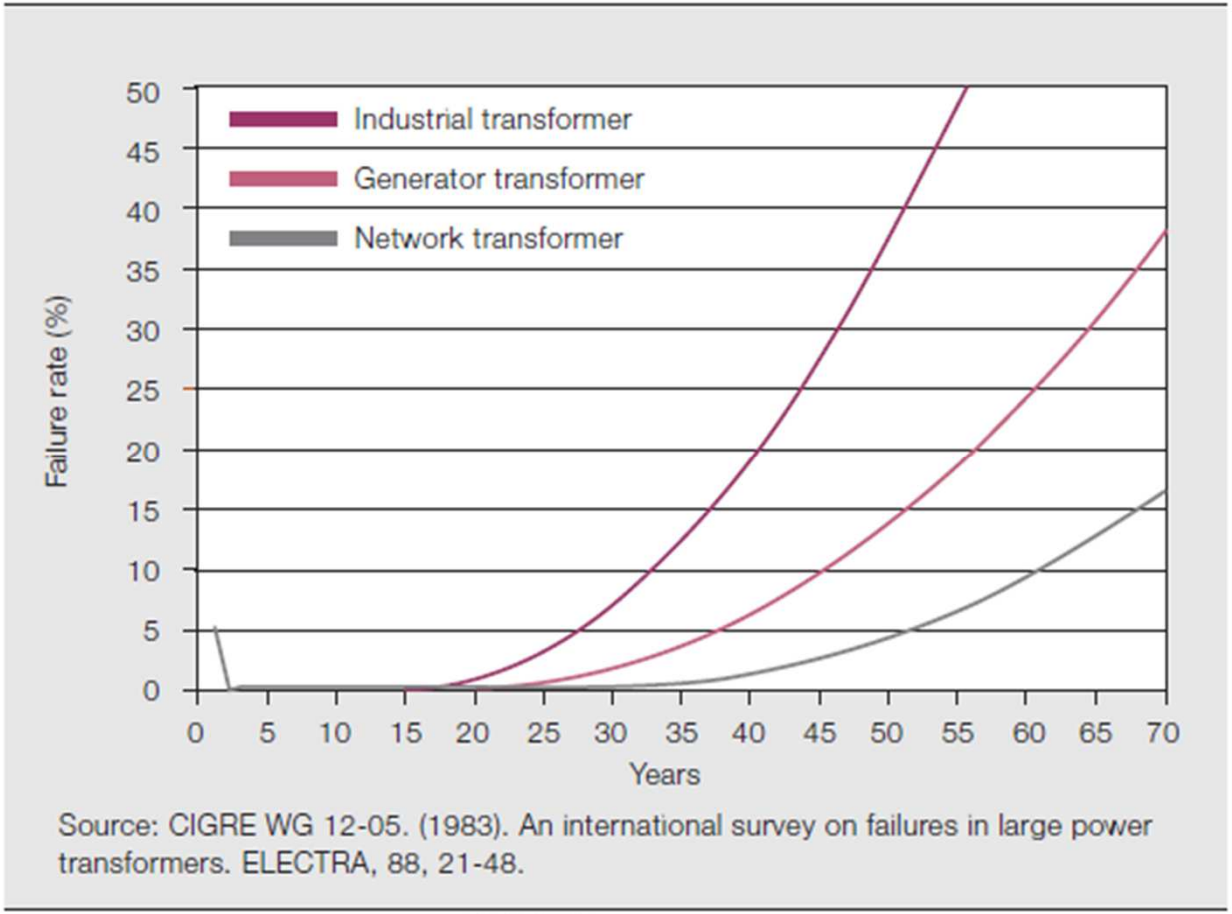
4. Failures

5. Drying methods

6. LFH concept

7. Reference jobs

8. Summary



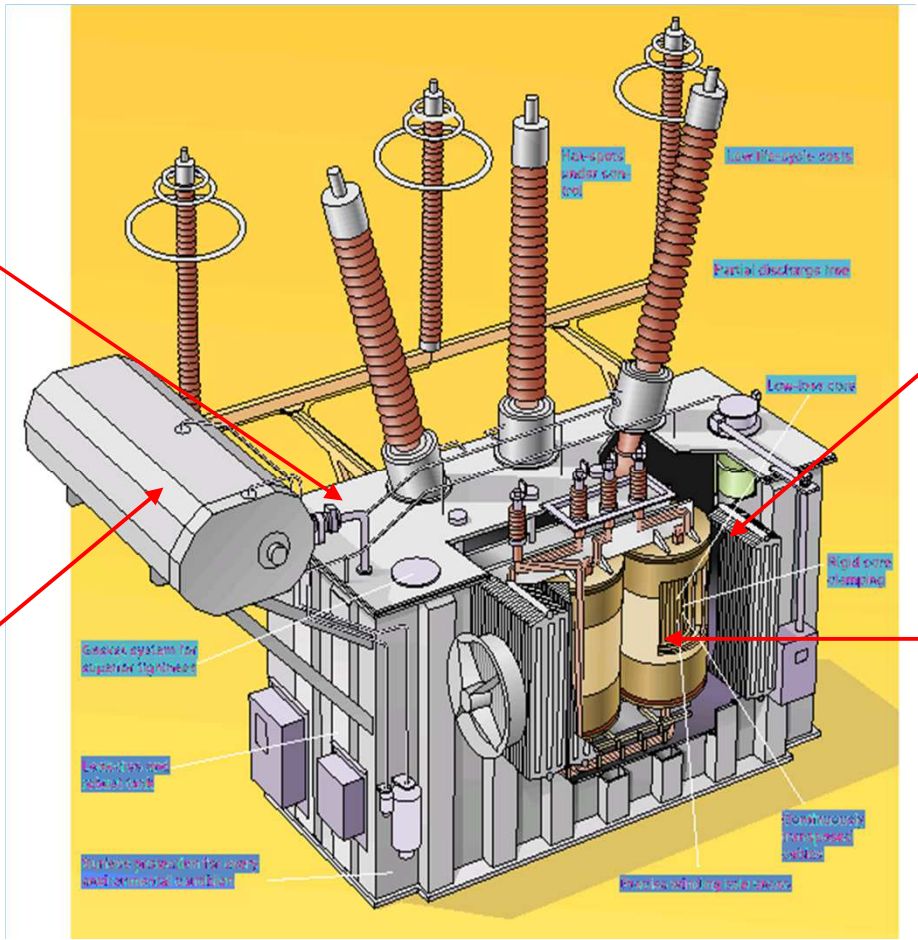
Source: CIGRE WG 12-05. (1983). An international survey on failures in large power transformers. ELECTRA, 88, 21-48.

SOURCE: CIGRE SC A2 COLLOQUIUM 2015, SHANGHAI

LFH transformer drying
Where does water in insulation come from?

1. Initial moisture remaining after production process

2. Defective / aged sealing



3. Exposure to atmosphere (inspections, repairs, ...)

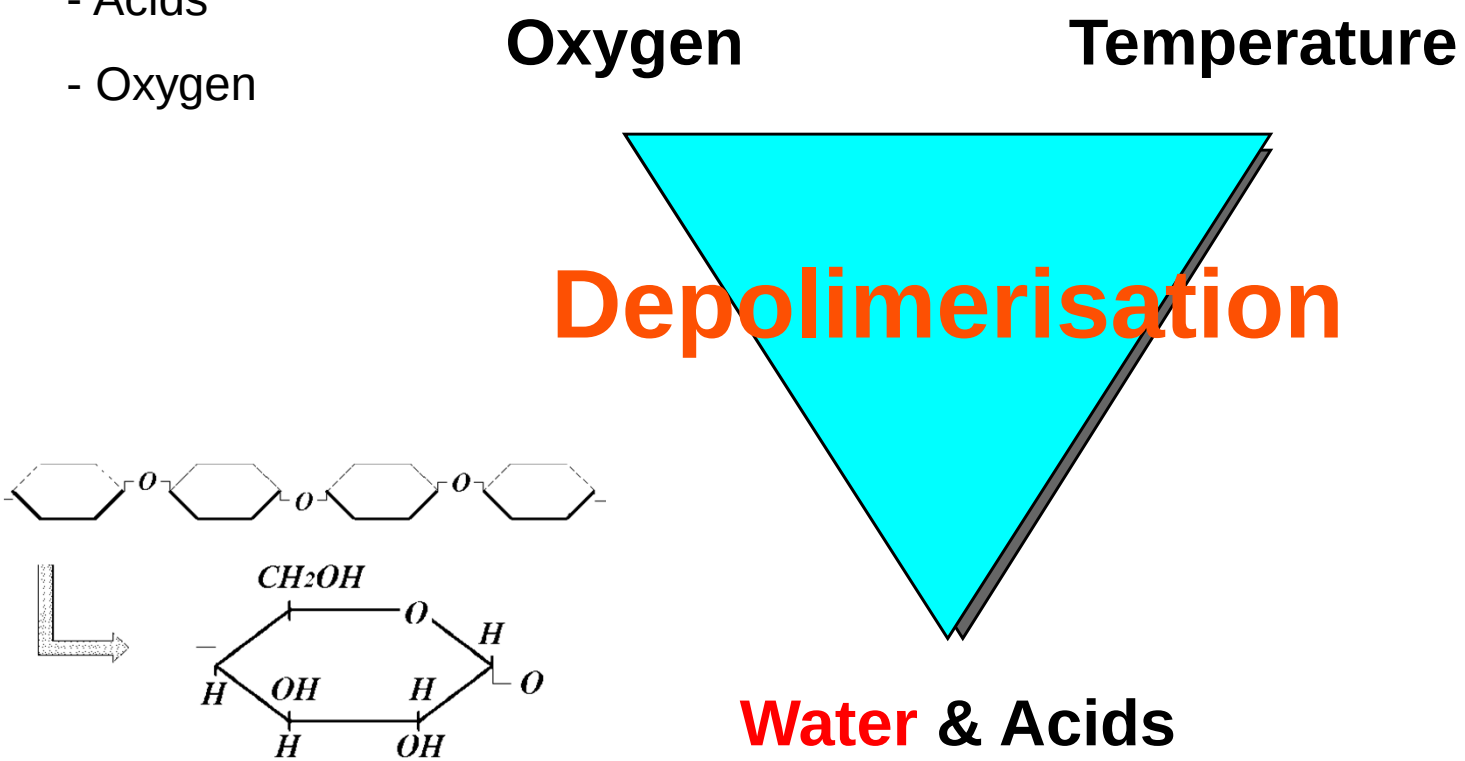
4. Open conservator 0.1 - 0.2% per year

5. Paper degradation 0.4 - 2%

LFH transformer drying
Paper degradation

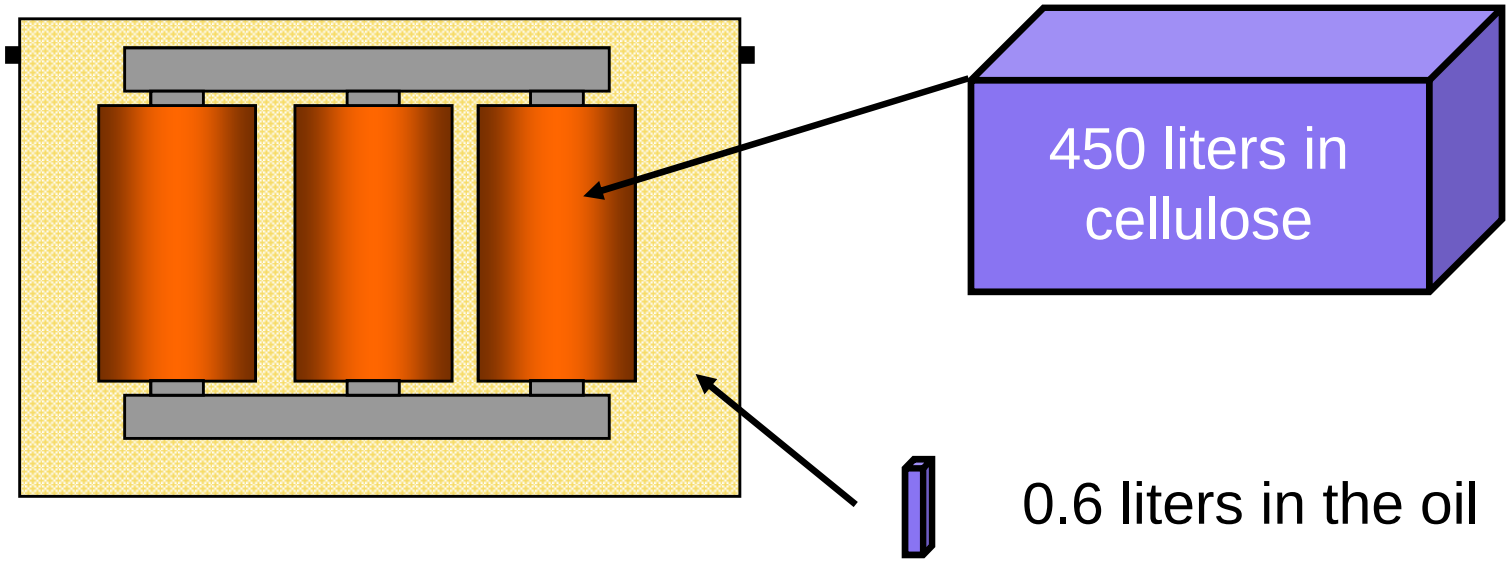
Paper depolimerisation under the effect of temperature is accelerated in the presence of:

- Water
- Acids
- Oxygen



LFH transformer drying
Moisture distribution in transformer insulation

Example:
400 MVA unit with 15 tonnes cellulose insulation and 60 tons of oil
3% average moisture in cellulose @ 30°C average oil temperature

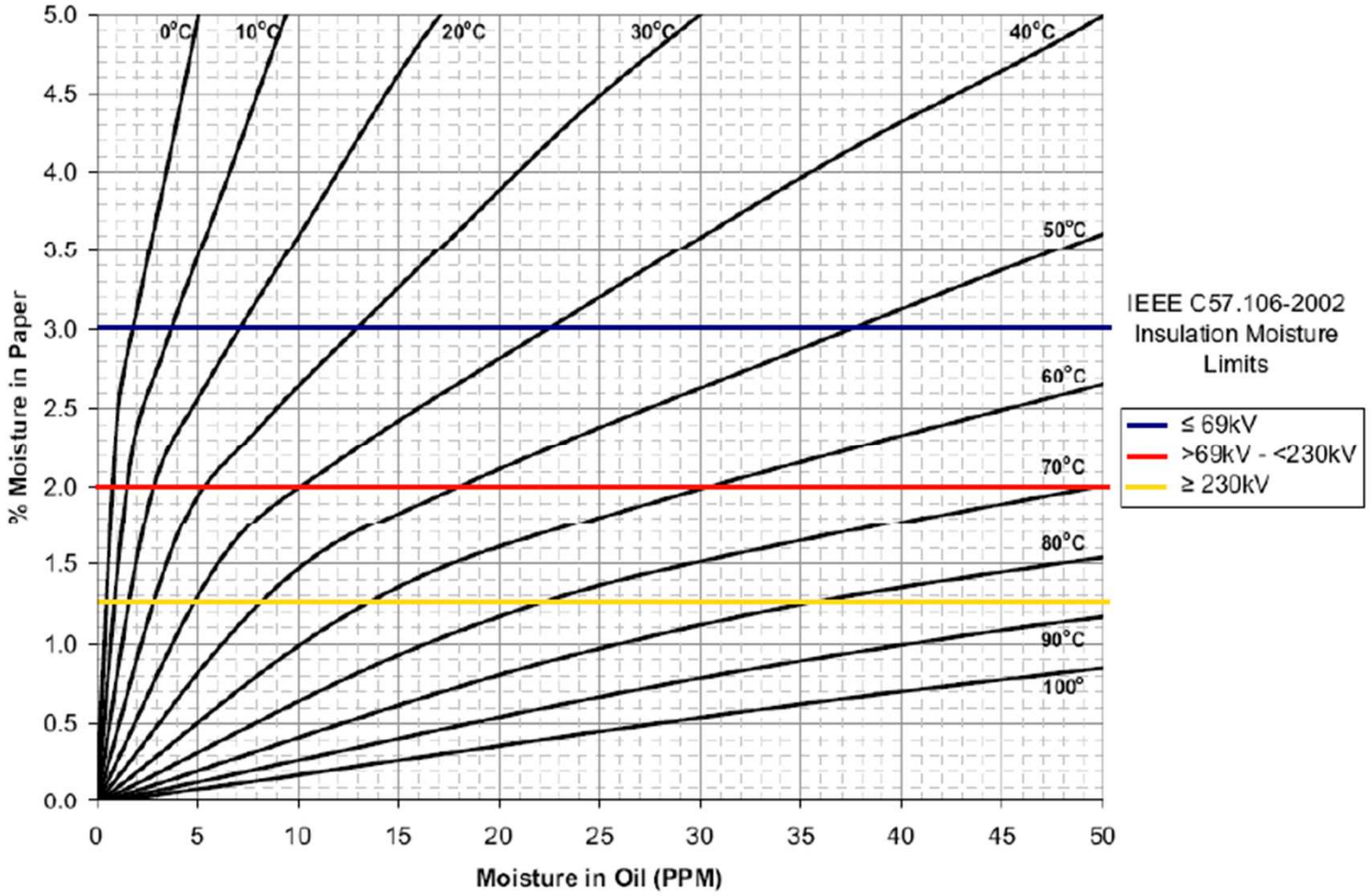


Over 99 % of the moisture is collected in the cellulose!

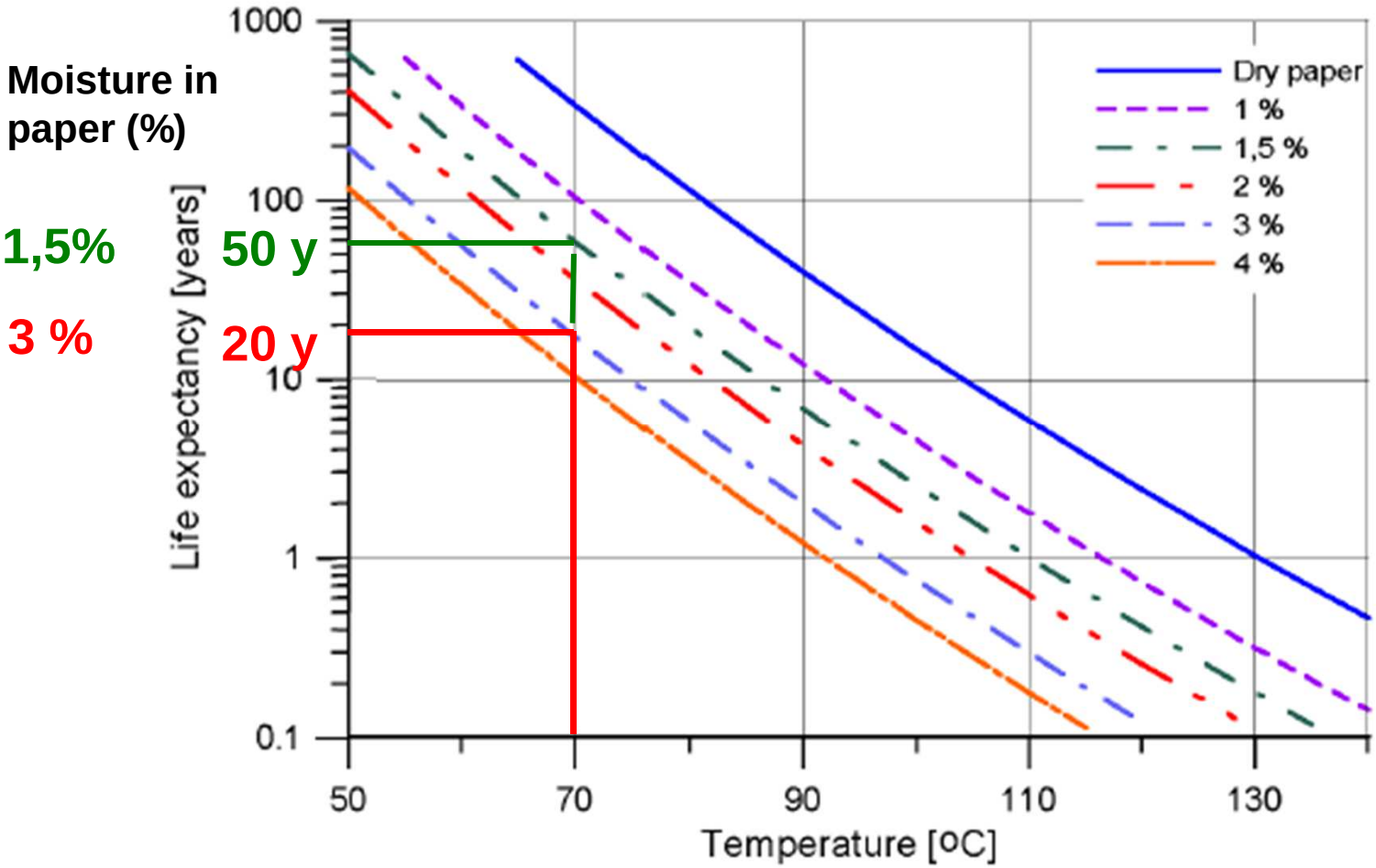
LFH transformer drying
Moisture distribution in transformer insulation

Water balance between paper and oil at different temperatures

IEEE insulation moisture limits !



LFH transformer drying
Moisture content vs transformer lifespan



Source: SINTEF

LFH transformer drying
Moisture induced aging and bubble effect

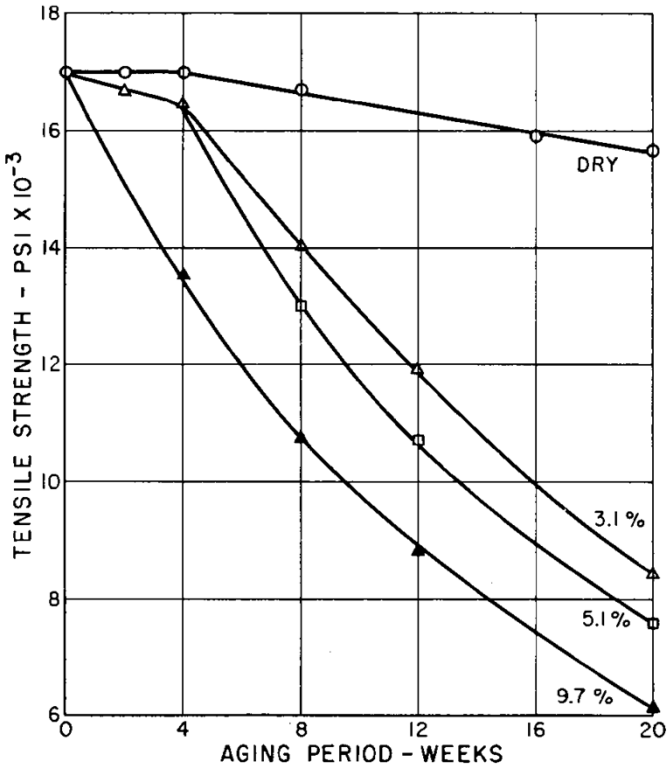
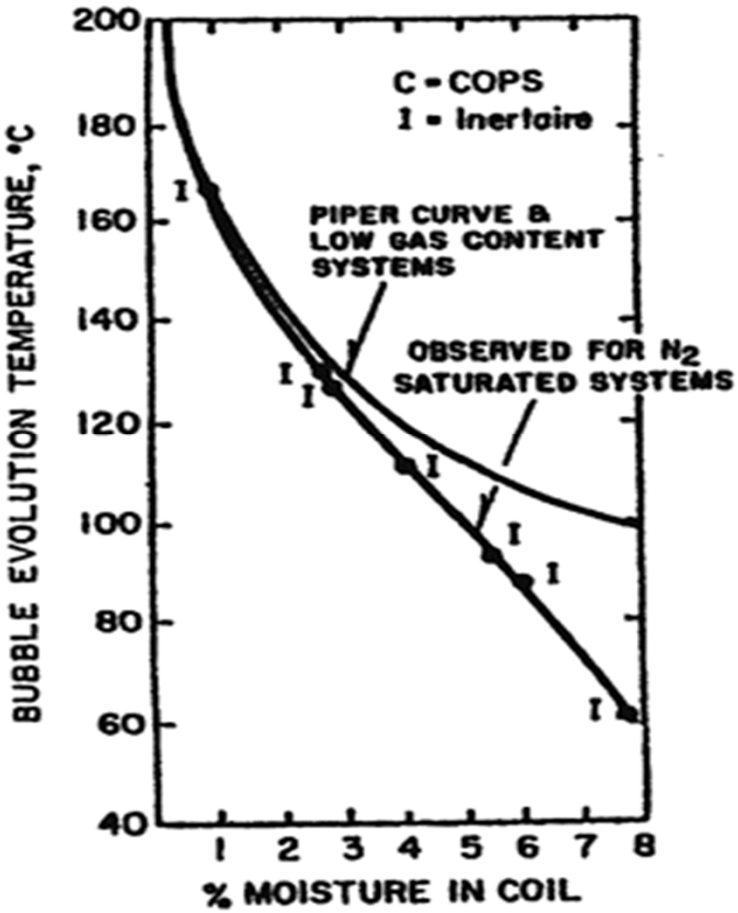


Figure 23
The aging of manila cable paper as affected by the presence of moisture when sealed in glass tubes and heated at 75°C in the presence of nitrogen.
The moisture contents of the papers tested are indicated on each curve in percent by weight.



LFH transformer drying
Water in insulation - Summary

Water reduces transformer “performance”

- Speeds up ageing: **Reduces life time** of the solid insulation
- Increases risk of flashover: **Reduces reliability** in case of overload

1) Reduced life time

1% has the same effect as an increase of operative temperature by 8 °C
(doubling the depolymerisation speed)

2) Reduced reliability

- With **4% moisture at 50°C** one may observe **free water already at 20 °C**
- With 2-3% @ hotspot - higher risk of **bubble formation** (overload)

LFH transformer drying
Failure example Canada

Failure at Hydro One (Canada)

1) Circumstances

- Hydro one transformers fleet is strategic for transmission grid of Ontario
- The transformers are critical for secure reliable energy transmission
- High failure rate for 750MVA units was observed

2) Autotransformer failure 750MVA 500/230 kV:

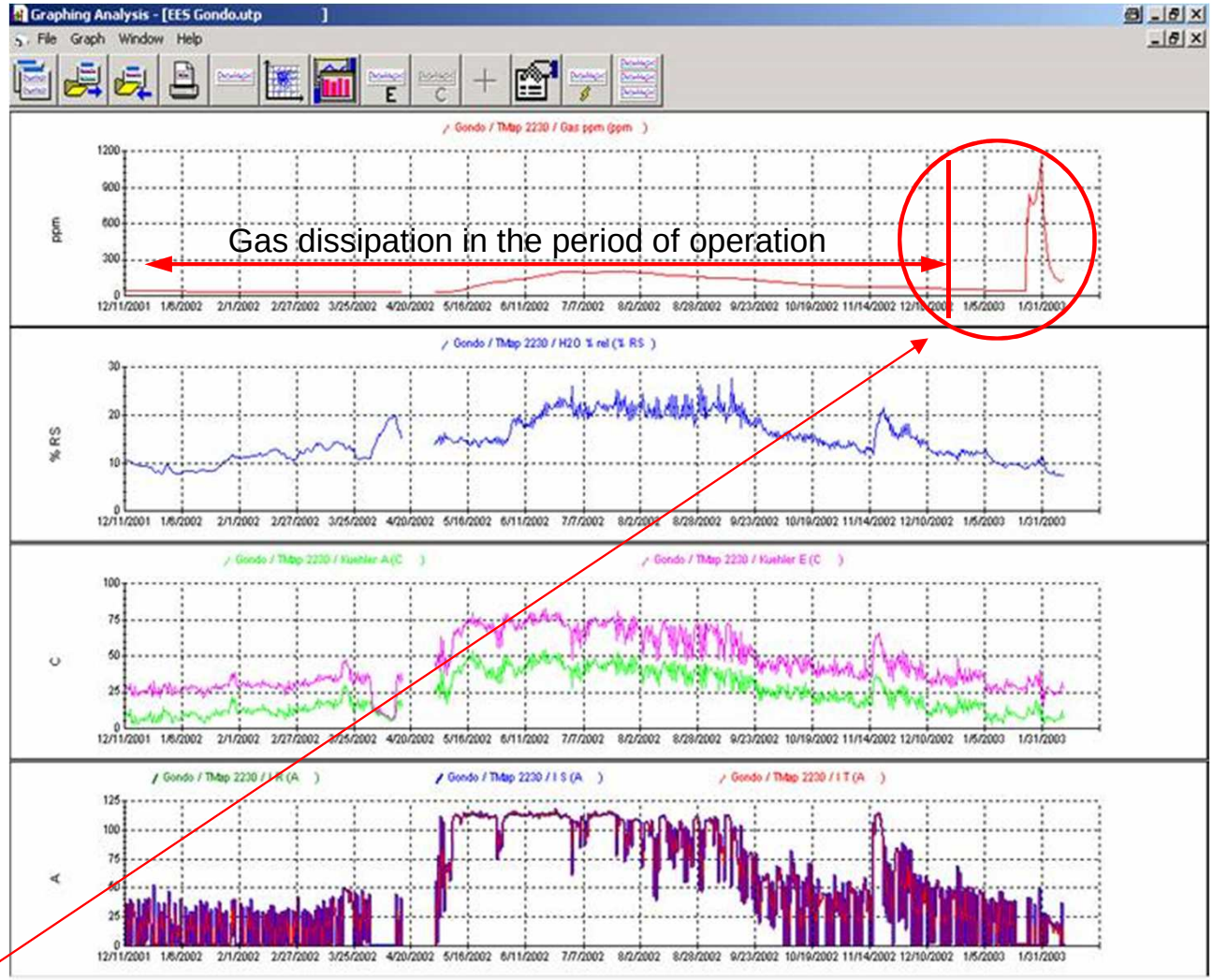
- The main reason identified after investigation – water in insulation
- Water content analysis indicates moisture level of 1.5 %
- Nominal parameters of all 750MVA units are decreased for safety reasons

3) Customer decides on wide-scope service programme

HOV – traditional method of drying based on vacuum and oil treatment
does not bring any significant improvement
LFH method is accepted, customer engages ABB to perform LFH drying
of all 500kV units (over 20 units between 2007-2011)

Method	Drying efficiency	Drying time
HOV	0,3%	28 – 56 days
LFH	easily above 1,0%	12 days

LFH transformer drying
Failure example Switzerland



Transformer energization after a shut-down:

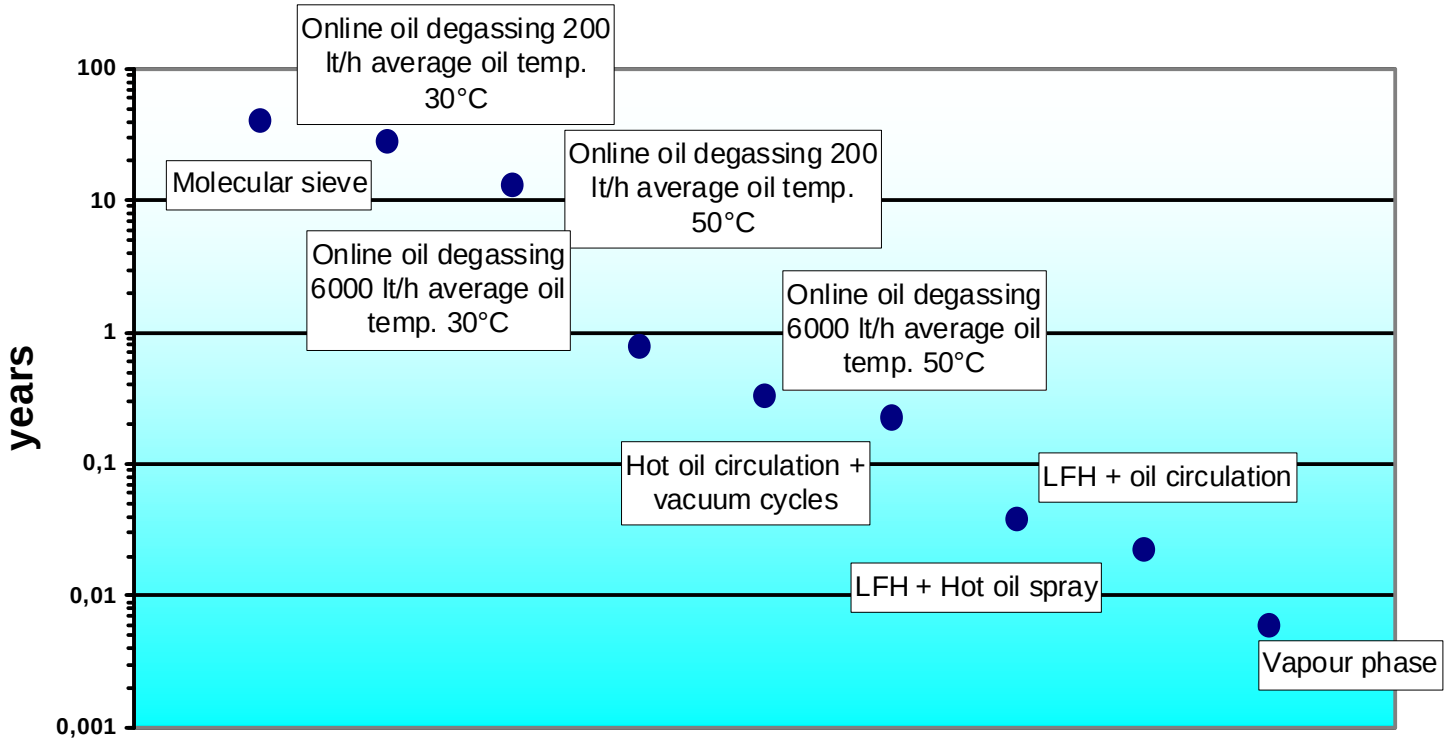
- Transformer cools down,

- Free water forms and dissipates in solid insulation,

- Buchholz relay trips at rapid gas increase

LFH transformer drying
Alternative drying methods

Drying time to dry a 400MVA transformer with 14t of insulation from 3% down to 1.5% avarage humidity



Temperature and vacuum are key components of any drying procedure

LFH transformer drying
Alternative on-site drying methods

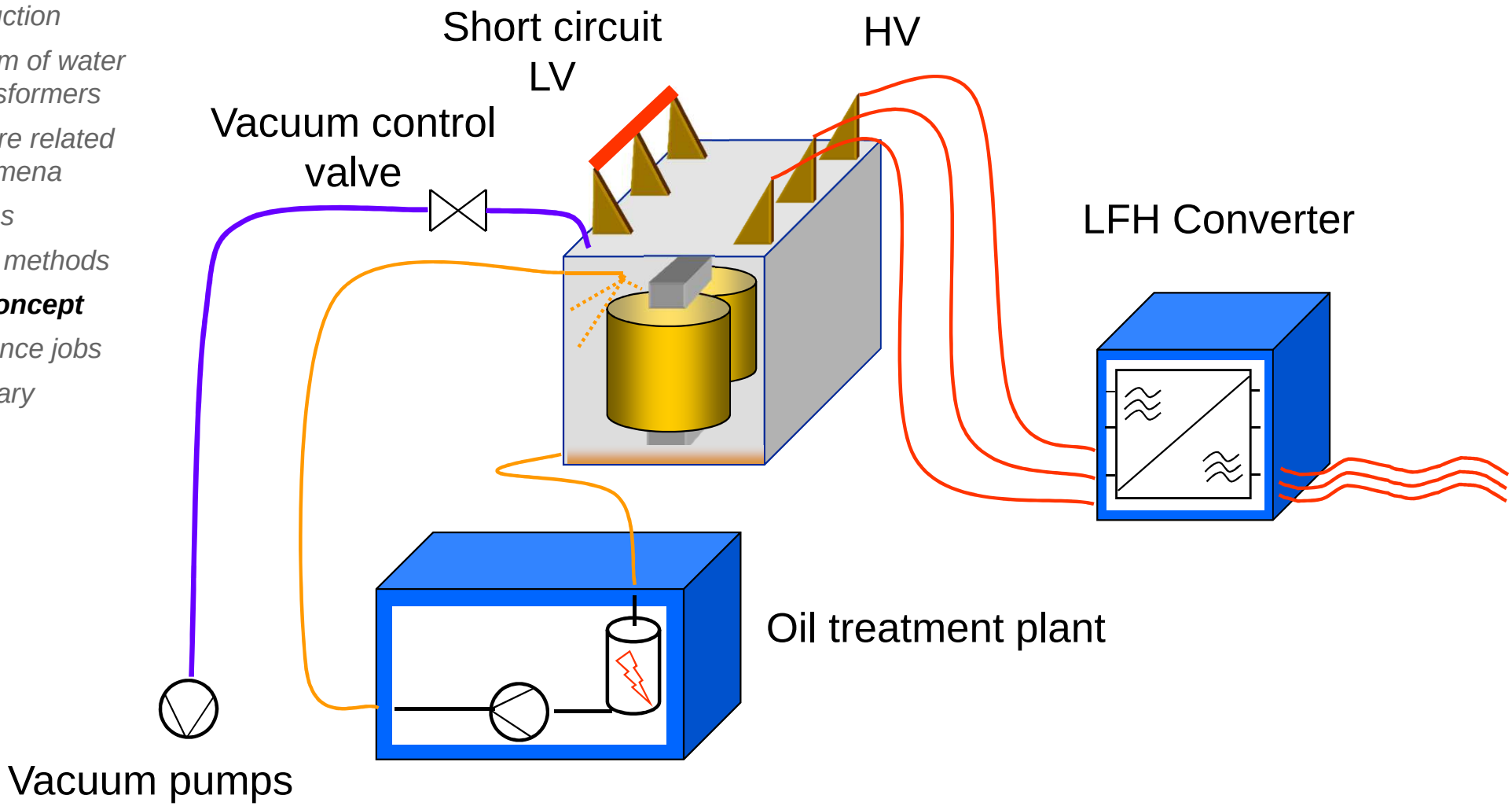
Water extraction through oil treatment
– highly inefficient

Online circulation
– takes long with limited results

Drying without current flow
– low efficiency

Drying with direct current flow
– high risk of insulation damage or limited efficiency

LFH transformer drying
Low Frequency Heating on-site setup



LFH transformer drying
Low Frequency Heating method

Concept:

- Remove as much moisture as required in the shortest possible time
- Controlled heating speed to avoid overheating
- Uniform heating for best drying results
- Temperature monitoring
- No condensation on cold transformer parts
- Intelligent process selection for safe operation

LFH transformer drying
Low Frequency Heating method

Why low frequency current drying ?

Heating up of coils from the inside by applying 20 – 50% of nominal current

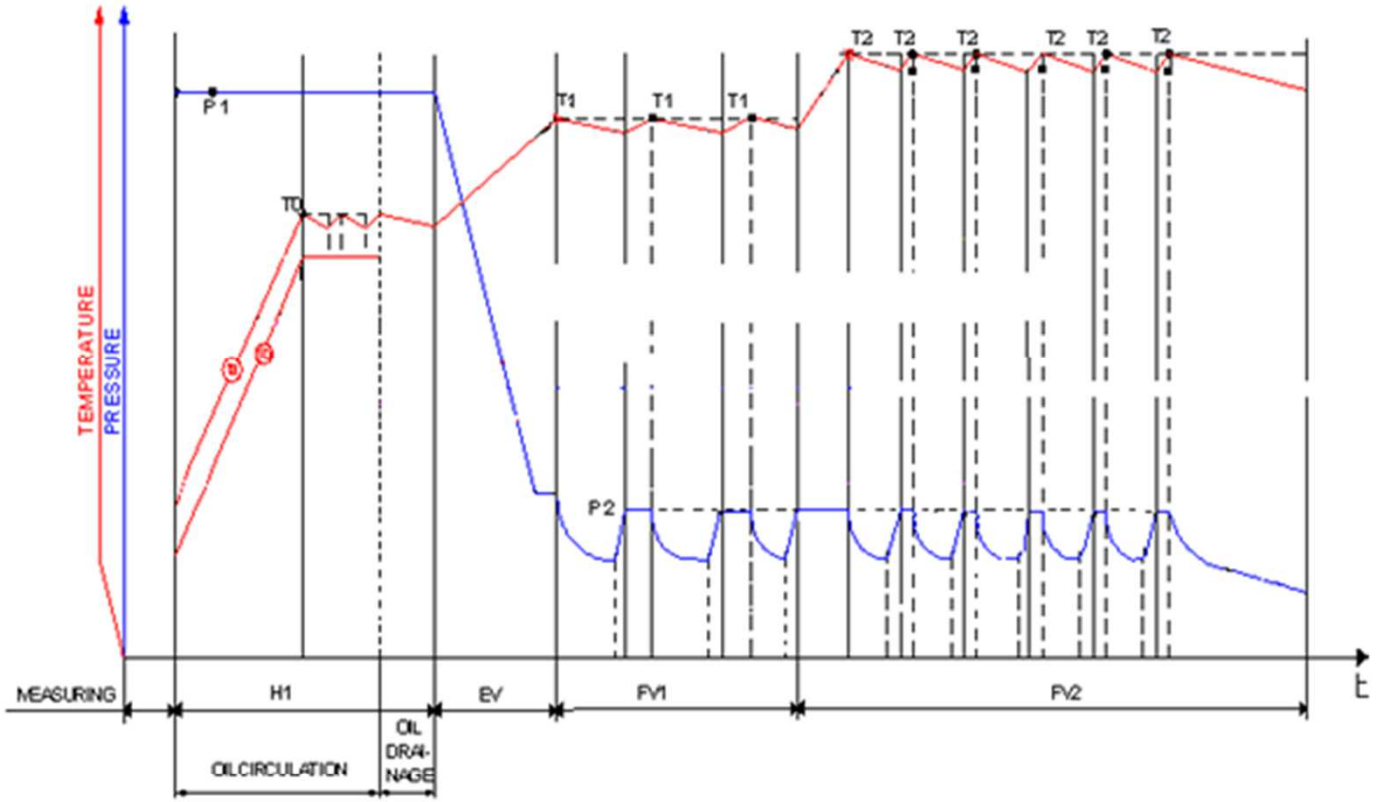
Using the lowest possible voltage to avoid flashover in vacuum (considering the Paschen law)

Perfectly controllable temperature inside the transformer

Shorter processing time
- 30 – 50% shorter drying time than conventional hot oil + vacuum

High quality of drying
- Lower remaining moisture in paper and board

LFH transformer drying
Low Frequency Heating proces diagram



Simulation of key parameters during drying process

LFH transformer drying
Low Frequency Heating method

Criteria to stop the drying process depends on many parameters:

- Remaining moisture, size, insulation level, insulation weight, drying temperature, vacuum level, measuring method for extracted water, cooling temperature on condensers, vacuum pumps, ...
- Drying time can be indicative (own formula)
- Litre of water extracted during the last 12 h under 1 mbar and 85 °C

Quality control

- Dielectric Frequency Response tests

Remaining moisture depends on the type of transformer, the reason of the drying, and expected remaining life time

- 0.5 % , 1% or 2%

LFH transformer drying
Monitoring of critical process parameters

Sensors located on transformer:

- Windings
- Core
- Oil

Constantly monitored winding temperature

- Safety alarms & shutdowns
- Continuous surveillance of current and resistance with automatic shut off
- Adjust frequency for winding heating

LFH transformer drying
Drying recommendations

Moisture in solid insulation: decide when to dry

- Try to keep the moisture in service < 1%
- 1% < H% < 2%: monitor the moisture content and consider drying
- 2% < H% < 3%: Plan for drying
- H% > 3%: Dry as soon as possible. Avoid overloading.

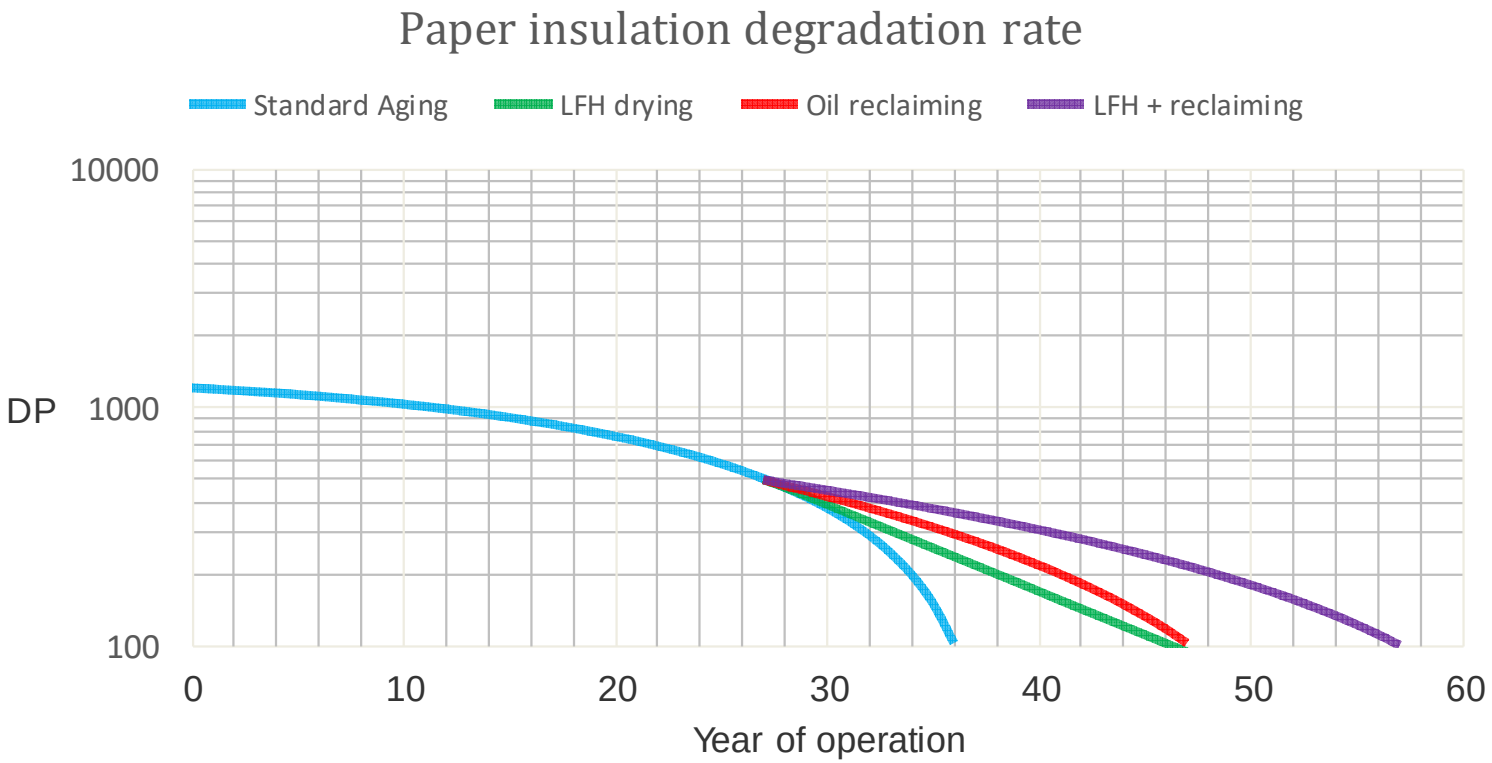
Decision to invest in a drying operation depends on:

- Condition of the transformer
- Expected remaining life time
- Need for overload
- Maintenance and investment strategy

LFH transformer drying
Transformer life expectancy

Low frequency heating combined with transformer oil reclaiming is a cost-effective solution which allows:

- ultimate improvement of insulation condition
- maximum transformer life-time extension



LFH transformer drying
Examples of LFH drying duration

▪ 290 MVA 400 kV	3 % → 1%	8 days
▪ 200 MVA 300kV	2,5 → 1 %	7 days
▪ 130 MVA 300 kV	1,5% → 0,5%	5 days
▪ 130 MVA 300 kV	4,5% → 1,5%	4 days
▪ 110 MVA 70 kV	3,2% → 1%	4 days

- More than 200 transformers dried out with LFH by ABB
- From 20 MVA / 63 kV till 750 MVA / 500 kV

LFH transformer drying
Success story: Hydro One drying program

Canada 750MVA 500 kV

Manufactured:	1974
Rated power:	750 / 750 / 150 MVA
Nominal voltage:	500 / 230 / 28 kV
Insulation weight:	15 100 kg
Oil weight:	150 000 kg
Date of service:	2007
Drying duration:	12 days
Moisture content drop:	from 1.5 % to 0.5 %

LFH transformer drying
Success stories Poland 2013 - 2016

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7. ***Reference jobs***
8. *Summary*




LFH transformer drying
Summary

- ABB developed state of the art technology to extend transformer life-time and improve reliability
- Moisture level limits are defined in selected standards
- On-site service → no risk of transport → quicker & cheaper
- Perfectly controllable, safe and effective process
- Best results when combined with oil reclaiming for transformer life-time extension
- Over 200 successfully dried transformer around the globe
- ABB provides case-based expertise to help choose the best possible solution

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for a better world™