ARS ALTMANN PRESENTATION
2005

1. Introduction

ARS-Altmann method is based on three widely accepted facts:

- **the transformer stock is aging , life-span of transformers is limited and unit replacement costs are huge**
- **transformer life enhancement methods can stabillize and improve their operational reliability**
- **deferred replacement will normally mean significant savings**

2. Basic Economic Decisions

The decision to replace / not replace an aging transformer may be governed by many different technical factors:

- **the predominant factor is the operational reliability of the transformer**
- **the predominant long-term criterion is always operational economy :**

is the future operation of aging transfomer profitable compared with a new installation ?

The most precise criterion can be expressed as comparison of Relative Differential Loss (%) :

$$RDL = \frac{\text{losses of old transformer} - \text{losses of new transformer}}{\text{purchase price of new transformer}}$$

and Interest Rate (IR) of the bank used for the purchase of a new transformer.

Then there are three basic scenarios :

RDL >> IR	**....**	relative losses are a lot of higher than the interest rate, **old transformer should be replaced as soon as possible**
RDL ≈ IR	**....**	relative losses are approx. the same as the interest rate, **decision about replacement versus life-extending has to be based on other criteria**
RDL << IR	**....**	relative losses are a lot of lower than the interest rate, **application of life-extending methods allows considerable savings**

For a reasonable economic decision it is always necessary to colate and process a relatively large amount of information gained from at least five sources:

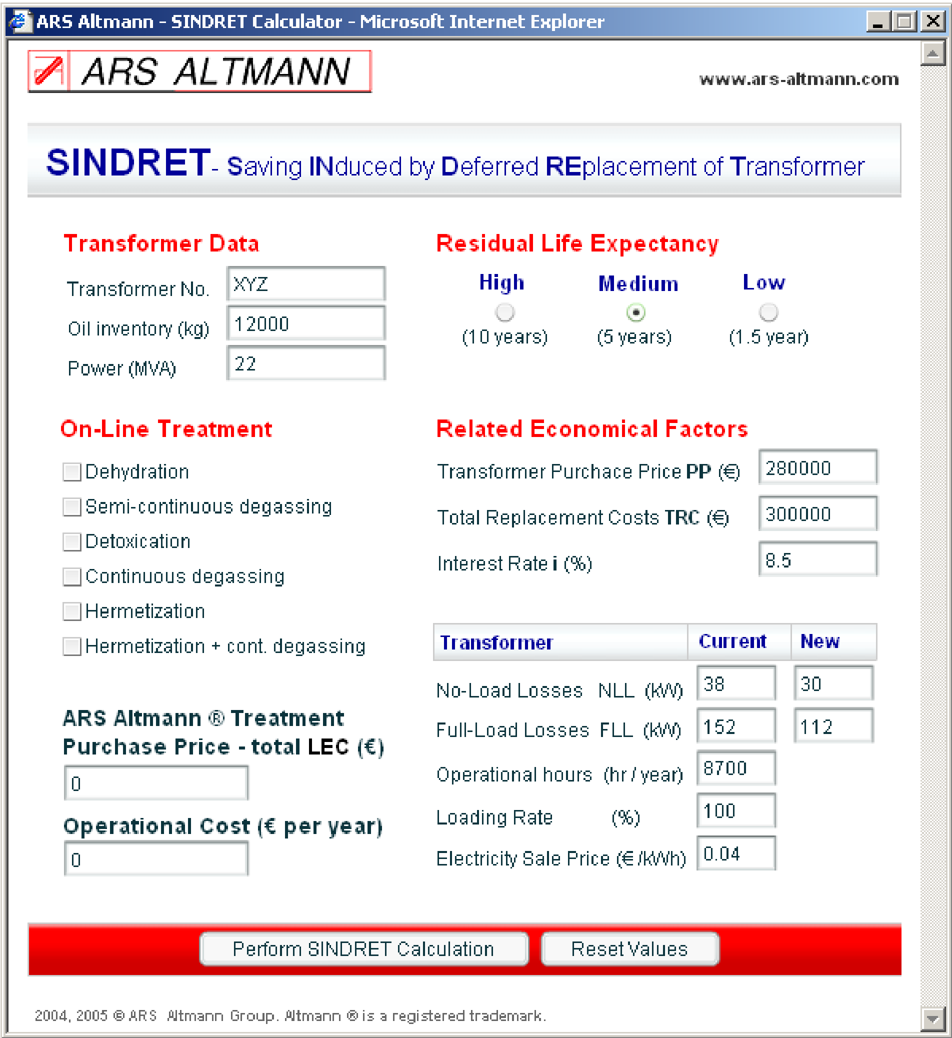
Bank	…..	Interest Rate
Supplier of new transformer	…..	No-Load Losses (**NLL**), Full-Load Losses (**FLL**), Transformer Purchase Price (**PP**)
Client (old transformer)	…..	**NLL**, **FLL**, Operational Hours per year (**OH**), Loading Rate (**LR**), Total Replacement Costs (**TRC**) etc. …
Supplier of electricity	……	Electricity Price of in situ (**EP**)
Diagnostic	……	Residual Life Expectancy of aging transformer (**RLE**)

The basic parameters of aging and new transformer (**NLL** and **FLL**) are constant , but the other parameters as a **IR, EP, OH, LR** or **RLE** may be highly volatile.

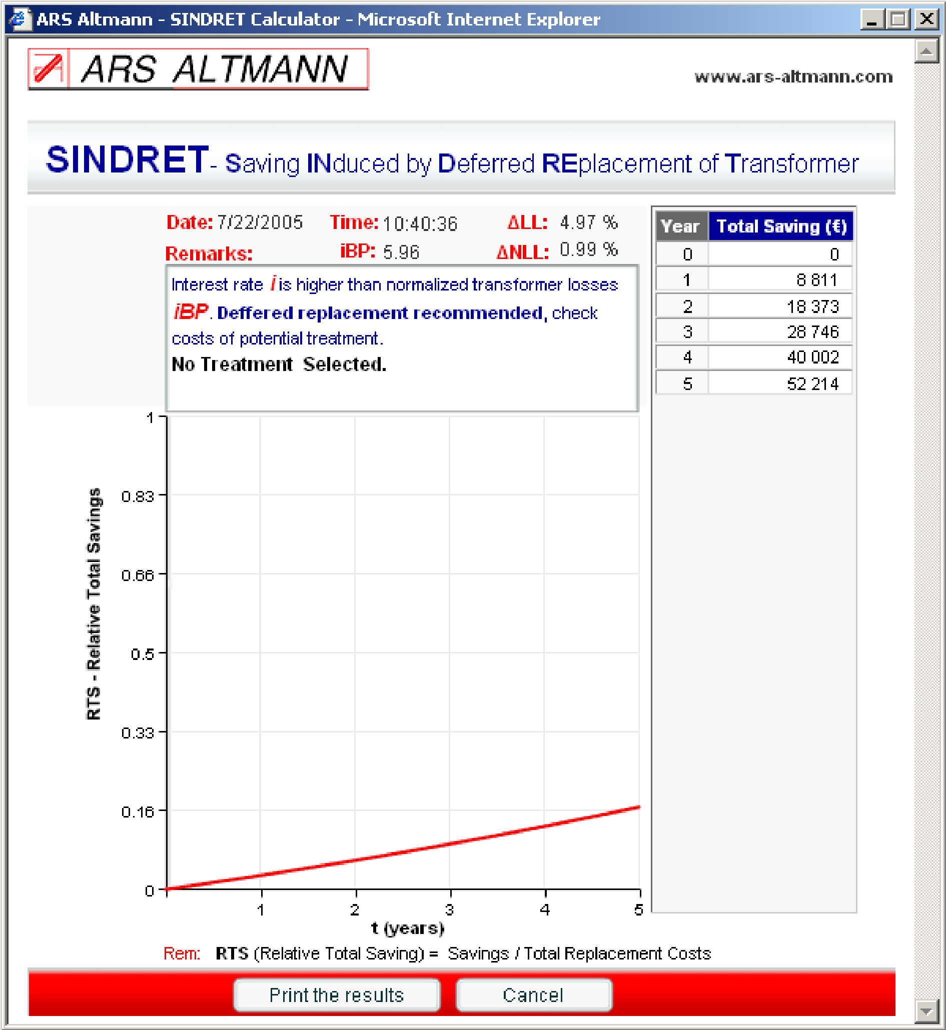
It is always necessary therefore to specify long-term projections of potential changes of **RDL** versus **IR.**

To limit potential (human) errors, ARS-Altmann have developed a special freeware **SINDRET –** See **www.ars-altmann.com**.

The first window of SINDRET enables easy input of all these parameters



and all required calculations will flow from this including the time related savings.



In this case it can be seen quite clearly, that the deferred replacement of the old transformer is profitable – we can save ca € 52 000.- (or 16% of the purchase price of the new transformer) over the next five years.

Sound economic analysis is, almost exlusively, essential before proper management assessment can be taken.

For future profitable transformer operation the relationship **RDL << IR** should be seen as the only reasonable and proven basis for the management discussion and the subsequent selection of life-extending methods for aging transformers.

3. What can strongly and negatively affect the operational reliability and the life-expectation of a transformer ?

The long-term reliability of any transformer is predominantly affected by the aging of its cellulose insulants (oil can be always reclaimed or replaced). There are four main elements which strongly accelerate degradation:

I. **temperature**
II. **water**
III. **oxygen**
IV. **oil aging products**

Facts :

ad I - Temperature (heat)

- **law of 8 centigrade** - any 8 C increase of the transformer temperature , will double the velocity of aging of the cellulose (only if the oil inventory is fully saturated with air)

ad II - Water (moisture)

- **avalanche effect** – water works (with heat) as a strong accelerant of cellulose oxidation → oxidation splits the cellulose and produces more water → more water works as a even bigger accelerant and works in this manner as a **very dangerous positive feed-back effect**
- **hydrolysis (depolymeratization)** - reduction of the tensile strength of wet paper, together with thermal aging, reduces impulse strength and transformer ability to withstand short circuits
- **water soluble acids -** promotes corrosion of metals and degrades the cellulose
- **water heavily decreaes the dielectric strength of oil**

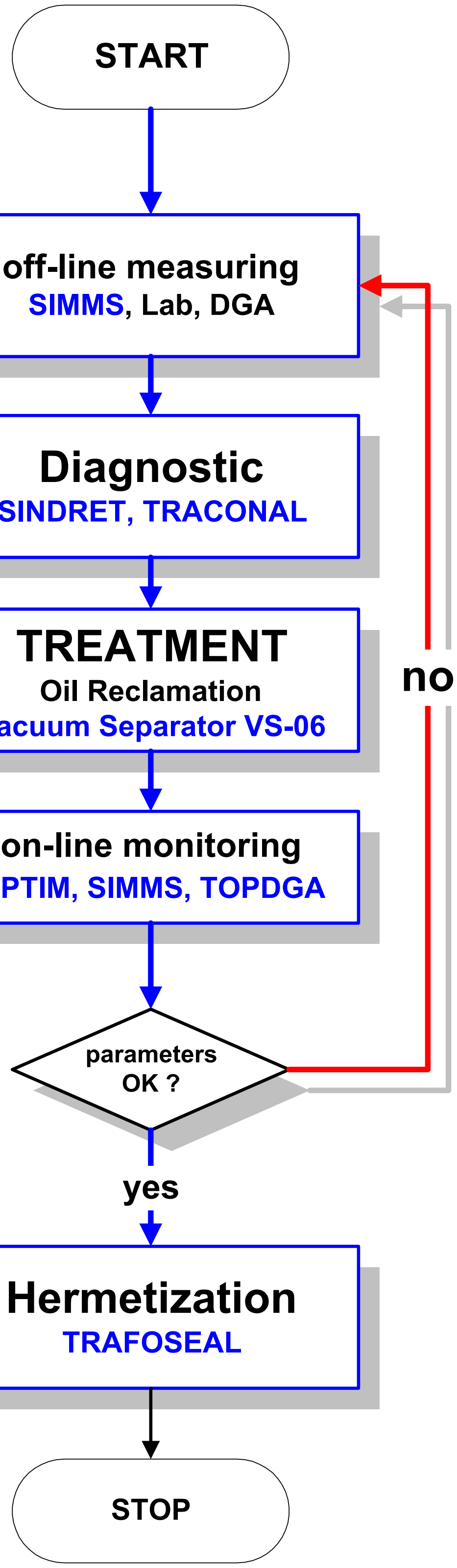
ad III - Oxygen

oxidation, heat and moisture work in combination with one another – or, are synergetic:

- **oil degradation** - oxidation and diluted water are arch enemies with heat as the primary accelerator
- **paper degradation** - heat and moisture are arch enemies with oxidation as the primary accelerator

ad IV - oil aging product – peroxide, water soluble acids, fatty acids, alcohols, metalic soaps, aldehydes, ketones and sludges. The cellulose reacts with most of the mentioned products with embrittled insulation materials as a result. Such embrittled insulation cannot withstand the shock produced by surge voltage.

4. ARS-Altmann approach



5. On-Line Measuring - SIMMS

The key <u>input</u> information about a transformer is always the precise measuring of the water content in the oil and an averaged temperature of the transformer under equlibrium conditions.

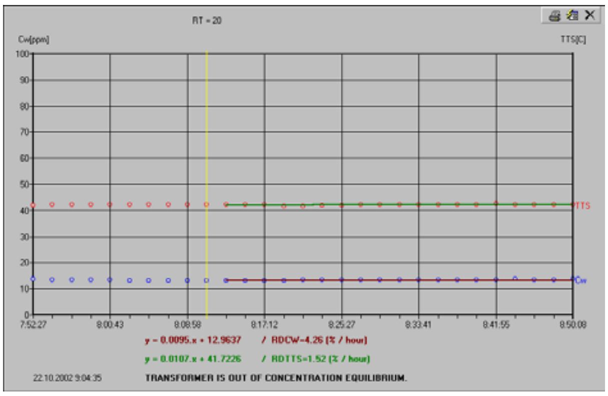
Drawbacks of present methods :

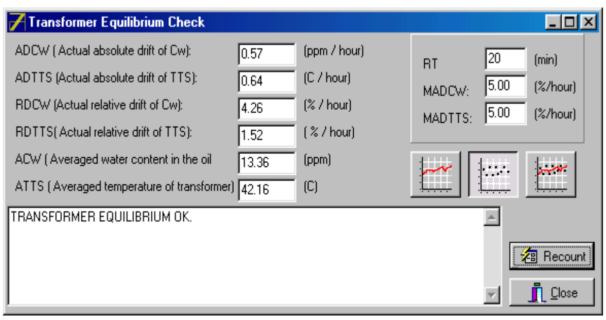
- **On-line : oil sampling method**
  - humidity contamination of the oil during sampling
  - distortion of Karl Fisher reading due to acids in the oil
  - non-existent evaluation of equlibrium conditions
- **Off-line : dielectric response methods** (RVM, PDC, FDS),
  - costly
  - time-consuming (transformer has to be disconnected long-term),
  - low precision and repeatability (by RVM and PDC) .

ARS-Altmann solution of these problems is **SIMMS** (**S**olid **I**nsulants **M**obile **M**easurement **S**ystem)

Main features of the new approach:

- a portable **on-line** apparatus
- **easy connection** to the transformer's sampling points
- **oil contamination** is excluded
- **independence of acids content in the oil**
- **time-related measuring** of water content in the oil and both temperatures (upper / bottom) of transformer





The subsequent connection of the SIMMS to lap-top enables:

- visual evaluation of time-related changes of the water content in the oil and the main temperature of the transformer
- **direct and precise evaluation of the equlibrium conditions in the transformer based at pre-defined deviation limits.**

DO NOT FORGET - only equlibrium conditions (**no water migration between oil and cellulose**) guarantee:

- precise reading of water content in oil
- precise reading of the transformer temperatures

and subsequently the precise evaluation of water content in the cellulose by the **TRACONAL**.

6. Moisture & Dielectric Diagnostic - TRACONAL

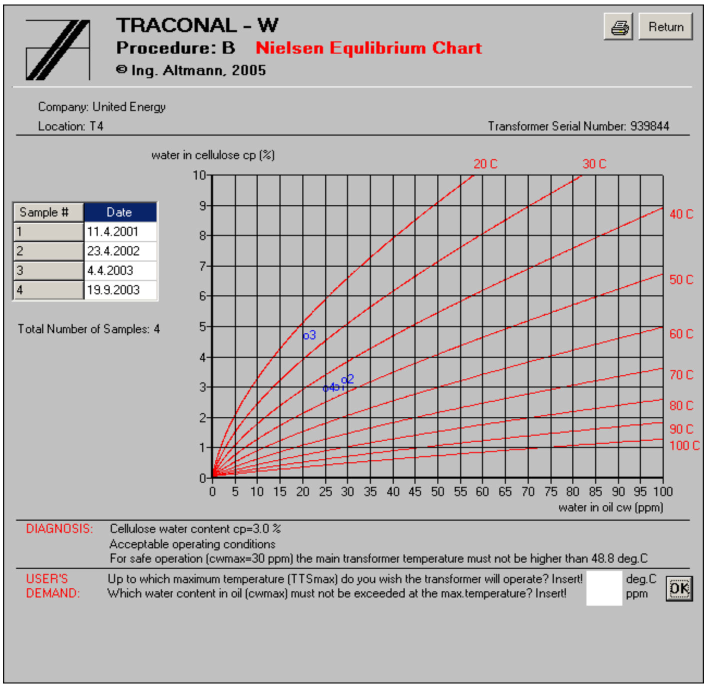
The key diagnostic <u>output</u> about any transformer is the <u>water content in its cellulose materials</u> because only this value:

- **exactly describes the moisture problem of the transformer** (98% of the water in the transformer is in the cellulose, only max. 2% in the oil)
- represents **a temperature invariant of the transformer** – water content in the cellulose does not change with the actual temperature of the transformer
- enables the direct **linkage between the dielectric strength of the oil and the temperature of the transformer.**

To exlude potential human errors by the evaluation of Moisture & Dielectric Diagnostic procedures, ARS-Altmann released the software packet **TRACONAL** (**TRA**nsformer **CO**ntamination **A**na**L**yse software).

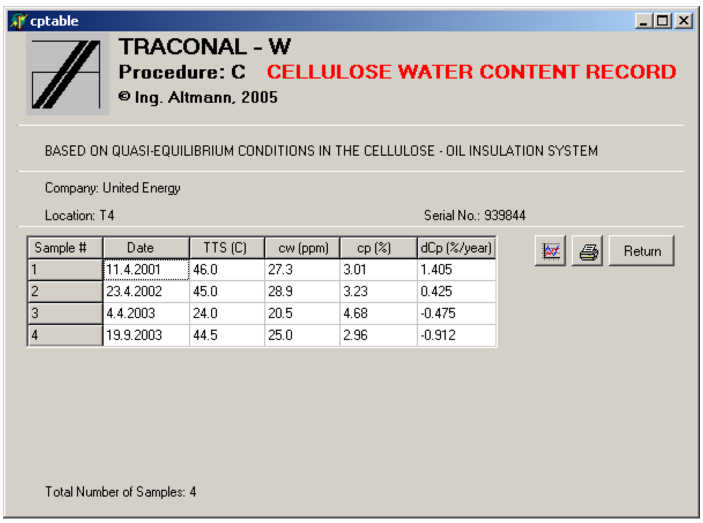
Data collection is provided by the freeware OilEdit, for more details See www.ars-altmann.com

TRACONAL evaluation procedures



Step 1 - **Nielsen equlibrium chart**

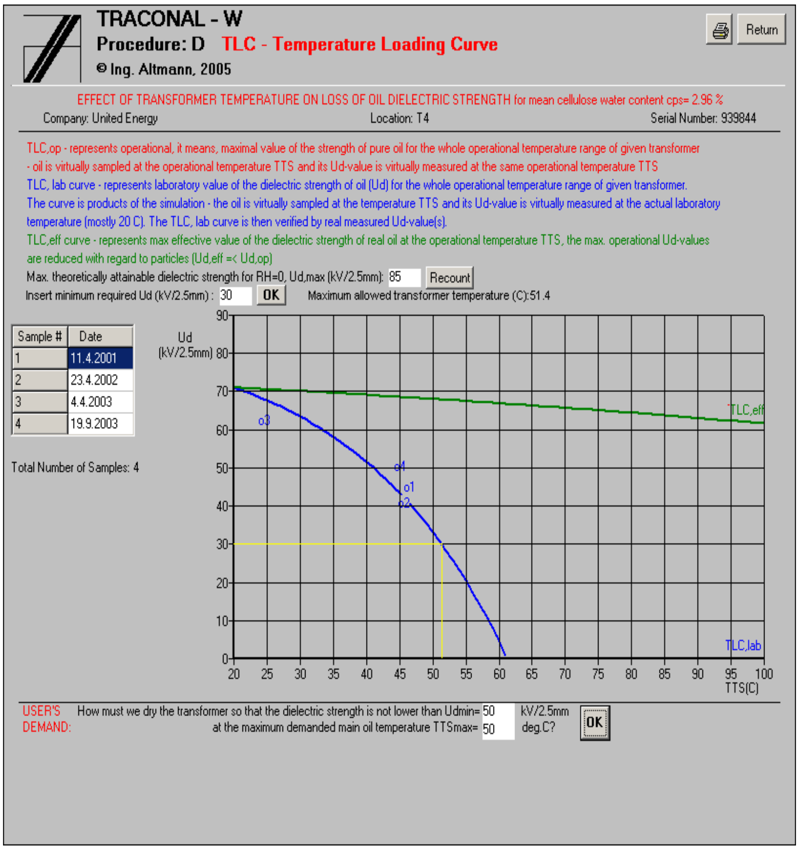
- review of the moisture evolution in the transformer
- determination of the actual water content in the cellulose
- determination of the transformer safe temperature limits based at max. DIN or EEC required water level in the oil
- amount of water which should be removed to meet user demands based at:
  - max. allowed water content in the oil
  - max. allowed temperature level of the transformer).



Sample #	Date	TTS (C)	cw (ppm)	cp (%)	dCp (%/year)
1	11.4.2001	46.0	27.3	3.01	1.405
2	23.4.2002	45.0	28.9	3.23	0.425
3	4.4.2003	24.0	20.5	4.68	-0.475
4	19.9.2003	44.5	25.0	2.96	-0.912

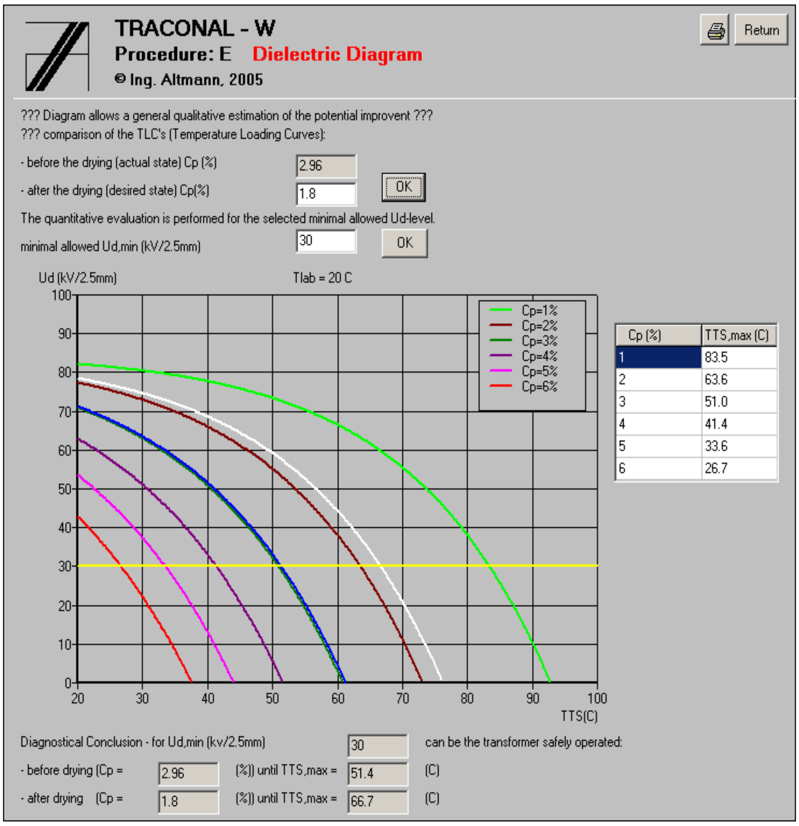
Step 2 – **Cellulose Water Content Record**

- time-related **trend of the moisture evolution** in the transformer
- critical assesment of all measured data and exclusion of wrong readings
- evaluation of the effectivity of the drying



Step 3. **Temperature Loading Curve (TLC)**

- determination of the relation between the dielectric strength of the oil and the transformer temperature (for given water content in cellulose) for the whole range of operation temperatures (**TLC curve**)
- verification of predicted **TLC curve** by measured values of dielectric strength
- prediction of the amount of the water which should be removed to meet user demands based at:
  - min. required dielectric strength of the oil
  - max. required temperature level of the transformer



Step 4. **Dielectric Diagram**

general assessment of qualitative and quantitative targets of transformer´s potentional treatment based on:

- comparison of TLC curves before – after the treatment (drying, filtration)
- determination of the allowed transformer temperatures - based on:
  - min. required dielectric strenth of the oil for the whole temp. range
  - for the whole water-in-cellulose range

7. On-Line Transformer Treatment – Vacuum separator VS-06

On-line dehydration, degassing and filtration of power transformers:

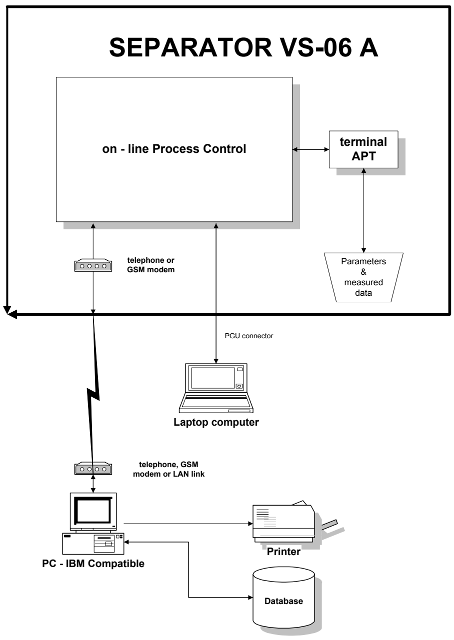
- no disconnection of the transformer under treatment, not even during the installation of a separator
- installation and service with minimum manpower and energy
- quick restoration of dielectric strength of oil
- direct verification of the dehydration efficiency via the volume of removed water
- no negative impacts on the chemistry of the insulating oil
- no over-drying of the transformer
- application of advanced and patented technologies like "hydraulic piston" for vacuum building and "bubble bed" for moisture separation
- all weather cover of the separator (CLIMABOX) and (on-demand) installed air-conditioner quarantees the trouble-free operation under very heavy conditions

Regardless of how efficient any method of **oil** dehydration might be - the first law of the on-line dehydration of **transformers is** always :

water removal from cellulose materials of the transformer has to be safe and effective

Any **on-line** transformer dehydration is ultimately governed by slow diffusion of the moisture from cellulose in the oil and this process can be accelerated only by a significant increase in temperature. But the second basic law of any on-line dehydration limits the effort because **:**

high transformer temperature → high water content in oil → high separation rate



means

→ low dielectric strength of oil → low immediate reliability of transformer

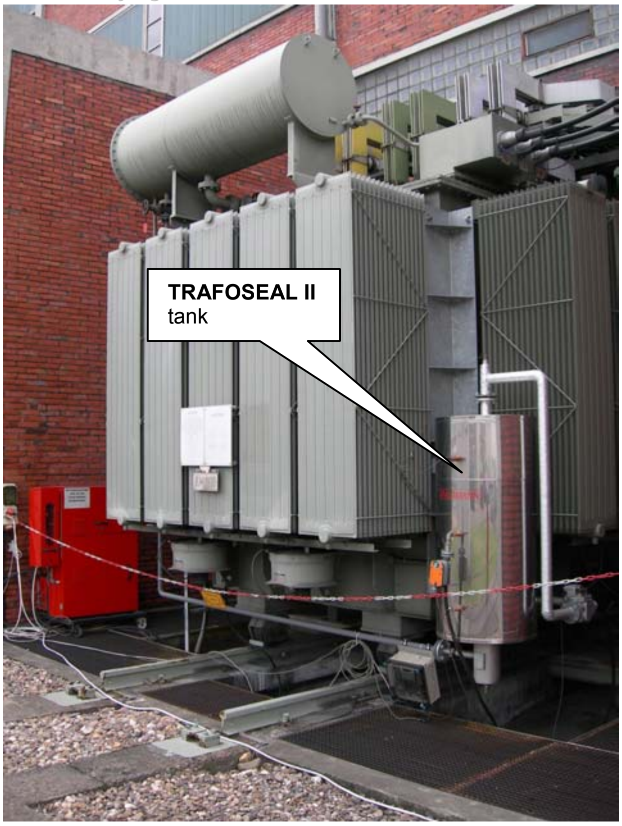
In order to avoid the lowering of the immediate reliability of the transformer, it is necessary to tune at least two antagonistic criteria in the whole process of dehydration :

- max. separating efficiency of dehydrator (max. water removal rate)
- dielectric strength of oil - has to be maintained or improved

To achieve this target the separator VS-06 A can be programmed directly (manually) via terminal of PCD 1 or better remotely with the use of suitable PC or lap-top on the basis of actual and previously measured values. **This way is possible not only to monitor and optimize the separator function but to optimize the whole dehydration process as well.**

8. Hermetisation of power transformers - TRAFOSEAL II

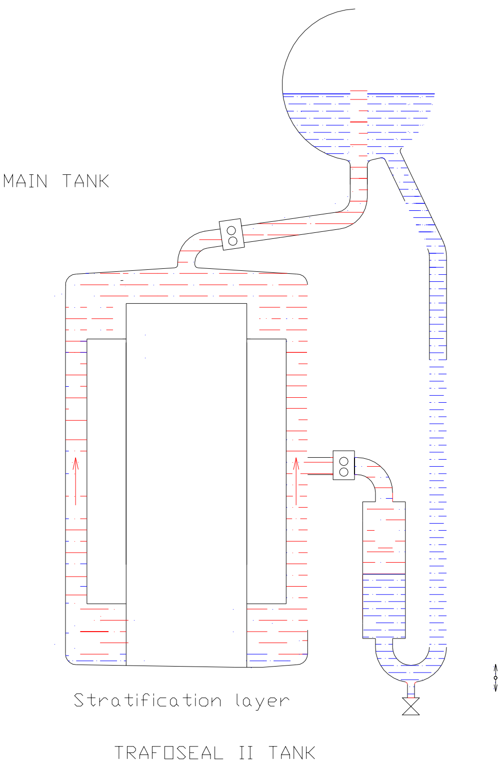
•no over-drying of the transformer



ARS-Altmann released a new art of hermetization of power transformers by means of thermal stratification layer which is spontaneously created as an „interface“ between **hot oil** (in main tank) and **cold oil** (in conservator).

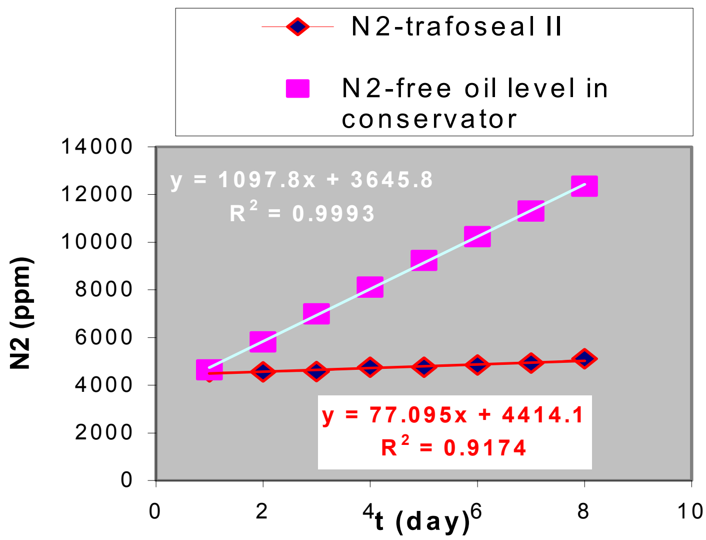
Main features

- permanent low oxygen level in the oil induces the high-order decreasing of the degradation of the oil-cellulose system of a transformer
- free mixing of **hot oil** from the main tank with the **cold and oxygen contaminated oil** from the conservator is effectively obstructed
- easy and simply installation – no modification of conservator and main tank of transformer is necessary
- no maintenance – „sealing element“ as a natural phenomenon of the oil is indestructible



Experimental verification of TRAFOSEAL function by the gradient method:

- degassing of the oil inventory of transformer
- comparison of the N2-saturation gradients by the same transformer with- and without the TRAFOSEAL II



Schematic lay-out of the TRAFOSEAL II