TRACONAL - W

TRAnsformer **CON**tamination **A**na**L**ysis
W **-** Water

Operational Manual

2012

ATTENTION : In accordance with IEC Norm the Cw - and Cp- value is in this version of Manual replaced by Qw and Qp, the signification and dimensions of both values remain the same as before.

1. Introduction

The software packet **TRACONAL - W** (**TRA**nsformer **CON**tamination **A**na**L**ysis - **W**ater) serves to easy , explicit and the comprehensible diagnostic of the moisture and subsequently the dielectric problem of the power transformers .

The present theoretical back-ground contained in **TRACONAL** allow us simple and logical interconnection all important directly measurable values as a:

- water content in the oil **Qw** (ppm)
- transformer temperature **T** (C)
- dielectric strenght of oil **Ud** (kV/2.5mm)

based on the not directly measurable

- **average water content in the cellulose Qp** (weight %).

The **TRACONAL** evaluation of all relevant sampling records enables us:

- the basic examination of the impact of the moisture on the oil-cellulose system
- the critical examination of the accuracy and the plausibility of all in-situ measured values
- the determination of the amount of water which has to be removed
- easy and plausible check of the effectiveness of any water-oriented treatment of the transformer
- the estimation of the intensity of ageing
- the identification of the potential sources of the decrease of the dielectric strenght of the oil
- the determination of safety limits of transformers
- the basic examination of the impact of particle content on the dielectric strenght

For more detailed description and a comprehensive understanding of the theoretical background of the TRACONAL W See articles at www.ars-altmann.com \News:

The Oil - Moisture Diagnostic Problem of Aged Transformers

The dielectric strenght of the transformer oil and its impact on the diagnostic of power transformers

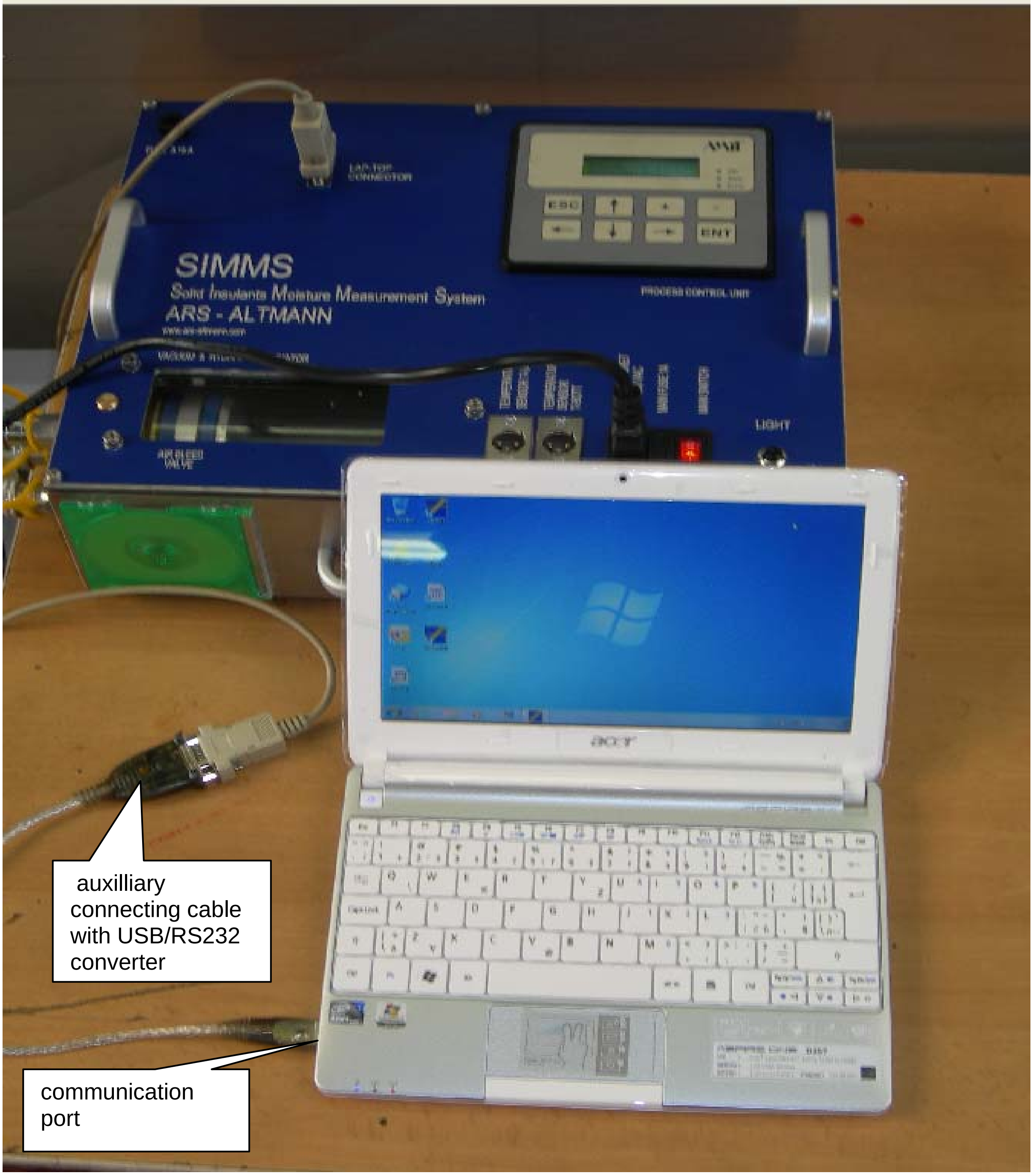
Dielectric Diagram

The Water Problem of Aged Transformers

2 . Program installation

Program TRACONAL - W is installed into small lap-top delivered with the SIMMS (is situated in its alu-container).

No additional setting of lap-top is necessary and allowed.



The lap-top contains all programs for the reading and implementation of the measured values and the main program (TRACONAL - W) for the their evaluation.

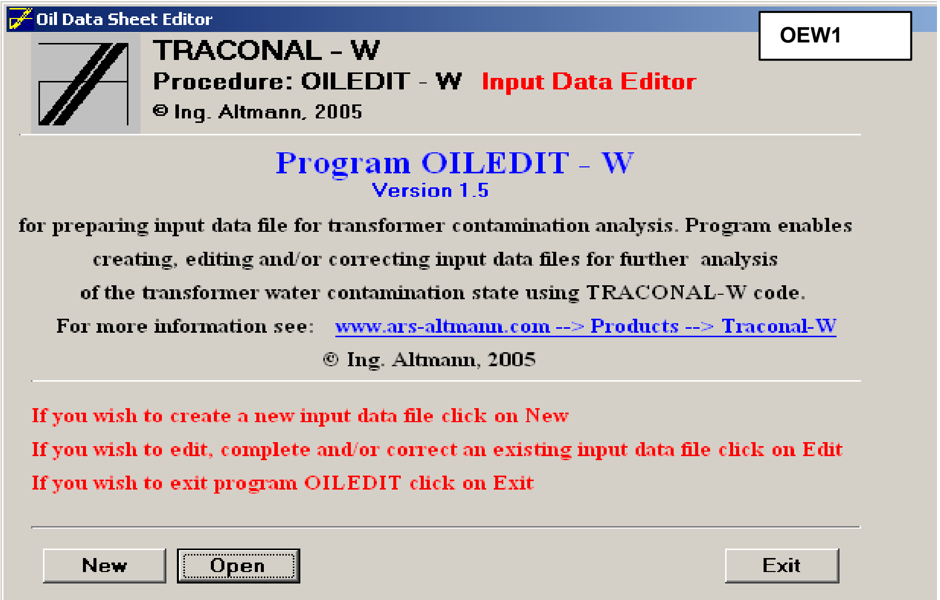
For communication with SIMMS use determined port only.

3. OILEDIT - W

The auxiliary free-ware program OILEDIT - W enables us the easy and comprehensive data collection.

OILEDIT- W is inicalized by double.clicking on the icon

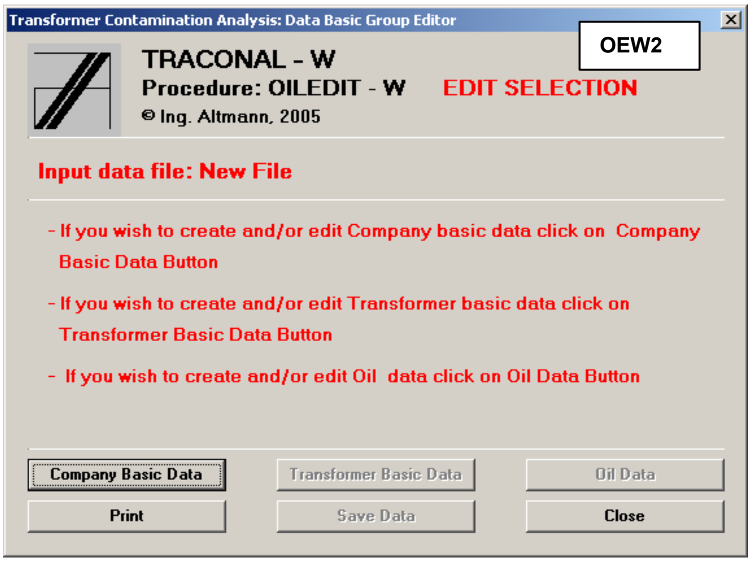
and program shows us the basic window (OEW1)



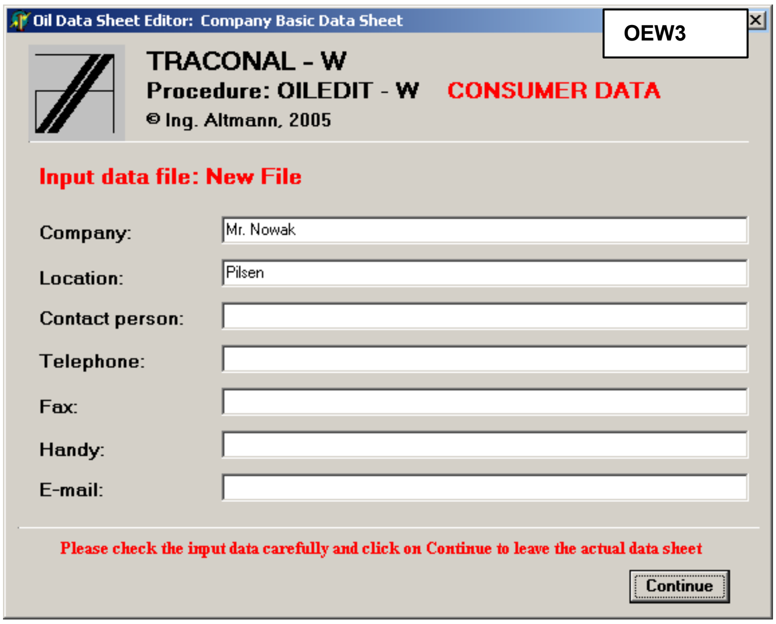
- If you want create new file (e.g. for new transformer) click on **New**
- If you want edit an existing file click on **Open**
- If you want terminate OILEDIT click on **Exit**

3.1 Creation of the new file

Let suppose we want create a new file – then we can open by double-clicking on **New** a window and we get the decision window (OEW2)



by click on the **Company Basic Data** Sheet (Consumer Data – window OEW3) is opened.

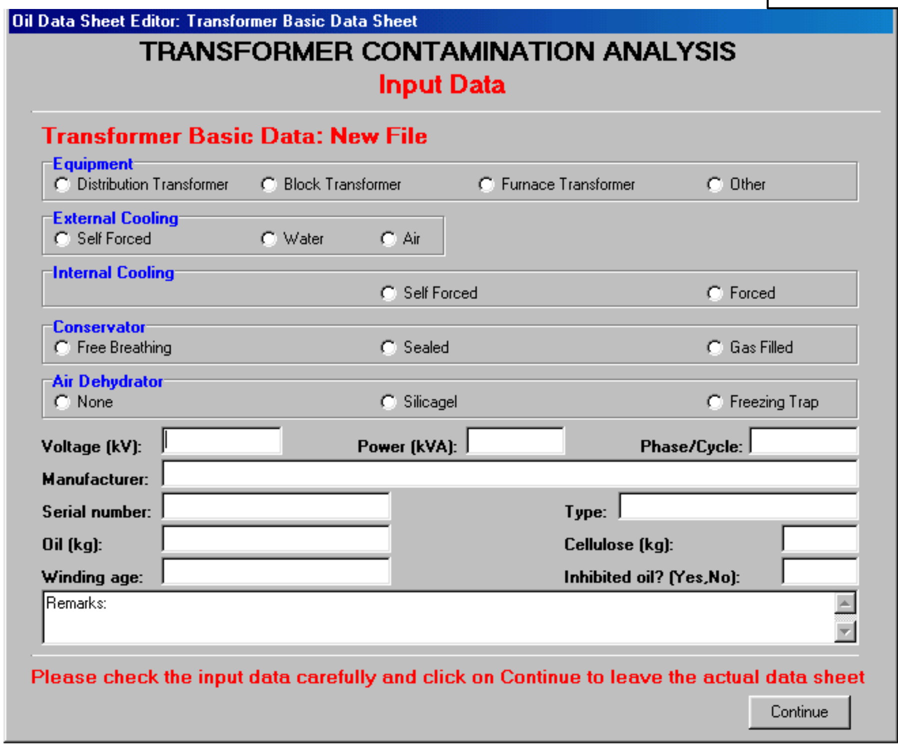


It is neccesary, before you click on **Continue**, to describe at least the rows **Company** and **Location -** or you get Warning message.:

After click on **Continue** the program offers empty **Transformer Basic Data (OEW4)** data-sheet for detailed description of the transformer.

For the description and specification of your transformer configuration and equipment, simply click inside internal disc-shaped icons – e.g. in the row Equipment on Distribution Transformer

OEW4

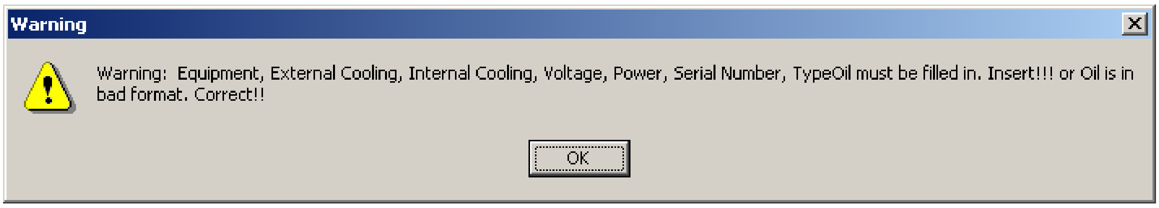


All mentioned data are important to the description of the transformer and for the proper and precise diagnostics of its insulating system

Please fill it out carefully

Most important value is <u>Oil (kg</u>) , the mass of Tx oil inventory

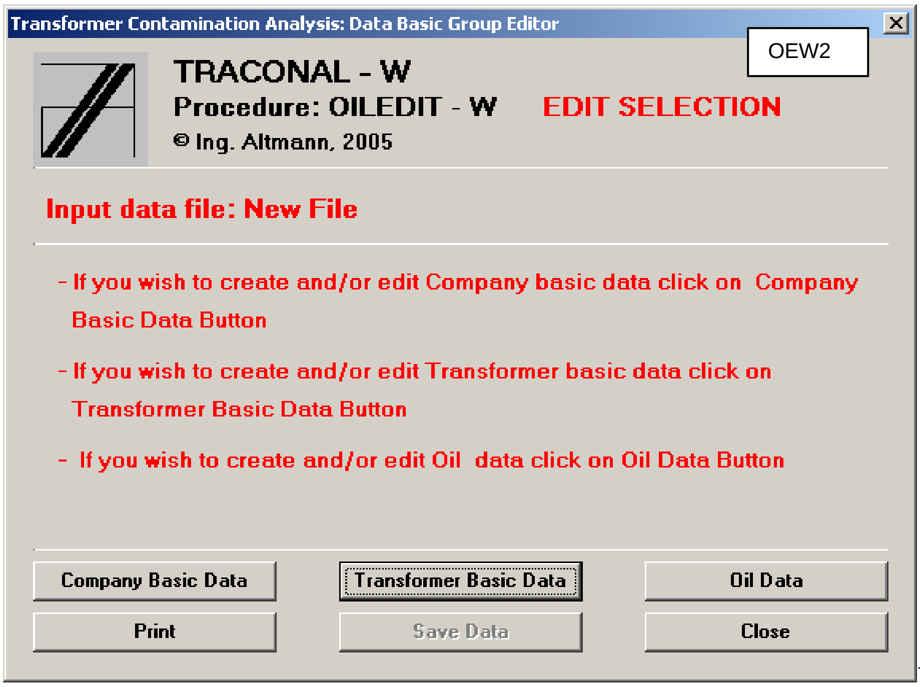
The program requires a certain minimal amount of parameters again – if is this demand not fulfilled - you get Warning message again



Attention

Without the proper fill-out you can not go forward by click by Continue to next step – Oil Data

After the click on **Continue** of the Basic Data Sheet the decision window OEW2 is displayed again

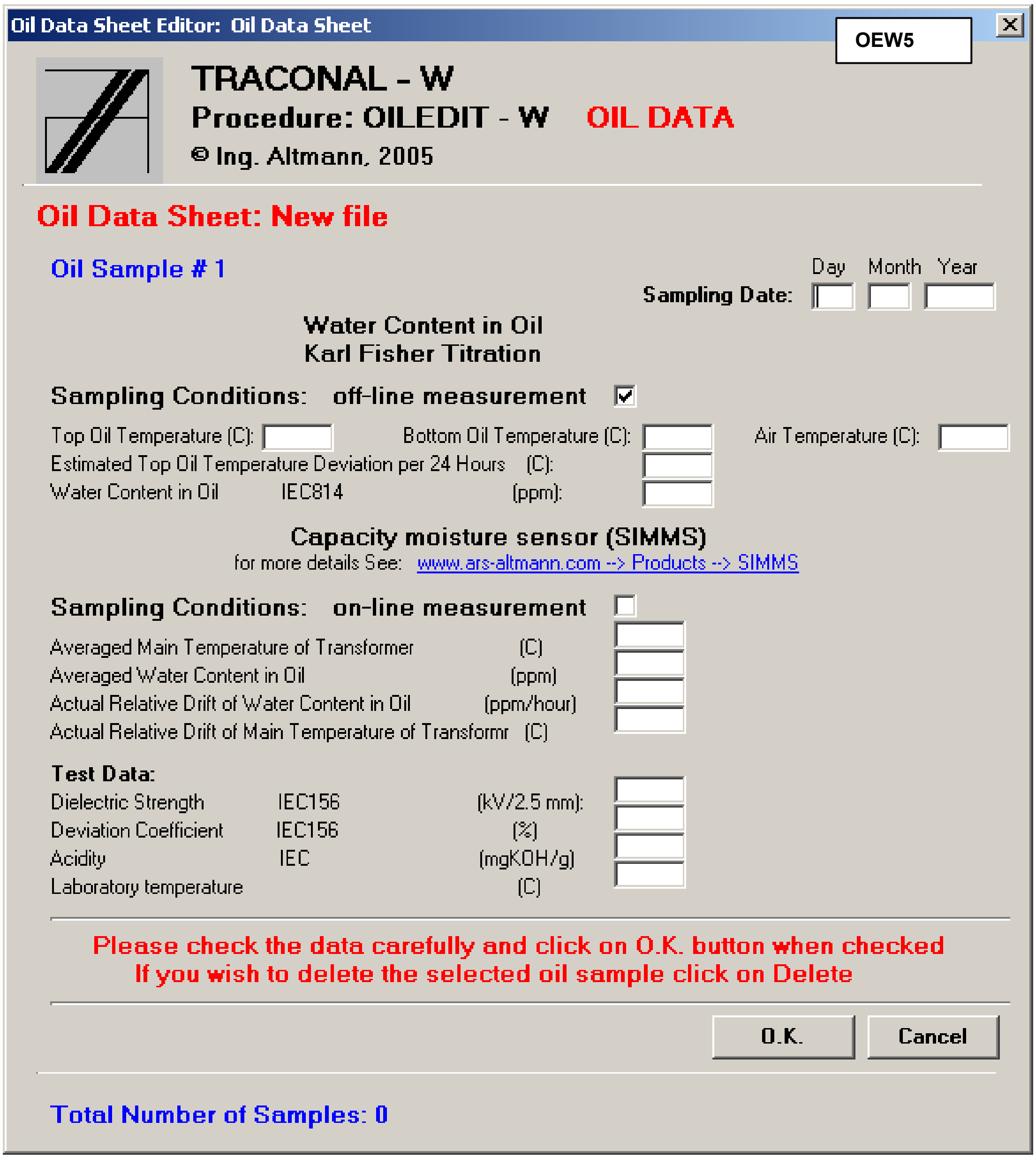


and the data collection continues by click on **Oil Data** Sheet: New file - an empty OIL DATA sheet (OEW5) is displayed.

The version 2005 of the **OilEdit** enables easy implementation results of two independent readings of the water content in the oil by:

- clasic Karl Fischer (KF) titration
- capacity moisture sensor (SIMMS – Solid Insulants Mobile Measurement System)

In principle both KF and SIMMS data can be measured the same day and therefore we are able them consequently implement into a one (day) file - KF and SIMMS data are then in the TRACONAL-W distinguisched by different graphical indicators and their mutual precision and plausibility is critically evaluated.



and the sheet have to be carefully filled out.

The plausible evaluation and the simulation of the transformer dielectric by the TRACONAL W, is always based not only at the precise reading moisture levels by KF or SIMMS but as well at the reading:

- o top and bottom temperature of the transformer
- o temperature of the oil in the lab before the measuring of the Ud-value – this temperature should not vary more than ± 5C

and – it is very important - at the proper evaluation of equilibrium condition of the transformer along the sampling procedure.

If the precise measuring of all temperatures and a proper evaluation of equlibrium conditions is not assured the following precise evaluation of the transformer dielectric by the TRACONAL-W is de-facto excluded.

all relevant data have to be very rigorously recorded in the sheet OEW5:

Off-line Sampling Conditions - standard oil analysis

Attention ! *Immediately by the standard one-shot oil sampling procedure (oil is sampled from a transformer by means of a sampling cock in the suitable flask) should be precisely measured all relevant temperatures of the transformer:*

Top Oil Temperature (C), Bottom Oil Temperature (C), surrounding temperature (C) and the estimation of the Top Oil temperature Deviation (C / 24 hour).

For the basic evaluation by the TRACONAL at least the Top Oil Temperature of the transformer is necessary.

Do not forget !
The precise evaluation of an equilibrium condition of the transformer based only on one-shot measurement of transformer temperatures is in principle impossible.
Therefore any following evaluation of the water content in the celulose and the evaluation of the transformer dielećtric is inevitably not very precise

The standard output of the oil analysis in the laboratory is then:

- **water content in oil Qw_{KF}** (ppm) measured most often by Karl Fischer titration,
- **dielectric strenght of oil Ud** (kV / 2.5mm),
- **acidity of oil** (**NN** – Neutralization Numer mgKOH/g oil)
- **laboratory temperature** (or better the temperature of an examined oil in the tub of the Ud-value tester).

❑ On-line Sampling Conditions - SIMMS

The SIMMS reads the water content in oil which is continuously drained from the oil inventory of a transformer, oil is then by-passing the humidity sensor (Vaisala MT162) and is forced back in the mentioned inventory. Simultaneously SIMMS enables us the on-line measuring of the top- and bottom temperature of the transformer and in the selected time period. For more detailed description of the SIMMS features See: SIMMS Operational Manual www.ars-altmann.com /Manuals.

Data aquired by the SIMMS can be in situ down-loaded in the lap top and evaluated. The result is then always qualitatively better as any off-line measuring procedure, because the equilibrium condition of the transformer can be easy and immediately evaluated this manner.

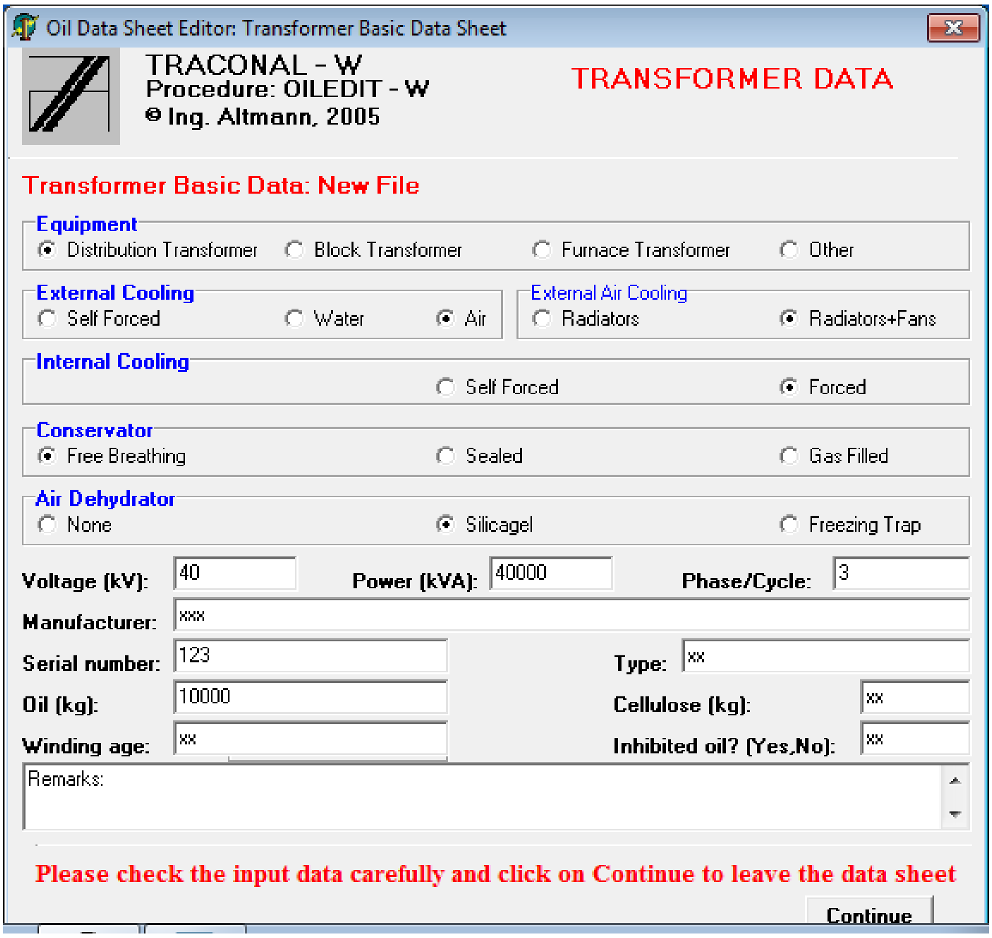
The standard outputs of the lap-top which are implemented in OEW5 :

- averaged main temperature of transformer (C)
- averaged main water content in oil (ppm)
- actual relative drift of water content in oil (ppm /hour)
- actual relative drift of main temperature of transformer (C/hour)

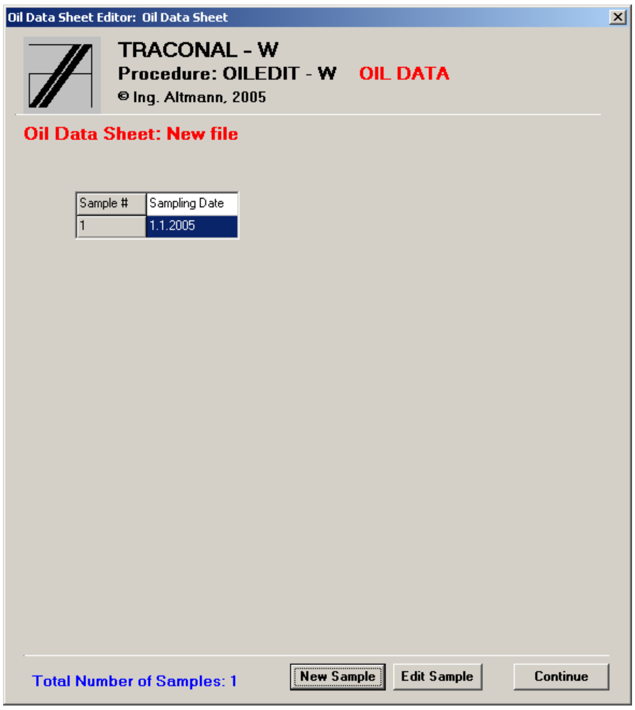
clicking on the O.K. is the collection of all new data finished and we can down-load collected data in the file.

Example : the creating of the new data file by OilEdit always begins by OEW1, continues by OEW2 and a declaration of basic information OEW3 of the client.

The Transformer Basic Data Sheet (OEW4) then specifies the transformer e.g.



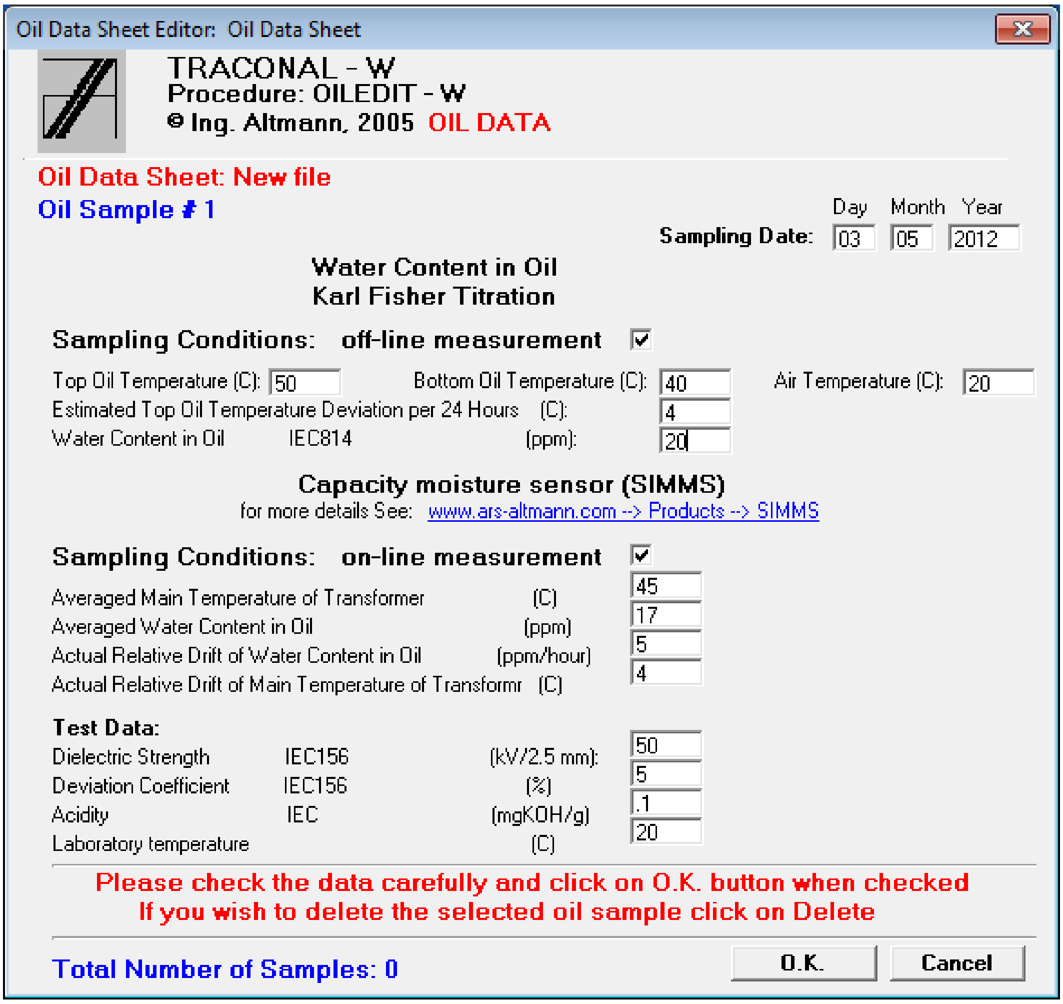
.By click on **Continue** we get Decision window OEW2 again and by click on **Oil Data** you can makes the program following proposal



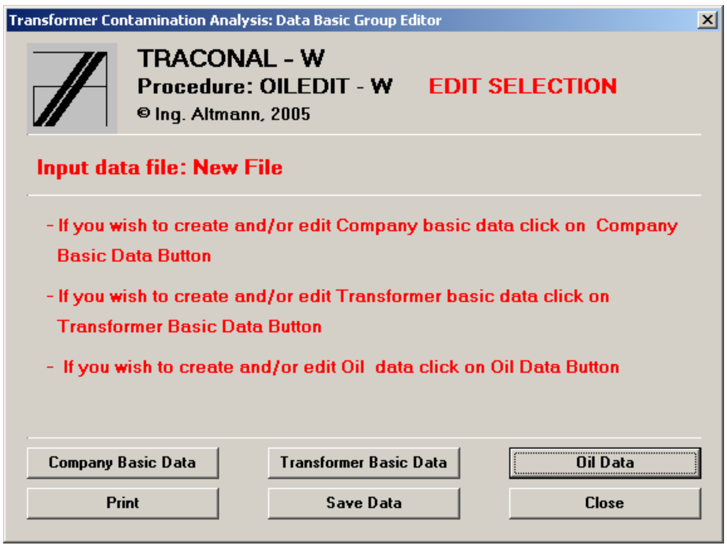
For a new file simply click on **New Sample** and you get empty **Oil Data Sheet** (OEW5)

Attention: this example shows off-line (lab data) and on-line reading (SIMMS data) together. There is of course no problem to implement only one of them into OEW5.

If all desired data are fulfilled

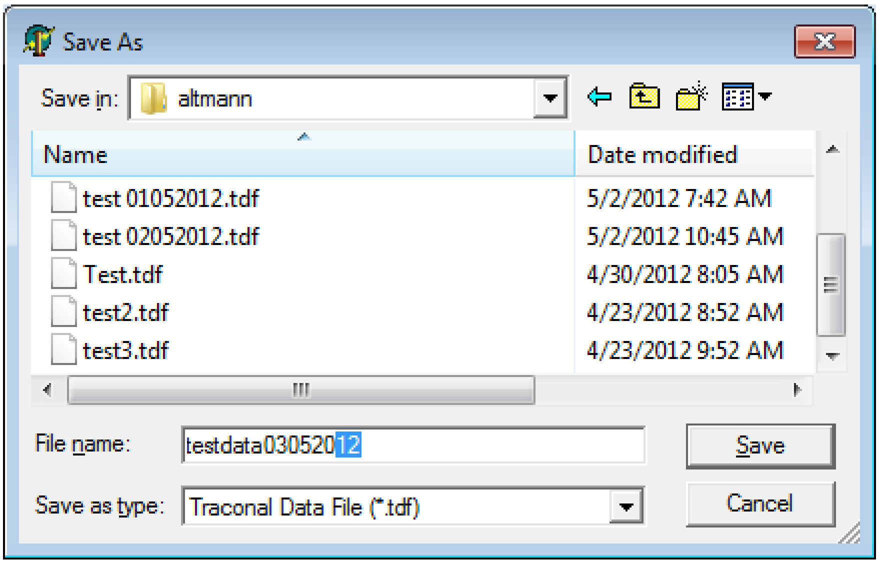


Click on OK finish the procedure and you get the sheet OEW2 again.

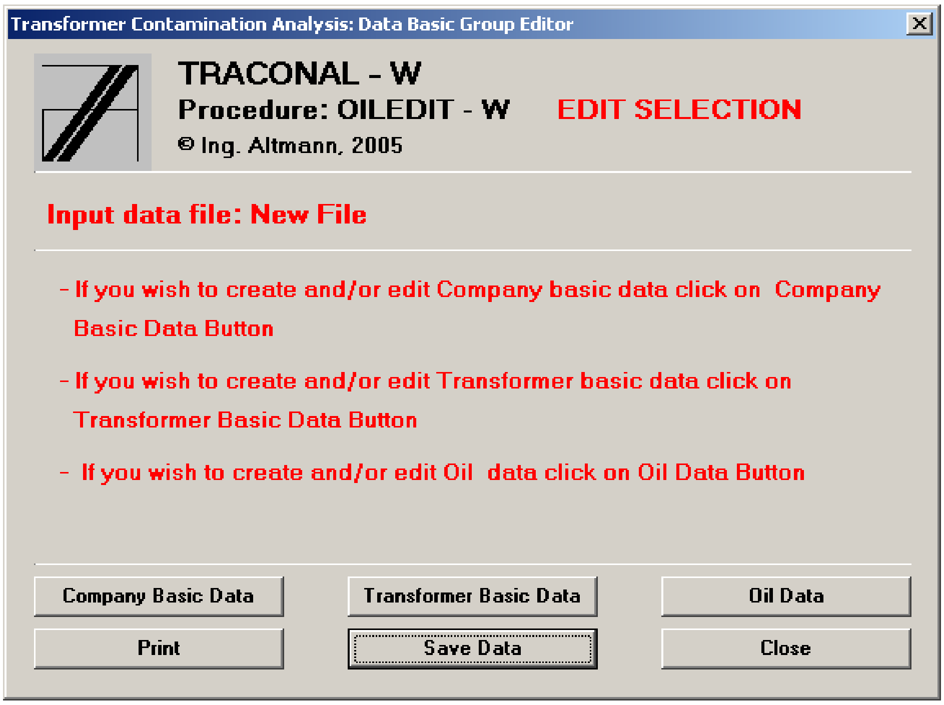


and you can save the data by click on **Save Data.**

An standard Windows sheet Save as is opened and you can down-load your data under selected name .



The whole procedure is finished by click on the Save and the sheet OEW2 is displayed again

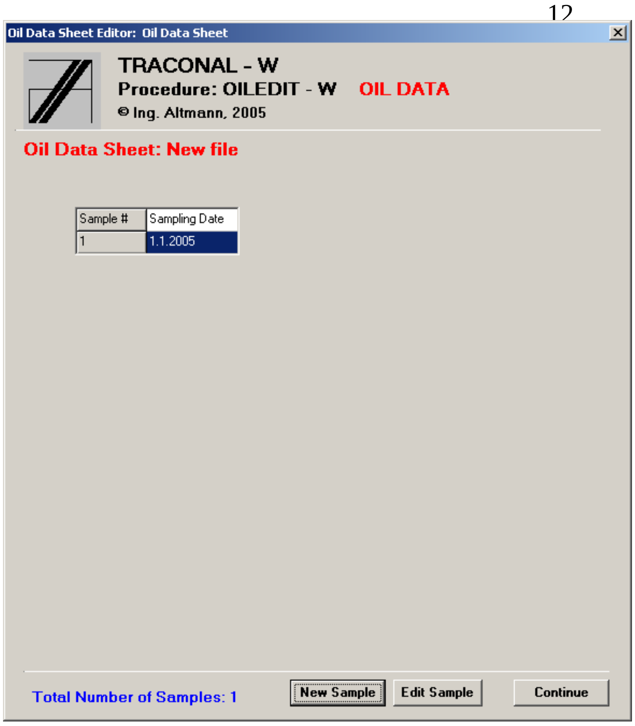


and by the click on **Close** the new data collecting procedure is finished.

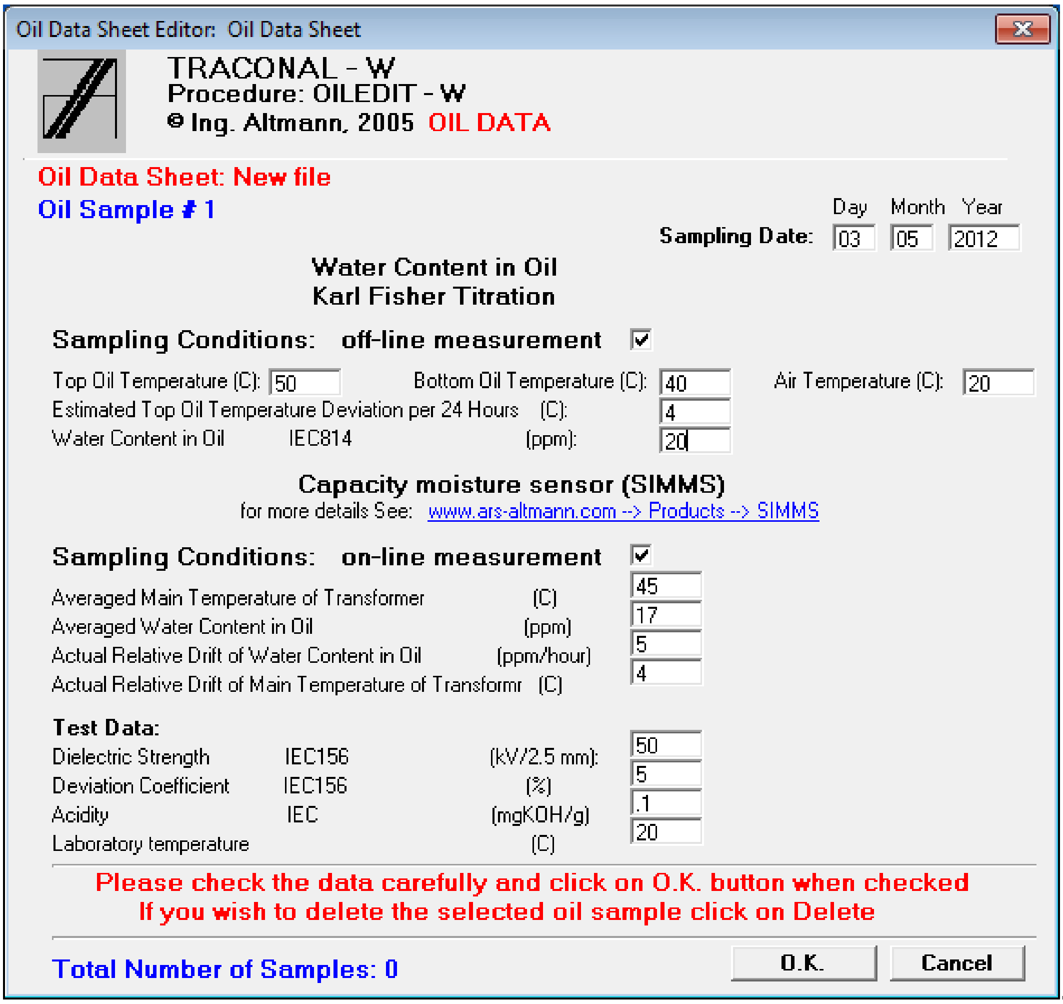
3.2 Edition of recorded data

The edition of existing data can be any time performed :

- click on Company Basic Data and Transformer Basic Data opens both windows directly. The data edition is then performed by the simple overwriting of the existing record + the confirmation by **Continue**
- click on the Oil Data opens at first the procedure



and the click on the Edit Sample opens existing Oil Datasheet

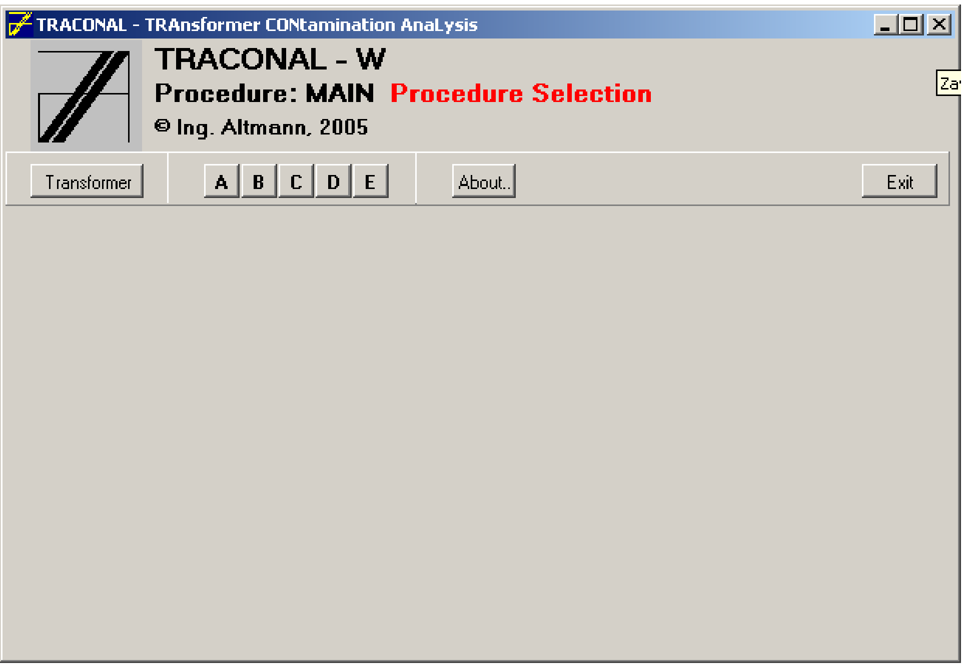


The data edition is then performed by the simple overwriting of the existing record again. The confirmation is then performed the same way by the **OK** .

4. TRACONAL W – TRAnsformer CONdition AnaLysis - Water

The TRACONAL program is started by clicking on the icon TRACONAL in the Main window .

This will bring up the main screen (shown below) to allow selection of the OILEDIT data base and commence analysis.

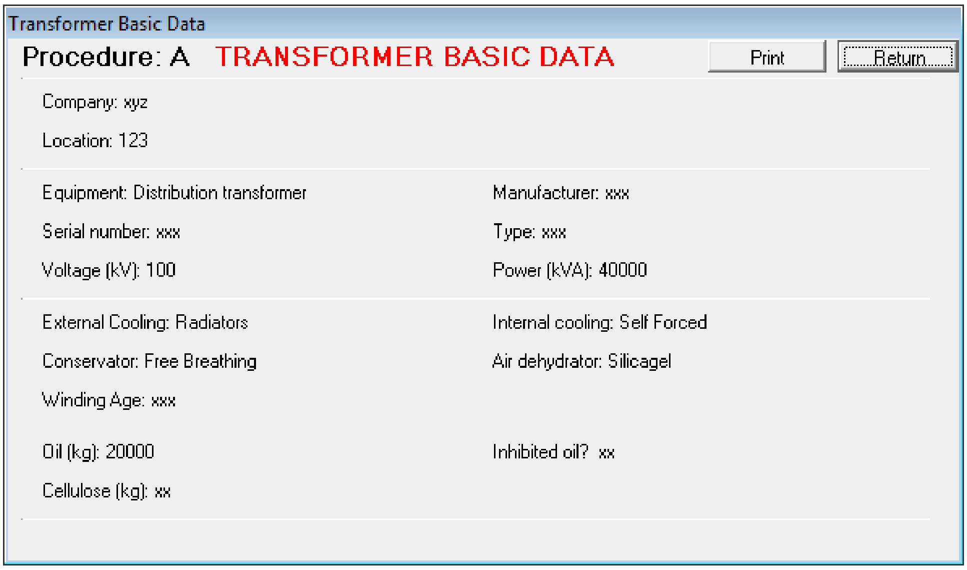


To retrieve the OILEDIT data file on the transformer to be analysed click on the **Transformer** button and select the OILEDIT data base from the file of the specific transformer that it is stored in.

Once selected click**,** and this will return you to the original main screen for the selection of analysis functions (selection buttons) A to E.

4.1 Procedure A.

Click on button **A**, and it will show the information relating to the consumer and specific basic data of a transformer . The page is usually used as the front page of the evaluation report being written. To copy this page (or any of the others) to a word or other document press ALT and Print Screen and paste it to the required document. If a printout is preferred click the printer button at the bottom of the page.



By clicking on **Return** (in the **Procedure: Main**) we go back to the main page.

4.2 Procedure B, uses the water content in oil (Qw - ppm) and transformer temperature(s) contained in the OILEDIT - W file. This gives an evaluation of the percentage of water in the cellulose insulation by weight (Qp) and how much water must be removed from the insulating system to obtain the desired dielectric strenght etc.

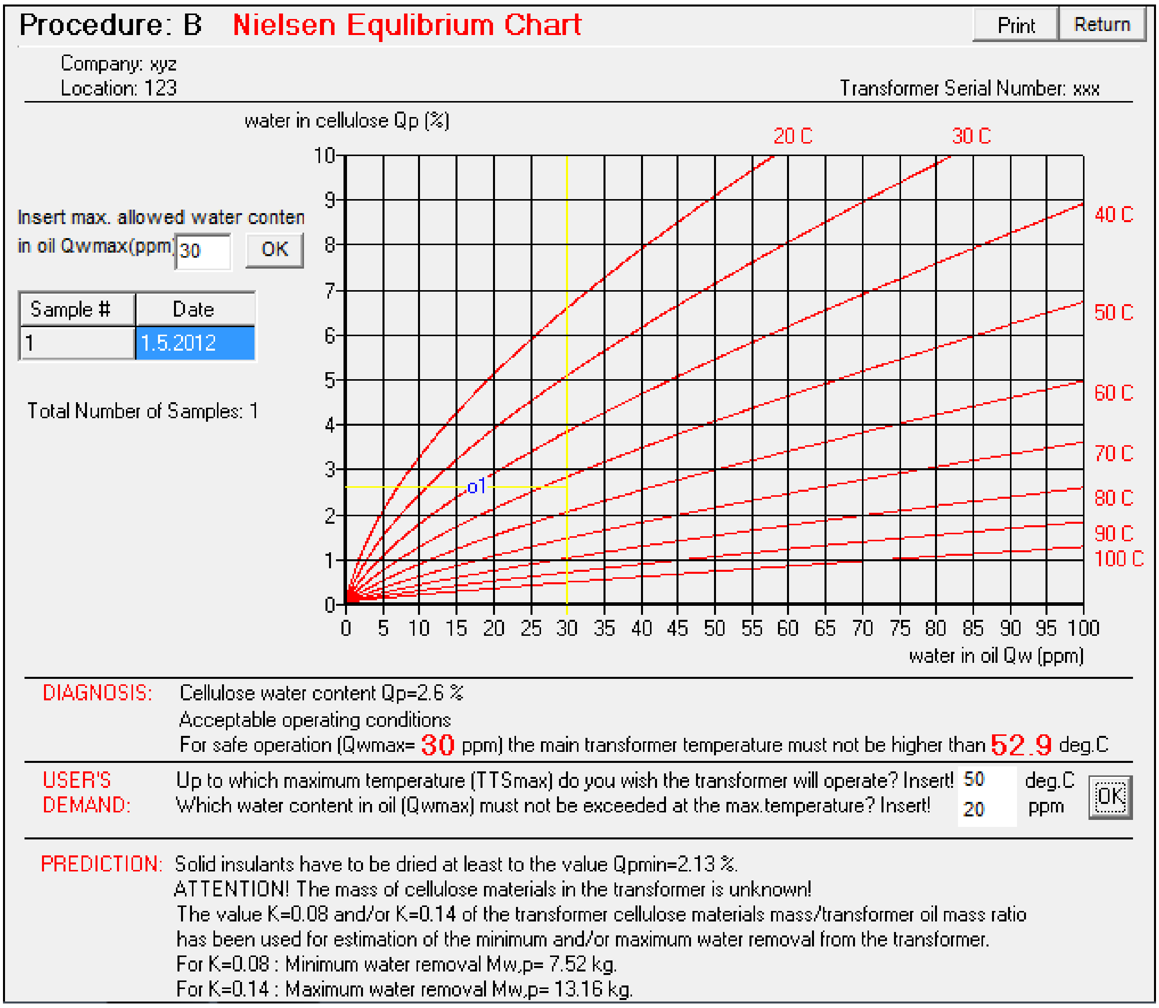
The value Qp (weight %) is used for the condition evaluation because we know that:

The calculated Qp value represents the average water content of <u>all</u> of the cellulose insulants in the transformer, and, that the Qp volume does not change with the transformer temperature !!

In practicle terms, if we take an oil sample from the transformer under any temperature we must (under equlibrium conditions) get the same Qp value.

The Qp value is <u>temperature invariant</u>, and therefore this key value alone is fundamental for determining the moisture related problems of any transformer.

The Function B page is started by clicking on B, which shows the Nielsen diagram.



The OIL EDIT data is shown on the Nielsen equilibrium chart as **Qp** values of all samples obtained by the classic KF and by the SIMMS reading.

Blue rings (and records in the left table) correspond to KF readings and alternatively yellow rings (and records) correspond to SIMMS readings.

The points are chronologically numbered – the highest number represents the last sampling.

The Qp value from the last sample is used as the current water content of the insulating cellulose and that value alone is used as the basis for diagnosing the state of the transformer.

The **DIAGNOSIS** procedure shows that in this specific case **the average water content in solid insulants** Qp = 2.6%.

The interactive procedure then allows to determine the next, very important parameter of any transformer : **max. allowed operational averaged temperature** without a transgression of maximal allowed water content in oil (Qwmax)

For the norm-demanded Qwmax = 30 ppm, the averaged temperature of this specific transformer should not exceed **52,9C**.

The **USER´S DEMAND** procedure is interactive again and allows the maximum operating temperature and the maximum allowed ppm of water in the oil to be entered.

Let's suppose that we want the water content in the oil (Qw) to not exceed 20 ppm at the maximum average temperature (TTSmax) of 50C.

Then press OK.

This will display in the **PREDICTION** section how the Qp-value of the cellulose must be reduced to (Qpmin = 2.13% in this case) to meet the required operating temperature and the water contents in the oil.

As the volume (weight) of the cellulose insulation is usually not known two parameters are given for water removal guidance.

K=0.08 calculates the water removal on the basis of an 8% cellulose to oil weight ratio,

and K=0.14 on 14%.

All standard power transformers have cellulose to oil weight ratios between 8% and 14%.

Start by removing water based on the lower calculation and confirm the cellulose ratio as the water is removed (by measuring the removed water).
The USER´S DEMAND procedure can be repeated at will for any temperature and ppm values with resulting recommendations for water removal predictions.

The basic diagnosis of the state of the transformer can be based on the following table:

Qp (%)	Transformer condition
< 0.8	new or properly dried
0.8 - 2.0	good operational state
2.0 - 3.3	paper starts to deteriorate
3.3 – 4.5	check the intensity of the celulose aging
> 4.5	flashover possible at 90 ^{o}C
> 6.5	flashover possible at 50 ^{o}C
> 8.0	immediately shut-down and drying

For our transformer the last sampling was Qp = 2.6% and according to the demand (20 ppm at 50C) should be reduced to 2.13% , it means that the amount of water to be removed is between:

Minimum : 7.52 kg

Maximum: 13.62 kg

4.3 Function C, shows the trend of the moisture in cellulose problem over the time frame of the given samples.

Thesis

The moisture problem of the transformer cannot be exactly determined on the basis of ONE oil-sample.

The reason is simple – from one-shot oil sample result we cannot:

- verify the data using the cross-correlation of the time-related sampling data
- find the source of water problem (e.g. ***ageing or leaks***) of the system which is always identified by the time-related process
- judge and examine the time trends of the ageing intensity versus the moisture increase and, perhaps even forcast the future danger potential.

Thesis 2

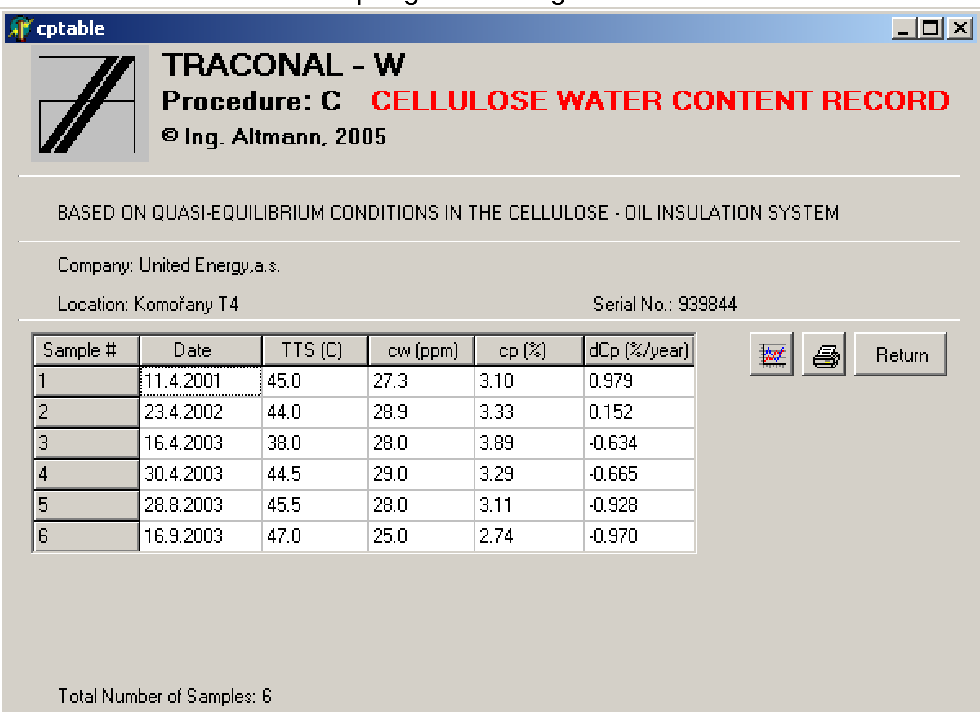
The moisture problem of the aged transformer cannot be properly determined on the basis of the Karl-Fisher reading of the water content in the oil because KF reads not only diluted water but in acids bonded water as well. A suitable humidity sensor must be used.

For the most comprehensive analysis of the transformer moisture problem, it is necessary to use all available oil sample records and then analyse the Qp trend over the sampling time frame.

The Qp value, which represents the moisture problem of the transformer, under operational conditions can only either remain constant or slowly and continuously increase over time.

Data verification

Click on **C** we can for example get following **Cellulose Water Content Record** (table)



cptable

TRACONAL - W

Procedure: C CELLULOSE WATER CONTENT RECORD

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BASED ON QUASI-EQUILIBRIUM CONDITIONS IN THE CELLULOSE - OIL INSULATION SYSTEM

Company: United Energy,a.s.

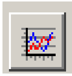
Location: Komořany T4 Serial No.: 939844

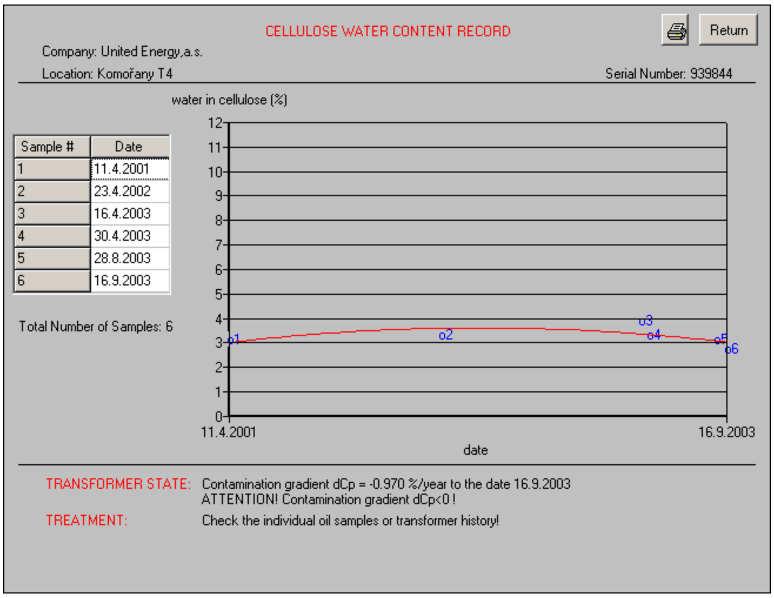
Sample #	Date	TTS (C)	cw (ppm)	cp (%)	dCp (%/year)
1	11.4.2001	45.0	27.3	3.10	0.979
2	23.4.2002	44.0	28.9	3.33	0.152
3	16.4.2003	38.0	28.0	3.89	-0.634
4	30.4.2003	44.5	29.0	3.29	-0.665
5	28.8.2003	45.5	28.0	3.11	-0.928
6	16.9.2003	47.0	25.0	2.74	-0.970

Return

Total Number of Samples: 6

The dQp (% / year) shows the contamination gradient over the sampling time, which should be either constant or a slight increase. But the example contamination gradient change rises and drops significantly on the third sample, and out of reasonable range of the other three samples. Therefore is there is something wrong with this sample data.

For time-oriented graph we can click the button 

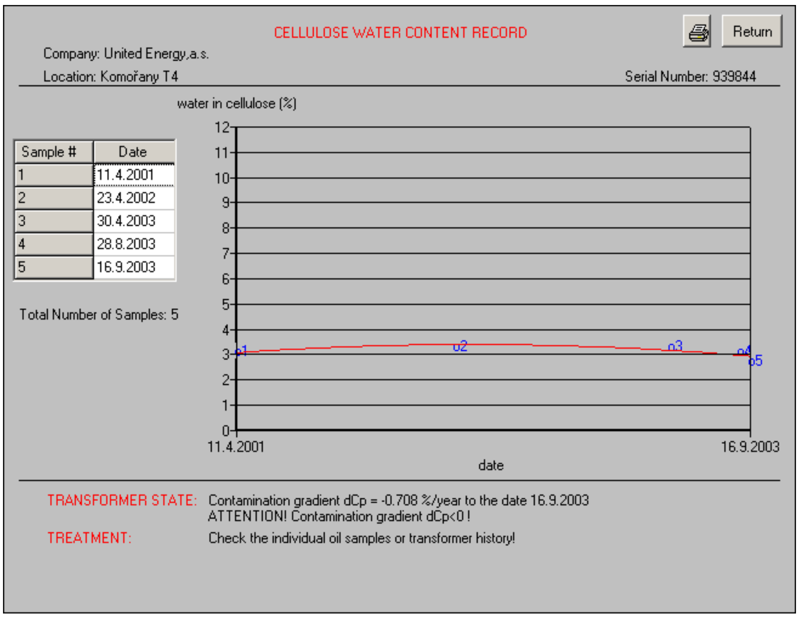


From this graph and we can examine the plausibility and accuracy of all data in detail on the basis of the time-related correlation curve. This way we can easy recognize abnormal data and make changes to the OILEDIT data base.

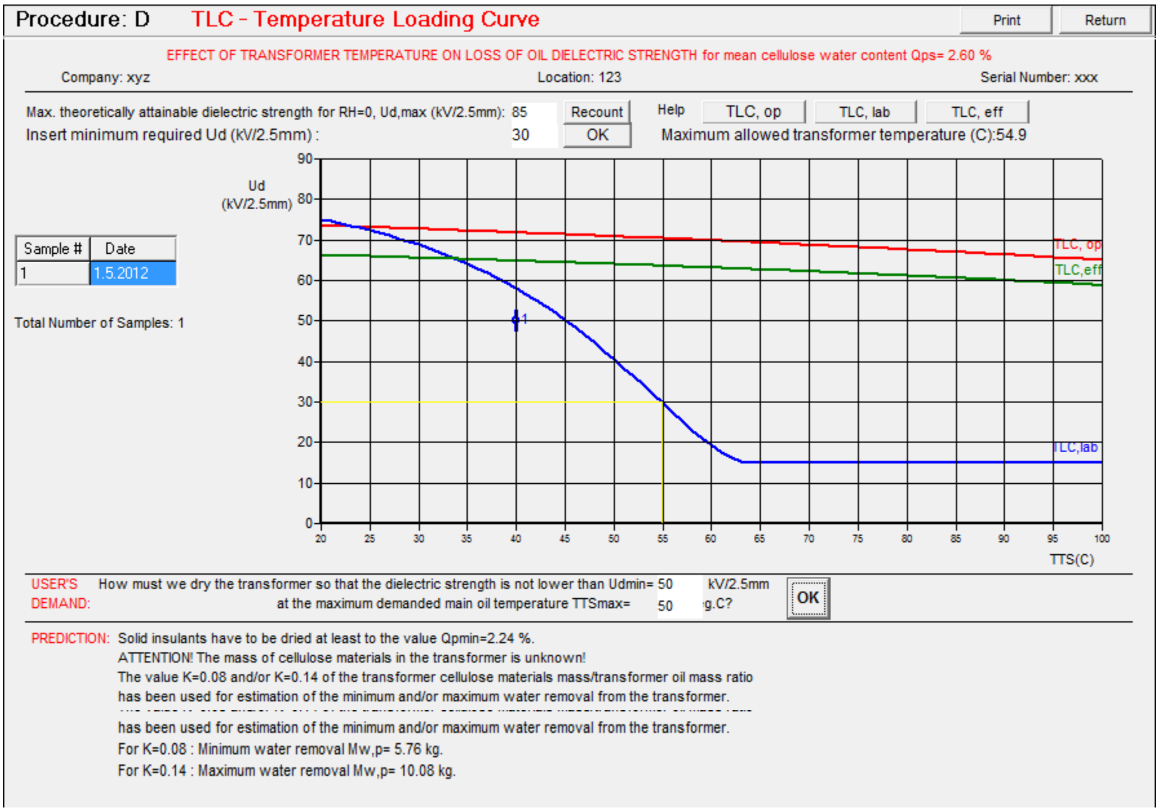
We can see that the third sample point is obviously wrong (Qp-value sudenly increases and decreases) and the sample 3 must be oviously excluded from the data-log. Sampling errors are not uncommon when traditional laboratory methods are used, especially if is a sampling performed under non-verified equilibrium conditions of the transformer – the investigation has confirmed that the temperature of the transformer was sinking.

We therefore must go back to the OILEDIT program, click on **Edit** to bring up the United T4 data file and select and delete corresponding oil data sheet .

New evaluation by the C procedure then shows essentially better results.



4.4 Procedure D, describes the effect of the temperature change on the dielectric strength of the oil in the transformer for the whole operational range of given transformer See following diagram.



The effect on the reduction in the dielectric strength (Ud-value) with temperature is described by :

- **Blue curve, the TLC** represents the traditional diagnostical approach – the ***oil is sampled at operational temperature of the transformer (in this case at ca 40C)*** and ***measured in the laboratory at approx. 20C***. The temperature drop causes an increase in relative saturation of the oil and a corresponding reduction in Ud-strength.
- **Red curve** shows the maximum attainable dielelectric strength, if the ***oil is tested in the lab at the same temperature as it was collected at (40C)***

TRACONAL solves the particle problem (decrease of Ud-values) by introducing another "**green**" curve which respects the effect of the particles. The presence and the effect of the particles in the oil can be easy indicated by the comparisson of the real (measured) and theoretical Ud-values.

In the oil without particles the red and green curve are of course the same.

Diagnostic tools:

1. **determination of maximum allowed operational averaged temperature** without a transgression of **minimum allowed dielectric strenght of oil** (Udmin), here 30 kV/2.5mm. Click on OK give us Tx-temp. 54.9C. The same graphic result is shown in the left bottom part of diagram (yelow lines).
2. **amount of water which has to be removed from Tx** to meet requested Ud-value at requested (averaged) Tx- temperature.

The input of procedure is under the **USER´S DEMAND** again.

Let’s suppose that we want the dielectric strength of the oil (Udmin) doesn´t decrease under 50 kV/2.5mm at the maximum average temperature (TTSmax) of 50C.

Then press OK.

This will display in the **PREDICTION** section how the Qp-value must be reduced to (Qpmin = 2.24 in this case) to meet the required operating temperature and the Udmin-value in the oil.

The amount of water to be removed to meet the target is then between:

Minimum : 5.76 kg

Maximum: 10.08 kg

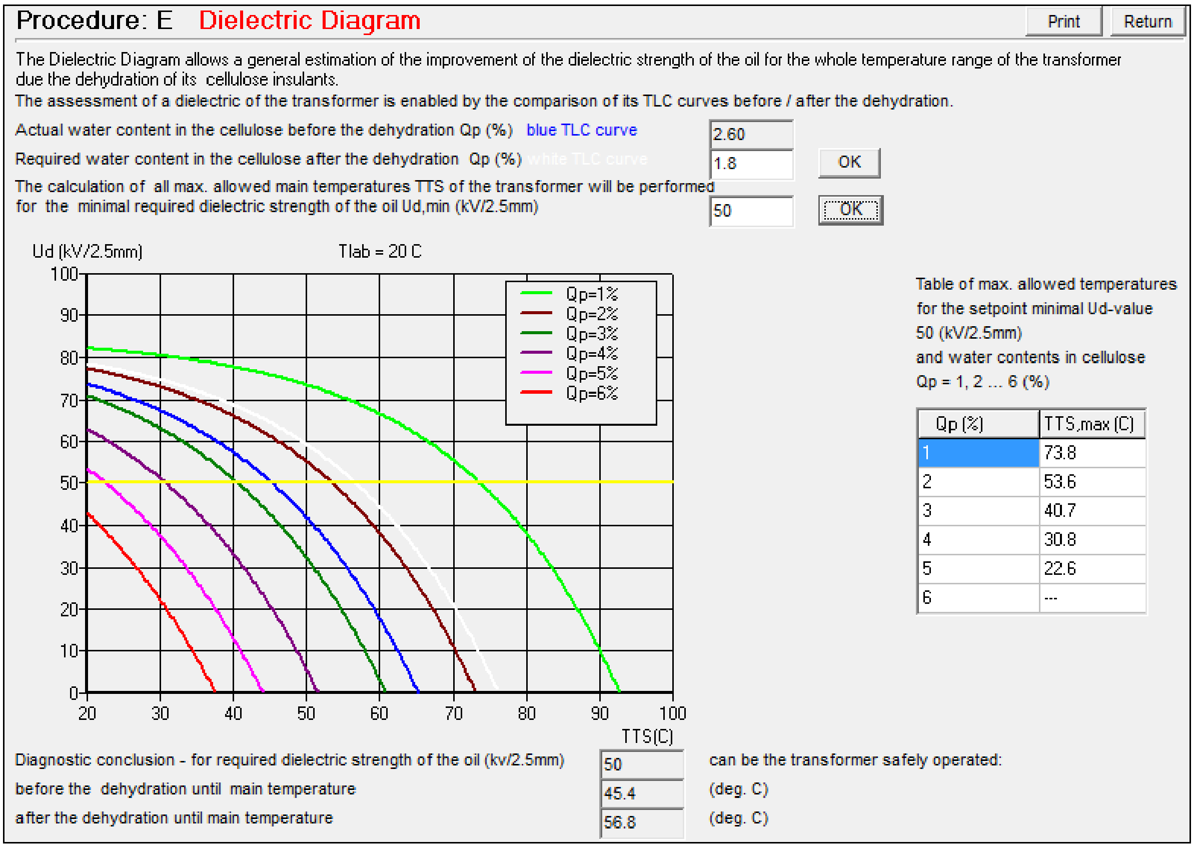
4.5 **Procedure E** - Dielectric Diagram

Up to now, we have been only interpret readings or outputs of measurement methods concerning transformers.

But our ultimative target should to be always a deeper insight into a dielectric problem of the given transformer.

In our case, we have to therefore not only find the quantitative impact of all relations between the dielectric strength of oil (Ud-value), the temperature invariant of the water content in cellulose (Qp-value), and the examined transformer's average temperature (TTS), but we should qualitatively understand the transformer dielectric behaviour as the whole.

This target can be relatively easy achieved by means of Dielectric Diagram (See: www.ars-altmann.com /News) under the Procedure E by using a **before – after dehydration** approach.



BEFORE – blue TLC curve (before drying)

original averaged water content in the cellulose is Cp=2.6 % , the desired Ud-value 50 kV /2.5 mm corresponds maximal allowed (averaged) transformer temperature TTS = 45.4 C

AFTER – white TLC curve (after drying)

New (requested) averaged water content in the cellulose is Cp=1.8% , the transformer can be for now loaded till maximal (averaged) temperature TTS = 56.8 C, and the Ud-value remains over 50 kV/2.5mm.

The same procedure can be of course done for any desired (or normed) Ud-level, to achieve a general insight in the dielectric problem of the given transformer.

The results is – we understand (and "smell"!) what is possible or necessary.