Tx–MultiScan

Portable Online & InSitu Transformer Diagnostic System

Tx-MultiScan Service Unit

Operational Manual

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1. Introduction

Collecting one oil sample per year and processing it a lab, cannot provide the acurate data that is vital for avoiding failures and the subsequent management of the appropriate treatment program of the wet, gas saturated and/or aged transformer.

Generally are there three basic diagnostic problems:

- **moisture problem** – the standard reading based on the Karl Fisher method only shows very often the deep inconsistency between the predicted and real amount of removed water
- **dielectric problem** – the lab reading of the dielectric strength of aged oils is very often inconsistent with the water content in the oil acquired by the Karl-Fisher method.
- **gas problem** – the Total Gas Content in the oil (the TGC-value) that is necessary for the examination of the real condition of a transformer which could not be evaluated in-situ.

The first and second problem can be very effectively solved by the implementation of the direct on-line reading of the relative humidity of the oil , the reading of the operational temperatures of the transformer and their proper evaluation.

On the other hand, the gas problem has two different but very important diagnostic aspects:

- **short-term reliability** of a free oil level transformer – especially the prediction and evaluation of its shut-downs induced by oversaturation of the oil filling (due Buchholz Relay actions)
- **long-term reliability** of a hermetized transformer - especially the evaluation of the efficiency of its sealing elements and subsequent prediction and evaluation of its life-expectancy (ingress of the O2 : intensity of oxidation aging of its insulants).

Today, neither of the above diagnostic aspects are executable in situ.

The **ARS-Altmann** has therefore released the **Tx-MultiScan** , version 2011**,** a miniaturized portable oil sampler & evaluation system which enables the **in situ** of the correct samplings and corresponding relevant readings and evaluations of all above mentioned values. The **Tx-MultiScan** can be easily used for the reading of any kind of a transformer.

The basic readings and diagnostic results achieved by the **Tx-MultiScan** system covers the following diagnostic areas:

- ⇒ water content in oil – Chapter 1.1.
- ⇒ water content in cellulose + ***determination of amount of water to be removed to meet norm-required water content in oil at requested temperature of transformer*** - Chapter 1.2.
- ⇒ TLC relation, the prediction of the dielectric strength of oil (Ud-value) as the function of the temperature of the transformer + ***determination of amount of water to be removed to meet norm-required value of dielectric strength in oil at requested temperature of transformer*** – Chapter 1.3
- ⇒ actual (theoretical) dielectric strenght of oil - Chapter 1.4.
- ⇒ total gas content (Qp-value) in oil – Chapter 1.5.

The major advantages of the **Tx-MultiScan** are:

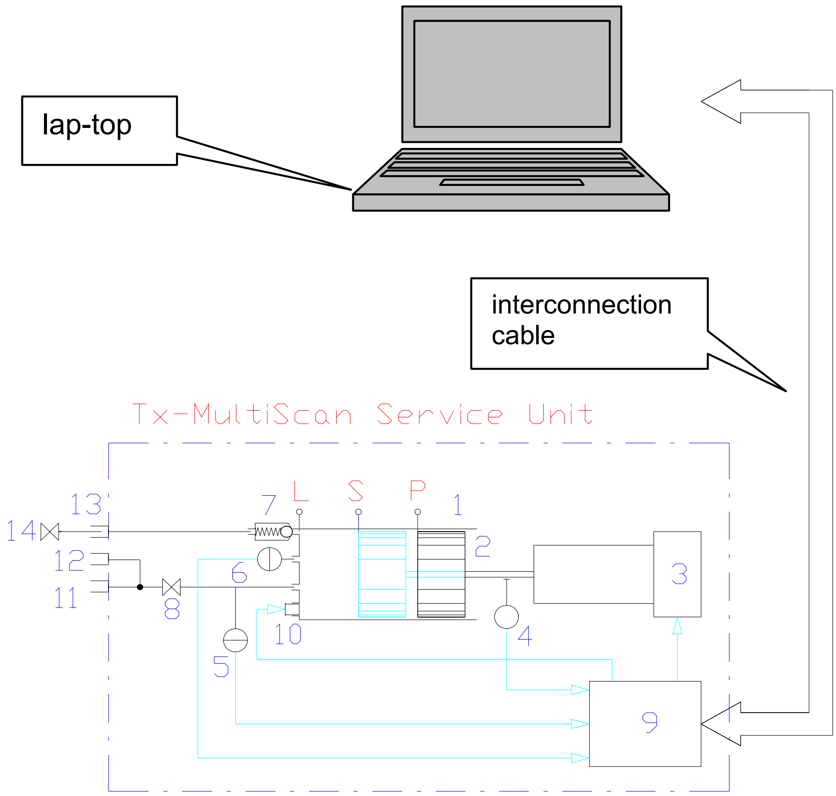
- **on-line reading** – under normal operational conditions of a transformer
- **no contamination of oil within sampling & reading**
- **no loss of oil due to sampling**
- **first results are available in situ, in hours**

The **Tx-MultiScan system ,** See Fig. 1 consists of :

- **Tx-MultiScan Service Unit** (**SU**), the mechanical/hydraulical system See Fig. 2, 3 which samples the oil from the oil filling of a transfrormer, then reads the basic data giving the relative moisture of the oil, its gas content and temperatures, analyses and evaluates them and forces the oil back into the transformer.

The SU can always be used separately, but only for acquiring of elementary data of a transformer.

- **lap-top** interconnected to the **SU** via a data and control cable, then reads the information preprocessed by the **SU**, evaluates them in more detailed manner and offers their time-related visualization and interpretation.



1		Glas cylinder	7		Non-return valve
2		Piston	8		Hydraulic Switch
3		Actuator	9		PCD AMIT
4		Stroke (piston motion) sensor	10		Hydrodynamic stirrer
5		Moisture sensor (Vaisala MMT 162)	11,12, 13		Hydraulic Quick Coupling QC1, QC2 and QC3
6		Pressure sensor (DMB331)	14		Flash Cock

Fig. 1 The operating diagram of the Tx-MultiScan system (version 2012)

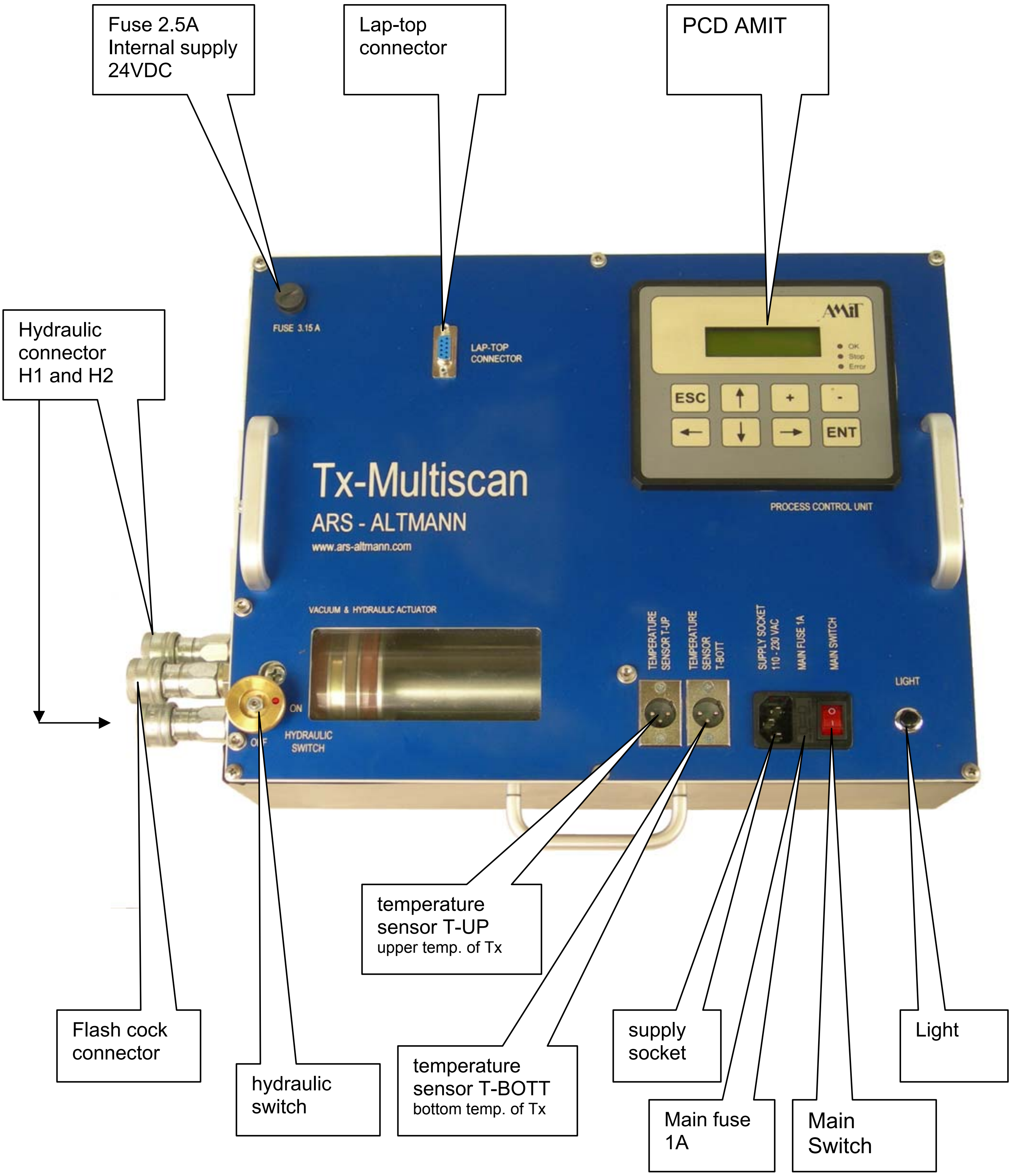


Fig. 2 The face-plate of the Service Unit (**SU**)

1.1. Water content in oil

The reading of the water content in the oil filling of a transformer is performed by the humidity sensor Vaisala MT 162 situated in the **SU** box :

- **semi-continuously** – oil is periodically drained from the oil filling of a transformer into the **SU** and forced back via **one single hose connection** between the (selected) sampling cock at a transformer and the **SU** - See. Fig. 4.
- **continuously** – the oil is permanently being drained from the oil filling via the first sampling cock and the first hose into the **SU ,** analyzed and then forced back via second hose and the second sampling cock into the oil filling – See Fig. 5.

The application of the precise humidity sensor eliminates the basic disadvantage of standard lab Karl Fisher readings:

- **the reading of water content in aged oils is to too high**, *the KF-methods reads not only relevant (diluted) water in the oil, but the bonded water in acids as well.*

But:

*between cellulose materials and oil filling migrates **diluted** water only*

it means

only diluted water is relevant for evaluation of the water contamination of a transformer

.

This basic disadvantage of KF-readings then inevitably leads to too high values of water content in **cellulose** materials

- **the discrepancy between the readings of water content and the Ud-readings of oil.**

The next advantage of the Tx-MultiScan system is the total exclusion of all external contaminations. After the installation on a transformer, all hydraulical connections between the Service Unit (SU) and the transformer are at first vacuated and their tightness is evaluated by the computer controlled vacuum test.

From the start of the operation, the sampled oil is in no way exposed to the atmosphere and therefore any kind of an external contamination is excluded.

The reading of the water content in the oil is the next part of the measuring procedure.

1.2 Water in cellulose

The evaluation of the water content in cellulose materials of a transformer performed by the **Tx-MultiScan** system is based on a time-related reading of :

- water content in the oil (the Qw-value) by a moisture sensor which reads the relative humidity of the oil
- the reading of the transformer temperature by means of two temperature sensors: the first is installed on its the upper part of the transformer and reads its upper temperature (the T-Up-value) and the second one is installed on its bottom part and reads its bottom temperature (the T-BOTT value).

All mentioned values have to be read under equilibrium conditions of a transformer, where the water migration between the cellulose and the oil filling is insignificant and the oil-cellulose equilibrium conditions for the relevant evaluation of the water content in the cellulose, is quaranted.

This is of course an ideal case. The “absolute equilibrium condition” in a real transformer, under continuous and inevitable change of its oil temperature, is unattainable under operational conditions.

The **Tx-MultiScan** system solves this specific “equilibrium” problem by the on-line reading and the subsequent evaluation of the time-variation of both values during the pre-defined time-period:

- ⇒ If the variation of values remain in predefined limits, this state is considered as the acceptable quasi-equilibrium, corresponding readings are therefore considered relevant and can be used for the subseqent evaluation via an equilibrium “chart”.
- ⇒ If this is not the case – the reading is potentially not correct and should be terminated

The outputs of both temperature sensors and the oil humidity sensor are processed by PCD AMIT of the **SU** (See Fig. 2). All time-related data are continuously loaded in the AMIT memory and are available for additional processing by laptop.

A good accurate snapshot can be made within ca 30 - 60mins, more accurately than using any other traditional methods. In order to follow the migratory patterns in seeking the equilibrium, more time is recommended to produce the snapshot. This is a simple, accurate and cost effective means for determining the level of water in the paper.

Tx-MultiScan visualization software implemented in the lap-top gives us then the desired overall time-related profile - water content in oil Qw = Qw (t) and both temperatures Tu = Tu (t), Tb = Tb (t) – upper / bottom transformer temperatures, auxiliary temperature level of moisture transmitter TV = TV(t) and mean temperature level of transformer TTS = TTS (t).

After checking the proper equilibrium state of the measured transformer, the averaged (mean) Qw and TTS values are immediately used to calculate the water content in the cellulose Qp and Temperature Loading Curve (TLC) of the given transformer.

Tx-MultiScan system diagnostic procedure for the evaluation of the water content in cellulose uses two kind of readings of the transformer :

1.2.1 **SU – 1P Connection** (single oil connection between the **SU** and a transformer)

SU - 1P is usually connected to one of the oil sampling point (See Fig.3) e.g. mid way up the main tank.

At first, **SU** checks the tightness all hydraulical connections by the vaccum test. Then, **SU** draws the oil sample down periodically from the oil filling, analyses it and returns it back to the transformer.
The connnecting hose, between the **SU** and a transformer, used for the 1-P reading always has to be a short one. This ensures that the sample is always representing the pattern of the oil inventory. It is very convenient for smaller transformers, or even larger ones **where the oil sample cock is directly connected to the oil in the main tank** without internal piping (if there are any doubts, always use the **2P Procedure** !!).

Temperature sensors are connected to the bottom and top sleeves connecting the main tank with radiators allowing an average (mean) temperature to be established.

The SU -1P is mostly used for quick online snapshots of the water (or gas) content in the oil and temperature profiles. For more precise reading the 2-P connection is always used.

1.2.2 **SU – 2P** Connection

The **SU** is connected to two oil sample taps, one at the top, one at the bottom of a transformer. Then, both connecting hoses are emptied of air to avoid any contamination. The tightness of all hydraulical connections is then checked via the vacuum test .

Afterwards, the oil is drawn (**D**own – **U**p or **U**p – **D**own, See Fig.4) continuously through the **SU** unit and passed back to the transformer. Independent temperature sensors are fitted to the identified top and bottom positions at the transformer.

Once the **SU–2P** version is installed, connected and started up, the transformer´s top and bottom temperatures and water content in the oil (ppm) are recorded on a time based log. Within ca 40 - 60 minutes accurate snapshot decision information is made by the laptop connected to the **SU** .

1.2.3 **Transformer Equilibrium Check**

The primary question after carrying out this specific measurement is : Are the adequate equilibrium conditions (approximately constant average temperature TTS and water content in oil Qw) in the transformer reached or not ?

This evaluation can be made:

- after the measurement of the water content in cellulose by the **SU** is finished
- simultaneously: the time-related values are on-line evaluated by the lap-top

If **YES** (the transformer is in an acceptable equilibrium), all the necessary calculations (average water content in cellulose, the Qp-value, Temperature Loading Curve - TLC …) can be made immediately by the laptop (and corresponding software).

If **NO**, the on-line measurement for a twenty-four-hour period (or a complete load cycle period) is usually necessary. That allows us to reach the desired accuracy in determining the average water content in the solid insulation, and the temperature related to the temperature-related movement and time lag of the water movement between the paper and the oil.

1.2.4 **The evaluation of the water content in cellulose**

This procedure is performed by the connected lap-top and uses measured values of water in the oil the Qw-value (ppm) and upper temperature of the transformer, the T-UP-value and bottom transformer temperature, the T-BOTT-value, for the evaluation of the percentage of water in its cellulose insulation the Qp-value (weight %).

Subsequently, the amount of water is calculated which has to be removed from the insulating system to obtain the desired, or norm-requested, water content in oil and the actual (theoretical) dielectric strength of oil (the Ud-value).

The Qp -value is used for the condition evaluation because we know that:

The calculated Q_p value represents here not only the average water content of cellulose insulants in the transformer

but

<u>its temperature- invariant parameter</u>

because

the Qp-value of any transformer doesn´t substantially change by the temperature-driven water migration between oil and cellulose because the amount of water which migrates between the celluse insulants and oil filling is very low compared to amount of water absorbed in the celluse .

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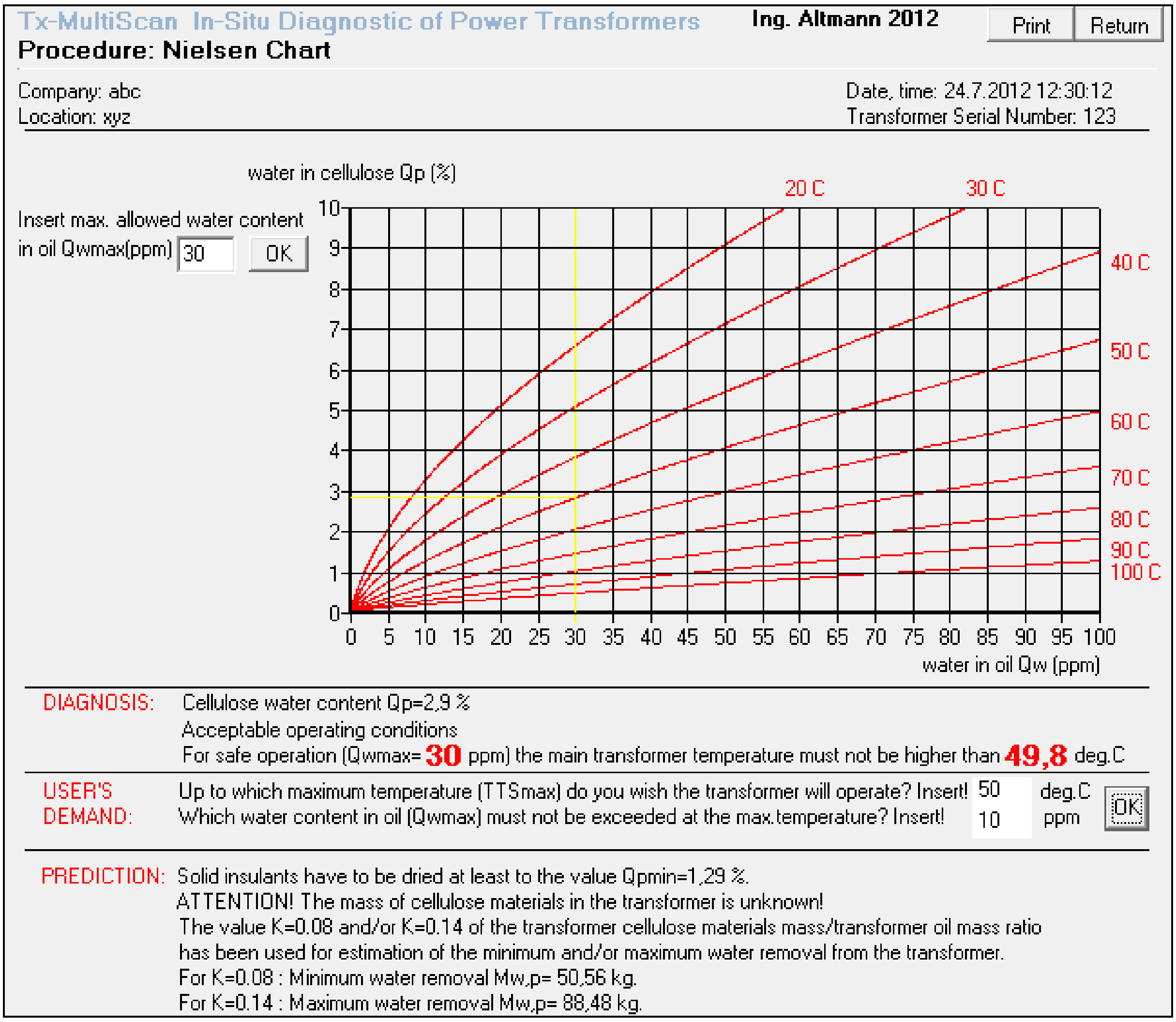
In practical terms, if we take an oil sample from the transformer under any temperature we must (under equlibrium conditions) get approximately the same Qp-value.

The Qp-value as an almost temperature constant, represents the key value of a moisture related problems of any transformer. which **enables the prediction of the most important (Qw, Ud) values for the whole temperature range of the transformer**

For the easy interpretation the improved and experimentally verified Nielsen equilibrium chart (relation) is used.



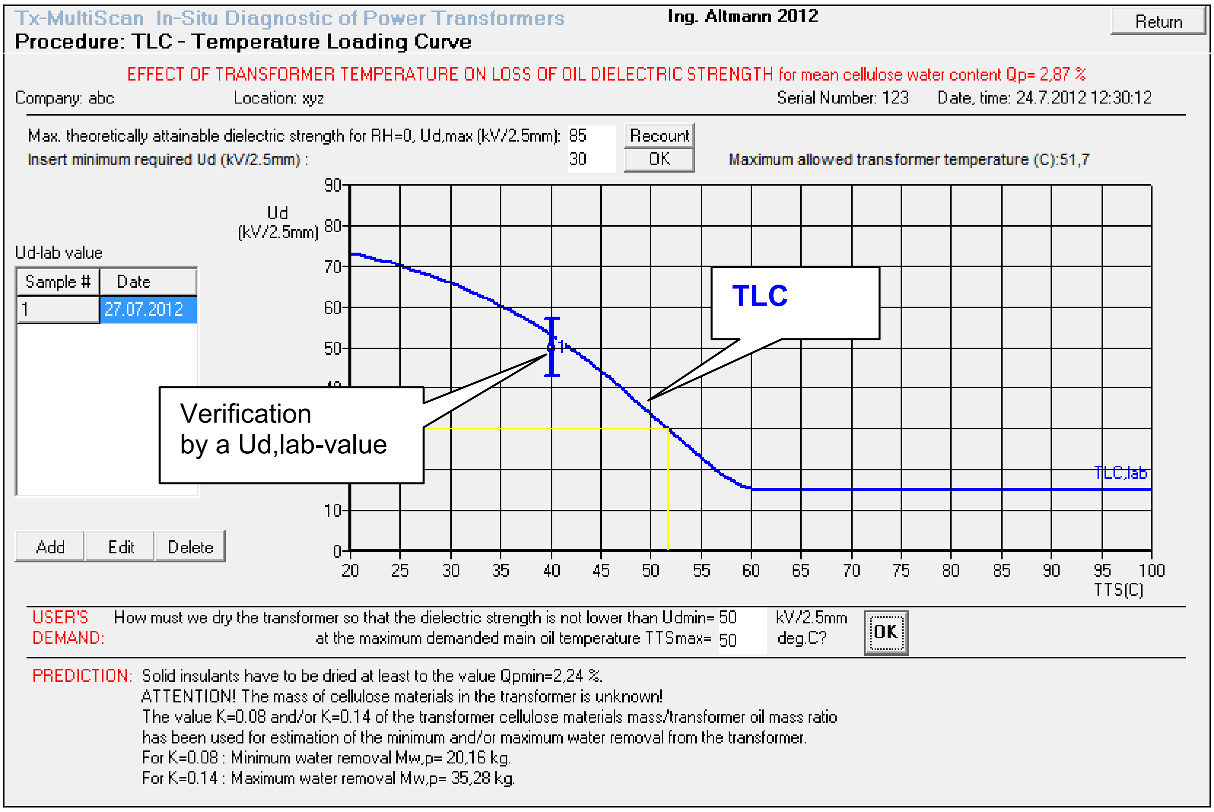
- **Diagnosis** section then interprets the reading and calculates the averaged water content in cellulose (here Qp= 2.9%). Based on the entry of target value of water content in oil Qwmax = 30ppm and given water content in cellulose Qp = 2.9% then calculates the maximum allowed operating temperatures of the transfomer, here **49.8C** (indicated as the point of intersection of both yelow lines)
- **User´s demands** section is interactive and allows clients to enter pre-demanded values of:
  - maximum operating temperature of transformer (50C)
  - maximum allowed water content in oil (10ppm)

for further predictions.

- o **Prediction** section then calculates how much water has to be removed from this specific transformer to meet given demands (minimum ca 50 kg of water has to be removed in this case).

1.3 TLC-relation

This procedure uses the given Qp-value (%) for the calculation of the TLC-relation. The TLC(Temperature Loading Curve) then **predicts the dielectric strength of oil, the Ud-value**, **for the whole temperature range (here 20 – 100C) of this specific transformer.**



Simultaneously, based on the calculated TLC and allowed dielectric strength of oil (30 kV/2.5mm , horizontal yelow line), the maximum allowed temperature of the transformer (vertical yellow line : ca 51.7C) is determined.

The next calculation (Prediction) shows how much water must be removed from the insulating system (at the given temperature of the transformer) to meet the pre-determined miminum (e.g. norm-requested) dielectric strength of oil in its oil filling.

User´s demands section is interactive again and allows the entry of values:

- (minimum-requested) dielectric strength of oil
- requested operating temperature of transformer

for further predictions.

Prediction section then calculates how much water has to be removed from this specific transformer to meet these demands.

Verification of diagnostic results by Ud-lab value(s) based on the comparison of theoretical Ud-value (TLC-curve) with the Ud-lab value (See point **1** with error bars) at the same sampling time and the same temperature of the transformer.

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1.4 Total Gas Content (TGC-value) of oil

The reading of the TGC-value of the transformer is based on the volumetric reading of gases liberated from the oil under gradually increasing vacuum and the intensive stirring of the oil.

To preserve the objectivity and repeatibility of TGC-readings, the gas contamination of oil in the measuring cylinder of the **SU** has naturally to be the same as the gas contamination of the oil filling of the transformer.

The sampling procedure is therefore perfomed at the end of the 1-P or the 2-P procedure when the measuring cylinder of the **SU** and connecting hose(s) is always properly rinsed out by the oil from the oil filling of the transformer.

The gas separation / gas content reading procedure consists of following steps:

1. the **SU** draws the exact defined volume of oil from oil filling of the transformer into its measuring cylinder (piston moves from the position L to the position S , See Fig. 1.)
2. The measuring cylinder is hermetically closed by the hydraulic switch (See Fig.2)
3. The internal volume of the cylinder is gradually increased by the motion of the piston (from the position S to P) and the corresponding rapid decrease of the absolute pressure and the stirring of the oil causes the effective separation of gases from the oil.
4. liberated gases are gradually compressed by the motion of the piston in the opposite direction and their total volume is then evaluated under the normal conditions (pressure1b, temp. 20C) and the corresponding TGC-value is calculated.
5. The compressed gases are then expelled out of the cylinder via non-return valve.

The same separation / TGC reading procedure is repeated again and again. The sample of the oil is in that way exposed to a higher and higher vacuum to assure that dissolved gases in the oil are effectively removed and volumetrically measured. The process is finished when the pre-demanded measuring precision is met.

The time-related vacuum / compression process is continuously shown in the display of the PCD Amit and the final TGS-value is shown on the SU display and in the TGC window.

2. Tx-MultiScan Service Unit Specification

2.1 Technical data

Power supply voltage	80 – 250 VAC
Power supply frequency	50 - 60 Hz
Power consumption:	max 80W
Oil throughflow	0.02 m^3 per hour
Measuring range	
Water content in the oil	5 – 100 ppm (diluted water)
Temperature	0 – 100 C
Outlet /inlet filtering grade of preliminary filter	40 µm
Weight – inclusive lap-top, alu transport box and accessories	29 kg
Dry weight of the measuring unit only (without oil)	5 kg
Hydraulical connection	2 x flexible hose
Communication:	lap-top connector

2.2 Operational conditions

The **Tx-MultiScan Service Unit** is focused on the **quick and precise reading** of three basic time-related values of the transformer:

- Water content in the oil
- Upper (operational) temperature of the transformer
- Bottom (operational) temperature of the transformer
- TGC – Total Gas Content in oil

The interconnected lap-top evaluates directly in situ:

- Desired equilibrium condition of a transformer
- An averaged water content in cellulose materials
- TLC (Temperature Loading Curve) – predicts the relation between the dielectric strength of oil and transformer temperature

The reading of the TGC-value is performed, under standard conditions, after the basic reading of the water content is finished.

Please never forget

Tx-MultiScan system is designed for a quick reading and evaluation of basic parameters of a transformer in situ

Tx-MultiScan Service Unit is not designed for daily or weekly readings – customers need to have results in hours

The recommended reading period of a transformer should not exceed 1 – 2 hours, or in a extreme situation ca 24 hours.

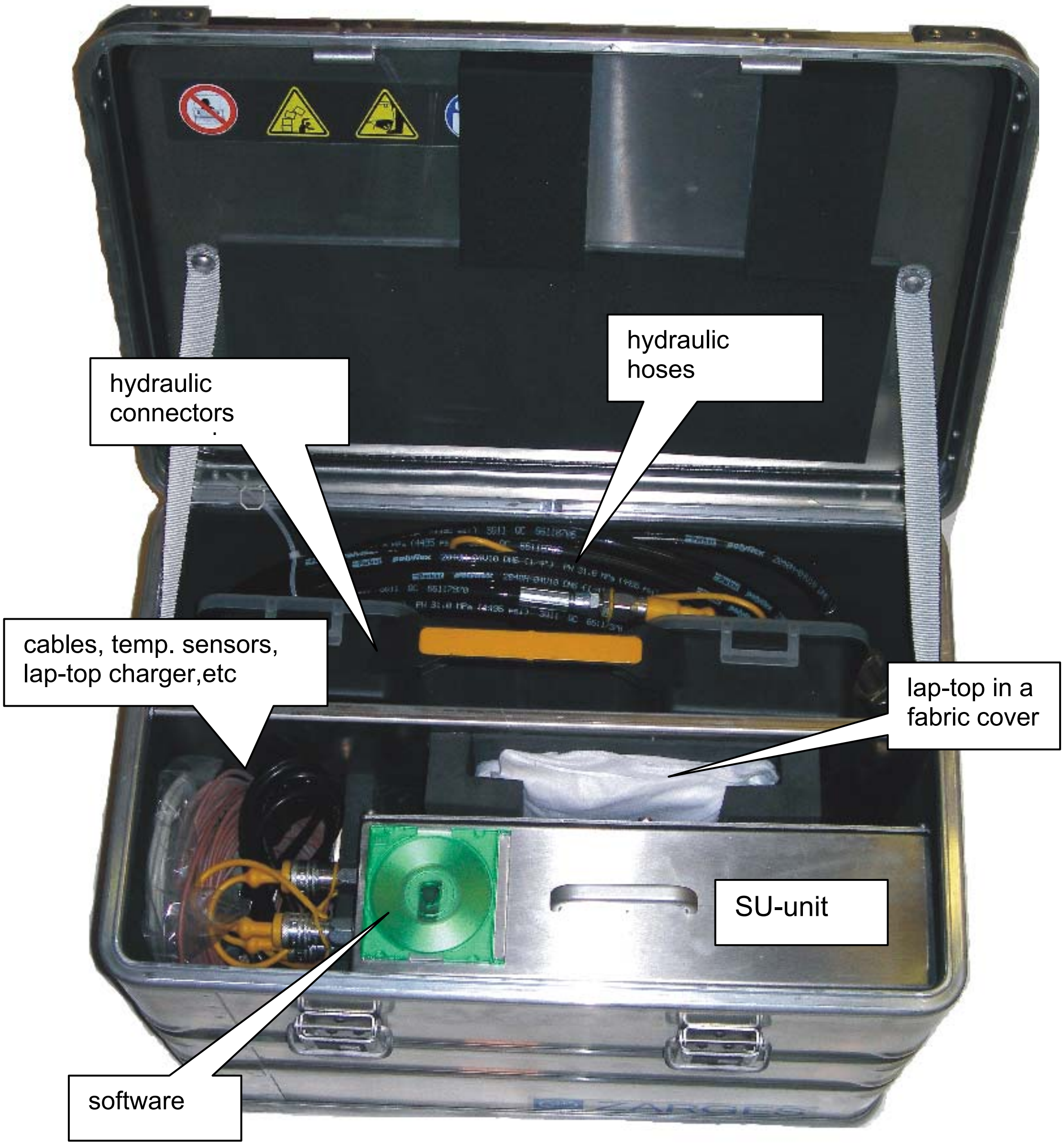
3. Transportations

Tx-MultiScan Service Unit is always transported, inlusively the lap-top and all accessories in:

- high resistant alu box intended for all-day operations under very heavy conditions

ATTENTION

Check the functionality of Tx-MultiScan Service Unit before taking it to the client.



To avoid delays and problems by the installation, always ask the client before, what potential connection points are available in situ.

4. Installation

Preparation for the installation of the SU

All possible connection points of the transformer(s) suitable for the **SU** installation should be properly checked before the installation.

Call the customer first and check all possible connection alternatives to their transformer(s)

Every transformer has at least, one of five accessible connection points:

- sampling cock (s)
- filter press valves
- drain valve (s) of main tank
- air cock of Buchholz relay
- discharge cock of conservator

4.1 Sampling cock(s)

The best **SU** connection points are sampling cocks e.g. DIN 42568 connected to the bottom and upper part of the oil filling of a transformer. This enables a very easy installation and the most precise measuring by means of the 2-P installation.

4.2 Filter press valves

The same opportunity offers “bottom” and “upper” filter press valves.

Attention - both valves (usually slide valves) are under normal operational conditions sealed by blind flanges. For an easy connection of hoses, it is necessary to provide both blind flanges with a ½ “ internal thread, or to select other suitable connection e.g. sleeves provided by the 1”, ¾” , ½ “ or 3/8” internal or external thread.

Call your customer first – any above mentioned adjustments needed to either flanges will significantly save time by the installation.

Do not forget:

1. ***internal space of a filter press valve – the volume between a closing element and the blind flange must be properly vacuated before the begining of any*** **Tx-MultiScan** ***measuring to prevent the ingress of air to the oil inventory of a transformer.***
2. ***When your measuring is finished and the filter press valve is closed again , the internal space of the valve must be sealed against the surrounding, by means of a suitable blind flange, cap or screw.***

4.3 Drain and slugge valve (s),

or even sludge cocks are generally not recommended, due to :

- potential danger of the infiltration of a dirt into **SU**.

potential distortion of moisture reading – the hot (relevant) oil in upper part of main tank is separated by thermal stratification layers from relatively cold oil in the bottom part of the main tank, where the drain valves are situated.

If there doesn´t exist any better connection point, the drain (sludge) valve can be used, but it is always necessary to discharge at least 10 lts of oil before the installation. The subsequent check of the oil quality is absolutely necessary as well, to exclude potential problems with the wear and tear of internal mechanical parts (cylinder – piston) of the **SU** .

At any transformer bottom exists always al least one drain valve which can be used for a Tx-MultiScan measuring (1P) procedure.

The connection of the **SU** to the standard drain & sampling point (DIN 4255) at German or German-made transformers can be easy performed by means of the ARS-adapter See Fig. 3

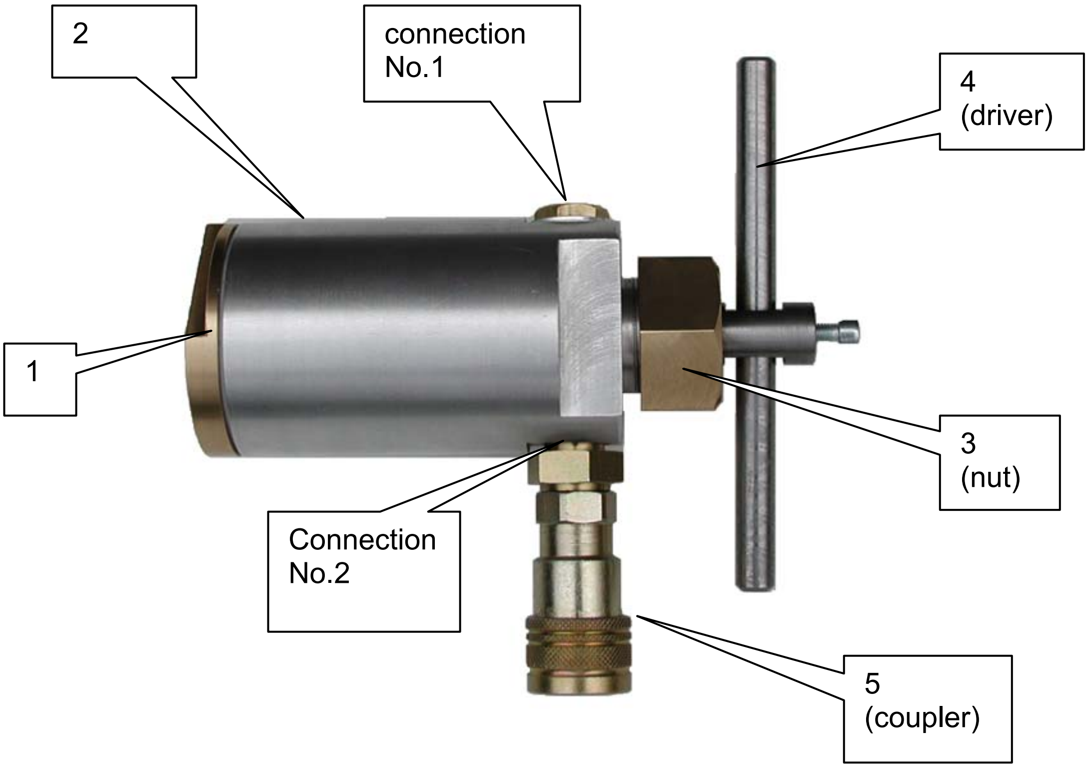


Fig. 3 The ARS – sampling adapter (only by special order) for the DIN4255 drain & sampling valve

The installation of the adapter at the transformer:

- disassemble cap of the drain & sampling valve
- check the dimension of the drain valve thread and select the proper thread of the adapter. For threads M33 x 1.5 and M32 x 1.5 use the reduction (1), for the M48 x 2 you can directly use the internal thread in the body (2) of the adapter
- loosen the nut (3) of the sealing of the adapter (2) and push out the driver(4)
- screw the adapter on the thread of the drain valve and tighten it up
- connect the adapter to the **SU** via coupler (5)
- push back the driver (5) and find its proper position against the head of internal plug of sampling valve
- tighten the nut (3) and turn the driver in counter-clockwise direction
- start the **SU** and check tightness of the connection

4.4 Deaeration cock of Buchholz Relay (BR)

The BR connection is generally very suitable (if accessible under normal operational conditions) due the continuous throughlow of the oil between the main tank and conservator. This connection is then especially suitable for the 1-P connection. A proper connection needs a special adapter (only by special order).

If the 2-P connection is used, the oil from the **SU** can be brought back into the oil filling via the plug or sludge cock of the conservator.

4.5 Discharge cock of conservator

is not recommended for 1-P procedure, due to potencial dirt content and relatively high internal oil volume in a connecting tube, but can be used for 2-P procedure as a discharge point (oil from the SU is forced back that way).

Preparation of the installation of the SU in situ

Hydraulic interconnection of a transformer and the SU

- if sampling points are directly connected to the oil inventory of the transformer use simplified procedures 4.5, for more precise readings is better to use 4.6.

- if sampling points are not directly connected to the oil inventory (between the sampling point and the oil inventory exists a detrimental space corresponding e.g. to the space between the slider and the blind flange of the filter press valve – See Fig. 4 , 5 - always use the full procedure 4.6, which allows the evacuation of the corresponding detrimental space. Check the internal connection between the valve and oil filling. The suction side of the SU should be always connected to the valve without an internal tube connection to achieve a direct connection valve – oil filling.

Measuring of transformer temperatures

For a precise evaluation of equlibruim conditions of the transformer and consequently a precise evaluation of the averaged water content its cellulose materials, it is necessary for a “ long-term “ reading of:

- upper temperature of the transformer
- bottom temperature of the transformer

Both temperatures are measured by means of enclosed cylindrical temperature sensors RAWET PT30, Ni 1000.

The optimal location of sensors is:

- upper tube (sleeve) of the radiator, which feeds the hottest oil representing the temperature of the upper part of the windings into a radiator.
- bottom tube (sleeve) of the radiator, which feeds the cold oil from the radiator into the bottom part of transformer which will satisfactorily represent the temperature of the bottom part of the windings.

The reading of both sensors is inevitably indirect, because sensors read not the oil temperature directly, but the temperature of surfaces of tubes which lead the oil in/out the radiator.

It is always necessary not only to perform the proper mechanical fixation of a sensor at the given tubing, moreover the sensor and the tube on its both sides should be thermally insulated as well.

The standard solution is that the temperature sensor is fixed at the tube by an enclosed rubber band or a suitable tape.

The pre-loaded rubber band safisfactorily fixes the sensor at the tube and simultaneously acts as a sufficient thermal barrier, which effectively eliminates the temperature difference between the throughflowing oil and the outer surface of the tube (and the sensor).

ATTENTION

- **all valves or cocks on the transformer which directly communicate with its oil filling is thereinafter called here the main cocks**
- **detrimental space means the space between the main cocks and the sampling cocks**
- **detrimental space must be evacuated before the the main cocks are opened to prevent the ingress of the air into the transformer**

4.5 SU – 1P (one-point Installation) - See Fig.4 -

suitable only for a direct hydraulical connection

between oil filling and sampling cock

- join the hose **H1** at a **sampling** cock and the opposite end of **H1** with the **preliminary filter** join at the quick-coupling connector QC1 situated at the left side of the Service Unit (SU) .

Attention !!

never operate SU without the particle filter

The SU – 1P hydraulical connection between SU and transformer has to be short as possible

use always 3 m hose (H1) only

- join hose H3 with flash cock by quick coupling to the **SU** (See Fig. 2, or Fig.1 , Position 13) and connect the opposite end of the hose H3 to the tank of vacuum pump (See Section 9, Figure 9) .
- Install the first temperature sensor on the upper tubing (hot inlet) of the radiators and connect the sensor to the connector **T-UP**.
- Install the second temperature sensor on the bottom tubing (cold outlet) of the radiators, connect the sensor to the connector **T-BOTT**.
- Check the correct level of supply voltage (required 110 - 230 VAC, 50 –60 Hz).
- Connect **SU** to the power supply by the **SUPP** connector (See Fig. 2 and Fig.6).
- Connect **SU** to the lap-top

This way Tx-MultiScan Service Unit is ready to operate.

Attention

The Fig.4 shows a connection:

- o **with sampling cock (s) directly connected to the oil filling of main tank**. Only hose H1 has therefore to be evacuated to avoid an infiltration of the air into oil filling of the transformer and any subsequent potential action the the Buchholz relay after the opening of the slide valve
- o take care by the selection of the place where the sampling cock will be installed. If there exist a possibility that the connection between the cock and the oil filling includes any internal “dentrimental” spaces , it means, any space(s) where the oil cannot directly communicate with the “circulating” oil filling, find and choose a better connection point.

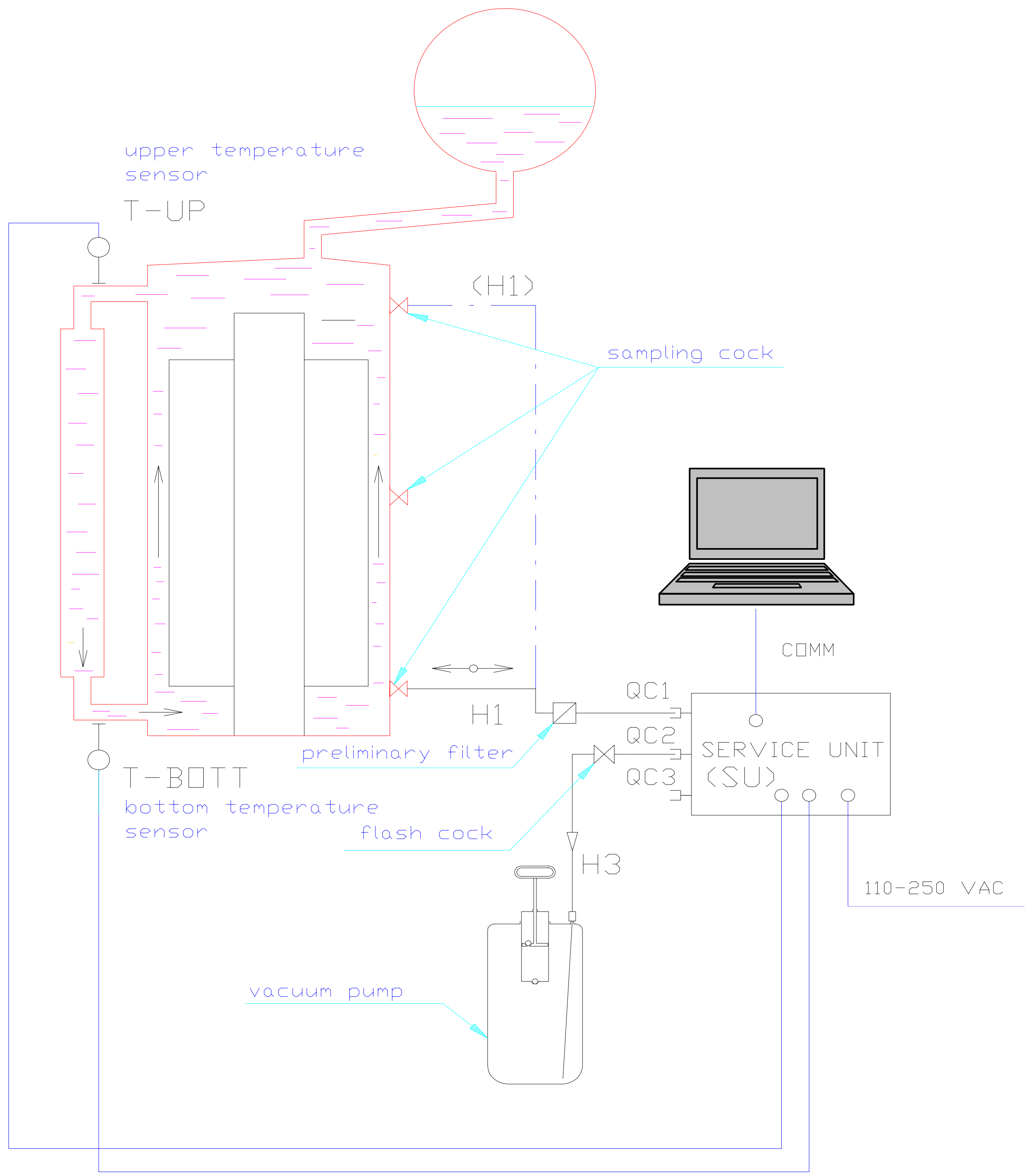


Fig. 4 Connection Diagram **SU - 1P = alternate oil flow** : the oil flow uses onĺy one way (one hose) connection:

- from the bottom part of the transformer is repeatedly fed into the **SU** and forced back
- from the upper part of the transformer into the **SU** and is forced back

4.6 SU – 2P(two-point Installation) – Up-Down, See Fig.5.

- Attach the **Valve 1** at the first **main cock** (e.g. upper filter press valve or upper sampling cock See Fig.4) of the transformer and connect it with hose H1 and the opposite end of hose H2 (with the preliminary filter) connect to the first quick-coupling connector QC1 of the **SU**.
- Attach the **Valve 2** at the second **main cock** (e.g. bottom filter press valve or bottom oil sample cock) of the transformer and connect it with hose H2 and the opposite end of hose H2 (with the preliminary filter) connect to of the second quick-coupling connector QC3 of the **SU**.

Attention !!

never operate SU without particle filters

- Connect the bleeding valve hose **H3** (with flash cock) into the connector QC2 and connect the opposite end to the tank of vacuum pump.
- Install the first temperature sensor on the upper tubing (hot inlet) of the radiators and connect the sensor to the connector **T-UP**. Install the second temperature sensor on the bottom tubing (cold outlet) of the radiators and connect the sensor to the connector **T-BOTT**.
- Connect the **SU** to the power supply 110-230 VAC, 50-60 Hz by connector
- Connect the **SU** to the lap-top (see Fig.5).

Rem. For precise and long-term measurement the status **SU - 2P UD (Up-Down)** is mainly used.

Rem 1 . The installation procedure is the same for status **SU - 2P DU** (oil flow direction **D**own **–U**p**)** and the status **SU - 2P UD** (oil flow direction **U**p **– D**own) - with the exception of the settings of the both Valves 1 and 2 - See Fig.5.

Rem 2. both Valves (1 and 2) are part of the delivery.

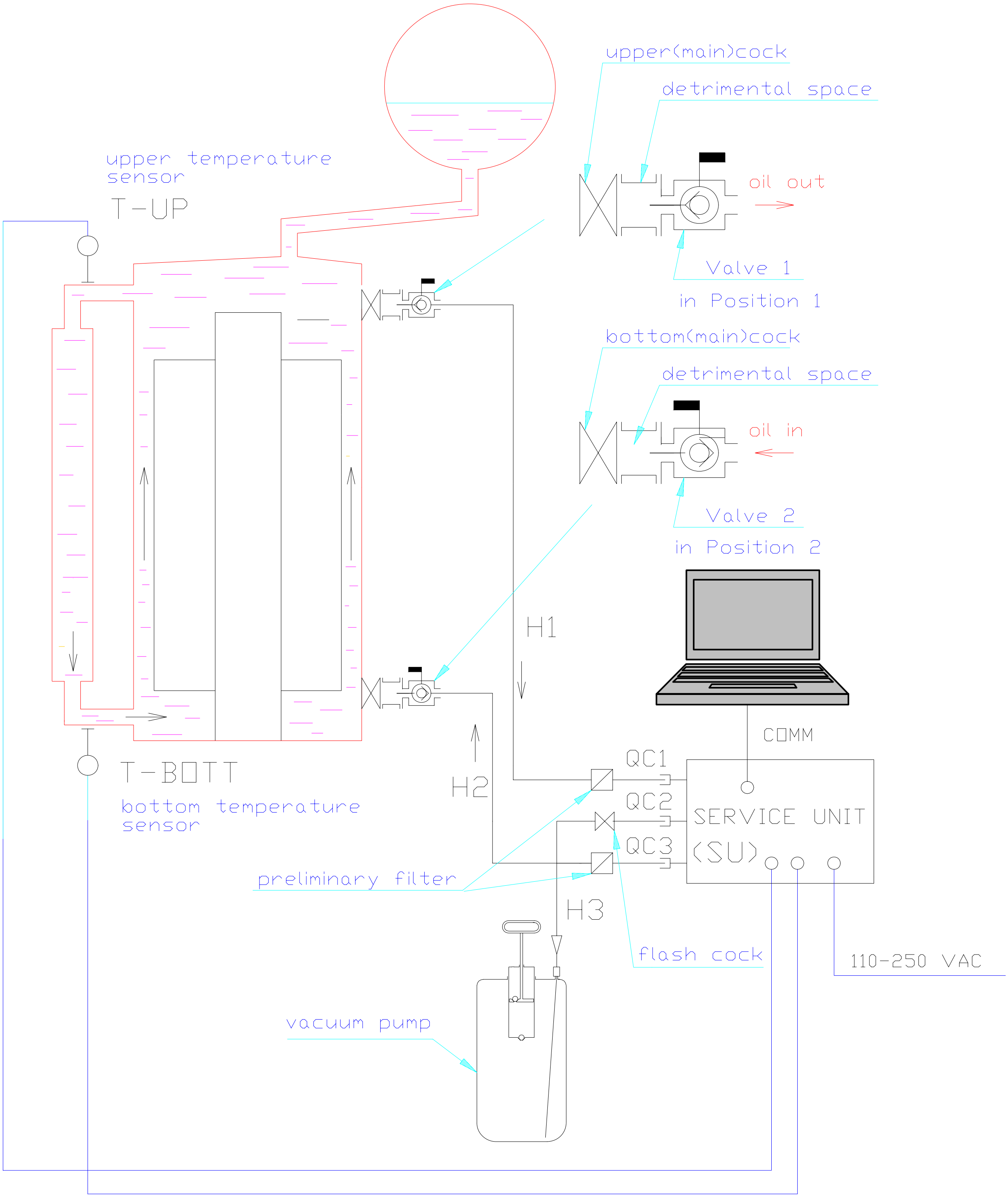
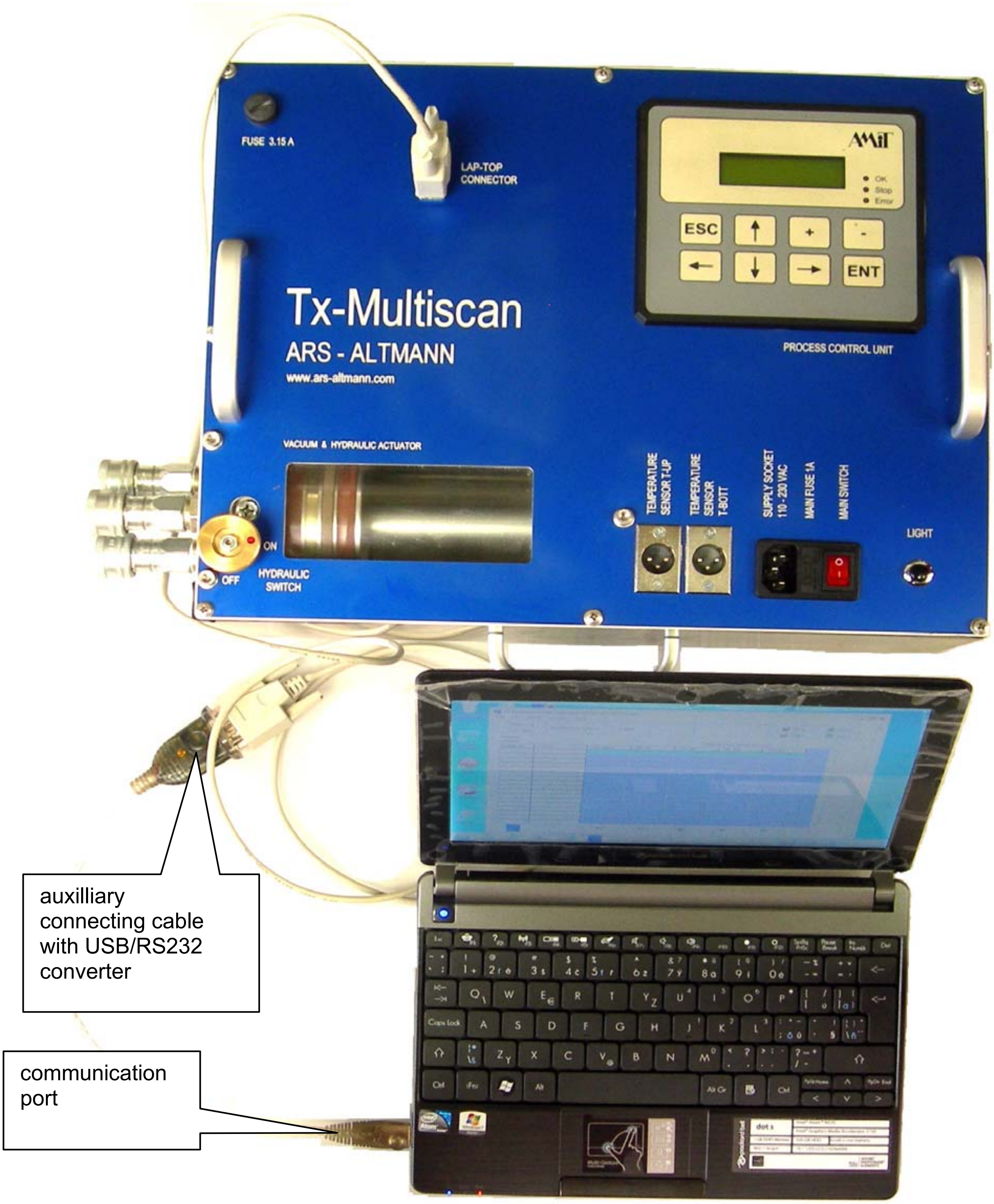


Fig.5 Connection Diagram **2P UD** – oil flow direction **U**p-**D**own (oil flows from the upper part of transformer via hose H1 into the **SU** and is forced back via hose H2 in the bottom part of transformer)

To meet plug & play features of Tx-Multiscan, the inherent part of the delivery is pre-programmed lap-top to avoid any communication and evaluation problems.



ATTENTION :

TO AVOID COMMUNICATION PROBLEMS USE DETERMINED USB PORT ONLY

Fig.6 The example of interconnection of **SU** and lap-top for a data transfer.

5. Start-Up

ATTENTION

The Tx-MultiScan reading must always be performed on transformers under operational conditions.

For the desired precision reading of the water content in the oil, the precise evaluation of the water content in oil (the Qw-value), the relevant evaluation of the water content in cellulose (the Qp-value), the theoretical dielectric strength of oil (the Ud-value) and the reading of the Total Gas Content in oil (TGC-value),

the average temperature of a transformer during a reading should always be over 30 C.

To avoid the loss of data or diagnostic results the check of the full charge of the lap-top battery is highly recommended before any start-up.

The substantial advantage of the advanced time-related approach is an eventual and direct intervention from the lap-top into all processes :

- to evaluate the equilibrium conditions of the transformer
- to improve or change of conditions of data flow
- to improve the precision of diagnostic results .

To start the **SU** following steps are necessary:

- to provide hydraulical 1-P or 2- P connection between Tx and **SU**
- to connect the **SU** to the vacuum pump
- to connect the unit to the suitable power supply (See Specification)
- to open the hydraulic switch ON (See Fig. 2 – for full open: the switch is shifted vertically up and fixed by 90^{o} turning in the upper position – the red dot at the button is in the position ON)
- to connect the **SU** to delivered lap-top with the Tx-MultiScan software
- to switch on the main switch QM1 ON.

Attention:

- **if you use only the SU (without lap-top connection) reading data are shown only on the display of PCD AMIT.**
- **if you use only the SU (without lap-top connection) all procedures should be properly finished to the end of the program – it means that the measuring should be finished without any interuptions until the preprogramed parameter TD (Test Duration) expires.**

In the case that the last measuring is interrupted – e.g. before the **TD** parameter (Test Duration) expires, the **SU** will always evaluate the switching OFF/ON as a supply outage / supply recovery and after **60 sec** will try to continue the last stage of measuring.

This “automatic restart” can be easy interrupted by the click on an arbitrary button of the AMIT PLC in the beginning of a new job of the **SU**.

The old data remaining in the **SU** can then be downloaded into the lap-top.

On the other hand, if the interconnection of the **SU** and a lap-top exists, the corresponding data can be downloaded into the lap-top for the evaluation and are simultaneously visualized in the corresponding windows.

The "old" data remains in the **SU** till a new On-line Measurement of the Transformer begins. The begining of a new job is always defined by the selection and the confirmation of 1-P or 2-P regime. Up to this confirmation it is always possible to download the "old" data into the lap-top. After the confirmation all data are erased from the AMIT memory.

The PSD AMIT of the **SU** asks at first for confirmation of the proper position of hydraulic switch

H SWITCH ON ?
YES PUSH ENTER

in the second step the definition of operation regime is requested

MANUAL = +
AUTOMAT = -

By pushing (**+**)proceeds the **SU** to the manual control regime, where the piston movement is governed by pushing (←) , - the piston moves to the left-, or (→) - the piston moves to the right.

By pushing (**-**) proceeds the **SU** to the full automatic control regime and asks for **TD** (**T**est **D**uration) parameter, if the **TD** is not defined, the display will automatically show the preset parameter TD = 60 (min):

TD = (min)
+/- PUSH ENTER

This parameter can be altered by pushing (+) / (-) buttons, the TD-value will be changed in time-periods of 10 min. (min. duration of the test is 20min, max. 1550 min) or, under operation conditions, the TD-value can be arbitrary changed in the Parameter Table (See 5.1).

But never forget – your Tx-MultiScan Service Unit is the apparatus for the quick, reliable reading and evaluation of the status of a transformer and not for its quasi-on-line measurement (e.g. more days) !

By pushing ENTER, the **SU** proceeds to the Menu procedure and the display shows :

1P REGIME = +
2P REGIME = -

By pushing (**+**) status **SU - 1P** is selected**,** Menu procedure is finished and the **SU** goes forward directly to the **START-UP 1P** procedure (See Section 3.1).

By pushing (**-**) the **SU - 2P** status is selected (See Section 3.2)

By clicking on the (-) or (+) this automatically interrupts the "automatic restart" of the SU and the data of the last assesment is erased.

Rem. Should anything malfunction during the Menu procedure, simply shut-down the **SU** by the main switch QM1 and restart the whole menu operation again.

5.1 Parameter Table

Parameters of the SU unit can be changed by means of the Parameter Table.

The Table is any time accessible by click on the button → on the AMIT keyboard and selected parameter can be changed by pushing of buttons + and - . The parameter selection is performed by rolling of the display by buttons ↑ and ↓. Return to the main display is then performed by the click on ← .

Parameter		Description	Standard setting
TD	....	Time-period of reading of Tx-values	60 min
Pvyfmax	...	max. exhaust pressure (if P> Pvyfmax ⇒ Flasch Cock is closed and has to be opened)	200 kPa
Pminvac	...	min. requested vacuum (P > Pminvac ⇒ the whole hydraulic system of of SU and connected lines is probably untight)	10 kPa
Pmax	....	max. allowed pressure (P > Pmax usally ⇒ Hydraulic Switch or sampling cocks or main cocks were not properly opened or b are closed by mistake	250 kPa
Pmaxvac	....	Vacuum Alarm ⇒ intake of oil into SU is blocked	5 kPa
NA2	....	Number of measuring steps ⇒ predefined oil volume for gas separation	950
NFmax	....	Number of steps for flashing (gas removal)	20
TS	....	Stirrer ON for given time-period	200 sec
Imax	....	Number of degassing cycles	3
PR	....	Reading Pressure for evaluation of gas volume	90
Stirrer	....	switched ON by clicking on (+) , switched OFF by (-)	
K0	....	Calibration value: mechanical hysteresis of kinetic system	4

.All predetermined values can be changed any time via **SU** display and AMIT keyboard. Simply click on (→) and change the arbitrary value by (+) and (-). For the change of another value roll the display by click on (↓) or (↑) . Click on (←) for the return to main display.

The parameter levels are optimally preseted by the producer, don´t change them only if absolutely necessary.

5.2 STARTUP 1P Procedure

The startup 1P procedures is controlled by the pressure P which is continuously measured in the **SU** measuring cylinder.

Immediately after the pushing (+ ⇒ 1P regime), the **SU** starts the evacuation of hose H1.

The **SU** at first checks the internal pressure in the glas cylinder (and in hose H1) and the position of the piston.

The piston will automatically go in the left position and gradually compress the air :

- If the internal pressure in the cylinder is lower as ca 150 kPa, the following message is displayed :

WAIT PLEASE
P = xxx **kPa**

- if the internal pressure is higher than ca 150 kP and increasing, the pressure shown on the display and the **SU** demands:

OPEN FLASH COCK
P = xxx **kPa**

Flash Cock is situated in hose H3 connected to SU via quick coupling QC3 – See. Fig.1, Position 14

- if the pressure exceeds an allowed pre-programmed level (See Pvyfmax in the Parameter Table), the piston stops and the **SU** asks if the flash cock (See Fig. 1. Position 13) is opened.

If opened, the air is expelled from the glass cylinder and escapes outside via hose H3. The gas discharge decreases the pressure in the glas cylinder and automatically restarts the motion of piston in the left direction again.

When the piston reach the left terminal position is the removal of air finished and the evacuation procedure begins.

The display reads:

VACUUM BUILDING
ON P = xxx **kPa**

The piston is moving to the right now and sinking pressure P is measured and displayed at the **SU** display.

When the piston stops at the right terminal position and max. vacuum level is reached, vacuum (tightness) check begins.

The **SU** compares the reached absolute pressure level **P** with the desired pre-programmed parameter (See **Pminvac** in the Parameter Table):

- when **P > Pminvac**, the whole hydraulic system of the **SU** is probably leaking,

VACUUM ALARM
P= xxx **kPa**

which necessitates checking all hydraulic connections at first.

The **SU** must be switched off, the leak must be repaired and a new evacuation procedure must be performed.

- when **P ≤ Pminvac**, the system is considered tight and the display reads

OPEN SAMPLING
COCK, PUSH ENTER

And because by the 1P connection doesn´t exist any main cock and therefore a detrimental space between main cock and sampling cock as well, push ENTER immediately after the

OPEN MAIN COCK
PUSH ENTER

is displayed.

When the piston achieves the left terminal position, the flash cock has to be closed to avoid the potential throughflow of oil from the transformer to the vacuum pump.

CLOSE FLUSH COCK
PUSH ENTER

and the first measurement procedure begins (See Section 6).

5.3 STARTUP 2P DU Procedure

The start 2P DU (Down Up) procedure is a bit more complicated because we have to evacuate two potential detrimental spaces situated between main cocks and sampling cocks See Fig. 5.

Both non-return (180-degree rotary) valves connected to both sampling points (Main Cocks) at a transformer have to be turned **<u>in the Position 1</u>** (See: Fig. 5). This position ensures the easy and rapid degassing of both detrimental spaces and hoses.

The **SU** at first asks if both valves (Upper and Bottom) are in Position 1 – the detrimental spaces between the main cock and valves are hydraulically interconnected to the SU .

VALVES IN POS 1. ?
YES = ENTER

and then checks the internal pressure in the glas cylinder (and in the whole hydraulic system) and the position of the piston.
The piston automatically goes into the left position and gradually compresses the air:

- If the internal pressure in the cylinder is lower as 150 kPa, the following message is displayed :

WAIT PLEASE
P = xxx **kPa**

- if the internal pressure is higher than 150 kP and increasing, the pressure shown on the display and the **SU** demands:

OPEN FLASH COCK

P = xxx **kPa**

Flash Cock is situated in hose H3 connected to SU via quick coupling – See. Fig.1, Position 13

- if the pressure exceeds an allowed pre-programmed level (See Pvyfmax in the Parameter Table), the piston stops and the **SU** asks if the flash cock (See Fig. 1. Position 13) was opened:

If opened, the air is expelled from the glass cylinder and escapes outside via hose H3. The gas discharge decreases the pressure in the glas cylinder and automatically restarts the motion of piston in the left direction again.

When the piston reach the left terminal position is the removal of air finished and the evacuation procedure begins.

The piston moves to the right and SU reports it by the display

VACUUM
BUILDING ON

When the piston achieves the right terminal position, the vacuum check of the connection of the **SU** + both hoses + both main cocks begins.

The PCD AMIT compares the reached absolute pressure level with the desired pre-programmed parameter (See **Pminvac** in the Parameter Table) :

- when **P > Pminnvac**, the vacuum level is too low and the **SU** demands higher vacuum

USE VAC PUMP
P= xxx **kPa**

To mimimize a time-period necessary of the evacuation of the whole system(hoses H1 and H2 + detrimental spaces) the external vacuum pump (See Section 9) connected by the quick coupling of hose H3 to the connector H1 and H2 of the SU is recommended.

The air removal from SU, hydraulic hoses and dentrimental spaces between main cock and both valves as shown at Fig.5 is then performed in two steps:

Step 1 - Air removal from hydraulic system consisting of hose H2 and the bottom dentrimental space:

I. disconnect the quick coupling of hose H1 from the socket QC1 and connect the hose H3 (which opposite end is connected to vacuum pump) to the QC1
II. use hand actuated vacuum pump to achieve requested vacuum
III. when the desired vacuum is achieved, the vacuum check begins

To avoid any distortion of pressure / tightness reading of given hydraulic system the SU asks for the hydraulic disconnection of vacuum pump

CLOSE FLASH COCK
PUSH ENTER

and the SU checks the change of pressure in the given hydraulic system for preprogramed time period.

VACUUM CHECK
WAIT PLEASE

The increase of pressure over preprogramed value means the untightness of the whole system (**SU**, hydraulic hoses, cocks etc.) and the SU reads

VACUUM ALARM

which necessitates checking all hydraulic connections at first.

The **SU** must be switched off, the leak must be repaired and a new evacuation procedure must be performed again.

When the pressure change isn´t registered, the system is considered tight and the display reads

OPEN BOTT. COCK
PUSH ENTER

when the bottom cock is opened, the oil flows from the main tank into the bottom detrimental space and via **Valve 1** and hose **H1** into the cylinder of the **SU**.

The SU reads the pressure level in the cylinder and if the pressure exceeds 100 kPa, the display of the SU demands the turning of the Valve 2 in the Position 2 (oil can flow in the transformer only)

TURN VALVE 2 IN 2
PUSH ENTER

the inflow of oil into the SU-cylinder is immediately stopped way and the piston moves to the left position and compress and then expell the gas bubbles from the cylinder of the **SU** into the tank of the vacuum pump.

When the piston reach the left position, its motion is reversed and the piston moves to the right again and the vacuum is builded.

When the right terminal postion is reached, the evacuation of the upper part (upper detrimental space + hose H1) begins.

The SU reads the pressure in the cylinder:

- when **P > Pminnvac**, the vacuum level is too low and the **SU** demands higher vacuum

USE VACUUM PUMP
P= xxx **kPa**

When the desired vacuum level (P< Pminvac) is achieved, the SU demands the opening of the upper cock

OPEN UPPER COCK
PUSH ENTER

and the whole upper hydraulic system: consisting of the upper detrimental space, the Valve 1 and the hose H1 is rinsed by the oil from the main tank.

Simultanmeously, the piston moves to the left again to expell residual bubbles from the cylinder via flash cock and the hose H3 into the tank of vacuum pump.

If the piston reaches the left terminal position, the SU demands the closing of the flash cock by the display:

CLOSE FLASH COCK
PUSH ENTER

and the on-line reading of the water content of the oil and both temperatures of the transformer begins.

6. ON-LINE Measurement of Transformer

At present the piston is moving continuously between both terminal positions and our on-line measurement can begin.

The pressure in the **SU** is continously measured to avoid a potential damage induced by the not-allowed overpressure.

When the P > Pmax (250 kPa) the display shows it as warning:

OVERPRESSURE
P = xxxx kPa

and the motor-actuator is immediately switched off.

When a source of the overpressure is identified and removed, the **SU** continues automatically .

The Pmax level is predefined at 250 kPa, but can be any time changed in the Parameter Table by pushing →, overwriting the number by using of +/- and by pushing ←.

When the piston achieves the right terminal position, values Qw, TV, TU, TB are always loaded in the PCD AMIT memory and actual values appear on the display.

Display shows

I = ...
t = ... (min)

where:	I	….	Number of Sample
	t	….	sampling time

In order to read other data gained from Vaisala transmitter, the display is rolled down by ↓

QW = ... (ppm)
AW = ... (1)

where:	QW	….	water content in oil (in the ppm at time t)
	Aw	….	relative humidity of oil directly measured by Vaisala sonde (1)

The remaining data are available by another ↓

TU = … TB = …. (C)
TTS =

where: TU …. upper temperature of transformer at time t
TB …. bottom temperature of transformer dtto
TTS …. main temperature of transformer dtto

All measured data from the beginning are available at any time by means of laptop, which can be connected to the serial connector of the **SU**.

The end of our procedure is reported by

MEASURE FINISHED
PUSH ENTER

The following display demands the connection to the laptop. This connection is realized by delivered cable. The first connector is joined to the serial port of **SU** and the second one is attached to the first USB port of the laptop via special cable (with inbuild RS232/USB converter). See Fig.6 .

CONNECT LAP-TOP
PUSH ENTER

The **SU** then demands , if not connected to the lap top before, the download of measured data to the laptop memory.

CLICK ON
MULTISCAN ICON

7. Transformer Equlibrium Check

For proper data evaluation, the equilibrium operating environment of the transformer must meet the necessary criteria.

In practice, this means the following :

- time variation of the mean temperature of the transformer

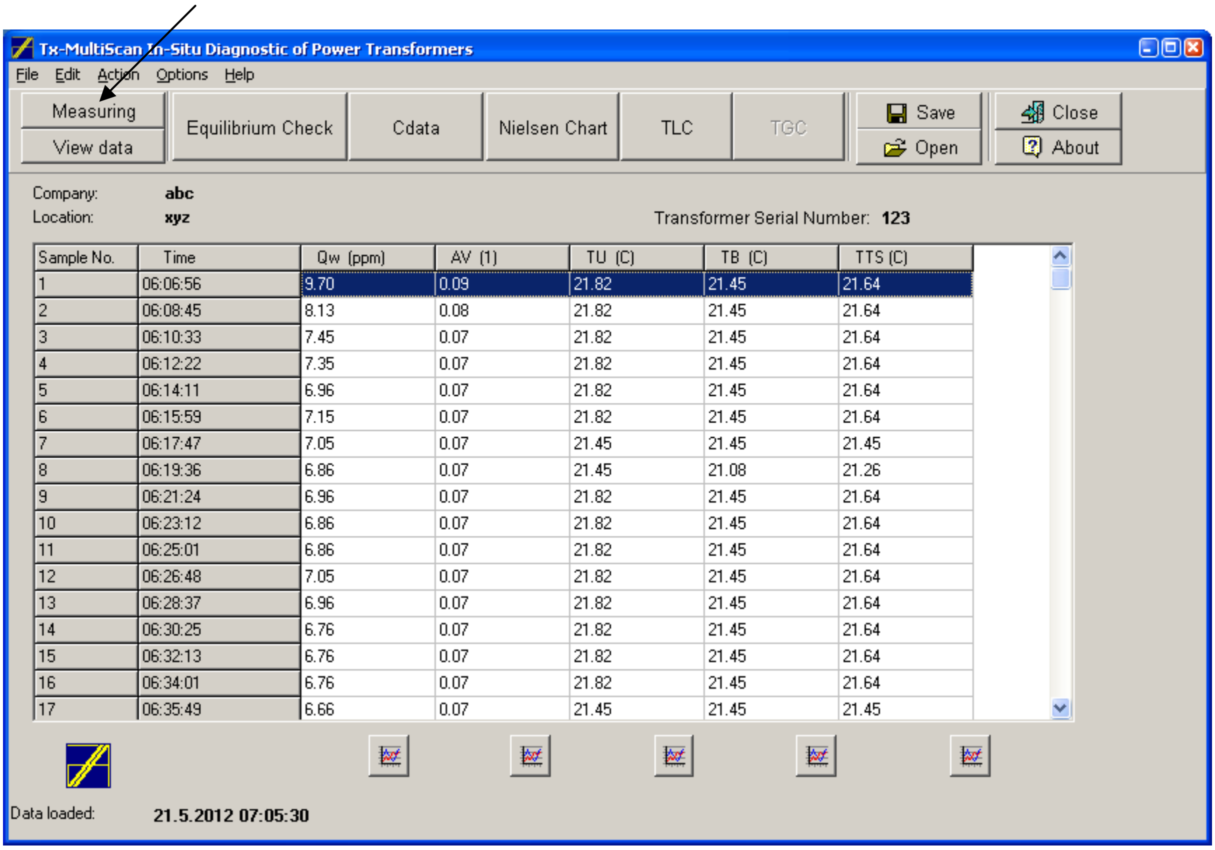
and

- time variation of the water content in the oil

must be simultaneously lower then predefined limits.

The **Tx-MultiScan** software solves the problem in the following steps:

- the program is started by clicking on the **MultiScan.exe** icon at the Main window of the lap-top and we get the main Tx-Multiscan window. By click on the **Measuring** button are data transferred into the lap-top and visualized in the form of the Data Table.



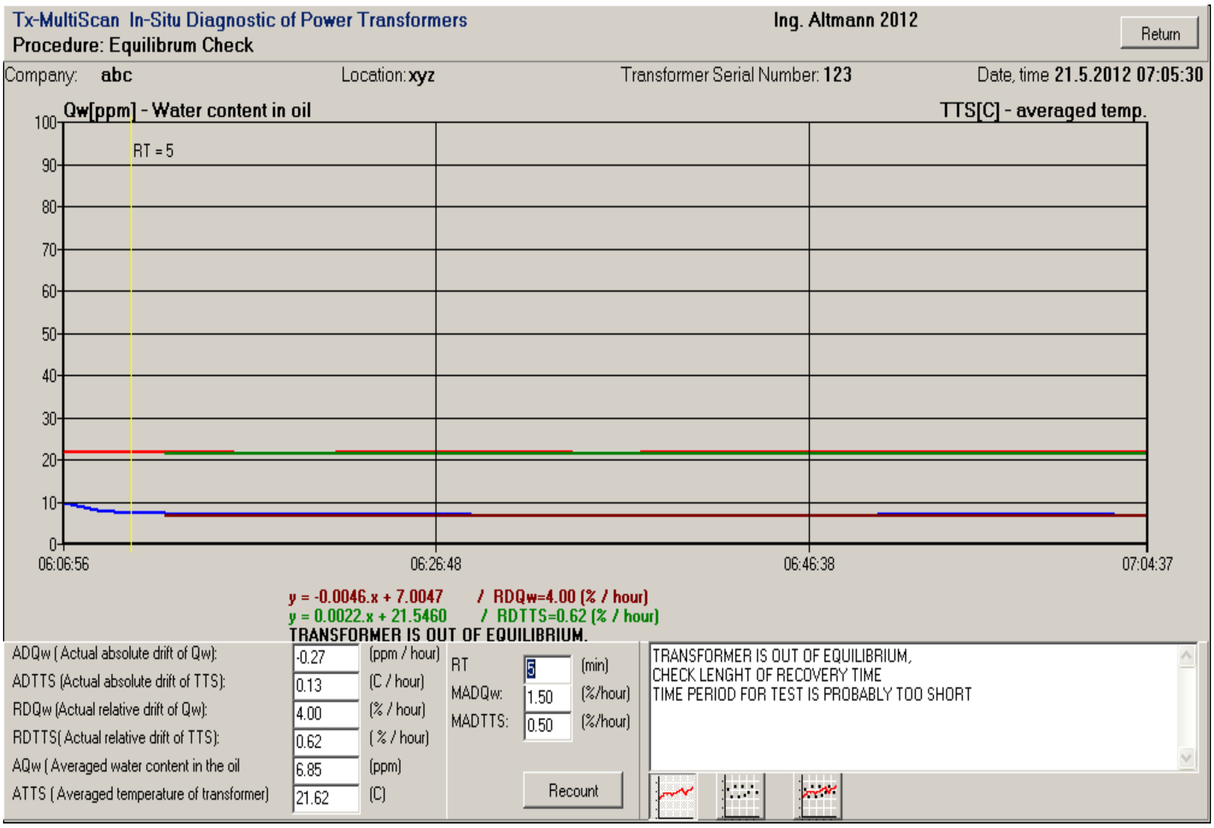
Sample No.	Time	Qw (ppm)	AV (1)	TU (C)	TB (C)	TTS (C)
1	06:06:56	9.70	0.09	21.82	21.45	21.64
2	06:08:45	8.13	0.08	21.82	21.45	21.64
3	06:10:33	7.45	0.07	21.82	21.45	21.64
4	06:12:22	7.35	0.07	21.82	21.45	21.64
5	06:14:11	6.96	0.07	21.82	21.45	21.64
6	06:15:59	7.15	0.07	21.82	21.45	21.64
7	06:17:47	7.05	0.07	21.45	21.45	21.45
8	06:19:36	6.86	0.07	21.45	21.08	21.26
9	06:21:24	6.96	0.07	21.82	21.45	21.64
10	06:23:12	6.86	0.07	21.82	21.45	21.64
11	06:25:01	6.86	0.07	21.82	21.45	21.64
12	06:26:48	7.05	0.07	21.82	21.45	21.64
13	06:28:37	6.96	0.07	21.82	21.45	21.64
14	06:30:25	6.76	0.07	21.82	21.45	21.64
15	06:32:13	6.76	0.07	21.82	21.45	21.64
16	06:34:01	6.76	0.07	21.82	21.45	21.64
17	06:35:49	6.66	0.07	21.45	21.45	21.45

At first, the Equilibrium Check of the SU reading has to be performed.

Corresponding window is opened by clicking on the Equlibrium Check button.

REM. In order to achieve the graphical form the clicking on the icone under the columns is necessary. But this technique is inadequate for proper and precise quantitative time-log analysis.

By click on the button Equlibrium Check the time-related diagram of Qw- and TTS-value (transformer average temperature) is shown.



then chose in the bottom part of the window:

- what **R**ecovery **T**ime (**RT**) will be used for data evaluation (in this way, we can “cut out” the undesired dynamical variation of the initial data (which can be caused by Tx-MultiScan alone). In the picture RT=5 min is used.
- what **M**aximal **A**llowed **D**rift:
  - MADQW – for water content in the oil Qw (%/hr), here 3%/hr
  - MADTTS – for main transformer temperature TTS (%/hr), here 3% /hr

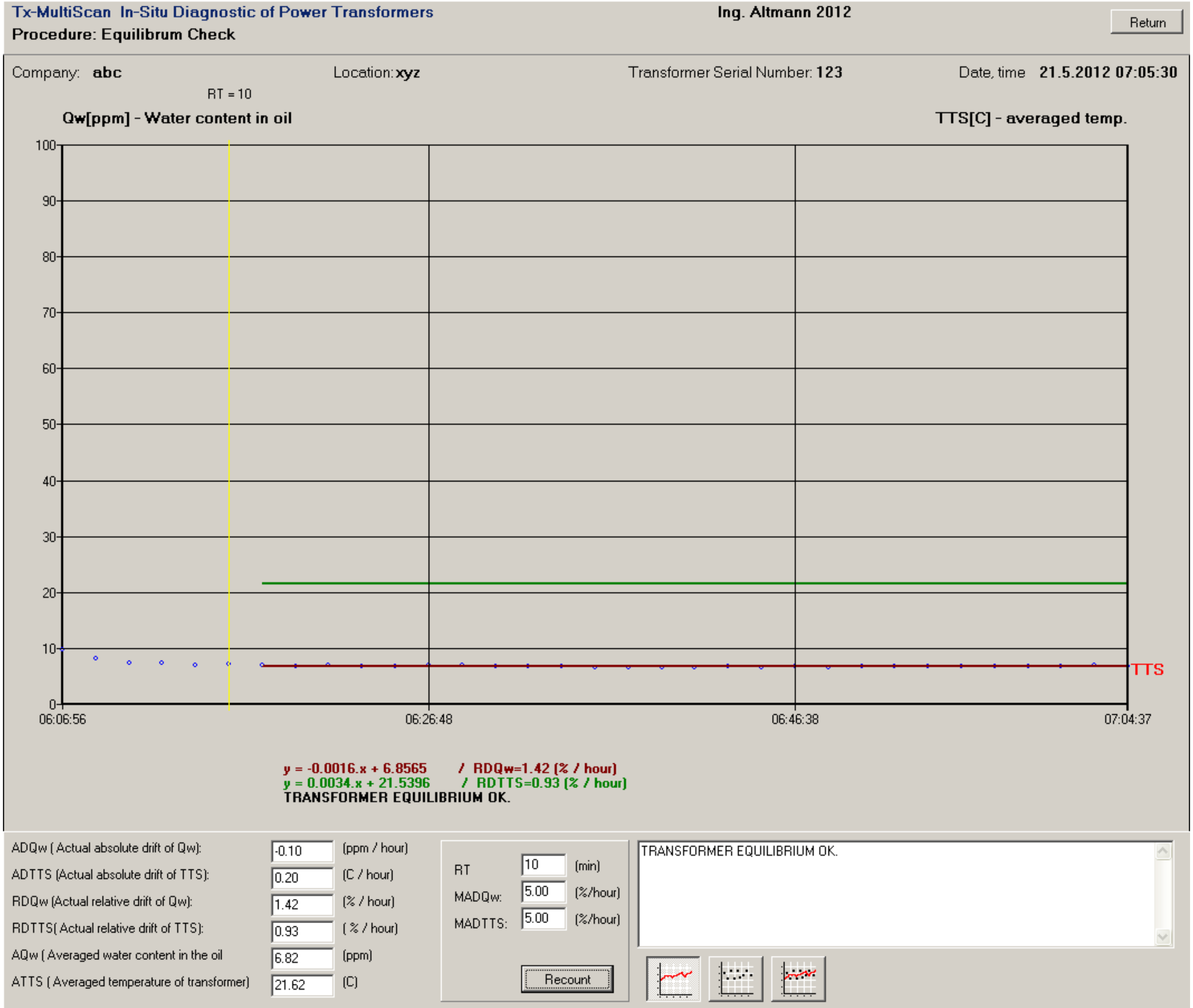
The value of the relative concentration drift of Qw (RDQW = 4.00%/hour) looks high.

Therefore computer evaluates this state as: TRANSFORMER IS OUT OF CONCENTRATION EQUILIBRIUM and subsequently offers : CHECK ………

Yet, when considering the relative temperature drift (RDTTS = 0.13 %/hour) the transformer **is** in the acceptable quasi-equilibrium.

This slightly diverges from the overall equilibrium of the transformer, but the absolute value of Qw, as well as the absolute drift ADQW = - 0.27 ppm/hr are relatively very low as well and near the calibration precision of the Vaisala transmitter. Thus, both AQW and ATTS values can be accepted for the following evaluation.

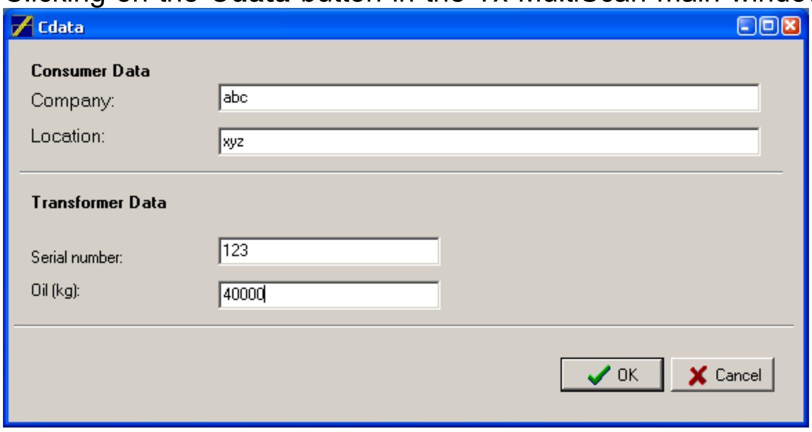
The conclusion is simple: the RT-value is too low and the MADQW and MADTTS values were set too low as well – acceptable quasi-equilibrium MADQW value ranges between 3-5 % /hour. On the other hand, the preset MADTTS values should never exceed 5-7% /hour. Therefore we will set both values on 5%/hour and the RT on 10, then, by click on button Recount we get a new evaluation of the current state of the transformer



The Tx is now in an acceptable equilibrium and next diagnostic step can begin.

8. Advanced Evaluation

Clicking on the **Cdata** button in the Tx-MultiScan main window opens the Basic Data logger

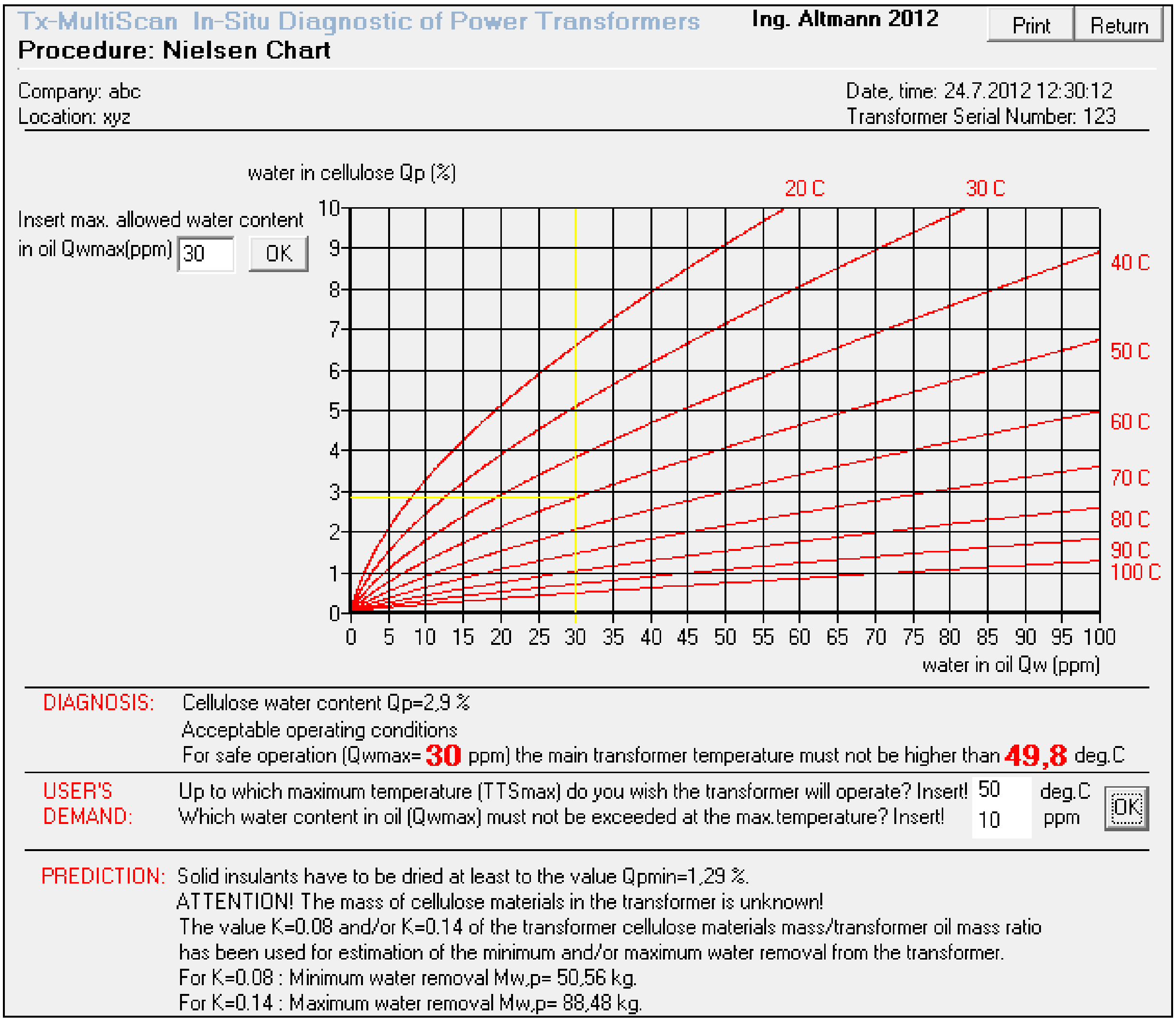


consisting from Consumer Data and Transformer Data.

All data have to be properly entered to avoid problems concerning:

- o proper indentification of the transformer
- o quantitative evaluation of the amount water which should be removed according to client ´s demand via Nielsen and LTC procedure

After clicking on the Nielsen Chart button the evaluation of water content in the cellulose is shown.



The Nielsen chart then enables in the **Diagnosis** section :

- quantitative evaluation of the average water content in hard insulants of the transformer (Qp = 2.9% in this case) based on the SU-reading of:
  - water content in oil
  - upper and bottom temperature of the transformer
  - equilibrium conditions
- the first determination of operation conditions is focused on evaluation of the ***maximum allowed temperature level of this transformer where <u>the water content in oil</u> doesn´t exceed allowed limit.*** See an example: the horizontal yelow line represents the calculated Qp-value (2.9%), the vertical yellow line represents the entered maximum allowed Qwmax-value (30ppm) and their intersection then determines the requested maximum allowed temperature of this transformer (**49.8** degC).
- evaluation of the amount of water which has to be removed, by given averaged temperature of the transformer, to achieve the desired water content in oil

The **USER´S DEMAND** section then enables to enter target values of this specific transformer:

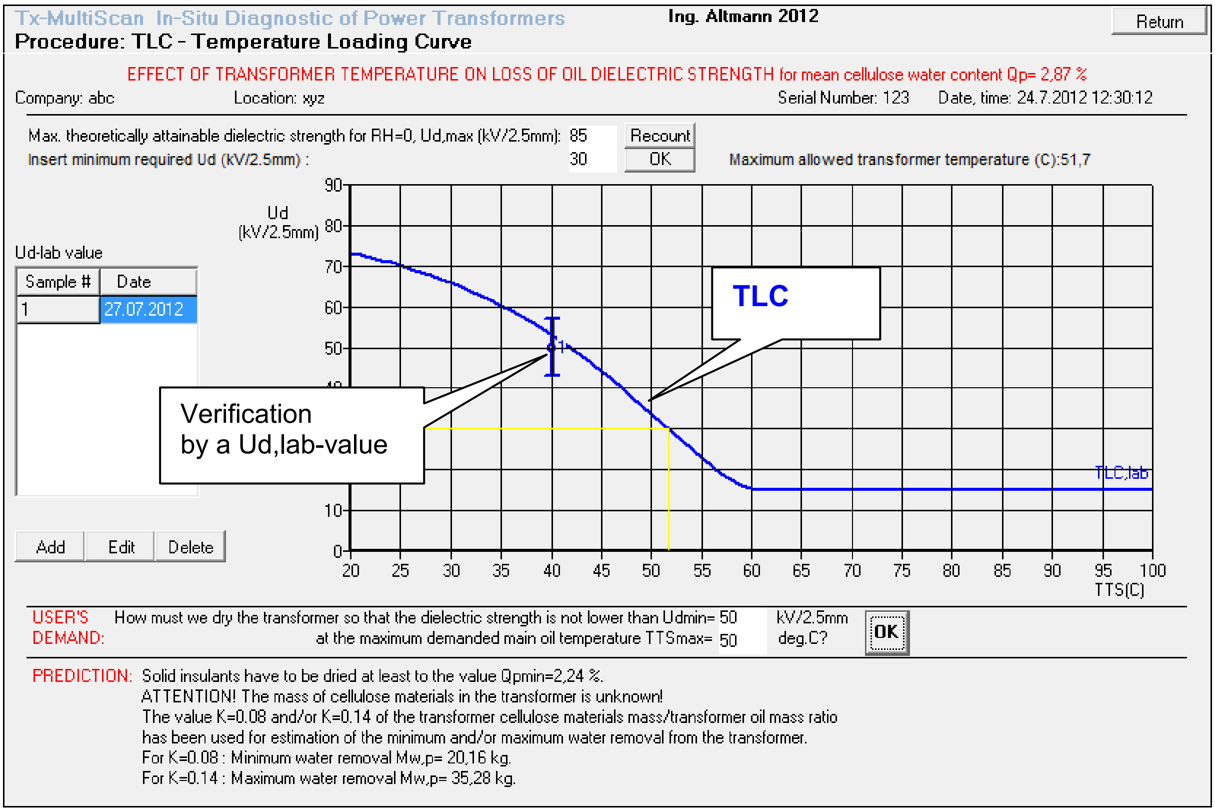
- the requested water content in oil (10ppm):
- at requested (averaged) temperature of its oil-cellulose system (50C):

After clicking on the OK button, the calculation of the amount of water which has to be removed from this transformer is performed and shown in the **PREDICTION**:

To fulfil input conditions (10 ppm, 50 C,) and after click on OK, the PREDICTION give us following results:

- o the water content in cellulose has to be reduced from 2.4% at 1.29%,
- o the minimal amount of water which has to be removed is ca 50 kg
- o the maximum amount of water which has to be removed is ca 89 kg

In the next diagnostic step, started by the click on TLC-button, the next very important relation between the theoretical dielectric strength of oil (Ud-value) and the averaged temperature of this specific transformer is established.

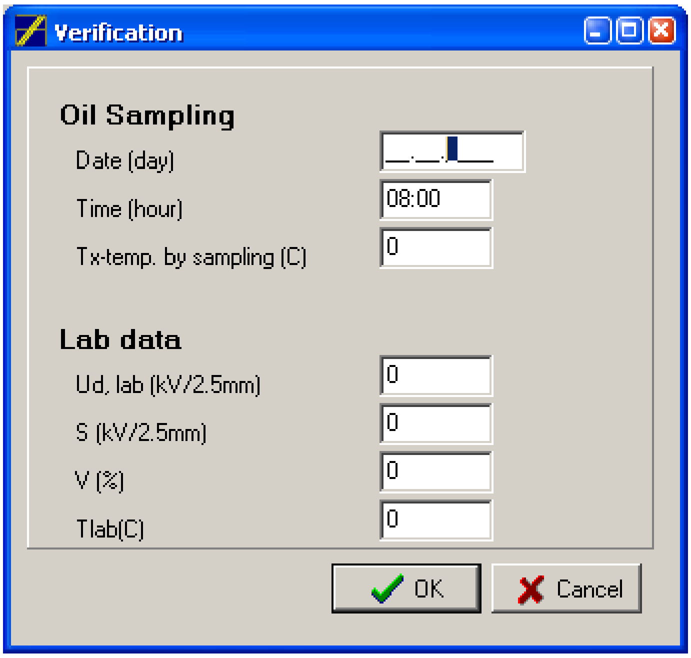


This step is extremely important especially for the determination of IEC-requested operation conditions of the transformer (the Ud-value has to be, under operation condition, always higher than IEC-given limit).

In contrast to standard diagnostic which gives us only **single Ud-value** at a sampling temperature and nothing else, the TLC-relation (Temperature Loading Curve) gives us substantially better insight because **describes the change of the Ud-value of oil within the whole temperature range of the given transformer .**

This approach enables us the another, extremely important step: the easy verification of the veracity of our TLC-relation (and therefore veracity of the whole diagnostics inclusive lab reading(s))) by **by the <u>independent</u> Ud,lab-measured value(s):**

The Ud,lab-value can be entered by the clicking on the Add- button under the Ud-lab Table (Sample #, Date] which opens window



where the **Oil sampling** data (Date, Time, Tx-temp by sampling) and the **Lab data** (Ud,lab-value, S.. Ud-deviation, V-deviation, Tlab-temp) can be easily entered.

The clicking on the OK button, then implements all data in the TLC-diagram and simultaneously shows the corresponding sample.

Verification results :

1. the lab Ud,lab-value at the sampling temperature is near enough of the TLC-relation: it means that the difference between Ud,t-value (maximum attainable dielectric strength corresponding TLC) and the Ud,lab is ca + - 10 kV/2.5mm ⇒ **The acceptable accuracy of the TLC-relation and the Ud,lab-reading.**

2. the Ud,lab-value is substantially lower (the Ud-lab value is vertically more than 20 kV/2.5 mm under the corresponding Ud,t-value (TLC): this difference indicates the potential presence of particles in oil (or a wrong reading of course). Should therefore be confirmed/disproved in the next diagnostic step (e.g.amount and size of particles has to be checked or a new Ud, lab -reading should be performed).

- o the Ud,lab.-value is substantially higher than Ud,t-value: is higher than the maximum attainable dielectric strength of oil ⇒ wrong lab reading or the wrong Qw-reading:
  - ❖ oil temperature before the BDV (Break Down Voltage)-test was probably substantially higher than the norm-requested 20C+/- 5C-level.
  - ❖ the Qw-reading is wrong : the Vaisala sensor has to be calibrated

ATTENTION.

According to IEC Norm the reading of Ud-value in a lab has to be performed under strictly defined conditions. One of most important parameters is the temperature of oil in the measuring vessel : the temp. has to be 20C +- 5C !!

For a proper evaluation and verification of data by means of the TLC, the Tlab-value (the temp. of the oil) is absolutely crucial: higher temp. of the oil means higher Ud-value of the oil and vice versa. The oil protocol without this specific temp. is therefore worthless.

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- **Determination of operation conditions**: the Ud-value must never be lower then e.g. IEC limit (say 30 kV/2.5mm)

  insert (in the left, upper part of the TLC-window):

  - minimum required Ud-value (here 30 kV/2.5mm),

  and the clicking on the OK button then gives you requested results : the maximum allowed (averaged) temperature of the transformer (ca 51 C)

corresponding relation is smultaneously shown in the diagram (30kV/2.5mm = horizontal yelow line, resulting 51 C = vertical yellow line)

The **USER´S DEMAND** section enables to enter target Ud-values of this specific transformer:

- the required Ud-value (say 50kV/2,5mm):

This target value of the oil has to be always substantially higher than the IEC-limit (mostly 30 kV/2.5mm)

- at requested (averaged) temperature of its oil-cellulose system (50C)

To fulfil input conditions (50kV/2.5mm, 50 C in this case), the PREDICTION give us following results:

- the water content in cellulose has to be reduced from 2.9% at 2.24 %,
- minimal amount of removed water is ca 20 kg
- maximum amount of water which has to be removed is ca 35 kg

8. Total Gas Content (TGC) Evaluation

Under standard condition is the TGC-evaluation performed immediately after the reading of the water content in oil (and corresponding evaluation of the equilibrium of the transformer). The PCD Amit of the **SU** asks if the TGC-reading should to be performed or not

TGC Start ?
← Yes / No →

If **No** the **SU** measuring campaign is definitely finished

If **Yes** , the Calibration procedure begins

TGC CALIBRATION
Yes = (+) / No = (-)

If Yes , the SU reads

TGC CALIBRATION
Yes = (+) / No = (-)

If No, the Calibration is not performed and the **SU** goes into the TGC OIL INPUT step.

The stroke of the piston is measured in the both direction to avoid the measuring error induced by the mechanical hysteresis of the screw-female screw coupling of the SU kinetic system.

When the calibration doesn´t meet predetermined values, the measuring is stopped and the result is reported:

CALIB. FAILED
CALL SERVICE

The positive result is reported as

CALIBRATION OK

and the **SU** goes on the next step,

TGC OIL INPUT
PUSH ENTER

The **SU** then asks whether free oil inflow (from the oil inventory of the transformer to the **SU**) is granted , all cocks inclusive hydraulic switch have to be open

ALL COCKS OPEN?
PUSH ENTER

the piston is moving to the right until its pre-desired position is reached and the pre-defined volume of oil is delivered via a slight vacuum into the glas cylinder of the **SU**.

The **SU** then checks the time-related pressure equilization

PRES. LEVELLING
WAIT PLEASE

and subsequently requires the closing of the Hydraulic Switch (See Fig. 1, Position OFF) which driver is situated on the face plate of the **SU** (See Fig. 2):

For the closing the driver has to be at first vertically shifted up, turned to the proper position (red dot at the diver is positioned against OFF) and then dropped down.

The **SU** demands this specific procedure by display

CLOSE H. SWITCH
PUSH ENTER

The predefined volume of the oil is now "sealed" in the glas cylinder of the **SU** and the vaccum-driven removal of gases from the oil can beginn.

To avoid a wrong TGC-reading, the vacuum tightness of the internal space of the glas cylinder and the hydraulic switch has to be checked . The **SU** therefore moves the piston for predefined length to the right and attained vacuum is compared with the predefined pressure level.

The wrong position or an untightness of the Hydraulic Switch (or any other potential untightness of the cylinder) is reported

FULLY CLOSED ?
YES - PUSH ENTER

and the new vacuum test is performed.

The SU goes to the next step only if desired vacuum tightness is confirmed .

The flash valve (See Fig. 1, Position 13) has to be always fully open to enable the free release of liberated gases from the **SU** into surrounding (via hose H3 into tank of vacuum pump).

The **SU** asks therefore

OPEN FLASH COCK
PUSH ENTER

The proper position of the Flash Cock is tested by the PCD Amit again. The **SU** now moves the piston to the left and reads the attained pressure.

If the pressure increases over the predefined (allowed) limit, the Flash Cock isn´t fully open and the **SU** asks :

FULLY OPEN ?
YES - PUSH ENTER

if the pressure remains under the predefined limit, the **SU** goes on the first cycle of the gradual vacuum separation process begins.

The **SU** reads the internal pressure of cylinder and the position of the piston

VACUUM BUILDING
P= xxx **kPa, N =** xxxx

where:

P….. absolute pressure in the glas cylinder, N … number of measuring steps

the piston is moving to the right, the vacuum increases, the gases partially escape from the oil and create the gas "bubble" above correspondingly decreasing oil level in the glas cylinder.

This preliminary separation process continues till the piston reaches its right terminal position.

The **SU** notifies this stage by

GAS RELEASE
P= xxx **kPa, N =** xxxx

Because the gas release under a stationary vacuum is inevitably very slow, the release is accelerated by the hydrodynamic stirrer in the left, bottom part of the cylinder.

The stirrer piston vibrates in the predermined frequency mode and alternately draws the oil from the cylinder and forces it back in the oil inventory of cylinder. This process simultaneously generates the large interfacial area between oil and rarefied gas (due to large number of bubbles) and the strong mixing of given oil inventory.

The gases are transported into bubbles subsequently driven by the buyonancy over the oil level. This very intensive degassing is performed for the pre-defined time period .

The separation process is finished after ca 2 min. and in the next step the liberated gases are compressed and expelled out of cylinder.

The motion of the piston is therefore reversed and the piston moves to the left:

COMPRESSION
P= xxx **kPa, N =** xxxx

The gas "bubble" over the oil level in the cylinder is gradually compressed and when the internal pressure reaches the predermined level (P ≈ 100 kPa), the volume of gases is measured and the first TGC-value is calculated.

To ensure the better vacuum level in the next cycle, the gas buble is expelled via non-return valve (See Fig. 1, Position 7), quick-coupling (position 12), and open flash valve (Position 13) freely in the tank of the vacuum pump.

To remove all gas residuals, the upper part of the glas cylinder and the return valve is subsequently rinsed by the oil from the glas cylinder and the process si indicated as

FLUSHING

and the first "estimation" of the TGC-value of given oil is showed on the **SU** display

TGC(I)= xxx **(%)**

The first gas-removal / compression cycle (I=1) is finished and the second one begins.

VACUUM BUILDING
P= xxx **kPa, N =** xxxx

followed by

GAS RELEASE
P= xxx **kPa, N =** xxxx

and

COMPRESSION
P= xxx **kPa, N =** xxxx

and

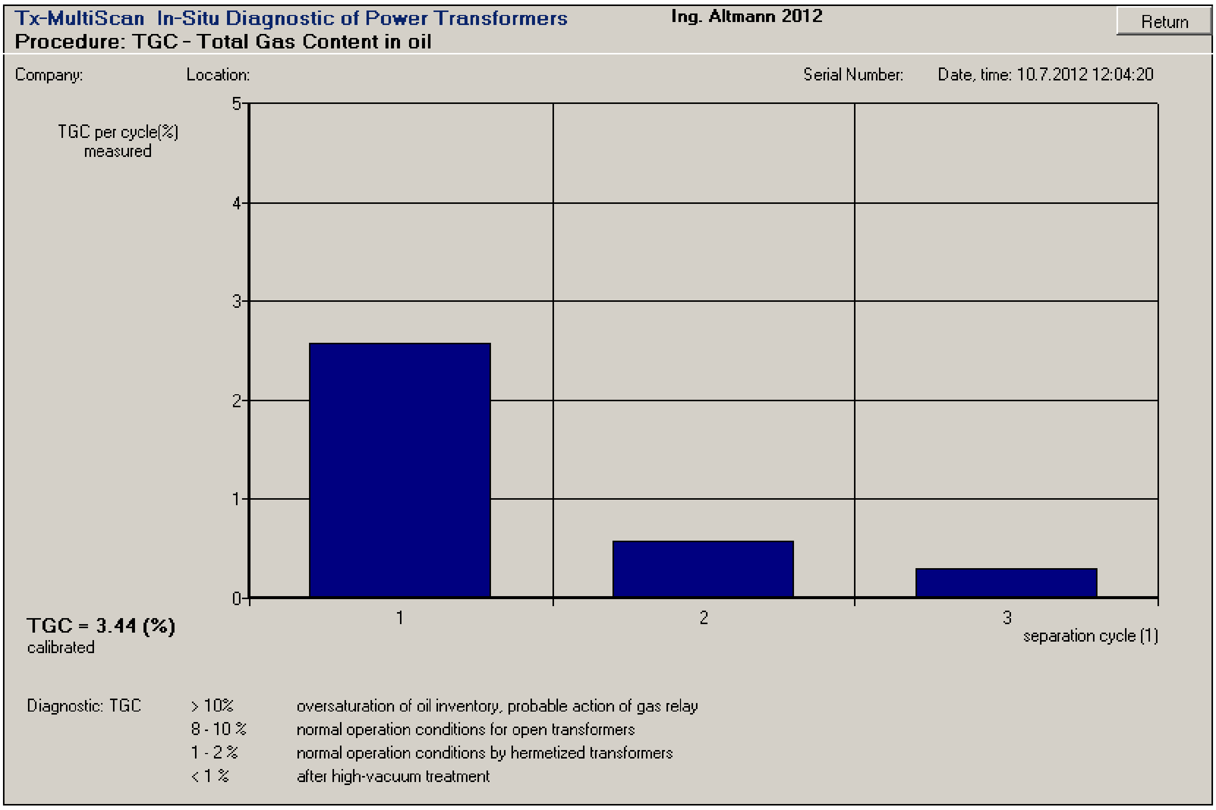
FLUSHING

The whole process is repeated again and again until the requested precision of the TGC-value is reached and the final result is displayed:

END, TGC = xxx **%**
PUSH ENTER

By click on the Measuring and the TGC-button in the Main window the dynamics of whole gas separation process is shown.

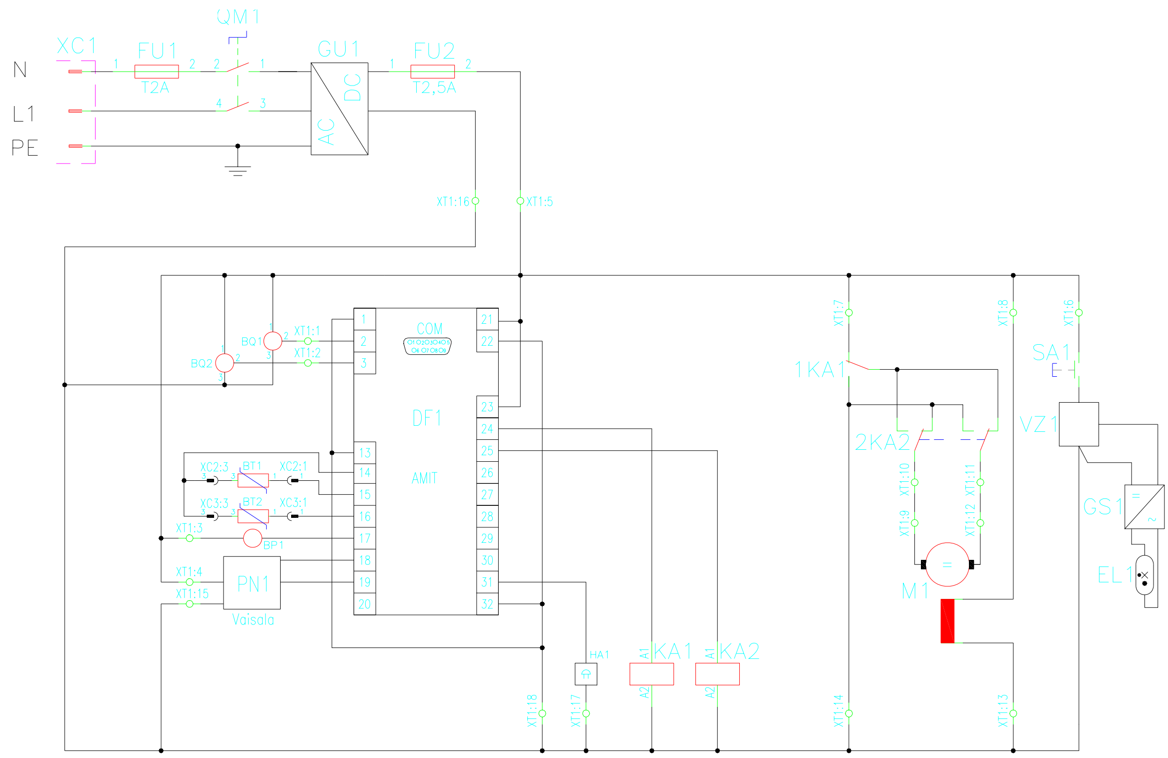
All three degassing cycles and corresponding TGC-values inclusive the total TGC-value, TGC = 3.44% in this case are shown.



The Multiscan TGC-reading is suitable for a quick information about a TGC-content in oil in face of the Tx.

9 . Electrical circuits .

Power Circuit diagram of the SU is shown on Fig. 5, components location is shown on Fig.7



Name	Function	Designation	Qty	Producer
QM1	Main switch 10A, 240V	Best.Nr. 501638	1	Conrad
XC1	Power supply connector	Best.Nr. 501638	1	Conrad
GU1	Power supply	TXL 070-24S	1	Traco Power
FU1	230 (110)VAC T 2A tube fuse	FST01	1	GES Electronics
FU2	24 VAC T 2,5A tube fuse	FST02	1	GES Electronics
DF1	Proces Control Unit	ART 267 A	1	AMiT
BQ1, 2, 3	Position sensor	TCST 2103	3	GES Electronics
BT1, BT2	Temperature sensor	PT30, Ni 1000	2	Rawet
BP1	Pressure sensor	DMP 331, 0-6bar	1	BD Sensors
PN1	Humidity sensor	MMT 162	1	Vaisalla
HA1	Buzzer	PEB 457	1	GES Electronics
KA1	Relay 24V DC	40.61	1	Finder
KA2	Relay 24V DC	40.52	1	Finder
KA3	Relay 24 C DC (solid state)	3TX7004-3AC04	1	Siemens
M1	Servodrive 24DVC , 45 rev/min	K7A3	1	ATAS
SA1	Push button switch	B 1383	1	GES Electronics
GS1	Converter	Best.Nr. 581770	1	Conrad
ST	Stirrer		1	Altmann
EL1	Fluorescent tube	Nr. 58 17 70	1	Conrad

Fig. 7 **SU** Circuit diagram

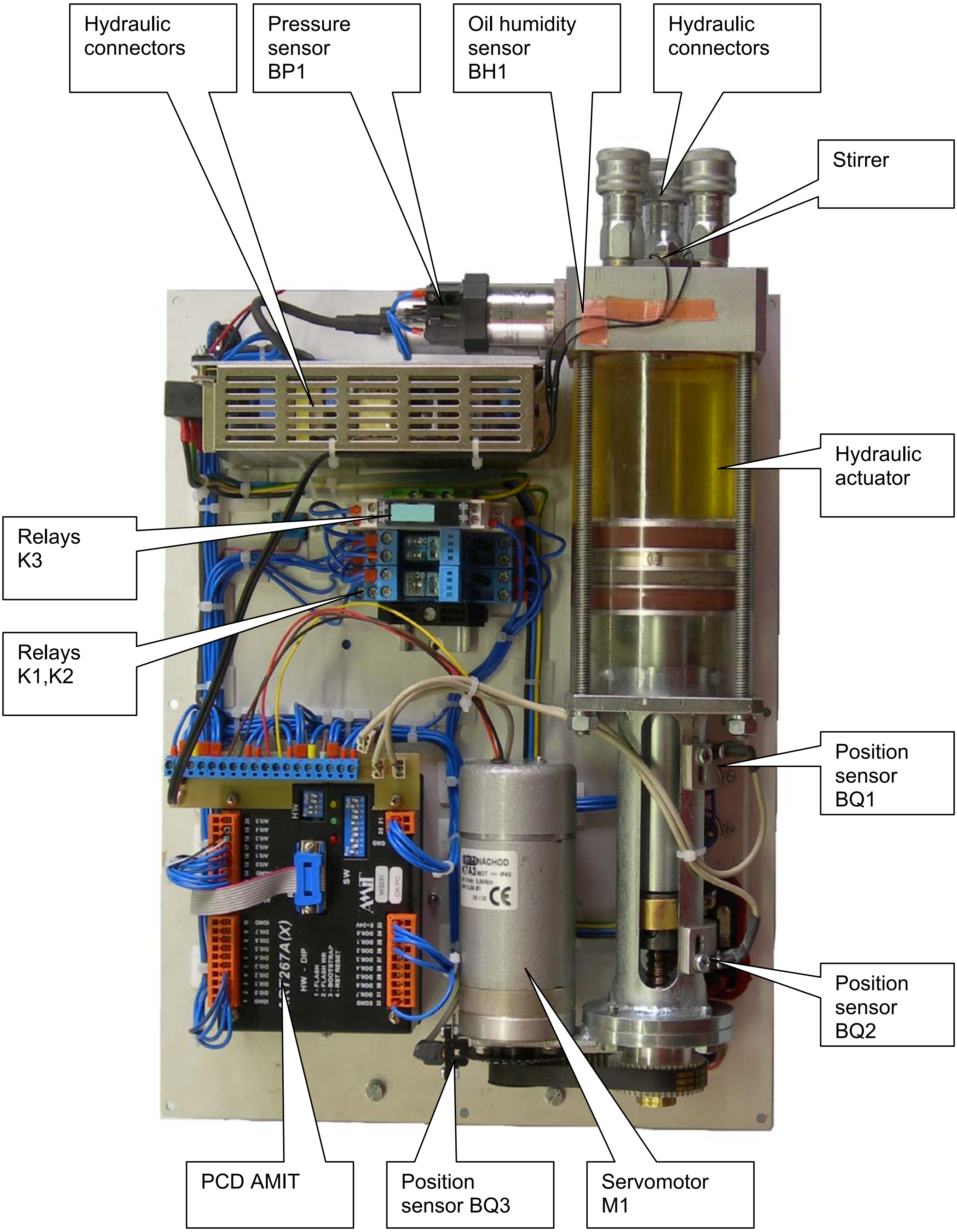
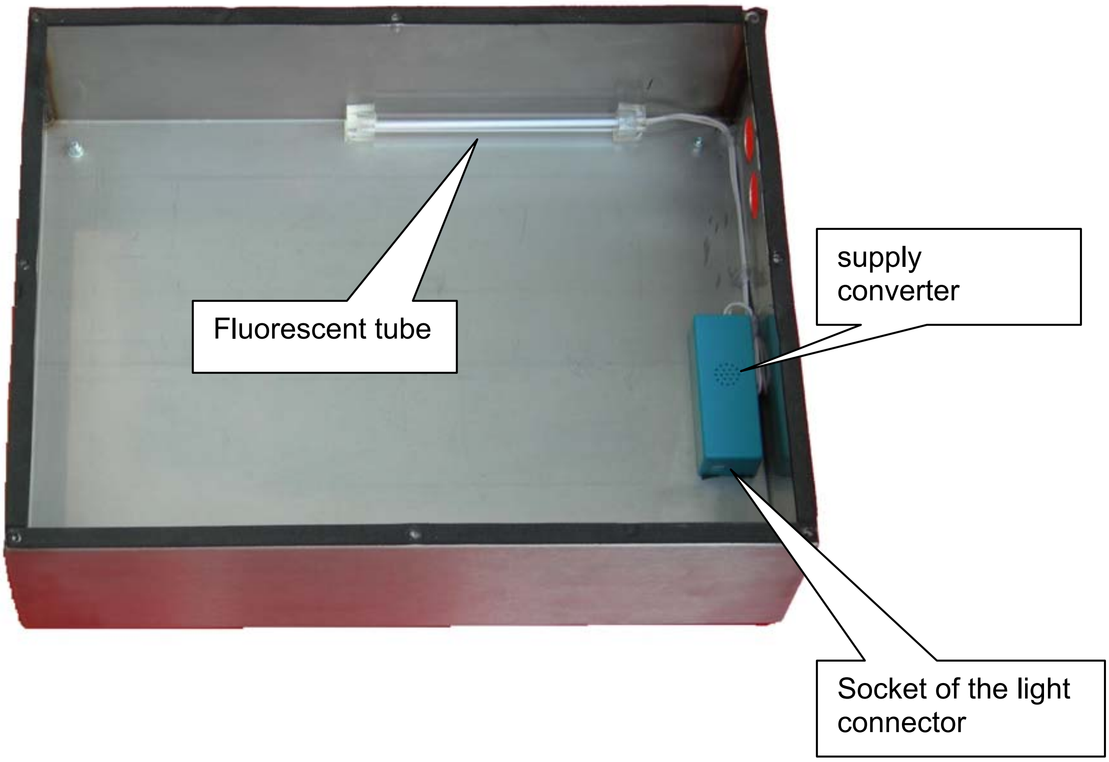


Fig. 7 **SU** Component location



ATTENTION !

disconnect the lighting connector
before the final lifting of the face panel of the TX-MULTISCAN

Fig. 8 The case of the **SU**

9 . Recommended Accessories

For a rapid start-up of the **SU** which is installed on the transformer with large dentrimental spaces, the most simple and suitable answer is the hand-operated vacuum pump See Fig. 9.

Fig. 9 Hand-actuated vacuum pump with the connecting hose and the quick-acting coupling

The pump is connected to the de-aerating connector of the **SU** (See Fig. 2) via the hose H3 and quick-acting coupling. At first, the desired vacuum in the pump is created by a means of the hand-operated piston, and the proper level of the internal vacuum is evaluated by the vacuum gauge.

Then the flash cock of the hose is opened and the internal space of the **SU** and the hose H1 (eventually H2) is that way hydraulically connected to the internal space of the pump.

If the internal pressure of this whole system is higher then required (vacuum is too low), the pressure is reduced by a repeated motion of the piston until the required vacuum level is met.

The effect of detrimental spaces is evaluated and, if necessary the required vacuum is improved by hand-driven vacuum pump:

⇒ **1-P connection:** open the sampling cock, check the vacuum level and if necessary reduce it to desired level by repeated motion of the pump piston

⇒ **2-P connection:** open both - Valve 1 and Valve 2 in the Position 2, check the vacuum level and if necessary reduce it to desired level by repeated motion of the pump piston.