SIMMS 2.2

Solid Insulation Moisture Measurement System

Portable Online & InSitu Transformer Diagnostic System

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Solid Insulation

The accurate recording and managing of the water content in the transformer's solid insulation Qp (%), the tracking and limiting of the impact on the aging rate of the paper, and the maintaining the desired dielectrical strength of oil Ud (kV/2.5mm) at maximum process temperatures, have never been cost effective and easy to achieve. However, it is one of the most pro-active, pro-safety , life extending, and cost reducing preventative strategies available to a transformer manager.

One oil sample a year collected in a glass bottle or syringe, processed in a lab, with a high degree of variability due to the sampling process and lack of controls, does not provide the degree of data and accuracy necessary for the competent failure risk management and for managing the appropriate insulation treatment program of the transformer.

With the release of the SIMMS 2.1 portable online oil and solid insulation water diagnostic system, ARS Altmann Systems has produced and sent out this key transformer information.

SIMMS 2.1 is a portable oil sample and temperature diagnostic system, without the sampling contamination and variance risk. Simply connect SIMMS to the oil sampling points of a transformer, connect the two temperature sensors, plug in, and start. From this moment on the sampled oil is by no means exposed to the atmosphere. Oil will flow from the transformer through SIMMS and return to the transformer.

SIMMS gives us then the all desired time-related profile - water content in oil Qw = Qw (t) and both temperature Tu = Tu (t), Tb = Tb (t) – upper / bottom transformer temperatures and TTS as main (averaged) transformer temperature. Both averaged Qw value and TTS value can be accurately used for calculating the water content in the cellulose Qp = Qp (Qw, TTS).

SIMMS is basically used for two diagnostic procedures of transformer :

- **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.

Both problems 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.

The **ARS-Altmann** has therefore released the **SIMMS 2.1**, version 2015**,** 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 SIMMS 2.1 can be easily used for the reading of any kind of a transformer.

The basic readings and diagnostic results achieved by the **SIMMS 2.1** system covers the following diagnostic areas:

⇒ water content in oil

⇒ 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*** .

⇒ TLC relation, the prediction of actual (theoretical) dielectric strenght of oil 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***

The major advantages of the **SIMMS 2.1** are:

- **easy installation and commissioning**

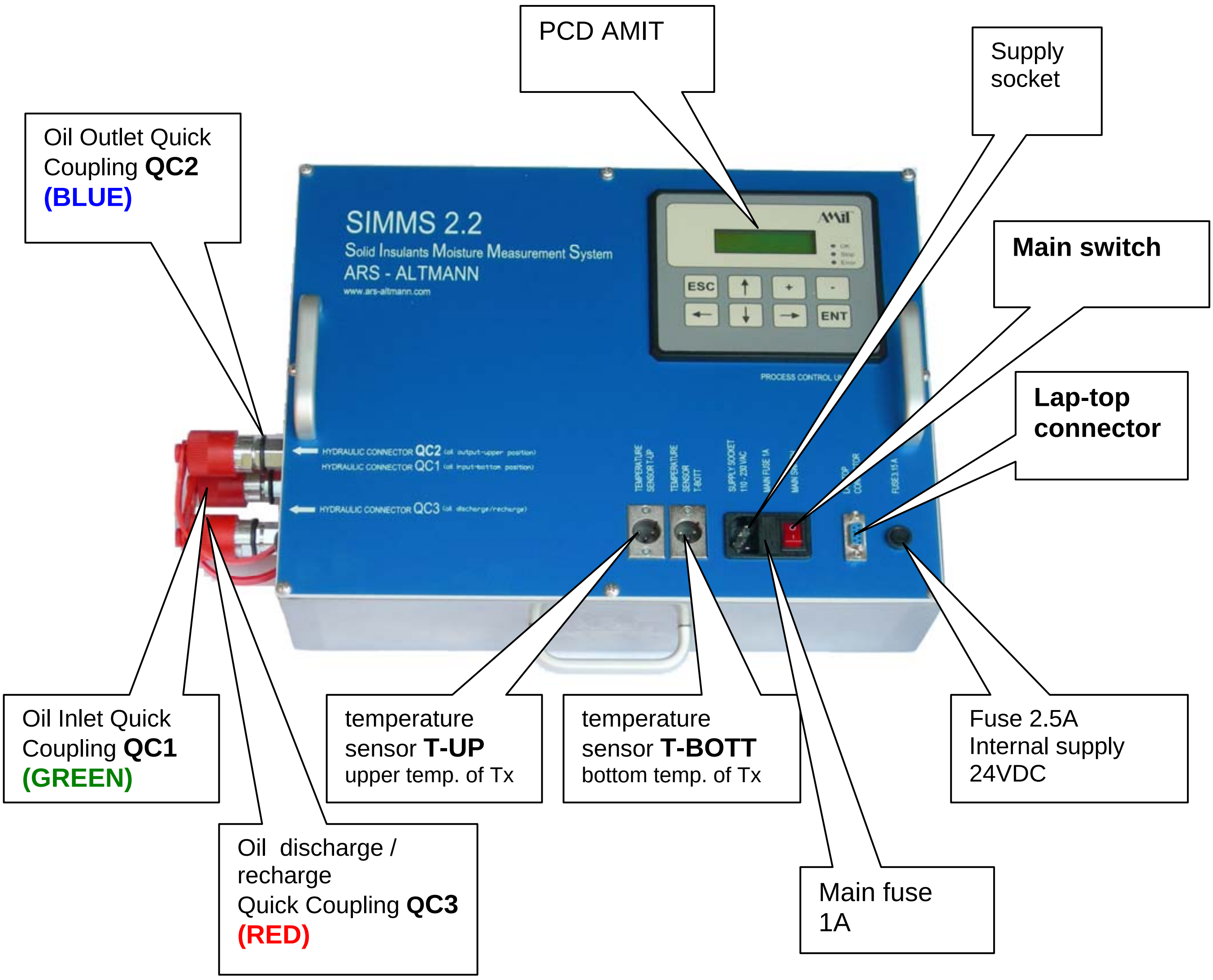
- **on-line reading** – under normal operational conditions of a transformer
- **no contamination of oil within sampling & reading**
- **no loss of oil due to sampling**
- **first results are available in situ, in hours**

The **SIMMS 2.1 ,** consists of :

- **Service Unit** (**SU**), the hydraulical system which samples the oil from the oil filling of a transfrormer, then reads the basic data giving the relative moisture of the oil and transformer temperatures, analyses and evaluates them and forces the oil back into the transformer.

The SU can 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.



Service Unit (SU)

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Water content in oil

The reading of the water content in the oil filling of a transformer is continuously performed by the humidity sensor Vaisala MT162 situated in the **SU** box. The oil is permanently being drained from the transformer 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 of transformer

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

- **the reading of water content in <u>aged oils</u> <u>is to too high</u>**, *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 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 to avoid an oil contamination and/or air ingress into oil inventory of transformer (potential Buchholz trip).

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.

Water in cellulose

The evaluation of the water content in cellulose materials of a transformer performed by the **SIMMS 2.1** 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 **SIMMS 2.1** 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**. 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.

SIMMS 2.1 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.

1.2. **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 solid insulants, and the temperature related to the temperature-related movement and time lag of the water movement between the paper and the oil.

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 : the amount of water which migrates between the celluse insulants and oil filling is very low compared to amount of water absorbed in the cellulose .

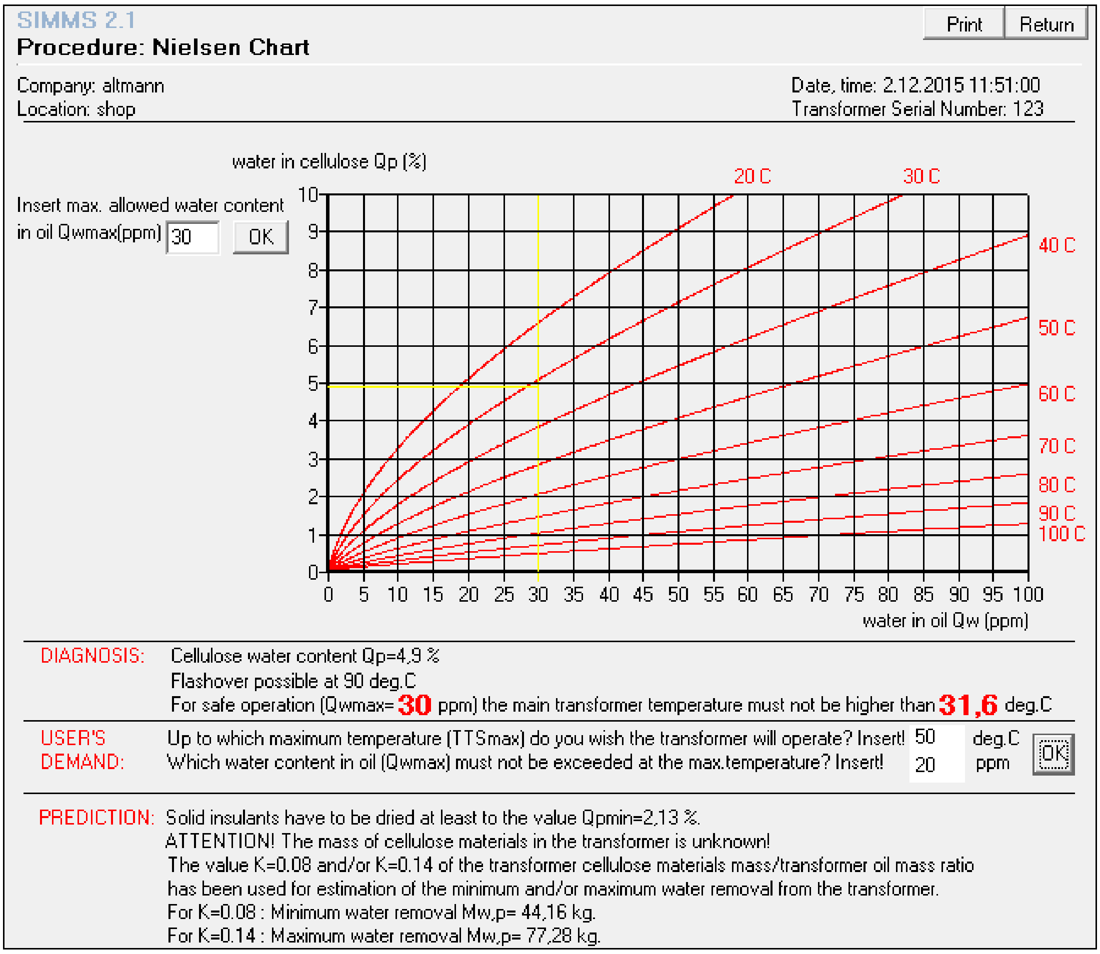
In practical terms, if we take an oil sample from the transformer under any temperature we must (under equlibrium conditions) get approximately the same Qp-value.

The Qp-value as an almost temperature constant, represents the key value of a moisture related problems of any transformer.

which

enables <u>the prediction</u> of the most important (Qw, Ud) values <u>for the whole temperature range of the transformer</u>

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



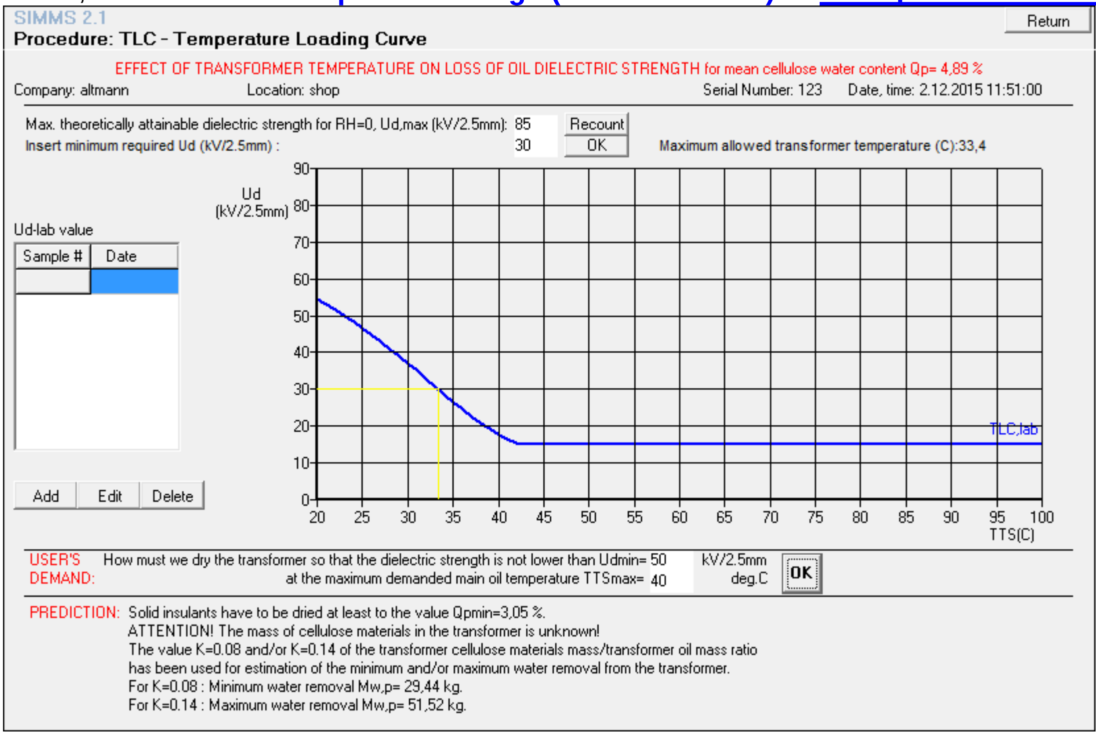
- **Diagnosis** section then interprets the reading and calculates the averaged water content in cellulose (here Qp= 4.9%). Based on the entry of target value of water content in oil Qwmax = 30ppm and given water content in cellulose Qp = 4.9% then calculates the maximum allowed operating temperatures of the transfomer, here **31.6C** (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.
- **Prediction** section then calculates how much water has to be removed from this specific transformer to meet given demands (minimum ca 44 kg of water has to be removed in this case).

1.2 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 **33.4C**) 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.

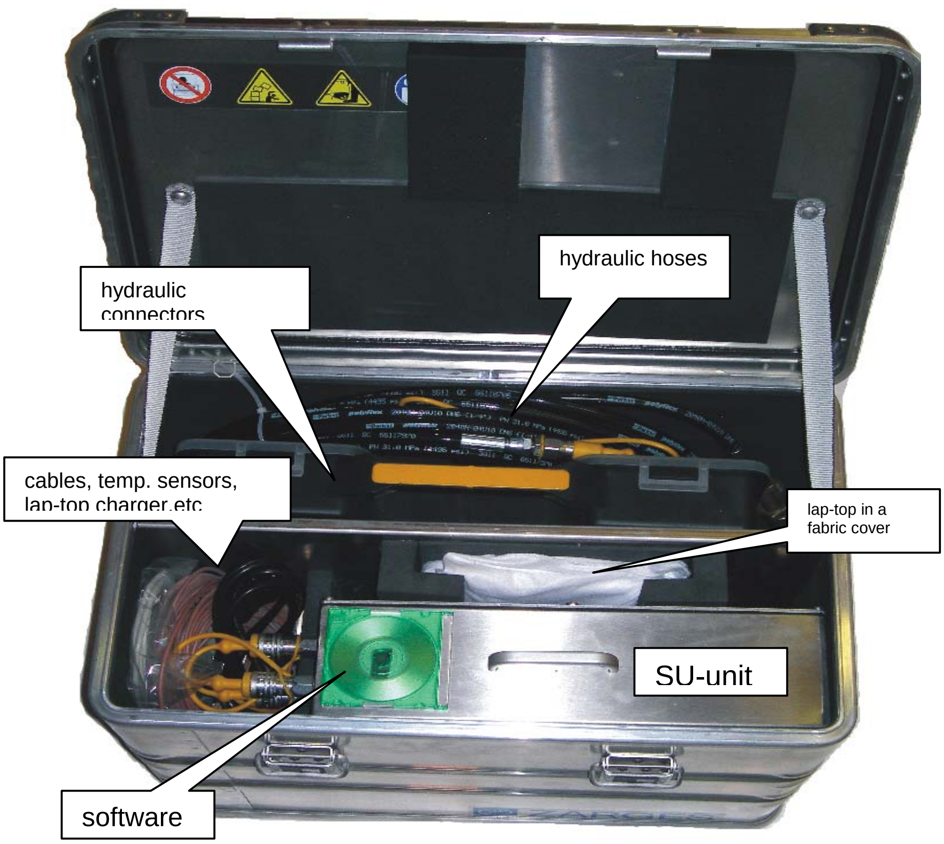
Verification of diagnostic results by Ud-lab value(s) based on the comparison of theoretical Ud-value (TLC-curve) with the Ud-lab value at the same sampling time and the same temperature of the transformer.

2. SIMMS 2.2 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	max 100l 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	22 kg
Dry weight of the measuring unit only (without oil)	5 kg
Hydraulical connection	2 x flexible hose
Communication:	lap-top connector

3. Transportations



SIMMS 2.1 Service Unit is always transported, inclusively the lap-top and all accessories in high resistant alu box intended for all-day operations under very heavy conditions

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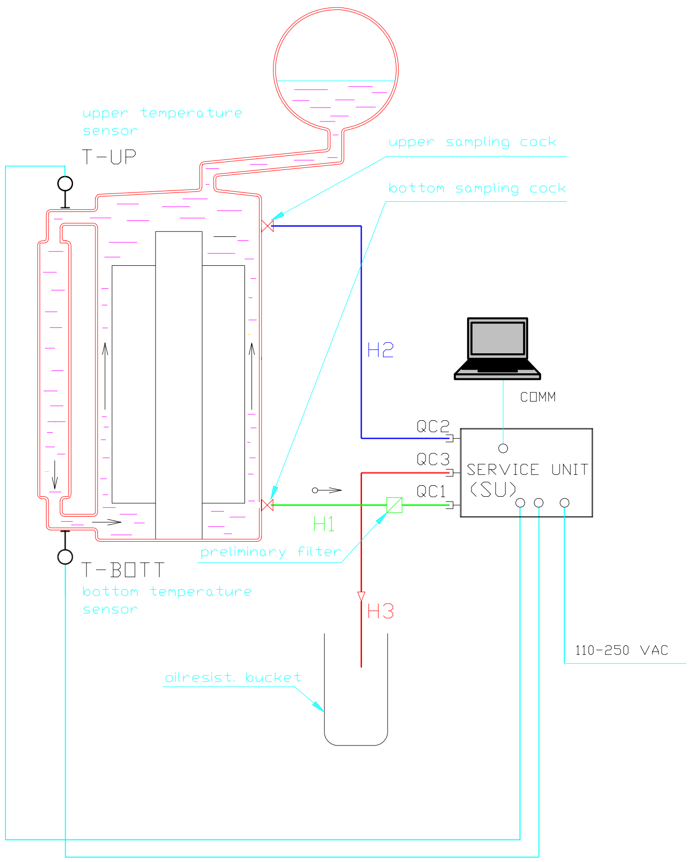
4. Installation & Commissioning



SIMMS is connected to two oil sample taps, one at the top one at the bottom. Then, both connecting hoses are evacuated to avoid contamination by air-moisture and a potential Buchholz trip. The oil is then drawn continuously through the SIMMS unit and passed back to the transformer.Independent temperature sensors are fitted to the designated top and bottom positions. Once SIMMS is installed, connected and started (ca 10 minutes), the transformer´s top (T-UP) and bottom temperatures (T-BOTT) and water content in the oil Qw (ppm) are recorded in a time based log.

Within 40 minutes an accurate snapshot decision info - if the adequate equilibrium is reached or not is obtained.
That allows precise accuracy in determining water content in the solid insulation, and the temperature related movement and time lag of the water movement between the paper and the oil. The dielectric strength and load risk at peak load can be determined more accurately. While online, the data can be accessed directly by lap-top, the graphs of trends produced, and saved as a file.
To meet plug & play features of SIMMS 2.1, the inherent part of the delivery is pre-programmed lap-top to avoid any communication and evaluation problems.

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) and the theoretical dielectric strength of oil (the Ud-value.

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

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