ON-LINE DEHYDRATION, DEGASSING AND ULTRAFILTRATION OF TRANSFORMERS

FOR VERY HEAVY WORKING CONDITIONS

VACUUM SEPARATOR VS-06 A

ON POWER RECOVERY OF DIELECTRIC STRENGTH

LIFE EXTENSION OF TRANFORMER

REMOTE PROCESS CONTROL AND MONITORING

MINIMUM SUPERVISION AND/OR MAINTENANCE

STRIPPING PROCEDURE FOR EFFECTIVE REMOVAL OF FAULT GASES

DIELECTRIC REMOTE SCREENING

Easy SMS Monitoring of function

Fa. Ing. Altmann ARS Altmann Group, Machova 142, 344 01 Domazlice, Czech Republic, European Union
Tel:+420-379 738 778, Fax:+420-379 738 775, Cell phone:+420-602 362 157 email:altmann@iol.cz, www.ars-altmann.com;

Drying of transformers

The presence of moisture in the transformer, to whatever degree, actually harms the insulation which will be permanently damaged. Drying methods can substantially reduce that deterioration.

The Vacuum Separator VS-06 is intended for mobile and preventative use on transformers with more than 2 - 2.5% water content in the cellulose, with particle contamination and excess gases. The **quick restoration of safe dielectric conditions, life-extending features and remote control** also forms part of this concept. The system can be installed regardless of the size of the transformer.

Main features of VS-06

- **Moisture, gas and particles content can be reduced to the level of a new transformer**
- **Quick restoration of dielectric strength of oil**
- **No impact on the insulating oil properties, no over-drying of the transformer**
- **No disconnection of the transformer under treatment, not even during the installation of the separator**
- **Installation and servicing with the minimum manpower**
- **Direct check of the dehydration efficiency by the volumetric measurement of separated water**
- **Remote monitoring & control of the drying & degassing processes and the permanent screening of the dielectric behaviour of a transformer**
- **Application of advanced and patented technologies like "hydraulic piston" for vacuum building and "bubble bed" for moisture separation**
- **Effective removal of fault gases via stripping procedure**

HOW MUCH MOISTURE IS "TOO MUCH MOISTURE" ?

Moisture enters the transformer either through external contamination, or is generated internally by the oxidation (ageing) of insulants. In either case, practically all the water present in the transformer (over 98%) is contained in solid insulants because the cellulose is very hydroscopic.

Figure 1 shows the equilibrium relationship between the water content in the oil Cw (ppm) and cellulose Cp (weight %) at different operational temperatures.

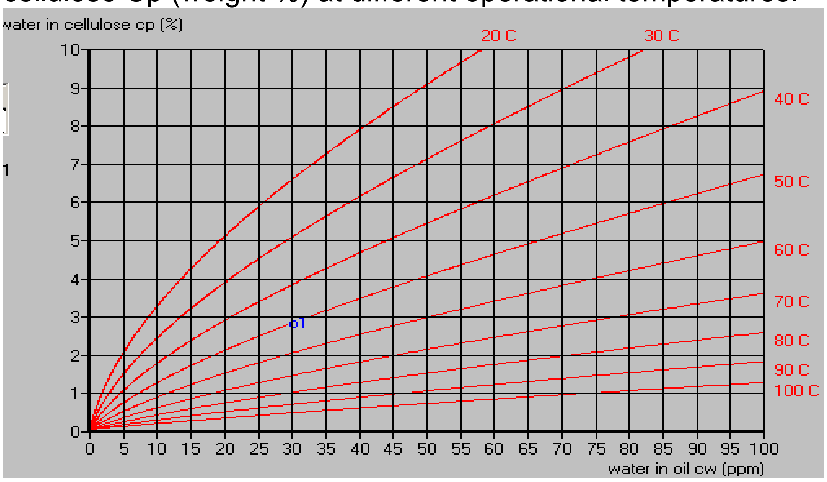


Fig.1 Moisture equilibrium chart (Nielsen diagram – TRACONAL 2005)

Example: **10MVA Transformer, 700 kg cellulose, 6000 kg oil**
Sampling temperature 50C, Qw = 30 ppm of water in the oil → Qp = **2.9%** weight percent of water in the cellulose.

Total amount of water in the cellulose: 700 x 0.029 = **20.3 kg**

Total amount of water in the oil : 6000 x 0.000030 = **0.18 kg**

If one wishes to reduce the moisture to an acceptable 2% boundary then: 700 x (0.029 – 0.02) = **6.3 kg** water must be removed from the transformer.

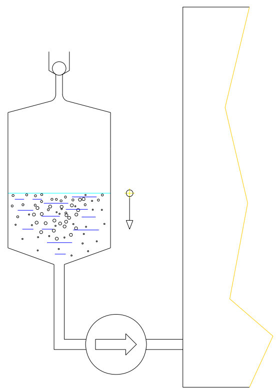
The effect of moisture on the transformer is summarized in Table 1.

Qp (weight % in paper)	**Transformer condition**
0.5	new or highly dried
2.0	acceptable condition
3.3	paper starts to deteriorate
4.5	flashover possible at 90C
7.0	flashover possible at 50C
8.0	who knows ?

In order to avoid the deterioration of solid insulants, the moisture content should be kept under 2%. If the moisture level is suspected to exceed 2% , the transformer must be dehydrated as a matter of preventive maintenance. For basic information about moisture impact in the dielectric behaviour of a transformer See www.ars-altmann.com / TRACONAL or / News.

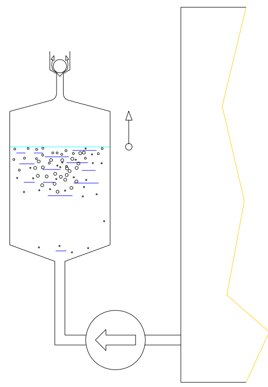
WHAT IS A LIQUID PISTON ?

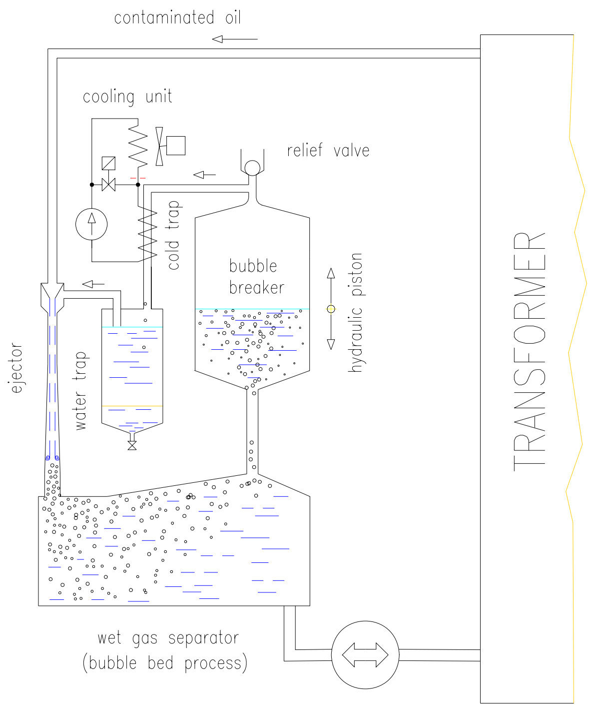
The Liquid Piston principle, which substitutes the vacuum pump, is created by the rising and falling of oil level which is caused by the cyclic operation of the robust gear pump.



The first stage (***evacuation***) is schematically shown on the left. The oil is drawn from the apparatus by the gear pump. The sinking oil level acts as a piston and creates the basic vacuum necessary to separate the gases and vapours from the oil

The second stage (***compression***) is schematically shown on the right. The run of the gear pump is reversed and the liberated gas-vapour mixture is gradually compressed by the rising oil level (upward motion of the liquid piston). When the pressure rises, first the condensation of oil vapours takes place and the **condensed light fractions are automatically mixed back into the oil. Only this way can it be guaranteed that under on-line long-term dehydration of a transformer that there is "no-impact on oil properties".** Subsequently, the gases are released via the non-return valve into the atmosphere. This process continues until the whole apparatus is filled with oil, then the gear pump is switched on into the direct run again and the next evacuation stage begins.





HOW ARE VAPOURS AND GASES SEPARATED FROM OIL ?

Vacuum, appropriate temperature and large interfacial area are essential for efficient separation.

Contaminated oil from the transformer is adjusted to an optimum temperature and the hot oil and the gas (previously separated from the oil) are mixed in a vacuum by the ejector in order to produce bubbles with a large interfacial area (bubble bed).

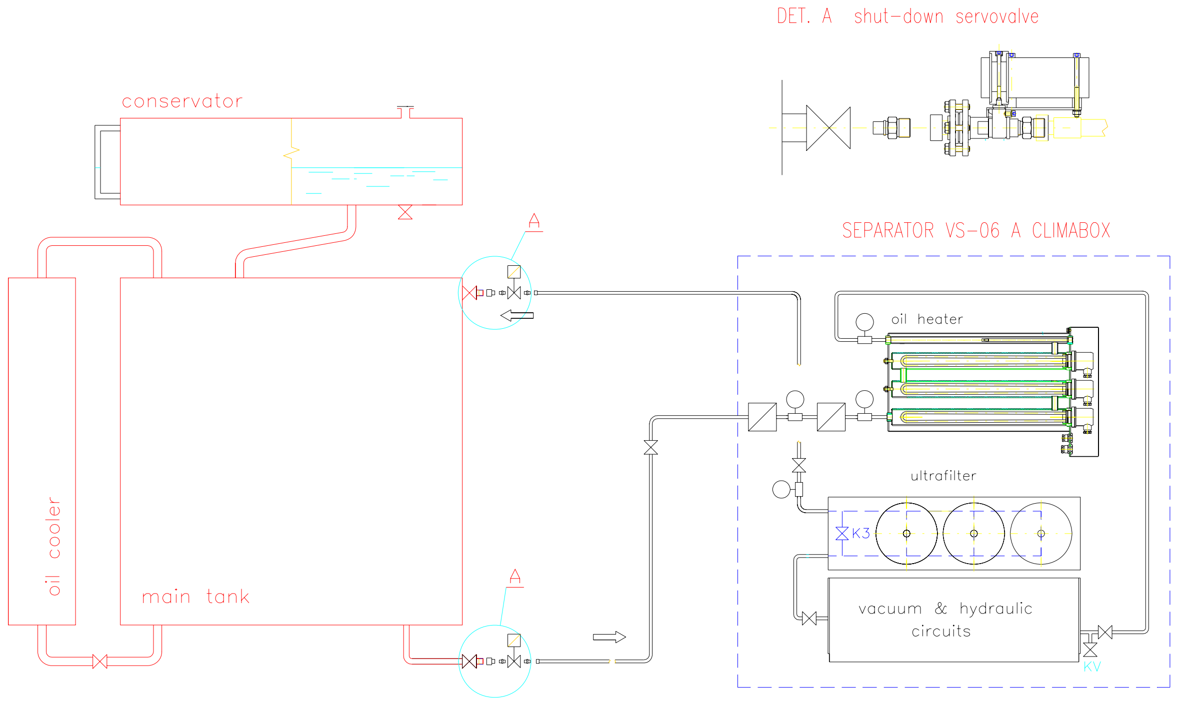
The intense diffusion of the moisture from the oil is enhanced by minimizing the partial pressure of the water vapour. This is achieved by undercooling the carrier gas to condense and freeze-out all traces of moisture prior to mixing with the contaminated oil.

Dissolved gases and vapours diffuse into bubbles which are then agglomerated, collected and broken. The released water vapour is then collected in the form of ice in the freezing trap, and periodically defrosted and collected as a liquid in the water trap.

Fa. Ing. Altmann ARS Altmann Group, Machova 142, 344 01 Domazlice, Czech Republic, European Union
Tel:+420-379 738 778, Fax:+420-379 738 775, Cell phone:+420-602 362 157 email:altmann@iol.cz, www.ars-altmann.com;

Note that only a simplified scheme is shown here for clarity.

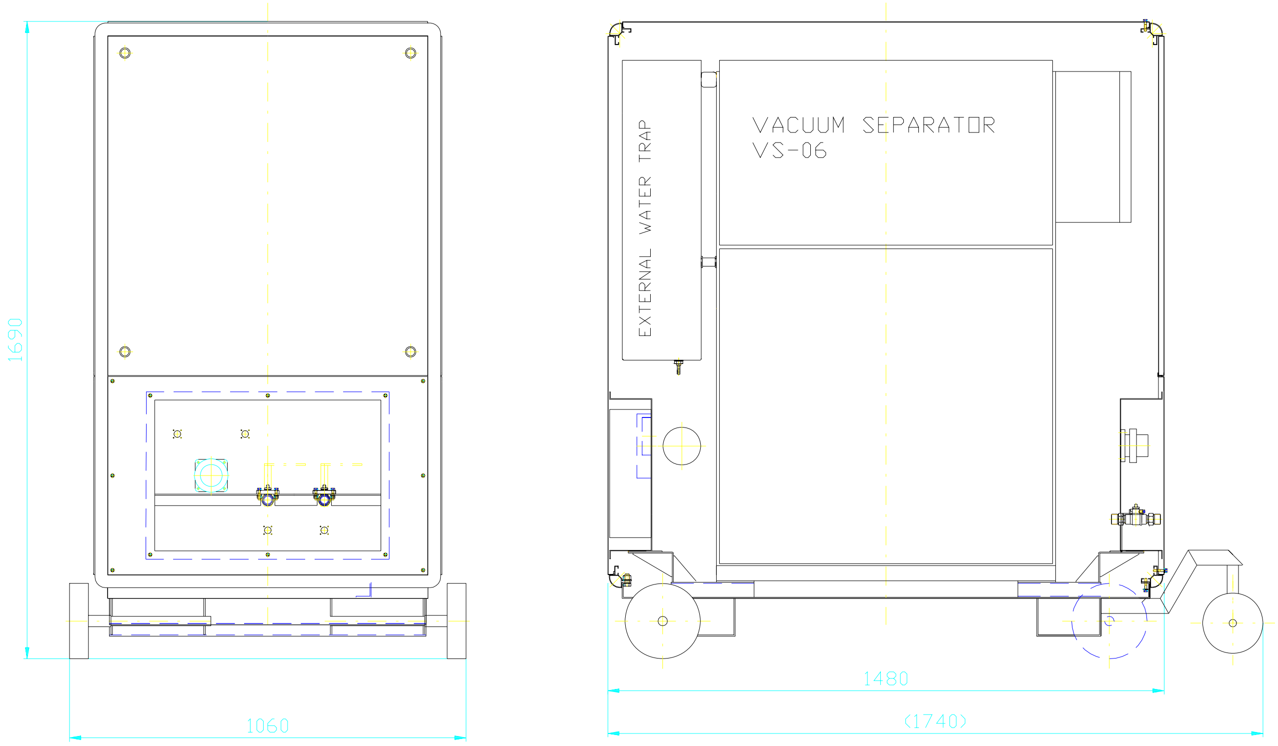
INSTALLATION



The separator can be connected to all types of transformers (i.e. open as well as sealed units). It should be located in close proximity to the transformer.

All treatment utilities (vacuum and hydraulic circuits, preheater, ultrafilter control circuits etc.) are installed in the moisture tight and internal air-conditioned CLIMABOX.
For detailed information See VS-06A CLIMABOX Operational Manual 2006

CLIMABOX DIMENSIONS



SPECIFICATION

Power supply voltage	400 V (or on request)
Power supply frequency	50 Hz (or on request)
Power consumption:	
without oil heater	850 W
with oil heater PO-01	6200 W maximum
air condition unit	300 W
Oil throughput	10 m^3 per day maximum
Outlet water content	10 ppm nominal , 4 ppm minimum
Outlet gas content	1% nominal, 0.3 % minimum
Outlet filtering grade	1 µm

Weight – CLIMABOX version (separator, heater ultrafilter, external water trap etc.)

Dry weight (without oil)	520 kg (+ autotransformer + aircondition, if requested)
Operating weight (oil filled)	580 kg
Hydraulical connection	2 x flexible 1/2“ hose
Communication:	faxmodem, GSM modem, LAN link, SMS
Moisture reading :	Vaisala humidity sensor: on request

PARAMETRIC REMOTE CONTROL

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

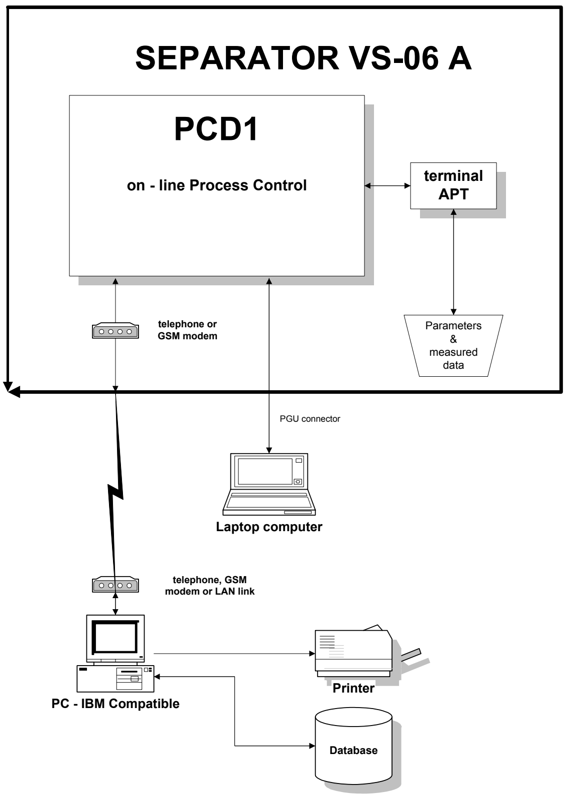
water removal from the cellulose materials of a transformer has to be safe and effective

Any **on-line** transformer dehydration is ultimately governed by the slow diffusion of moisture from the cellulose into the oil and this process can be accelerated only by a significant increase in temperature. But, be carefull:

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

which simultaneously means

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



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

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

To achieve these targets the VS-06 can be programmed directly (manually) via the terminal of PCD or alternatively by the PC or lap-top.

This way offers remote monitoring and optimalization of dehydration by strictly controlling warming-up of the transformer.

The figure on the left shows the structure of separator control systems and both connections between PCD1 and lap-top or remote PC.

The software for communication between the PCD1 and both computers - remote user PC and lap-top is provided by ARS.

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REMOTE SCREENING

For a better understanding of the long-term effects of dehydration by the VS-06 and the corresponding changes of the dielectric behaviour of the transformer two new communication /screening procedures are used:

- the **DDL** (**D**ehydration and **D**egassing **L**og)
- the **DSL** (**D**ielectric **S**trength **L**og)

Both procedures are started by clicking on the DDL or the DSL buttons in the Main window of the OPTIM D3L communication software which is installed in your PC or lap-top after the commissiong of the VS-06.

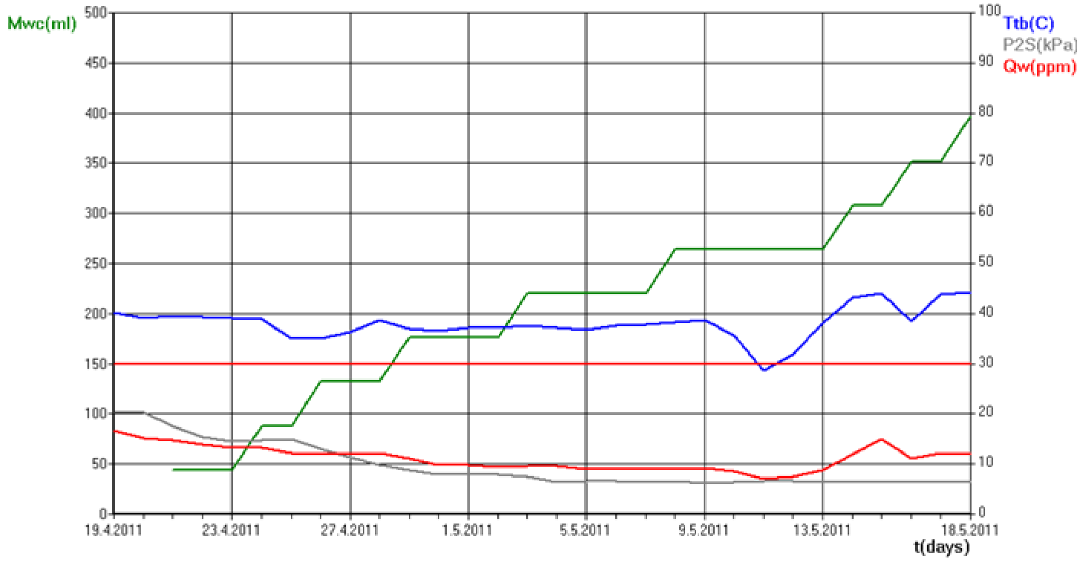
By clicking on the DDL the history of dehydration and degassing of the transformer is shown where all directly measured values are clearly defined in the form of a time-related diagram.

VACUUM SEPARATOR VS-06 - Main Data Log
OPTIM D3L (Dehydration **D**egasing **D**ielectric **L**og**)**
Procedure: DDL (Dehydration **D**egasing **Log)**
© Ing. Altmann, 2010

Transformer Location:	xxx
Transformer Serial Number:	xxx
VS-06 Serial Number:	xxx

Time-period of evaluation : 19.04.2011 - 18.05.2011

Norm requested value Qw,max - red horizontal line
Qw,max = 30 ppm... maximum allowed water content in oil



Mwc Amount of removed water (ml)
Qw Water Content in oil (ppm)
Ttb Transformer temperature bottom (C)
P2s Averaged vacuum in Separator (kPa)

ATTENTION.
Water content in oil Qw exceeded allowed Qw,max-limit:

Day	Qw(ppm)

Remarks & Recommendations

Date of evaluation: 19.5.2011

A new kind of assesment is used for on-line diagnostics and screening of dielectric behaviour of the transformer

Fa. Ing. Altmann ARS Altmann Group, Machova 142, 344 01 Domazlice, Czech Republic, European Union
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DSL – Dielectric Strength Log

This absolutely new approach enables the DSL to calculate the theoretical (instantaneous, maximum attainable) value of the dielectric strength of oil (the Ud,t–value) on the basis of direct measuring of the water content in the oil (the Qw-value).

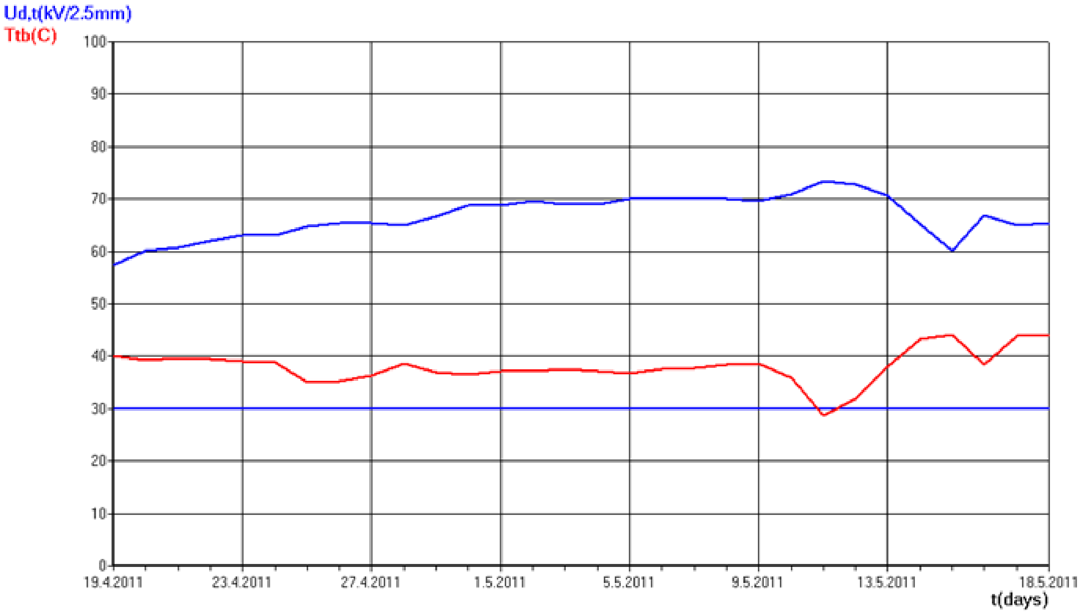
By clicking on the DSL button the change of the transformer temperature and the change of the dielectric strength of oil in a requested time-period is shown:

VACUUM SEPARATOR VS-06 - Main Data Log
OPTIM D3L (Dehydration Degasing Dielectric Log)
Procedure: DSL (Dielectric Strength Log)

Transformer Location:	xxx
Transformer Serial Number:	xxx
VS-06 Serial Number:	xxx

Time-period of evaluation : 19.04.2011 - 18.05.2011

Norm requested value Ud,min - **blue** horizontal line
Ud,min = 30 **kV/2.5mm**... minimal allowed dielectric strength in oil



Ud,t ... Theoretical Dielectric Strength of oil (kV/2.5mm)
Ttb ... Transformer temperature bottom (C)

ATTENTION.
Dielectric Strength of oil Ud,t decreased under allowed Ud,min-limit:

Day	Ud,t(kV/2.5mm)

Number of lab verifications: 1

Remarks & Recommendations

Date of evaluation: 19.5.2011

This mathematical model which is used for the calculation is based on the well documented near-linear relationship between the dielectric strenght (the Ud,t-value) and the relative humidity of oil (at lab temperature).

To obtain relevant diagnostic results, the accuracy of the Ud,t-simulation for the given time-period must always be correspondingly verified by the quantitative comparison of the Ud,t-value and the Ud,lab-value at the same time (the time of oil sampling).

By clicking on the Verification button in the DSL window, the Verification Table and the Verification Diagram is shown.

Fa. Ing. Altmann ARS Altmann Group, Machova 142, 344 01 Domazlice, Czech Republic, European Union
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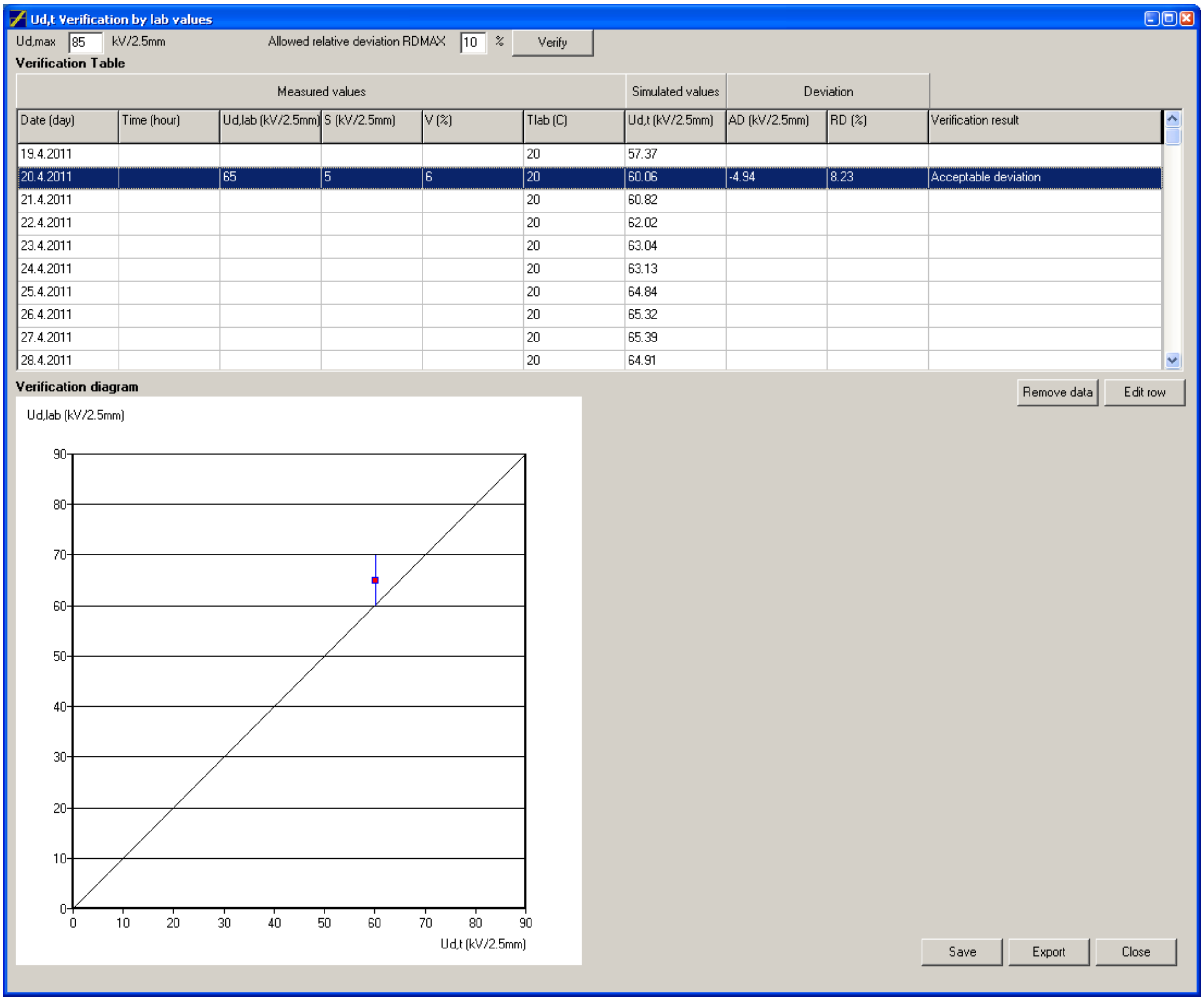
At first the time(s) of sampling and the corresponding Ud-lab value(s) and other lab values have to be entered into the Verification Table:



Measured values						Simulated values	Deviation		
Date (day)	Time (hour)	Ud,lab (kV/2.5mm)	S (kV/2.5mm)	V (%)	Tlab (C)	Ud,t (kV/2.5mm)	AD (kV/2.5mm)	RD (%)	Verification result
19.4.2011					20	57.37			
20.4.2011		65	5	6	20	60.06	-4.94	8.23	Acceptable deviation
21.4.2011					20	60.82			
22.4.2011					20	62.02			
23.4.2011					20	63.04			
24.4.2011					20	63.13			
25.4.2011					20	64.84			
26.4.2011					20	65.32			
27.4.2011					20	65.39			
28.4.2011					20	64.91			

Clicking on the button then gives the requested result(s), which is shown in the Verification Diagram in the bottom part of the window .

The Verification Diagram gives a direct and easy insight into the accuracy of on-line Ud,t-simulation and/or the Ud,lab-value :

- o if the Ud,lab≈Ud,t–point is situated in the 10kV/2.5mm band around the transverse 45^{o} line, the consistency of the simulated Ud,t-value and the Ud,lab-value is very good and the subsequent diagnosis of the dielectric behaviour of the transformer for the given time-period is precise enough
- o if the Ud,lab≈Ud,t–point is situated in the 20kV/2.5mm band, the consistency of simulated Ud-value and measured Ud-value is sufficient (for field conditions) and the subsequent diagnosis is acceptable
- o if the Ud,lab≈Ud,t–point is situated outside of the 20kV/2.5 band, means that either the simulated Ud,t-value or the Ud,lab-reading is not precise enough. The relevant check of a dielectric behaviour of the transformer is not possible. Therefore the veracity of both values has to be checked.

The mutual comparison of simulated and directly measured Ud-values gives an opportunity to check the plausibility of both values and to validate the diagnostic / screening process as the whole.

Fa. Ing. Altmann ARS Altmann Group, Machova 142, 344 01 Domazlice, Czech Republic, European Union
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Typical applications of the VS-06 Climabox

Indonesia:

Installation of VS-06 Climabox at block transformer
Improvement of Tx dielectric

Germany: 250 MVA Transformer

VS06 Climabox (and Online DGA)controlled life-extention of aged transformer

Fa. Ing. Altmann ARS Altmann Group, Machova 142, 344 01 Domazlice, Czech Republic, European Union
Tel:+420-379 738 778, Fax:+420-379 738 775, Cell phone:+420-602 362 157 email:altmann@iol.cz, www.ars-altmann.com;

Contacts

Producer:

ARS - ALTMANN RECOVERY SYSTEMS
Machova 142, 344 01 Domazlice
Czech Republic
tel.: + 420 379 788 391, + 420 379 738 778
fax.: + 420 379 738 775
handy: + 420 602 362 157
e-mail: altmann@iol.cz
www.ars-altmann.com

OUR PARTNERS

Fa. **Andreas Henghuber**
ARS - Altmann Systems
Eggenfeldener Str. 59 D – 84326 Falkenberg
Germany
Tel. +49(0) 8727 7180
Fax.. +49(0) 8727 96 9827
mob: +49(0) 171 547 5391
e-mail: Ahenghuber@t-online.de

STEVO Electric BVBA
Hamsesteenweg 22/6
3971 Leopoldsburg Heppen
Contact person: Stefaan VOLKAERT
Tel.: +32 11 341001
Fax.: +32 11 347977
Mob.: +32475823954
Stefaan.volkaert@stevoelectric.be www.stevoelectric.be

Boston Home Inc.
Industrial Supply
168 Apo St., Sta. Mesa Heights
Quezon City, Philippines
Tel +632 4123726
Fax +632 4150130
Contact person: Mr. Bernard Tiongson

Wuhan HengCheng EletriQpower Tech. Co.Ltd.
802 Room 5 Building
Wuhan, Hubei 430074
P.R.of China
Contact person: Mr.Yan Jie
Tel.:+86-27-87496061
Fax.:+86-27-59715145
Handy:+86-13909241723
Web site:www.hchco.cn
E-mail: hcqiye_wh_yj01@163.com.cn

METRACO Energy Ltd
38 Addington Street
Ramsgate CT11 9JQ England
Mülheimer Str. 1
56220 Bassenheim Germany
Contact person : Mr.Schmitz
Tel: + 49 172 1966 077 Germany
Tel: + 33 6 07 53 47 36 France
skype: metracoenergy
email: bs@metraco-energy.com
Web: www.metraco-energy.com

MTC Power Technology Ltd.
Kallipoleos and Ifigenias I,
Office 501, Amaral 30
Nicosia 1055, CYPRUS, EU
Email: sales@mtQpowertec.eu
Fax: +357 (22) 752009

VH Ingeniería
Ing. Luiggi 719- Bahia Blanca
Bahia Blanca – Buenos Aires
QPA (B8000JUO)
Argentina
Contact person:
Mr. Victor Vercellino
tel.: 54-291-4525662
handy: 54-291-154622310
E-mail: victor.vercellino@gmail.com

CTR Manufacturing Industries Limited
403B, Turf Estate, Shakti Mills Lane, Mahalaxmi (West)
MUMBAI 400011,
INDIA
Contact person:
Mr. D.S.Jain
e-mail: powerquality@ctr.in
TEL : 91.22.24920454

Integrated Golden Solutions Company (IGS)
PO Box 11546, Industrial Jubail city 31961, KSA
+966 13 362 8080 Fax: +966 13 362 2020,
Contact person. Mr. Gert Coetzee
Mob: +966 55 614 0055

URIM TS Industry Co., Ltd
61-28, OngJung-ri,Tonglin-Eup,Kimpo City, KyeongGi-DO
Korea 415-869
Contact person:
Mr. Kim
tel.: 82-31-988-6660
handy: 017-366 4007
E-mail: YURIMRMC@DREAMWIZ.COM

Technology Transfer Group Corporation (TT-Group)
Add: No.15 Lane 71, Do Quang street, Tran Duy Hung Avenue,
Trung Hoa, Cau Giay District,
Hanoi, Vietnam
Contact person: Mr. Trinh Ngoc Anh
handy: : +84 904 166 095
E-mail: anhtn@tt-group.com.vn