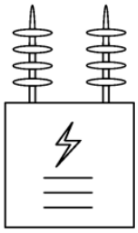
MOISTURE IN OIL TRANSMITTER

APPLICATIONS



- Lubricant Oils
- Hydraulic Oils
- Transformer Oil
- Industrial, medical, fluid-dynamic or aerospace fields

HIGHLIGHTS

- Wide range measurement of water activity
- Water activity (*aW*) accuracy: up to ±0.02
- Patented polymer die chemically resistant
- *aW* operating range: 0…1
- Excellent long term stability
- *aW* long term drift 0.005
- Factory calibration by laser trimming
- Low drift temperature compensated
- Temperature accuracy: up to ±0.2°C
- 16 bit ASIC core
- Multiple transmission data output

Moisture contamination, and in extreme cases water droplet formation, in transformer, hydraulic, and lubricant oils can lead to a variety of problems and impact their performance. Monitoring water activity in oil can provide valuable insights into the degree of degradation and thus prevent the formation of free water. In critical processes that rely on flawless oil performance, online monitoring of water activity is crucial. The SHT4xI-Digital sensor allows for monitoring dissolved water in oil to avoid reaching the saturation point and formation of free water, and therefore enables damage prevention, lifespan extension of machinery, and optimal performance throughout the lifecycle.

It is well known that moisture continues to be a major cause of problems in transformers and a limitation to their operation. Particularly problematic is excessive moisture in transformer systems, as it affects both solid and liquid insulation with the water in each being interrelated. Water affects the dielectric breakdown strength of the insulation, the temperature at which water vapor bubbles are formed, and the aging rate of the insulating materials. In the extreme case, transformers can fail because of excessive water in the insulation. The dielectric breakdown strength of the paper insulation decreases substantially when its water content rises above two to three percent by weight. Similarly, the dielectric breakdown voltage of the oil is also affected by the water activity (*aW*) of water in oil. The maximum loading that is possible while retaining reliable operation (i.e., preventing the formation of water vapor bubbles) is a function of the insulation water content (ppm).

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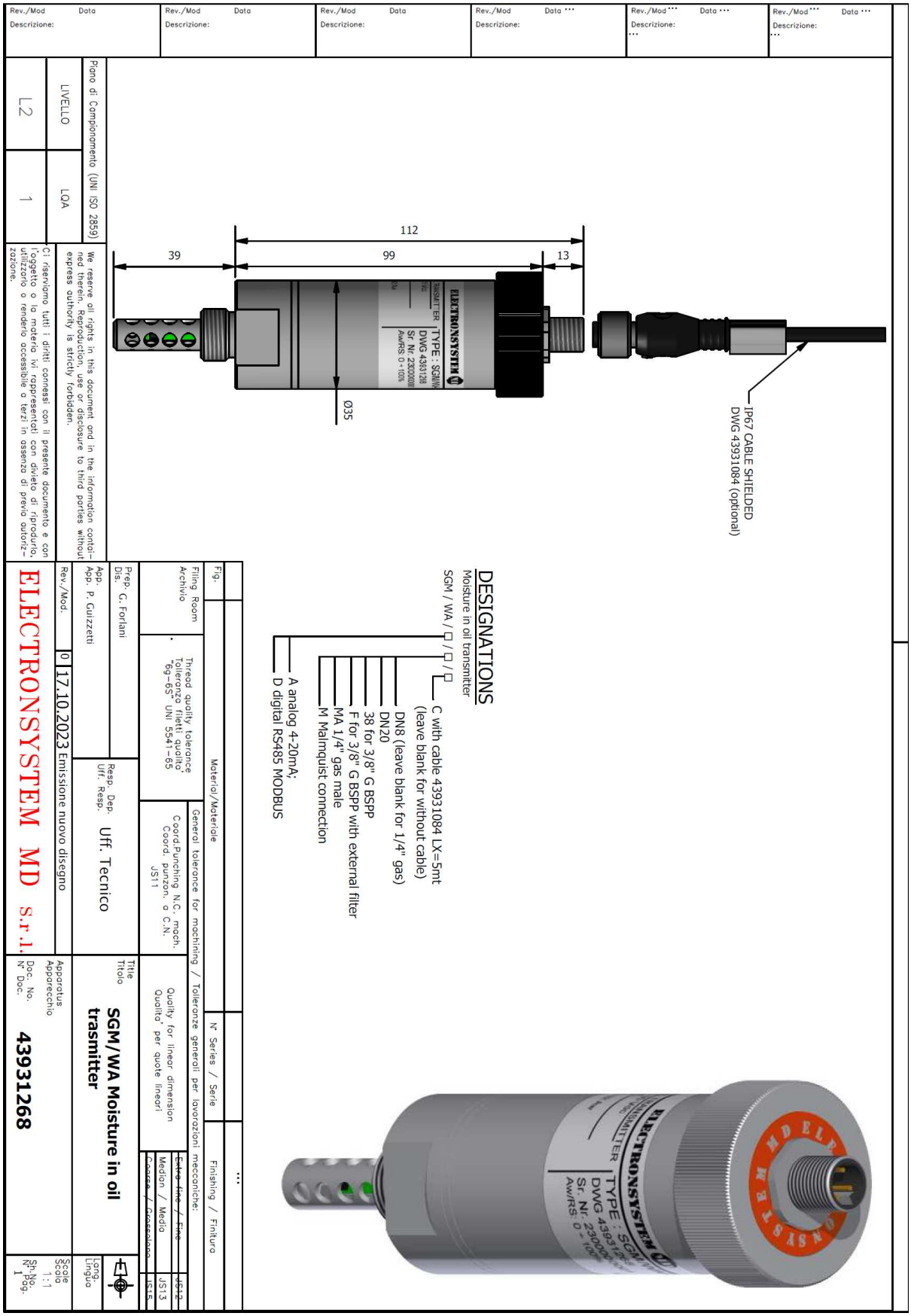

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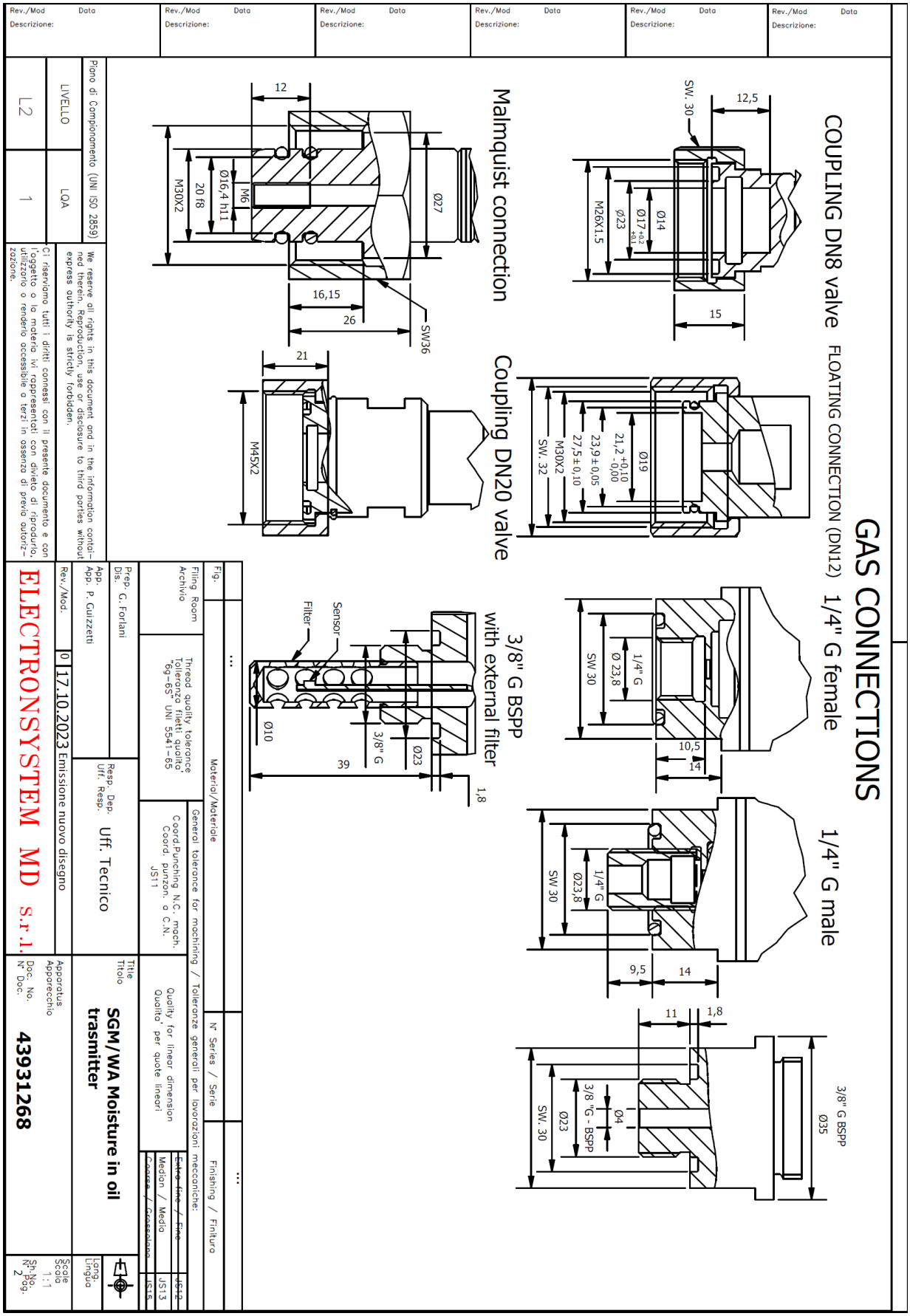

Rev./Mod Data Descrizione:	Rev./Mod Data Descrizione:	Rev./Mod Data Descrizione:	Rev./Mod Data Descrizione:	Rev./Mod Data Descrizione:	Rev./Mod Data Descrizione:

L2	LIVELLO	Piano di Campionamento (UNI ISO 2859)
1	LQA	

Rev./Mod.	App. P. Guizzetti	Prep. Dis. G. Forlani	Filing Room Archivio	Fig. ...
0 17.10.2023 Emissione nuovo disegno	Resp. Dep. Uff. Resp. Uff. Tecnico		Thread quality tolerance Tolleranza filetti qualita' "6g-6S" UNI 5541-65	Materiali/Materiale
			Coord.Punching N.C. mach. Coord. punzon. a C.N. JS11	General tolerance for machining / Tolleranze generali per lavorazioni meccaniche:
				Quality for linear dimension Qualita' per quote lineari
				Extra fine / Fine JS12
				Medium / Media JS13
				Coarse / Grossolano JS15
				N° Series / Serie ...
				Finishing / Finitura ...

ELECTRONSYSTEM MD S.r.l.

Title Titolo	**SGM/WA Moisture in oil trasmitter**
Apparatus Apparecchio	
Doc. No. N° Doc.	**43931268**
Scale Scala	1:1
Sh. No. N° Pag.	2
Lang. Lingua	

All specs are subject to change without notice

TECHNICAL FEATURES:

DESCRIPITION:
Moisture in oil transmitter

1 Materials:
1.1 Housing material : AISI 316
1.2 Inner o.rings material : EPDM70 peroxide cured
1.3 Primary sensing element: Patented polimer chemically resistant
1.4 Cable connection material: aluminium alloy nickel-plated
1.5 Conformity to 2002/95/CE (RoHS), Halogen free

2 Electrical data of sensors
2.1 Electrical data analog version
2.1.1 Output signal : 4 - 20 mA 2 wires loop system (see diagram 1)
2.1.2 Input voltage : 10-28 Vdc
2.1.3 Rload: Rin< 500 ohm
2.1.4 Output signal : RTU MODBUS RS485 (see diagram 2)
2.1.5 Data protocol: baudrate 9600, databits 8, parity even, stopbit 1
2.1.6 Current Consumption : 20mA typ. / 40mA max.
2.2 Common electrical data:
2.2.1 Input protection : overvoltage supressor and reverse voltage diode
2.2.2 Response time : <10 min. from dry to wet point in still oil
2.2.3 Calibration: laser trimmed, low drift digital asic core
2.2.4 Accuracy : water activity ±0.02 aw(0....0.9aw) ±0.03 aw(0.9....1aw)
2.2.5 Accuracy : temperature [C°], -40 to +80 (±0.5°C@20°C; ±2° C)
2.2.6 Isolation: max 250Vac 50Hz against mass
2.2.7 Resistance of insulation: >10Mohm
2.2.8 Terminal block : circular shielded M12x1 connector (see diagram 3)

3 Output range:
3.1 Water activity: 0....1aw (analog version)
3.2 Temperature: -40 ÷ +140°C *
3.3 Water content: 0 ÷ 1000 ppm Wc

4 Electromagnetic protection:
4.1 EN61000-4-2: ESD air 15kV
4.2 EN61000-4-3: Radiated immunity AM 10V/m 80...1000MHz,
PM 10V/m 900...2700MHz with 10m cord
4.3 EN61000-4-4: Burst 2kV withstand of the communication & power supply interfaces with 10m cord
4.4 EN61000-4-5: Surge 0,5kV withstand on the shield of 10m cord
4.5 EN61000-4-6: Conducted immunity 10V/m
4.6 EN61000-6-4: Radiated disturbances 30MHz-1000MHz class B

5 Working conditions:
5.1 Mechanical stresses:
Shockproof 30G on 3 axys
5.2 Max allowable pressure: 20 bar ABS
5.3 Sensor protection: stainless stell filter

6 Environmetal conditions:
Operating temperature:
Ambient temperature : -40°C to +60°C / -40°C to +80°C
Oil temperature : -40°C to +80°C / -40°C to +100°C
Transport and storage : -40°C to +60°C
Relative humidity 0÷100% HR
Solar radiation: <= 1000 W/mq
Wind: <= 34 m/s
Altitude: <= 2000 m
6.1 Pollution Class III IEC 60815, table 1
6.2 Corrosion class (according to DIN EN ISO 12944-6)
a) Indoor: C4, high
b) Outdoor: C5-M/I high
6.3 Protection degree (DIN EN 60529): IP65; IP67 on request

8 Weight : ≈ 250 gr

9 Primary element features
9.1 Technology: Patented new chemical resistant industrial grade digital sensor platform
9.2 Core chip: ASIC 16bit resolution factory calibrated
9.3 Measurements on chip: combined Water Activity (Aw) and Temperature °C
9.4 Protection: integrated filter resistant to dust and chemicals
9.5 Long term stability: 0,15%Aw in 5 years ; 2°C in 5 years
9.6 Reliability: MTTF: 9.312.507 hours

* according to customer requests

we reserve the rights to modify the drawing without notice

Rev./Mod.	Descrizione:	Data

Fig.	Material/Materiale	N° Series / Serie	Finishing / Finitura

Filing Room Archivio	Thread quality tolerance Tolleranza filetti qualita' "6g-6S" UNI 5541-65	General tolerance for machining / Tolleranze generali per lavorazioni meccaniche: Coord.Punching N.C. mach. Coord. punzon. a C.N. JS11	Quality for linear dimension Qualita' per quote lineari	Extra fine / Fine JS12
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Prep. Dis.	G. Forlani	Resp. Dep. Uff. Resp.	Uff. Tecnico	Title Titolo	SGM/WA Moisture in oil trasmitter	Long. Lingua
App. App.	P. Guizzetti					
Rev./Mod.	0 17.10.2023 Emissione nuovo disegno			Apparatus Apparecchio		Scale Scala 1:1
				Doc. No. N° Doc.	43931268	Sh. No. N° Pag. 3

Piano di Campionamento (UNI ISO 2859)	
LIVELLO	LQA
L2	1

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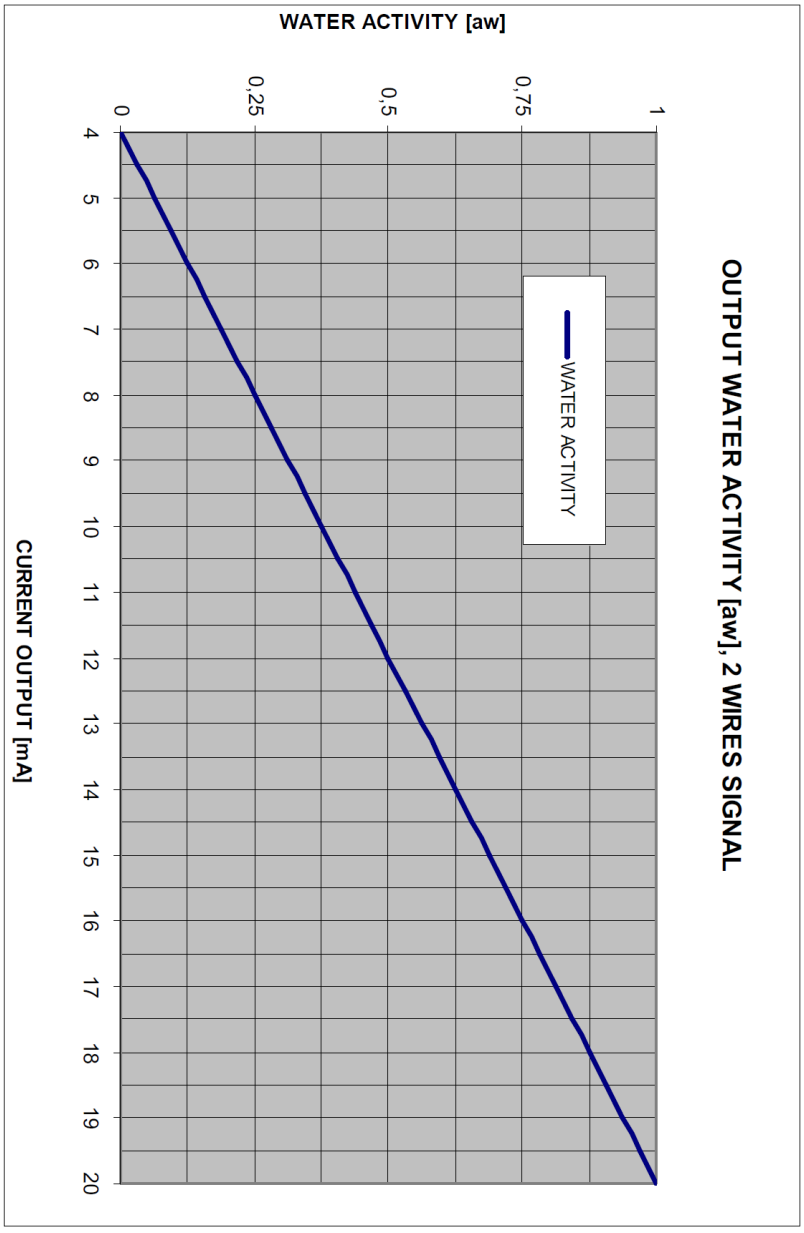
MOISTURE IN OIL TRANSMITTER

DIAGRAM 1: ANALOG SENSOR CODE SGM/WA/A

OUTPUT WATER ACTIVITY [aw], 2 WIRES SIGNAL



Rev./Mod Data Descrizione:

Piano di Campionamento (UNI ISO 2859)
LIVELLO: L2
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Rev./Mod. 0 | 17.10.2023 | : Emissione nuovo disegno

App. P. Guizzetti | Prep. Dis. G. Forlani | Resp. Dep. Uff. Resp. Uff. Tecnico

Filing Room Archivio

Thread quality tolerance Tolleranza filetti qualita' "6g-6G" UNI 5541-65

Fig.

Materiali/Materiale

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Coord.Punching N.C. mach. Coord. punzon. a C.N. JS11

Quality for linear dimension Qualita' per quote lineari

Extra fine / Fine JS12
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N° Series / Serie

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Scale Scala 1:1

Sh. No. N° Pag. 4

DIAGRAM 2: MODBUS RTU RS485 CODE SGM/WA/D

Registry	Information	Type	Function
Reg_0	ID_slave	Unsigned Int	Read/Write
Reg_1	Water activity aw [%]	Unsigned Int	Read only
Reg_2	Temperature.Read [°C/10]	Signed Int	Read only
Reg_3	Temperature Read [°K/10]	Signed Int	Read only
Reg_4	Water content WC [ppm]	Signed Int	Read only
Reg_5	Firmware release	Unsigned Int	Read only

Protocol settings

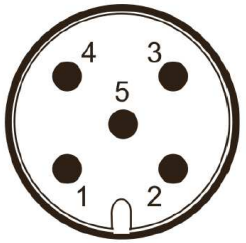
ADDRESS	128 default
Protocol	Modbus RTU RS485
	9600, **19200**, 38400, 57600,
Speed	115200 Baud
Data	8 bit
Parity	None, Odd, **Even** parity
Stop	**1**, 2 bit stop
Scan rate	50ms
Response time out	100ms
Delay	100ms

Note: bold value are the defaults,
others are programmable

EXAMPLE:

Registry	bit reading	value	Unit	Description
0	128	128		slave add
1	294	29,4	[%]	relative humidity
2	249	24,9	[°C]	temperature
3	57	5,7	[°C]	dewpoint temperature
3	57	5,7	[°C]	dewpoint temperature
4	1	1		FW revision

DIAGRAM 3: TERMINAL BLOCK



View on sensor plug

SGM/WA/A
3: +VDC
4: -VDC

SGM/WA/D:
1: +VDC
2: Modbus Gnd
3: -VDC
4: A(+) / TR (+)
5: B(-) / TR (-)

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Piano di Campionamento (UNI ISO 2859)	
LIVELLO	LQA
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ELECTRONSYSTEM MD s.r.l.			Doc. No. N° Doc.	Scale Scala 1:1
				Sh.No. N° Pag. 5

ELECTRONSYSTEM MD
Design and products for safety problem solving
in medium and high voltage electrical installations

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PRECAUTIONARY USE

1. The correct reading of instrument is strongly affected by boundary conditions of moisture environment. Due to this the time to get correct reading can vary a lot from few minutest to few hours, this is also strongly affected by temperature of media.
2. The suggestion to reduce equilibrium time is to dry the part (including the entire block to which the sensor is connected) before installation or in any case to avoid absolutely exposure to wet oil or contaminant.
3. Do not leave the sensor without protection in standard environment to avoid pollution to be stuck on primary element, be careful in handling.
4. External filter allow to protect inner primary element and guarantee the correct flow of oil and moisture, do not close the filter or check it is clean before use.

STORAGE

If the complex must be storage before use, please keep dry and repaired.
Do not leave outdoor.
Device is strongly sensitive to humidity hence avoid to store where relative humidity is more than 90%

STORAGE TEMPERATURE: -30°C ÷ +70°C
RELATIVE HUMIDITY: max 90% @ +40°C

MAINTENANCE

Maintenance of transmitter must be done compulsory in factory. We recommend every 2 years to send back transmitter for calibration check and inspection.

WARRANTY

Device is covered by 24 months after installation or max 36 months after delivery.
In case of service the transmitter must be sent back to factory for inspection.

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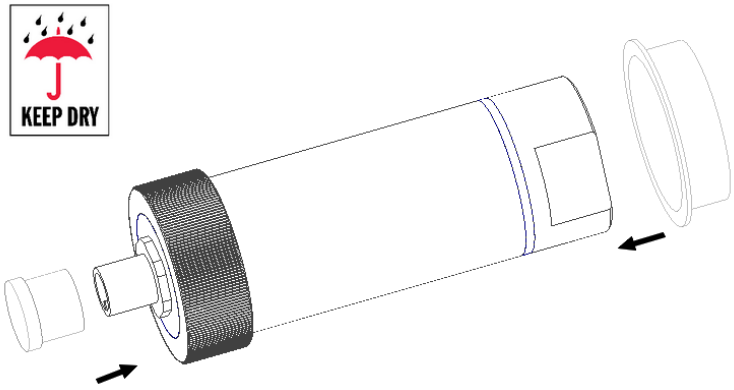
WARNINGS

CAUTION
Do not drop or hit the transmitter. The sensor is fragile and may break from sudden shock.
When transporting the transmitter, use the original shipping box from Electronsystem.

NOTE
Keep the transmitter dry and clean.
Do not remove the transparent transport protection caps before you are ready to install the transmitter.
Uncapped transmitter will absorb environment moisture which will affect the water activity measurement.



NOTE
Connect the transmitter directly to the main oil tank or apparatus volume, not behind a sampling line because this is the area where high humidity tends to accumulate.
In any case after first installation the transmitter will have a small amount of moisture inside the connection. In still dry oil it takes a long time until a vapour pressure inside the measurement cell reaches equilibrium with the main oil tank. It is usual for the stabilization of the water activity reading to take several hours after installation.

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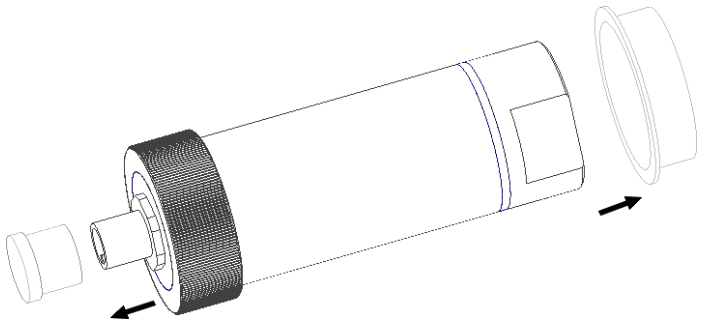
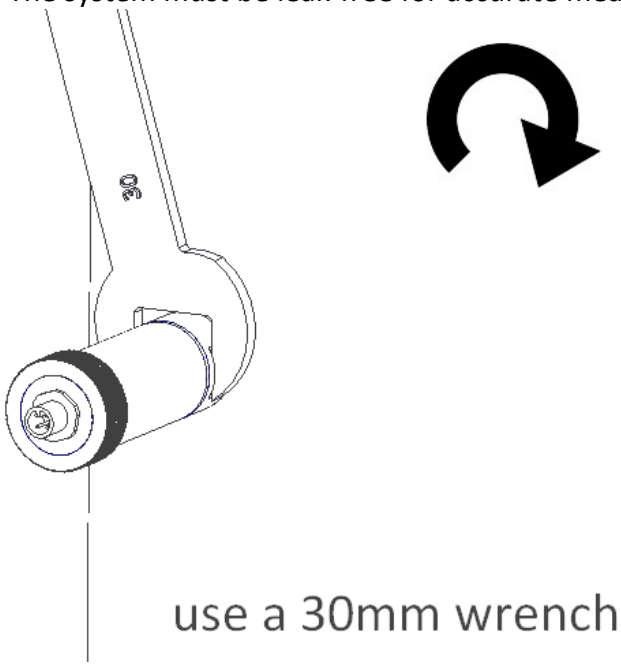
INSTALLATION

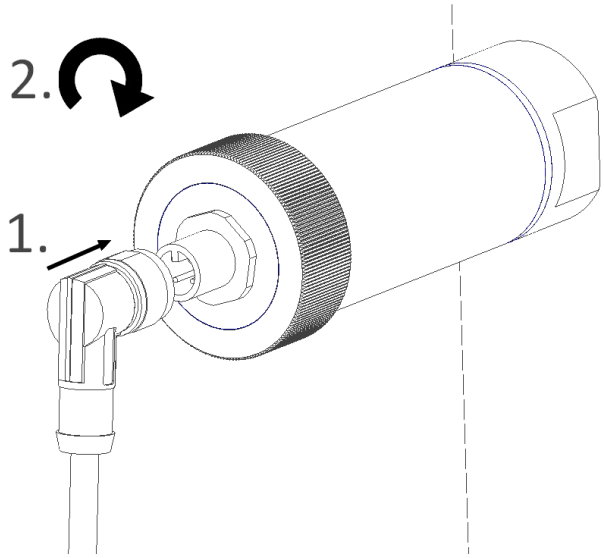
1. Remove the transparent transport caps when you are ready to install the transmitter. Check o-ring is clean without dust and properly assembled. If the transmitter is with filter check it is clean and not closed.



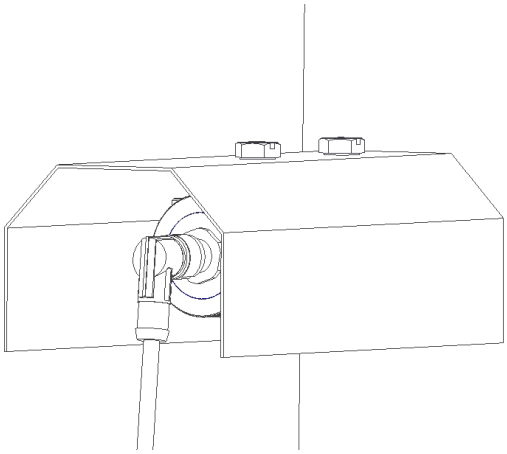
2. Install the transmitter to the mechanical coupling and tighten gently by hand. Then use a 30mm wrench to tighten the connection. Use a sufficient force to achieve a tight installation (recommended 10-15Nm) . The system must be leak-free for accurate measurement.

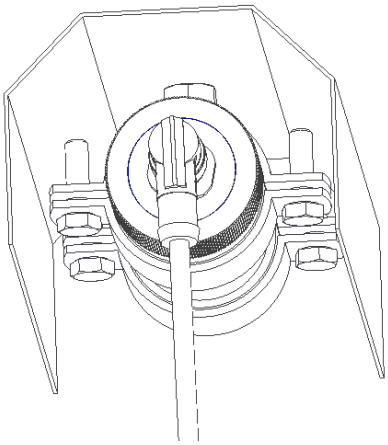


3. Connect proper circular wiring into the output port checking the correct polarization of the connector then turn firmly the rotating crown of the cable.
   Use a cable with a suitable outdoor IP67 connector for your installation (straight or angled)



4. In case the weather shield is needed (optional), can be added to the transmitter by fitting the two rubber clamps on the body of transmitter and tightening to assure it can remain in place.
   Assure that the stainless roof completely cover the transmitter and the cable connection.





5. Suggested installation hint to avoid inaccurate reading of water activity: never put the transmitter after a very small orifice or after a sudden bend. In addition please be sure the reading element is covered by oil

The primary element need to breathe to give an accurate response ; we suggest to positionate the transmitter in an area which is completely filled with oil and moreover that this area is the good one for the measurement. The sensor will give a water activity value correlated to nearby micro environment unless an oil flow allow the mixture.

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APPLICATION NOTES and FAQ:

- **What is the physical parameter transmitted by SGM/WA ?**

Water activity aW is a measure of absorbed water in a material. It is defined as the ratio of vapor pressure of water in a material p , and the saturation vapor pressure of pure water at the same temperature $p0$ in the same material. Water activity is typically measured on a scale from 0 … 1, with 0 representing a completely dry material and 1 indicating that the saturation point is reached and free water starts to form, see formula (Eq. 1) below. The saturation point in a material is the equivalent to the dew point in air when measuring %RH.

$aW = p/p0$ (Eq. 1)

Note that water activity does not specify absolute moisture content. Absolute moisture content is the water present in a sample divided by the sample's weight, expressed as a percentage or in parts per million (ppm), while water activity reflects the amount of absorbed water. This difference is significant for evaluating stability. Measuring water activity allows for better understanding of material purity and ensures the quality and safety of systems before the material functionality is impaired.

- **What is the saturation level of oil ? why ppm is another important way to measure moisture in oil ?**

In oil, water can appear in three different forms; absorbed, emulsified, and free. Absorbed water only interacts with the oil molecules on the atomic level, and is measured by water activity. Emulsified water is present as stabilized droplets, while free water is visible in the form of a separate phase. Each type of water presents different risks to product stability.
Absorbed water can cause hydrolysis, oxidation, and other types of chemical degradation, while emulsified and free water can additionally promote microbial growth and strongly affect electrical properties of the overall system. By measuring water activity, it is possible to understand the risk of hydrolysis and oxidation in oil and mitigate the risk of phase separation.
Water can infiltrate an oil system through different channels, such as absorption from the atmosphere during handling and storage or the decomposition of oil additives and chemicals in the system. Such infiltration can lead to corrosion or other types of damage that can affect the oil's ability to lubricate or insulate. In addition water activity is an early proxy that precedes acid formation. Particularly synthetic oils exhibit a propensity to react with water and deteriorate, often forming acidic compounds. These act as strong oxidizing agents and oxidation leads to the formation of deposits, sludge, and varnish in the oil.
This reduces the oil's performance and can potentially cause equipment failure. The formation of acidic compounds increases the corrosiveness of the oil, which can lead to damage to metal surfaces and other materials in the system.

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The water saturation point of oil is influenced by several factors, including the type of oil (mineral or synthetic), the presence of water-soluble additives, and the temperature of the oil. Mineral oils often have a lower saturation point than synthetic oils.
Mainly due to the addition of additives who allow to tune the oils saturation point. Hygroscopic additives can raise the saturation point of oil by dissolving and retaining water in the solution. Conversely, added surfactants can decrease the saturation point by improving emulsification and promoting phase separation.
Synthetic oils in particular tend to react with water and break down under acid evolution.

Oil type	Typical saturation levels
Synthetic oil	Saturation levels up to 10'000 ppm
Mineral oil	Saturation level around 100 ppm
Transformer oils	Saturation level around 10-100 ppm
Hydraulic oils	Saturation level around 100-1000 ppm
Lubricating oils	Saturation level around 500-5000 ppm

Table 1. Summary of how different parameters affect the water saturation point of an oil.

To show the effect of temperature on the saturation point of an oil refer to Table 2 below. Generally, higher temperatures lead to increased water absorption capabilities of oil.

Temperature	0 °C	20 °C	80 °C
Saturation point	150 ppm	300 ppm	500 ppm
Actual amount of water	200 ppm	200 ppm	200 ppm
Water activity a_W	1	0.63	0.4
Formation of free water?	Yes, ~50 ppm	no	no

Table 2. Example calculations showing the effect of temperature on water activity.

Summarizing

ppm = aW * SP (saturation content @T) (Eq. 2)

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- **Which are the application field of moisture in oil ?**

Lubricant Oils and Hydraulic Oils
As mentioned above, water activity plays a direct role in the aging rate of lubricating and hydraulic oils which has a direct effect on the durability of machine components relying on oil. Lubricant and hydraulic oils are designed to sustain high pressures while maintaining low compressibility and remaining chemically inert and unreactive. Water molecules in oil will be adsorbed mostly by hygroscopic additives or hydrophilic surfaces.
These hygroscopic additives can lose their intended functionality through hydrolysis, resulting in the formation of acidic by products, while the hydrophilic surfaces can oxidize in the presence of water, which is further enhanced by the aforementioned acidic by products.
This increase of oxidizing agents in the system enhances the process of oxidation, particularly in the presence of catalytic metals such as copper, lead and tin. Consequently, rust is formed, compressibility is reduced, and increased friction leads to worn out parts.

Transformer Oil
Oil serves several important purposes in a transformer: It helps to dissipate heat from the winding by transferring it to the surrounding air or water, acts as an insulator to prevent electrical discharge and breakdown, and lubricates moving parts within the transformer to reduce wear and extend the lifespan of the transformer. However, once the water activity in the oil increases and free water starts to form, it can lead to conductive creeping partial discharges, and even total failure of the transformer. There are several ways in which oil can enter a transformer, including through faulty gaskets, decomposition of the insulation paper or through ambient humidity during production and operation

- **Which are the typical saturation content ppm of water in oil @ T ?**

The saturation for mineral oil can be calculated using equation:

$\log So = -1567/K + 7.0895$

Where: So is the solubility of water in mineral oil , K is the temperature in Kelvin (°C + 273)

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Table 1 — Water in Oil Solubility as a Function of Temperature

Oil Temperature	Water Content in Oil, ppm
0°C	22
10°C	36
20°C	55
30°C	83
40°C	121
50°C	173
60°C	242
70°C	331
80°C	446
90°C	592
100°C	772

- **Which are the effects of *aW* on dielectric streng ?**

To properly maintain and operate transformers, an understanding of the effects of moisture on the dielectric breakdown strength of the electrical insulating liquids is necessary. Increasing moisture content reduces the dielectric breakdown voltage of insulating liquids.
The correlation between the Spring 2002 3 water content in new, filtered, mineral oils at room temperature and the dielectric breakdown voltage using ASTM method D 1816 (0.04 inch gap) is given in Figure 1 (water content, ppm). Of course, the dielectric breakdown voltage is also a function of the number and type of particles and their conductivity, not just the water content.

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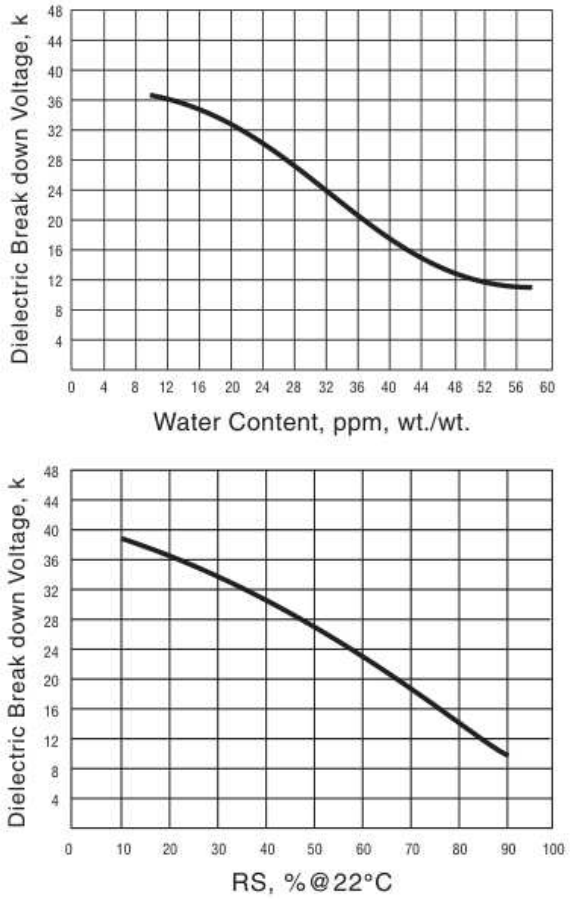

Figure 1— Dielectric Strength Versus Water Content and water activity/relative saturation (RS)

DISCLAIMER NOTE:

While we provide application assistance it is up to the customer to determine the suitability for its use.

Specification may change without notice.The information we supply is believed to be accurate and reliable as of this printing.
However we assume no responsibility for its use.

The quality of ElectronsystemMD products is guaranteed by a Quality, Safety and Environmental management system certified by DNV according to ISO 9001, ISO 18001 and ISO 14001. Electronsystem MD works in partnership with its customers in designing customized executions in order to meet specific requirements, please contact us.

BIBLIOGRAPGHY:

- R. Garvey, "Estimating Water Content in Oils: Moisture in Solution, Emulsified Water, and Free Water," p. 15, 1996
- Doble, F. “The Doble Water Extraction Method,” Minutes of the Thirteenth Annual conference of Doble Clients, 1946, Sec. 10-401.
- Griffin, P. J. “Water in Transformers – So What!,” National Grid Condition Monitoring Conference, May 1996.
- Lewand, L. R. and Griffin, P. J., “How to Reduce the Rate of Aging of Transformer Insulation,” NETA World, Spring 1995, pp. 6-11.

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