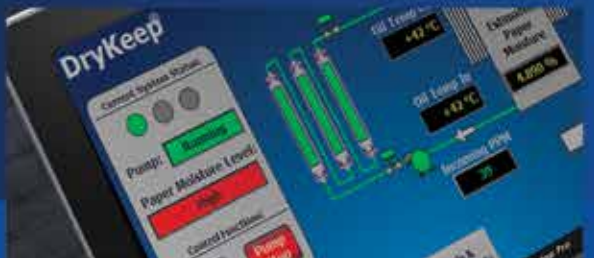
The Smart Solution to Power Transformer Life Extension

DryKeep®

The Online Power Transformer Dry-out System with Condition Based Monitoring!

Protecting your most critical asset.



DryKeep® is the proactive permanent solution for power transformer life extension.

THE PROBLEM:

Moisture build-up in power transformers is costly.

Power transformers are one of the most critical and expensive assets in an electrical transmission and distribution system. While extremely reliable, their failure is often a catastrophic event that results not only in the loss of the transformer, but power delivery to customers or critical operations resulting in loss of revenue.

Power transformers are designed with a nominal life expectancy under rated load and ideal conditions. Excluding extraordinary circumstances unrelated to the normal functioning of the asset, **failure is expected to occur when the cellulose insulation degrades to its mechanical and electrical stress limit.** Water, temperature and oxygen are the main accelerators of cellulose ageing and degradation. Natural cellulose ageing and degradation is a combination of hydrolysis, oxidation, and pyrolysis processes. These chemical reactions produce water. Since water is an accelerant to the ageing process, **ageing and degradation occurs exponentially if moisture is not constantly removed from the transformer oil and cellulose insulation** (See Fig. 1).

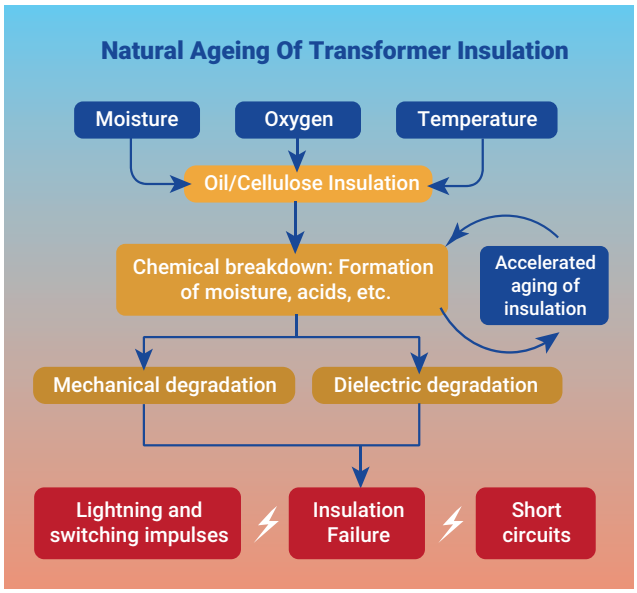


Figure 1

The presence of moisture in a power transformer, no matter how small, will decrease the dielectric strength of the oil and degrade and permanently damage the cellulose insulation. The oil can be recycled or replaced, but replacing of the cellulose insulation would require an expensive rewind.

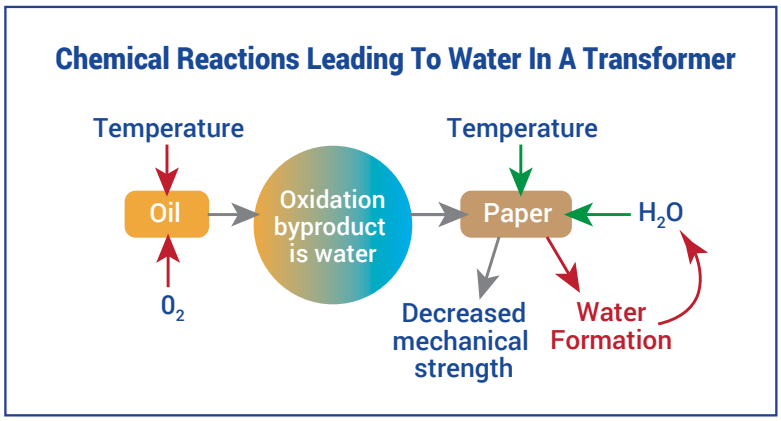


Figure 2

The use of silica gel breathers, sealed tanks, or nitrogen blankets only helps to prevent moisture from the atmosphere from entering the transformer. However, when the transformer is energized, the production of water inside the power transformer is a natural and inevitable occurrence over time. (See Fig. 2).

Current practices are costly, ineffective and NOT a permanent solution.

Traditional transformer moisture maintenance, both on or offline, has been a reactive approach.

Moisture Removal Options

Advantages per method	DryKeep®	Portable Mobile/Dryout	Field Dehydration	Factory Dry Out
Dries the oil	✓	✓	✓	✓
Dries the paper	✓	?		✓
All work is done on-site	✓	✓	✓	
Transformer remains energized	✓	✓	✓	
Remote monitoring	✓	✓		
Improves other oil qualities	✓	✓		
Prevents moisture build-up	✓			
Permanent solution	✓			
Proactive	✓			
Condition-based monitoring	✓			
Historical data logging/trend analysis	✓			
SCADA-ready	✓			
Remote access & control	✓			
Verifiable financial benefit & cost savings	✓			
Extends transformer life	✓			
Estimated days out of service	0	0	1-2	30-45

Figure 3

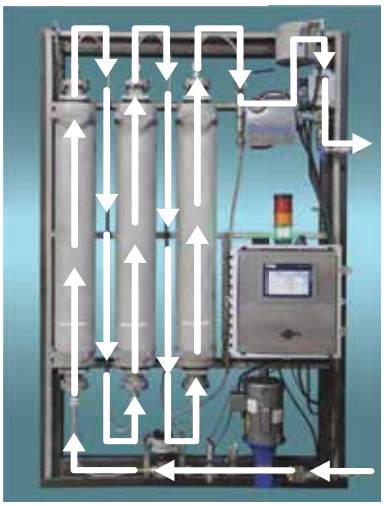
Simply regenerating or drying the oil alone is ineffective because only a maximum of 2% of the total moisture in the transformer is dissolved in the oil. Most of the moisture is held in the cellulose insulation.

Similarly, **drying the oil and the cellulose after increased moisture levels have been detected does nothing to resolve the irreversible damage to the cellulose insulation caused by the presence of moisture prior to the drying process.** This reactive approach also requires repeated maintenance at additional cost. The use of intermittent or portable units to dry out the oil, and hopefully some of the cellulose insulation, is a temporary stop-gap measure. After removal of a portable unit, moisture will once again accumulate naturally, further degrading the paper insulation irrevocably at an auto-accelerated pace.

Cellulose insulation ageing reduction must be a permanent consideration, not a short-term reactive fix using portable/mobile units, to achieve financial benefits and transformer life extension.

THE SOLUTION:

The installation of a SMART DryKeep® moisture monitoring and management system.



The implementation of an efficient proactive asset management system will help prevent the aforementioned problems. In addition, it will enhance the reliability and maximize the lifecycle of the power transformer.

DryKeep® is a permanently installed, on-line dehydration system that effectively slows the ageing process of a power transformer's cellulose insulation; **extending the transformer's life.**

DryKeep® uses an advanced molecular sieve adsorbent material. Even when saturated, the specialty coated beads will never allow the adsorbed moisture to return to the oil and they do not disturb any dissolved gasses, ensuring DGA integrity. A small positive displacement pump passively circulates the transformer's oil through the DryKeep® system. As the oil flows through the DryKeep® cylinder(s), the molecular sieve adsorbent within the cylinders removes the dissolved moisture from the oil. The dry oil is then returned safely back to the transformer. This process changes the moisture equilibrium between the oil and the cellulose insulation within the transformer, allowing more moisture to diffuse from the wet cellulose insulation to the dried insulating oil. Using the oil as a transfer medium, **DryKeep® absorbs the moisture from the cellulose insulation; the key to transformer life extension!**

TECHNICAL BENEFIT OF DryKeep®:

In December of 2002, experts with SINTEF Energy Research, one of Europe's largest independent, non- commercial research centers, published a study supported by the Norwegian Research Council, EBL-K and a group of Norwegian utilities titled "Ageing of Oil-Impregnated Paper in Power Transformers". The results of the group's extensive work confirmed earlier kinetic models. It confirmed the principle that:

- Moisture is released during the ageing of the cellulose,
- Moisture accelerates the ageing of the cellulose insulation,
- The process auto-acceleratory.

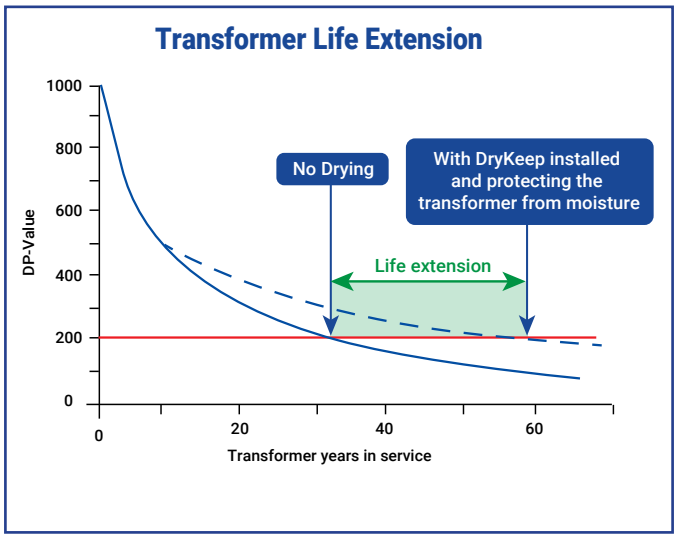


Figure 4

Cellulose insulation in a new transformer has a Degree of Polymerization (DP) of 800-1000. Once the cellulose insulation has reached a DP of 200, the cellulose insulation, and thus the transformer, is considered to be at the end of its useful life. Applying the kinetic parameters confirmed in the SINTEF studies, CIGRE (the Council on Large Electric Systems) Task Force D1.01.10 published a report titled "Cigré Brochure 323 - Ageing of Cellulose in Mineral-Oil Insulated Transformers" in October 2007. The task force report showed that **with a permanent moisture reduction strategy employed, transformer life extension would increase.** (See Fig. 4)

According to the chart in Figure 4, without a permanently installed drying system the transformer's paper will degrade to the end of its useful life (DP = 200) in 35 years.

However, if a DryKeep® system was installed in year 8, the transformer would reach the end of its useful life in 60 years; a life extension of 25 years!

FINANCIAL BENEFIT OF DryKeep®:

A permanently installed DryKeep® system will result in substantial financial savings by extending the life of a new or existing transformer. In simple terms, the minimum financial benefit is equal to the interest that could be earned on the deferred capital expense (CAPEX) that would otherwise be spent to replace the old transformer much sooner.

Example of Minimum Financial Benefit with DryKeep®

Initial Purchase Price of a three-phase 80 mVA 115/13.2kV transformer	US$ 540,000.00
Transformer Oil Capacity	16,630 liters
Moisture in Oil from Oil Test Lab Results, Year 8	22ppms at a top oil temp of 47°C
Estimated Total Amount of Moisture in the Transformer	40 liters
Estimated Percent Moisture in the Paper	2.5%
Moisture to be removed to bring transformer to safe level and keep dry	23 liters
Replacement Cost of the Transformer at End of Useful Life (C) *(keep constant for simplicity)*	US$ 540,000.00
Transformer Useful Life without DryKeep	35 years
Transformer Useful Life with DryKeep Installed in Year 8	60 years
Years of Deferred CAPEX from Life Extension by Investing in DryKeep (n)	25 years
Interest Rate on Investments (IR)	4%
Formula for interest earned by Investing Deferred CAPEX	$C ((1+IR)^n-1)$
Interest Earned over 25 years US$ 540,000 $((1+0.04)^{25}-1)$	US$ 899,551.62
Minimum Financial Benefit with DryKeep	**US$ 899,551.62**

Using a conservative 4% rate of return on the investment of the deferred replacement cost, the potential financial benefit with DryKeep® is enormous in this example. However, the example speculates that the deferred capital expenditure will be invested.

Using the same data, and including the median weighted average cost of capital for the US utilities sector of 8%, we can show the present value cost savings by comparing the transformer with and without DryKeep®.

FINANCIAL BENEFIT OF DryKeep® (Cont.):

Example of Net Cost Savings with DryKeep®

	Without DryKeep®	With DryKeep®
Life Expectancy	35 years	60 years
Initial Transformer Cost	US$ 540,000.00	US$ 540,000.00
Annual Straight-Line Depreciation	US$ 15,428.57	US$ 9,000.00
Present Value Cost of Transformer *(depreciated over full life expectancy)*	US$ 179,813.34	US$ 111,388.97
Present Value Savings on Initial Purchase		US$ 68,424.37
Net Cost Savings with DryKeep		**US $68,424.37**

It should be noted that other maintenance will most likely be performed according to the dissolved gas analysis (DGA), etc. DryKeep® removes the moisture only, at the molecular level, which increases the dielectric strength and lifespan of the paper insulation and oil. Even after including the very low total cost of ownership of a DryKeep system, **either through interest earned from deferred CAPEX investment, or the net savings from life extension, DryKeep® will safely and significantly improve your bottom line.**

Each application is different and there are many other variables that can't all be addressed in one example. In order to account for all of the other variables specific to your application, Drykeep® is developing a Financial Benefit Calculator on our website at www.drykeep.com to calculate your own projected financial benefit when using DryKeep®.

APPLICATIONS OF DryKeep®®:

Specifying DryKeep® on a new power transformer gives you the flexibility of having DryKeep® installed by the transformer OEM at their factory or by the installing contractor at the substation. DryKeep® will keep the oil and cellulose insulation at the factory-dry moisture level, **virtually eliminating the adverse effects of moisture in a transformer.**

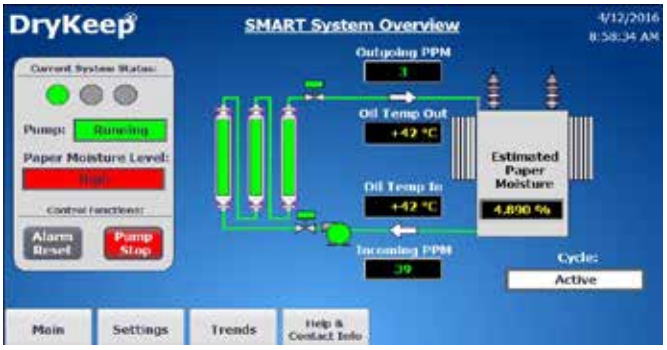
For transformers already in-service, DryKeep® removes moisture that had previously accumulated. Perhaps more importantly, DryKeep® keeps the moisture at that safe level going forward, **preventing further irreversible damage to the paper insulation.**





CRITICAL ASSET MANAGEMENT WITH CONDITION-BASED MONITORING:

SMART DryKeep® units are critical asset management systems that include integrated moisture-in-oil and oil temperature sensors that feed data to an intelligent controller. The software has embedded isotherms for both mineral oil and Envirotemp FR3 insulating fluids.



DryKeep Data Log

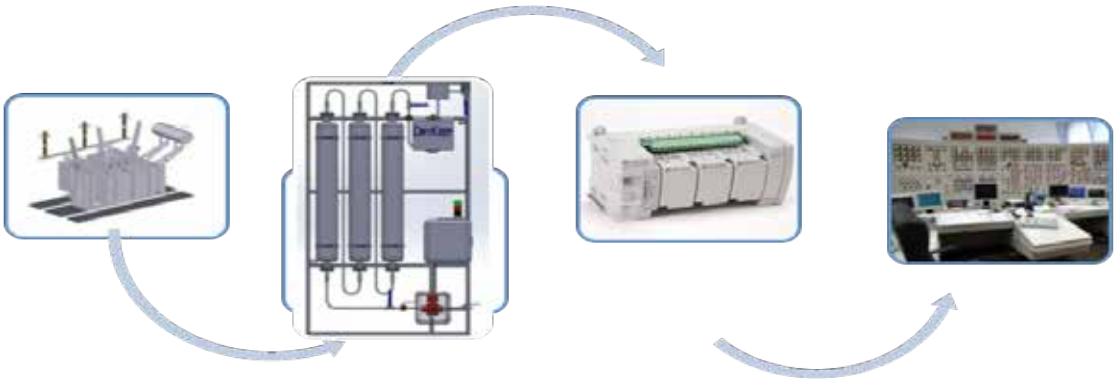
Date / Timestamp	Inlet PPM (Raw)	Outlet PPM (Raw)	Inlet Temp (Raw)	Estimated Percent Moisture (Raw)	Inlet PPM (Avg)	Outlet PPM (Avg)	Inlet Temp (Avg)	Estimated Percent Moisture (Avg)	Cycle Status
11/2/2017 21:05	23	5	29	5.315	23	5	29	5.315	Active Too
11/2/2017 21:05	23	4	29	5.315	23	4	29	5.315	Active Too
11/2/2017 21:05	23	3	29	5.315	23	3	29	5.315	Active Too
11/2/2017 21:06	23	4	29	5.315	23	4	29	5.315	Active Too
11/2/2017 21:07	23	4	29	5.315	23	4	29	5.315	Active Too
11/2/2017 21:07	22	3	29	5.156	22	3	29	5.156	Active Too
11/2/2017 21:07	22	4	29	5.156	22	4	29	5.156	Active Too

Every SMART DryKeep® system has the following features:

- ✓ Automatic monitoring and controlling of the dehydration process to prevent over-drying,
- ✓ Recording of all moisture-in-oil, estimated moisture in the paper, oil temperature, system status and alarm event data and total moisture removed.
- ✓ Allows the user to remotely monitor moisture content and temperature of the insulating oil on a real-time basis without having to take individual oil samples.
- ✓ Provides real-time, condition-based monitoring and data needed to effectively manage your most critical asset.

A built-in RTU provides remote access to all real-time and logged data, alarms, and full remote control of the system via cellular, Ethernet, fiber optic cable or WLAN. All SMART DryKeep® systems are also SCADA-ready with:

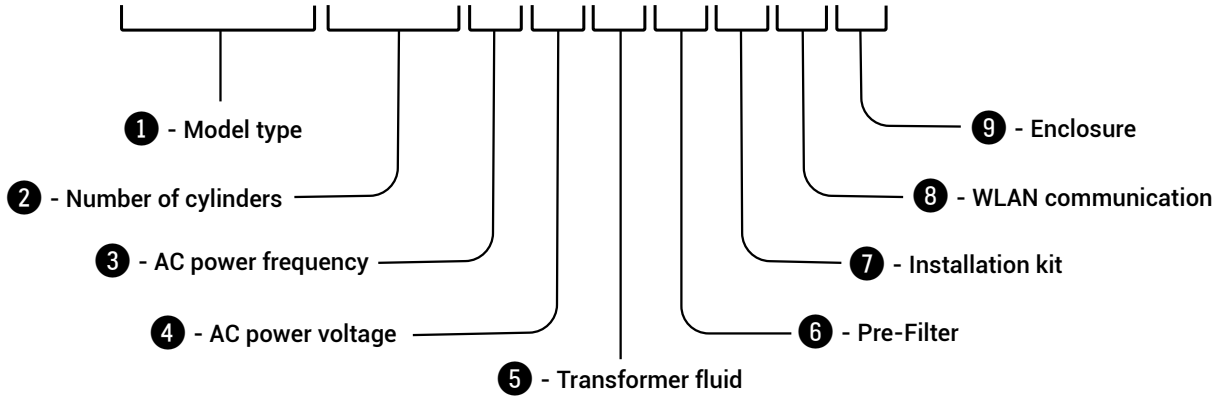
- **DNP3 – Slave SCADA and MODBUS RTU/TCP/ASCII/RTU protocols.**
- **RJ45 Ethernet ports,**
- **62.5/125 um (SC) Mulitmode Fiber Converter.**



How to order DryKeep®

DRYKEEP® CATALOG NUMBER CONFIGURATOR SAMPLE:

SMART RT-9-A-C-M-Y-K-W-F



1. **SMART:** SCADA-ready SMART DryKeep®
   Leave blank: Basic DryKeep® Dryout System
2. **RT-9:** 3 cylinders - transformer size 10MVA and larger
   RT-3: 1 cylinder - transformer size < than 10MVA
3. **A:** 60Hz customer supplied AC power
   B: 50Hz customer supplied AC power
4. **A:** 110V customer supplied AC power
   B: 220V customer supplied AC power
   C: 115V customer supplied AC power
   D: 230V customer supplied AC power
5. **M:** Mineral oil
   F: Envirotemp FR3
6. **X:** No pre-pump Y-filter
   Y: Pre-pump Y-filter
7. **X:** No installation kit
   K: installation kit
8. **X:** No WLAN communication
   W: With WLAN communication (requires SMART unit)
9. **X:** Frame mounted with no enclosure
   E: Frame mounted in free standing enclosure
   C: Frame mounted in free standing enclosure with climate control package
   U: Frame mounted in free standing enclosure with 24VDC UPS backup battery system
   F: Frame mounted in free standing enclosure with climate control package and 24VDC UPS backup battery system

DryKeep® *Model Examples*

EXAMPLE 1:

SMART, 3 cylinder, 60Hz, 115V, mineral oil, with pre-pump Y filter and installation kit, with WLAN communication in a free standing enclosure with climate control and UPS battery backup system

ORDER CATALOG NUMBER:

SMART RT-9-A-C-M-Y-K-W-F

EXAMPLE 2:

Basic, 1 cylinder, 50Hz, 230V, FR3 oil, with pre-pump Y filter, no installation kit, no enclosure

ORDER CATALOG NUMBER:

RT-3-B-D-F-Y-X-X-X

SMART DryKeep® System Specs

Application:	Suitable for any sized power transformer. Suitable for both mineral oil and Envirotemp™ FR3™ natural ester fluid insulated transformers.
Recommended DryKeep System Sizes:	One cylinder DryKeep systems (RT-3) for transformers up to 10mVA. Three cylinder systems (RT-9) for transformers larger than 10mVA.
International Standard:	Fully complies with ANSI/IEEE standard C57-140-2006, section 7.2.
Country of Manufacture:	Made in the USA.
Quality Control:	Manufactured in an ISO9001 certified facility.
Installation:	Directly mounted to the transformer, adjacent to the transformer, or mounted in a free standing enclosure.
Operating Ambient Temperature Range:	0 to +40 °C or -40 to +55°C with optional climate control enclosure package
System uses heat or vacuum:	No
Disturbs DGA:	No. DryKeep removes moisture and particles only to the exclusion of anything else, including gasses.
Removes oil inhibitors:	No. DryKeep removes moisture and particles only to the exclusion of anything else, including oil inhibitors.
Disturbs nitrogen blanket:	No. DryKeep removes moisture and particles only to the exclusion of anything else, including nitrogen blankets.
Over-drying prevention:	Automated control of the drying process to prevent over-drying and the resulting loosening of the windings.
AC power requirements:	Single-phase 50/60 Hz, 110/220/115/230 volts. System terminal blocks rated 600 V, 30 Amp, up to 10 AWG wire. System load is 6.5 amps at 115 V, 60Hz or 13.5 amps with climate control enclosure option. System load at 220V, 50Hz is 3.8 amps or 7.3 amps with climate control enclosure option.
Pump/motor:	0.33HP, 1-ph, 50/60 Hz, 110/220/115/230 volts, 1450/1750RPM, TEFC, Frame 56C positive displacement, external gear modular pump and motor. Viton lip seal and gaskets. 150PSI relief valve pressure setting for a maximum pumping height of 100 feet. Nominal capacity rating: 0.6/0.7 GPM (2.27/2.65 LPM).
Frame material:	304 stainless steel.
Hardware material:	All nuts, bolts, washers and hose clamps are stainless steel.
Manual valves:	1/2" 1000 PSI stainless steel locking ball valves at inlet and outlet of system.
Automatic Isolation valves:	UL Listed/CSA certified AC solenoid safety isolation valves at inlet and outlet.
Flow Indicator:	Stainless steel body, wetted part, Viton seals variable flow rate indicator. Automatic leak detection shutdown via 3-wire S.P.D.T size 3 adjustable switch.
Moisture Removal Cylinders	One (1) or three (3) 304 stainless steel regeneratable adsorption cylinders factory filled with the precise amount of highly porous, crystalline aluminosilicate adsorbent in beaded form with hydraulic quick couplers with thread-actuated chrome alloy ball valves for easy saturated cylinder removal and sealing while transformer remains energized and online.
Moisture Removal Capacity:	3.0 - 4.2 liters of moisture per cylinder before saturation.
Cylinder gaskets	TD 1049 cork compounded with Nitrile (NBR) rubber suited for mineral and silicone oil according to ASTM D3455 "Test Methods for Compatibility of Construction Materials with Electrical Insulating Oil of Petroleum Origin" and ASTM D5282 "Test Methods for Compatibility of Construction Materials with Silicone Fluid used for Electrical Insulation".
System hoses	Static dissipative core tube, 304 stainless steel braided, PTFE hoses to SAE 100R14B standard.
Air bleeder:	304 stainless steel de-aerator tank with ¼" stainless steel locking ball bleeder valve and hose.
Local Display (HMI):	7" Widescreen TFT color display touchscreen with: 12MB user memory, 16,777,216 colors, 800x480 pixels, 6-week backup retentive clock, 2 SD card slots, 2 GB SD card for .CSV data logging, CE mark, cULus, RCM, KC approval, ATEX Zone 2 and 22, IECEx Zone 2 and 22, cULus Class I Zone 2 Division 2, FM Class I Division 2.
HMI screen information:	Current system cycle and pump status, System alarms, Incoming PPM of moisture in oil and oil temperature, Outgoing PPM of moisture in oil and oil temperature, Estimated percent moisture in the paper insulation of the transformer, System settings, Data trend screens, Help contact details.
Data Logging:	Actual and average incoming PPM of moisture in oil, Actual and average incoming oil temperature, Estimated percent moisture in the transformer paper, system cycle status, system alarms, total moisture removed.
Sensors:	Two permanent moisture-in-oil and oil temperature sensors in compliance with EMC standard EN61326-1 with direct PPM and temperature outputs.
Remote Control and Communications	Remote monitoring and control of the entire process is provided via LAN: RJ45 Ethernet and 62.5/125 um (SC) Multimode Fiber Converter for wired access and control. Cellular: VPN over cellular for remote access and control, WLAN: IEEE802.11b/g/n wireless access point for wireless computer access and control
SCADA-Ready:	DNP3 – Slave SCADA and MODBUS RTU/TCP/ASCII/RTU protocols. RJ45 Ethernet and 62.5/125 um (SC) Multimode Fiber Converter for wired connection. IEEE802.11b/g/n wireless access point for wireless connection.
Alarms:	Saturated cylinder(s), Low Flow/Leak detected, AC power restored to system, AC power loss (requires UPS backup option) Low battery (requires UPS backup option)
Alarm Delivery:	Alarms sent/displayed: Locally on HMI, Locally via LED stack lights, Remotely via multi-carrier 4G LTE and 3G/2G fallback cellular, SCADA, Wireless via IEEE802.11b/g/n wireless access point.
System insulating fluid:	Factory-filled with severely hydrotreated naphthenic transformer oil that fully complies with: ANSI / ASTM D-3487, Type II, Doble TOPS-884, Inhibited Type II, BS 148:1984, Class IIA (Inhibited), CAN/CSA-C50-08, Type II (Class B), NEMA TR-P8-1975. (Other mineral oils and FR3 also available)
Server license for remote connections:	Included at no cost or annual fee
Particle filter:	1-micron with visual status indicator
Oil sampling ports:	Two (2) stainless steel oil sampling ports

DryKeep® System Components

1 De-aerator valve

2 Air bleeder hose

3 De-aerator tank

4 Oil Flow Meter

5 Outlet solenoid safety isolation valve

6 Manual outlet valve

7 Outgoing moisture in oil/oil temperature sensor

8 Oil Sampling Port

9 1-micron particle filter

10 Quick Coupler

11 Drying cylinders

12 LED status indicating light stack

13 RTU cellular antenna

14 WLAN access point

15 SMART system display and HMI

16 SMART system RJ45 Ethernet interface

17 Overdry prevention bypass valve

18 Incoming moisture in oil/oil temperature sensor

19 Oil Sampling Port

20 Pump/Motor

21 Inlet Solenoid Safety Isolation Valve

22 Manual Inlet Valve

23 Particle filter gauge

Optional Items

Pump Pre-Filter: 316 stainless steel Y-filter with 2PSI bypass and bypass indicator.

Custom Installation Kit: Designed for each specific transformer including two (2) static dissipative core tube, 304 stainless steel braided, PTFE hoses to SAE 100R14B standard and all necessary hardware for hose connections for inlet and outlet connections from the transformer to system.

Saturated Cylinder Regeneration Kit: Precise amount of DryKeep adsorbent in beaded form capable of adsorbing up to 4.2 liters for one cylinder. • TD 1049 cork compounded with Nitrile (NBR) rubber cylinder gasket suited for mineral and silicone oil according to ASTM D3455 "Test Methods for Compatibility of Construction Materials with Electrical Insulating Oil of Petroleum Origin" and ASTM D5282 "Test Methods for Compatibility of Construction Materials with Silicone Fluid used for Electrical Insulation" • Spanner wrench.

Spare Cylinders: New and unused, for all DryKeep® SMART and Basic systems: Factory-filled with the precise amount of proprietary sized and coated synthetic zeolite (sodium aluminosilicate) adsorbent capable of adsorbing a minimum of 3 liters and maximum of 4.2 liters of moisture before saturation • TD 1049 cork compounded with Nitrile (NBR) rubber cylinder gaskets suited for mineral and silicone oil according to ASTM D3455 "Test Methods for Compatibility of Construction Materials with Electrical Insulating Oil of Petroleum Origin" and ASTM D5282 "Test Methods for Compatibility of Construction Materials with Silicone Fluid used for Electrical Insulation" • Hydraulic quick couplers with thread-actuated chrome alloy ball valves for easy saturated cylinder removal and sealing • Factory-filled with severely hydrotreated naphthenic transformer oil that fully complies with ANSI / ASTM D-3487 Type II, Doble TOPS-884 Inhibited Type II, BS 148:1984 Class IIA (Inhibited), CAN/CSA-C50-08 Type II (Class B), NEMA TR-P8-1975.

WLAN Access Point: Client with two internal antennas (MIMO) WLAN 802.11 a, b,g, n, frequency: 2.4 GHz, 5 GHz (incl. DFS channels)

Free-standing Enclosure: NEMA 4, double-door, 12-gauge steel free standing enclosure • Lifting eyes • ANSI 61 gray polyester powder paint inside and out • 17" x 11" Lexan viewing window • UL listed type rating 4, CSA certified type rating 4 • System status indicating LED stack lights.

Climate Control Package: Two 1300 watt heater mounted in the enclosure extends aminet operating temperature range to -40°C. Additional UL/cUL Listed 2000 BTU/Hr. (586 Watt) enclosure cooling and heating package extends operating ambient temperature range of SMART DryKeep systems to +55°C. REQUIRES FREE STANDING ENCLOSURE OPTION

Backup Battery System: 24VDC back up battery UPS System keeps SMART DryKeep running after loss of AC power supply with: Two (2) 6-cell, 12VDC, 12.0 AH, rechargeable, sealed, lead acid batteries connecting in series • 24VDC, 10 A uninterruptible power supply • Battery below < 85% alarm • REQUIRES FREE STANDING ENCLOSURE OPTION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For more info, visit us at DryKeep.com
Fully complies with IEEE standard C57-140-2006, 7.2
Made In the U.S.A.