TRANSFORMER INSTALLATION AND MAINTENANCE

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IEEE Training, Houston, Texas ,
Oct.8-9, 2013

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Overview

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- Review of Basic Accessories
- Installation of transformer
- Transformer Maintenance

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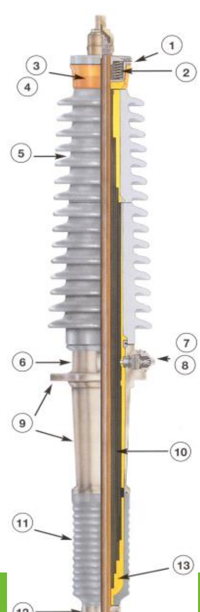
ACCESSORIES

Commonly supplied accessories are:

1. Bushings (e.g. PCORE-Lapp, ABB, HSP).
2. Winding Temperature Indicator.
3. Oil Temperature Indicator.
4. Oil Level Indicator.
5. Gas detector relay (e.g. ABB Model 11 or Buchholz).
6. Silica gel breather.
7. Fans.
8. Pumps.
9. Pressure Relief Device.
10. On-line monitors (ETM, DGA, PD, etc.).

In the next few slides photos of the above accessories and construction details of some accessories are shown.

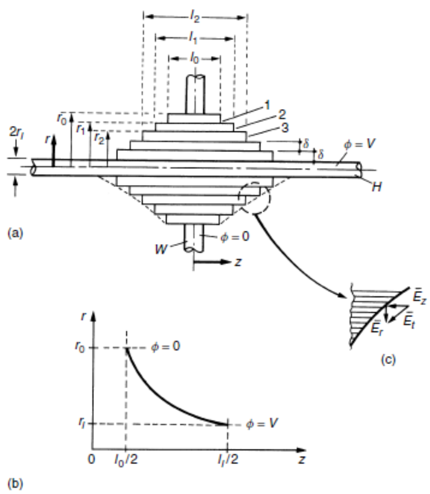
PCORE Lapp POC (paper-oil-capacitor) bushing



1.Gaskets - Cork-nitrile rubber gaskets are designed to provide oil-tight seals
2. High Compression Coil Springs -provide uniform, active compressive loading on gaskets.
3. Clear-View Oil Reservoir (Medium and High Voltage Bushings)
4. Magnetic Oil Gauge (Extra High Voltage Bushings)
5. Porcelain Housing - to provide the required leakage and strike distance and has ground surfaces on top and bottom ends for oil-tight gasket seals.
6. Name Plate Data - identifies the bushing by catalog number, serial number and year of manufacture with electrical ratings and factory measurement data.
7. Power Factor Test Tap (Medium Voltage Bushings) - 25 kV through 69 kV . The test tap is connected to the ground layer of the capacitor core.
8. Voltage Tap or Capacitance Tap (High and Extra High Voltage Bushings) - Bushings rated at 115 kV and above have a permanent internal ground. In addition, an insulated tap is connected to a floating capacitor layer. This tap, designated a capacitance tap or a voltage tap, is grounded except when used as a voltage source with a potential device.
9. Mounting Flange, Ground Sleeve Assembly
10. Paper-Foil Capacitor Core - Conductive layers of aluminium foil with high dielectric paper
11. Lower Porcelain Assembly
12. Bottom Cap Assembly - A confined cork-nitrile rubber gasket provides a leak-proof seal between the porcelain and the cap. For bushings rated 115 kV through 161 kV, the bottom cap is adaptable for use in draw-lead and bottom-connected applications.
13. Dried, Degassed Oil

http://www.hubbellpowersystems.com/bushings/pcore/poc-115kv-500kv/

Condenser bushing design principle



Assume $E_r = const$,
Then the voltage across each capacitor $\Delta V = E_r \delta$.
As this is a series connection of capacitors with same charge Q, it results in $C_1 = C_2 = \ldots C_n$

$$C_1 = \frac{2\pi\varepsilon l_0}{\ln(r_0/r_1)},$$

$$C_2 = \frac{2\pi\varepsilon l_1}{\ln(r_1/r_2)},$$

or

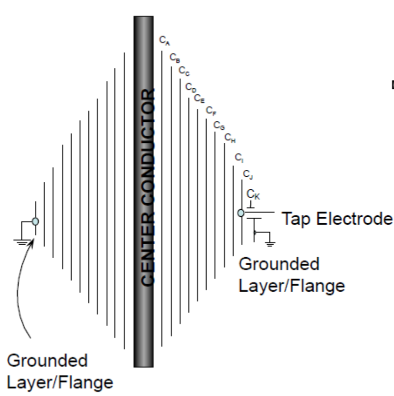
$$\frac{l_0}{\ln(r_0/r_1)} = \frac{l_1}{\ln(r_1/r_2)} = \ldots = \frac{l_n}{\ln(r_n/r_{n+1})}$$

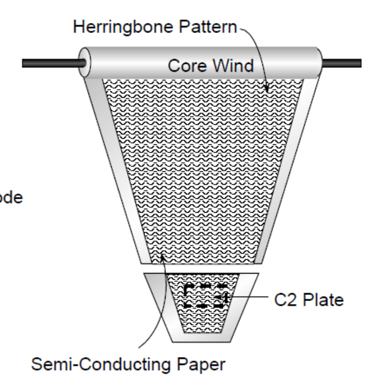
Which can be approximated as:

$$l_0 r_0 \cong l_1 r_1 \cong \ldots \cong l_n r_n,$$

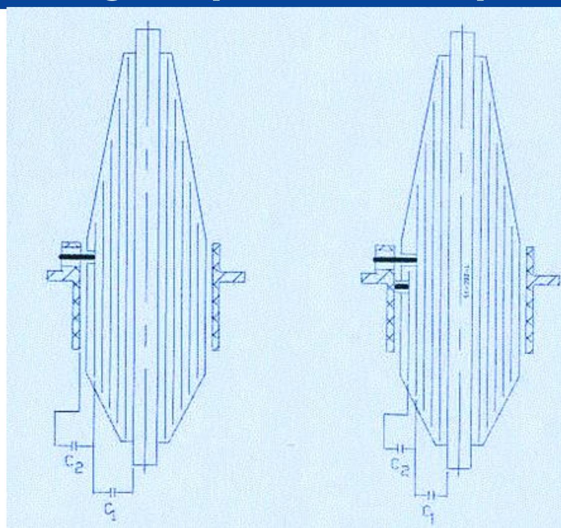
Source: High voltage Engineering – Fundamentals, E.Kuffel et al, Butterworth-Heineman, 2000

Condenser bushing construction

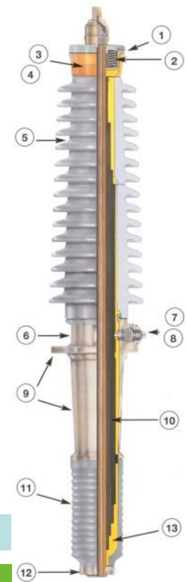




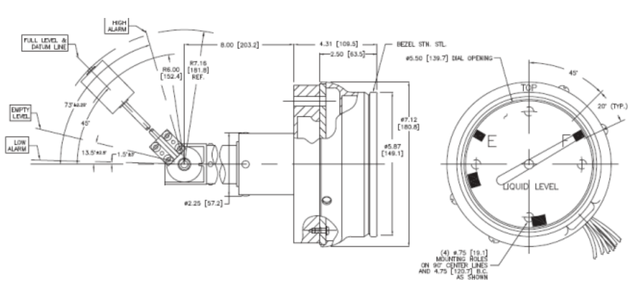
Voltage tap vs. test tap



Test tap, capacitance tap | Voltage (potential) tap



Liquid Level Gauge



Source: http://www.qualitrolcorp.com/Products/Liquid_Level/Large_Oil_Level_Indicators/

Remote Temperature Indicator

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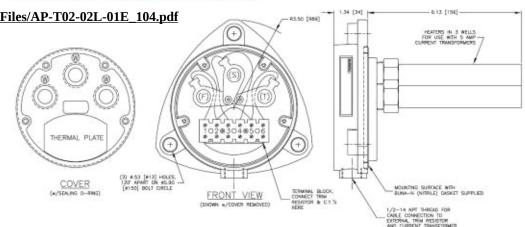
http://www.qualitrolcorp.com/uploadedFiles/AP-T02-02L-01E_104.pdf

Thermal plate (3 winding temperature model shown)

SOURCE: http://www.qualitrolcorp.com/uploadedFiles/AP-T02-02L-01E_104.pdf



SOURCE: http://www.qualitrolcorp.com/uploadedFiles/Siteroot/Products/AP-T03-01L-02E_130.pdf

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Winding Temperature Indicator

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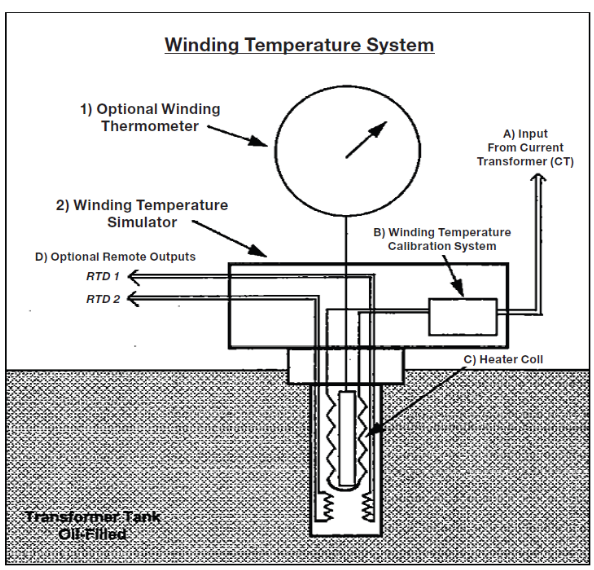

SOURCE: http://www.qualitrolcorp.com/uploadedFiles/Siteroot/Products/AP-T03-01L-02E_130.pdf

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SIMULATED HOT SPOT SCHEMATIC

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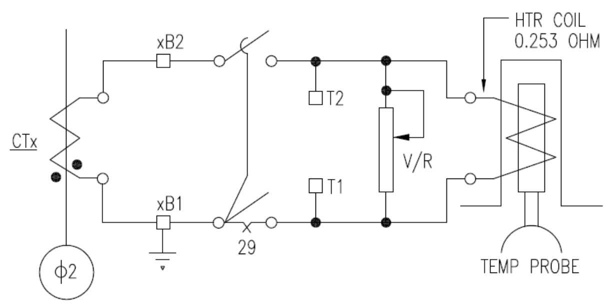

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Gas detector relay

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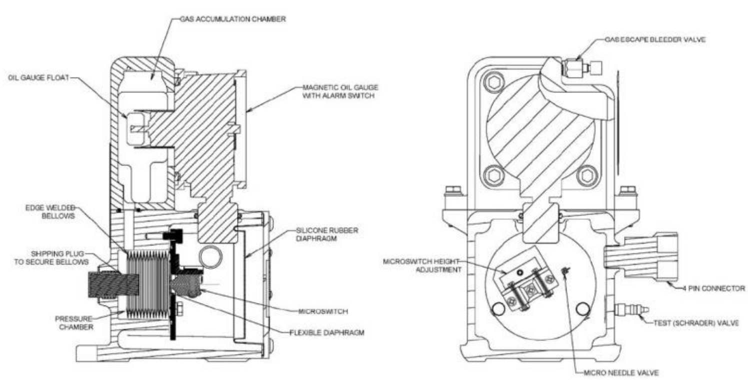

The gas detector relay (GDR) is a protective device that gives an early indication of faults occurring in oil-filled conservator type power transformers:

1. **Gas accumulation**: Faults of an incipient or minor nature resulting in a slow evolution of gas. This gas may be generated by local heating, defective insulating structures, improper joints, loose contacts, grounds, shorted turns, burning of core steel, or from air in the transformer.
2. **Rapid pressure**: Faults of a major nature that generates a sudden pressure wave. Major faults are usually caused by breakdown between energized parts, followed by short circuit.

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Sudden pressure relay SPR

Sudden Pressure Relay can only be applied to transformers with a gas space.

The Sudden Pressure Relay is a device designed to respond to the sudden increase in gas pressure in a power transformer which would be caused by an internal arc. The relay consists of:

(i) a pressure sensing bellows,
(ii) a micro switch and
(iii) a pressure equalizing orifice

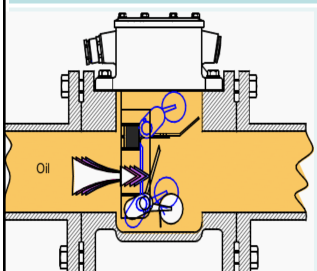
All parts are enclosed in a sealed case and mounted on the outside of the transformer at the gas space.

http://www.abb.ca/product/db0003db004283/c12573e70033046285256f82007b2ae7.aspx

BUCHHOLZ RELAY

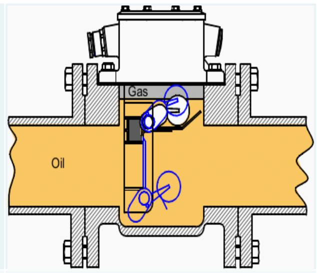
Operation of Buchholtz relay

Rapid liquid flow



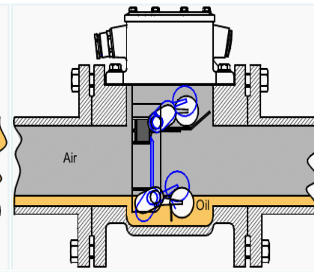
Fault: An internal fault generates a pressure wave moving toward the conservator.
Relay response: The liquid flow reaches a damper located in the liquid flow. If the flow rate exceeds the operating threshold of the damper, it moves in flow direction. Due to this movement a switch contact is actuated so that the transformer is de-energized.

Gas accumulation



Fault: Free gas is present in the insulating liquid.
Relay response: The gas in the liquid moves up, accumulates in the Buchholz relay and displaces the insulating liquid level. The moving float actuates a switch contact with an alarm signal. The lower float is not affected as from a certain gas volume the gas flows through a piping to the conservator

Insulating liquid loss



Fault: Insulating liquid loss
Relay response: As the liquid level falls the top float moves downward. An alarm is tripped. If the liquid loss continues, the lower float moves downward. The moving float actuates a switch contact so that the transformer is de-energized.

Mounting of Buchholtz relay

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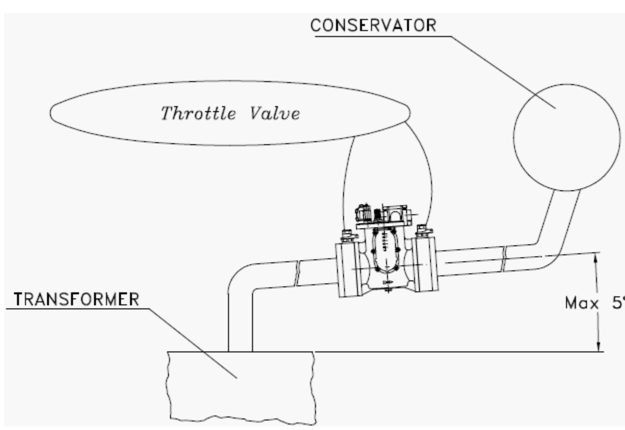

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Fans

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- Fans are used in, addition to radiators, to cool the oil in power transformer.
- Fans can be operated in stages, to turn on after a targeted oil temperature is reached.
- Fans are crucial for the transformer to work at peak load with minimal losses
- CG often chooses Krenz- vent fans unless specified elsewhere by the customer.
- Fans will either be mounted on the bottom or the side of the radiators.

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Fan Specifications

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FAN RATINGS

KRENZ & CO. PART NO.	***F26DBA-A9713***
HP	1/3
RPM	1140
VOLTS	208-230
PHASE	3
HERTZ	60
CFM (1)	7400
dBA (2)	61.6

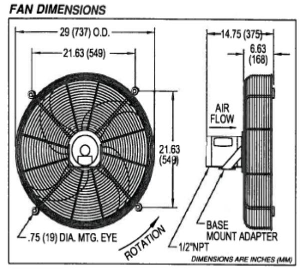
FAN ELECTRICAL DATA

VOLTS	208	230	240
FAN AMPS	1.17	1.21	1.23
FULL LOAD AMPS	1.4	1.4	1.4
STARTING AMPS	3.7	4.1	4.3
LOCKED ROTOR AMPS	3.7	4.1	4.3
FAN WATTS	296	308	320
POWER FACTOR %	70.3	64	62.7

All fans are very similar with only a few variations depending on the transformer requirements:

- Fan ratings(HP,CFM, dBA)
- Electrical ratings(V, Phases ,FLA, etc.)
- One or two blades per fan
- Rotation of blades
- Mounting Adapter

FAN DIMENSIONS



FAN FEATURES

FAN HOUSING
- BASKET TYPE WITH DISCHARGE GUARD.
- MEETS OSHA REQUIREMENTS.
- HOT DIP GALVANIZED STEEL.

FAN MOTOR
- TOTALLY ENCLOSED NON-VENTILATED, IP54 ENCLOSURE.
- NEMA 48 FRAME WITH .625" DIA. 416 STAINLESS STEEL SHAFT.
- PERMANENTLY LUBRICATED, DOUBLE SEALED BALL BEARINGS.
- CLASS F INSULATION, CLASS B TEMPERATURE RISE.
- 55°C (131°F) MAXIMUM AMBIENT TEMPERATURE.
- INTEGRAL CONDUIT BOX WITH 1/2" NPT CONNECTION HOLE.
- AUTOMATIC-RESET OVERLOAD PROTECTION.
- FOUR-STEP PROPRIETARY COATING SYSTEM.
- ANSI 70 GRAY FINAL COAT IS STANDARD.
- FOUR 1/8" NPT CONDENSATION DRAIN HOLES.

FAN BLADE
- ONE PIECE, 2-WING, CAST ALUMINUM.
- TWO BLADES PER FAN.
- COUNTER-CLOCKWISE FROM INLET SIDE.

WITH
- ACC-B10656 BASE MOUNT ADAPTER INSTALLED.

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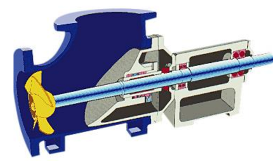
Pumps

Centrifugal

- Transformer pumps allow for maximum cooling which allows for peak load operation of oil cooled transformers.
- There are two types of pumps generally used, axial and centrifugal, with centrifugal pumps being the most common.

Axial

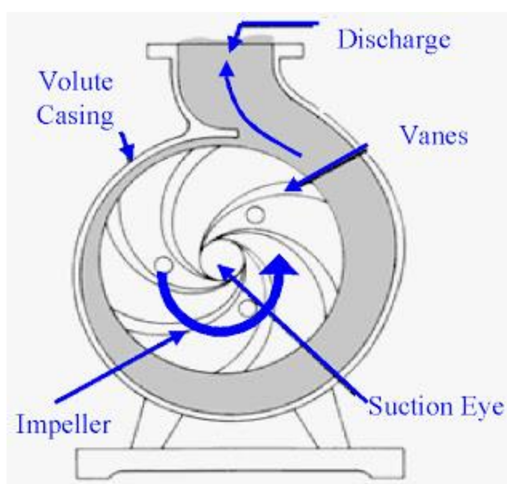


Centrifugal pump

Centrifugal pumps use the power of rotational kinetic energy to force fluid flow

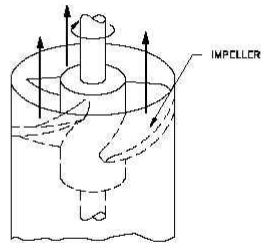
- Impeller is operated by a separate motor drive chamber.
- The Oil enters the pump impeller through the suction eye, usually near impeller's axis of rotation.
- Oil is accelerated by the impeller.
- Oil is forced flowing radially outward into a diffuser or discharge.

Due to separate motor chamber, there is no heat transfer from motor chamber to oil

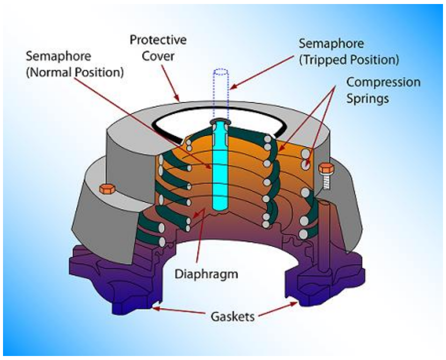


Axial pump

- Consists of a motor operated impeller inside of a pipe.
- Oil is pushed by the spinning blades of the impeller.
- The operation allows the pump to receive and discharge the fluid on nearly the same axis.
- Due to the small mechanical parts the axial pump is very efficient and relatively small while also maintain a high rate of discharge



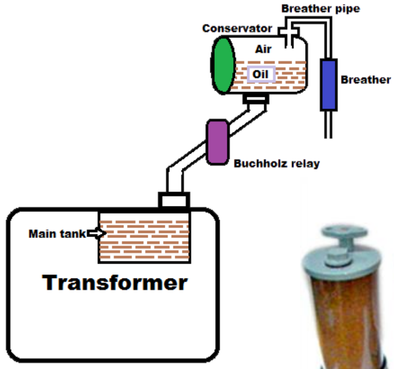
Pressure relieve device



Mechanical device for relief of excessive pressure accumulation of large volumes of gas or fluid in transformer. Gasket system provides quick response time and automatically reseals after pressure has subsided. Options include local operation indication, contacts (switches) for operation alarming, and directional shield for hot oil and gas exhaust control.

Source: http://www.qualitrolcorp.com/Products/Pressure_Controls_Gauges_and_Relays/Pressure_Relief_Devices/

Silica gel breather/ maintenance-free breather

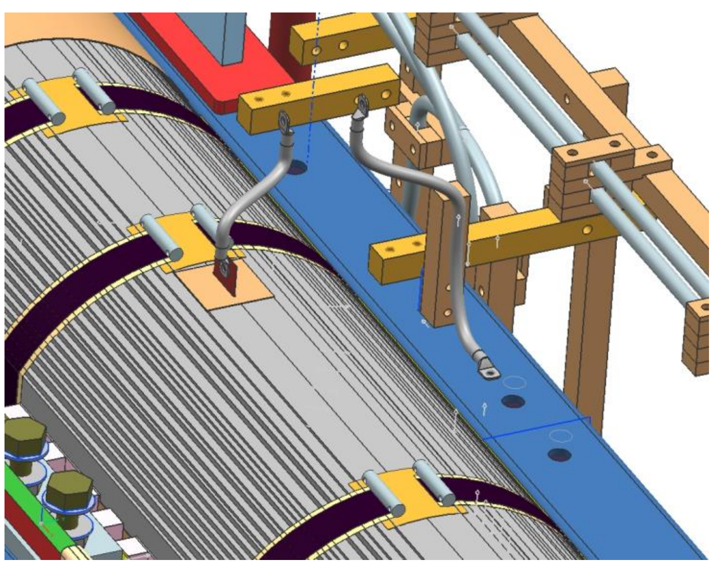


a) b)

a) Conventional with change of color from blue to orange, or b) maintenance free

Source: MR In-sight Magazine, 2009/4; www.reinhausen.com

Core and clamp ground



Transformer monitoring devices

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1. Temperature Monitoring

The traditional thermal mechanical analog gauges have given way to more dependable and accurate measurement of the top oil temperatures and modeling of the winding hottest spot temperature through Electronic Temperature Monitors (ETMs), typically based on the IEEE C57.91 [5] or the IEC 600354 [6] standard.

2. Dissolved Gas Analyzers

Dissolved Gas Analysis (DGA) of gases dissolved in transformer oil is perhaps the most sensitive and reliable technique which gives an early indication of abnormal behavior of a transformer.

3. Moisture in Oil monitoring

The user needs to keep moisture level under control as the detrimental effects of water in the oil include loss of insulating capabilities leading to dielectric breakdown.

4. Bushing Monitoring

Most transformer bushings are capacitive devices with a test tap provided in the flange area to permit access to the capacitive, metallic layers inside. Using this test tap one may check the condition of the bushing.

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Transformer monitoring devices cont.

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5. Partial Discharge detection and location

On-line PD detection can be used to monitor the condition of the transformer insulation. There are two main groups of methods for PD detection: (i) acoustic emission (AE) and (ii) electrical methods (narrow band, wide band, RF, UHF).

6. Cooling Equipment Monitoring

By monitoring the current to the cooling circuit one may obtain feedback on the operating status of all fans and/or pumps.

7. On Load Tap Changer Monitoring

One can monitor the LTC motor load current and look for the current values exceeding the norm and reflecting an indication of mechanism wear and restrictions. Trending these indicators will provide a gauge for maintenance needs. Through monitoring the LTC tap position and providing a running accumulation of the number of times the LTC had reached each tap, we can provide an indication of contact wear. A curve of that data should approximate a bell shaped curve with the center around the nominal position of the tap changer.

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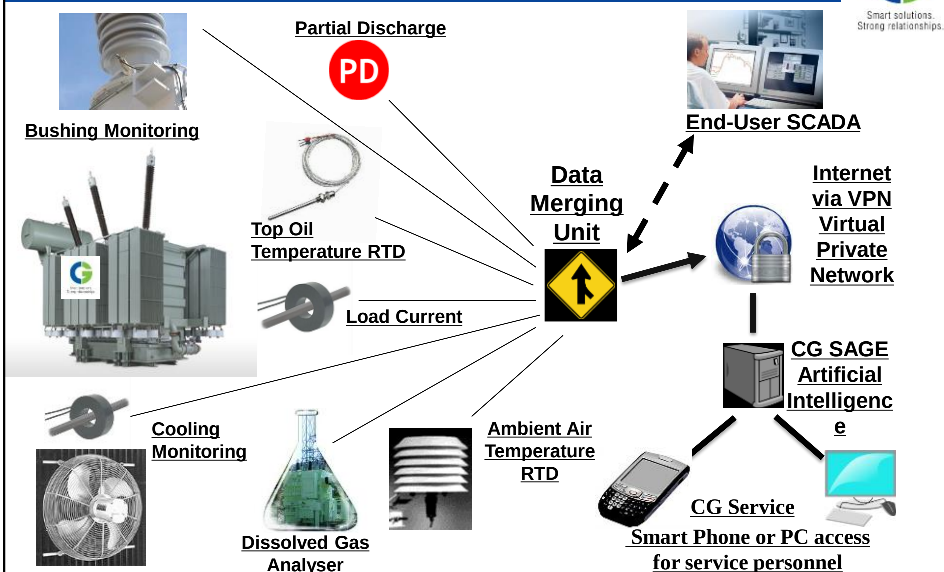
The Smart Transformer - Concept



MAINTENANCE NEEDS TO BE CONSIDERED

(a) AT PLANNING STAGE.

1. TRANSFORMER STATION SITE SELECTION (easy access to transport the transformer).

2. TRANSFORMER PARAMETERS: MVA, KV, TYPE OF COOLING, TERMINALS ARRANGEMENT ETC. (should be possible to easily install and maintain the transformer).

(b) SPECIFICATION PREPARATION STAGE.

1. CHANGES/ADDITIONS TO STANDARD SPECIFICATIONS (updated to include current trends).

2. SPECIFIC REQUIREMENTS FOR A PARTICULAR STATION (special cooling, special bushings, etc.).

3. SAFETY CONCERNS (fall arrest systems, emergency man-holes, etc.).

4. CHANGES TO ENVIRONMENT LAWS (restrictions on PCB, mercury contacts, etc.).

5. SPECIAL MAINTENANCE REQUIREMENTS (on-line monitors & tap-changer filters, etc.).

***Transformer supplier will work with customers to meet their specific requirements.

MAINTENANCE NEEDS TO BE CONSIDERED (continued)

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(c) TENDER EVALUATION STAGE.

1. REQUIREMENT OF SPECIAL TOOLS/PRECAUTIONS FOR EASY INSTALLATION & MAINTENENCE.
2. BUSHINGS TYPE/MAKE (availability of spares).
3. ACCESSORIES TYPE/MAKE (possible to repair/replace easily).
4. PRECAUTIONS IN VACCUM FILLING (refer TM-410.00).
5. OIL TYPE AND OIL QUANTITY (compatibility with user's standard oil).
6. EXCEPTIONS TO THE PURCHASING SPECIFICATIONS (should not cause problems to maintenance).
7. SUFFICIENT ROOM INSIDE THE TANK TO INSPECT AND TO MAKE REPAIRS AT SITE.
8. SPARE PARTS (should be possible to procure coils etc from repair shops at reasonable cost).
9. SAFETY CONCERNS (to provide emergency man-holes and other safety requirements).

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MAINTENANCE NEEDS TO BE CONSIDERED (continued)

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(d) DURING MANUFACTURE.

1. ATTEND DESIGN REVIEW MEETINGS.
2. DEVIATIONS FROM STANDARD MANUFACTURING PRACTICES (welding, brazing etc).
3. SPECIAL WINDINGS, MAGNETIC SHIELDING, ASSEMBLY ETC (should be possible to dismantle and reassemble easily).
4. DESIGN OF GASKET JOINTS AND GASKET MATERIALS (should not develop leaks during operation).
5. DESIGN PARTS FOR EASY SHIPPING, STORAGE AND ASSEMBLY .
6. PAINT FINISH (not to rust in the field).

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SHIPPING

1. DISASSEMBLE AND MATCH MARK PARTS SUCH THAT IT TAKES LESS TIME TO ASSEMBLE IN THE FIELD.

2. PACK THE PARTS SUCH THAT THEY CAN BE UNPACKED AND REACHED EASILY AND ORDERLY FOR FAST ASSEMBLY IN THE FIELD.

3. SHOULD BE NO SHORTAGE OF SHIPMENT OF PARTS.

4. PARTS SHOULD BE PACKED FOR OUT-DOOR STORAGE.

5. RECORD DRY AIR DUE POINT AND PRESSURE BEFORE LEAVING THE FACTORY. ALSO CLEARLY MARK THESE VALUES ON SHIPPING DOCUMENTS.

6. MEASURE CORE GROUND AND CLAMP GROUND RESISTANCES ON THE RAIL CAR AND RECORD THESE VALUES ON SHIPPING DOCUMENTS.

7. INITIATE IMPACT RECORDER AT CORRECT TIME BEFORE THE RAIL CAR LEAVES THE FACTORY.

8. SHIP MAIN UNIT AND PARTS SUCH THAT THEY ARRIVE AT PROPER TIME FOR ASSEMBLY WITHOUT ANY DELAYS.

RECEIVING (TM-201-00)

1. EXAMINE BRACING, BLOCKING AND BOLTDOWN CABLES FOR MOVEMENT/DAMAGE.

2. EXAMINE TANK FOR SCRAPES, DENTS AND DAMAGE.

3. CHECK THAT PARTS ARE RECIVED PER PACKING SLIPS.

4. EXAMINE CRATES, BOXES ETC FOR DAMAGES.

5. REPAIR THE DAMAGE ONLY AFTER APPROVAL FROM INSURANCE COMPANY.

6. RECORD DRY AIR PRESSURE IN MAIN UNIT.

7. DO FOLLOWING TESTS BEFORE UNLOADING THE TRANSFORMER FROM THE RAIL CAR.
   (i) DEW POINT, (ii) CORE GROUND. (iii) CLAMP GROUND.

8. IF READINGS ARE SUSPECIOUS COONTACT PAUWELS CANADA INC BEFORE PROCEEDING FURTHER.

9. BASED ON IMPACT RECORDER READINGS AND SIGNS OF DAMAGES, AN INTERNAL INSPECTION MAY BE REQUIRED.

INSTALLATION (TM-401-00)

1. EACH INSTALLATION IS UNIQUE. AS SUCH FIELD PERSONNEL SHOULD BE FLEXIBLE TO SOLVE SPECIFIC PROBLEMS TO A SITE.
2. PLANNING AND SCHEDULING.
3. A SHORT MEETING EACH DAY BEFORE START OF THE WORK WILL BE VERY USEFUL.
4. EQUIPMENT AND TOOLS.
5. CLEARANCES AND SAFETY.
6. MOVING THE TRANSFORMER (TM-301-00).
7. GROUNDING (AFTER PLACING THE UNIT ON PAD GROUND THE TANK BEFORE PROCEEDING FURTHER).
8. INSTALLATION OF ACCESSORIES. ADVISABLE TO CHECK BUSHINGS POWER FACTOR AND CAPACITANCE BY A BRIDGE BEFORE INSTALLATION.
9. VACCUM FILLING (TM-410-00).
10. ADVISABLE TO HIRE AN ERECTION CONSULTANT FROM TRANSFORMER MANUFACTURER.

INSTALLATION (CONTINUED)

EQUIPMENT AND TOOLS RECOMMENDED.

1. SAFETY EQUIPMENT: HARD HATS, SAFETY BOOTS, FLASHLIGHTS, SAFETY GEAR TO GO ON TOP OF THE TRANSFORMER ETC.
2. A SET OF LAGRE SOCKET WRENCHES WITH COMPRESSED AIR TOOL FOR USE OF SOCKETS.
3. CROWBAR AND CLAW HAMMER.
4. A SET OF LARGE OPEN END WRENCHES.
5. CABLE CUTTER.
6. NYLON ROPE AND SLINGS FOR BUSHING INSTALLATIONS.
7. A CRANE TO INSTALL BUSHINGS, CONSERVATOR, RADIATORS ETC.
8. CLEAN RAGS.
9. DRY AIR CYLINDERS.

FUNCTIONAL TESTS/CHECKS

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1. COOLING FANS (CHECK VIBRATIONS. ALSO CHECK STARTING AND RUNNING CURRENTS).

2. PUMPS (CHECK FOR CORRECT DIRECTION OF ROTATION AND UNUSAL NOISES).

3. TEMPERATURE GAUGES (GAUGES ARE CALIBRATED CORRECTLY).

4. LEVEL GAUGES (FLOAT WORKS CORRECTLY).

5. GAS DETECTOR RELAYS (TEST PER RECOMMENDATIONS OF THE MANUFACTURER).

6. LOAD TAP CHANGER (LTC) OPERATION (CHECK PER THE INSTRUCTION S OF LTCMANUFACTURER) .

7. CONTROLS AND PROTECTIVE DEVICES (CHECK FOR CORRECT OPERATION).

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TYPICAL FIELD TESTS

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1. INSULATION RESISTANCE (COMPARE WITH THE MEASURED VALUES IN THE FACTORY).

2. WINDING RESISTANCE (COMPARE WITH THE MEASURED VALUES IN THE FACTORY).

3. TURNS RATIO (BASED ON ACCURACY OF THE INSTRUMENTS, FIELD VALUE MAY NOT BE SAME AS THAT MEASURED IN THE FACTORY).

4. POWER FACTOR AND CAPACITANCE (DOBLE TEST, COMPARE WITH THE MEASURED VALUES IN THE FACTORY).

5. GROUND RESISTANCE (SAFETY CHECK).

6. INFRARED SCANNING.

7. CORE GROUND AND CLAMP GROUND (COMPARE WITH THE MEASURED VALUES IN THE FACTORY).

8. TESTS ON OIL ARE COVERED IN DETAIL IN THE FOLLOWING SLIDES.

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PRE-ENERGIZATION TESTS(TM-412-00)

1. CORE GROUND AND CLAMP GROUND.

2. RATIO AND POLARITY.

3. INSULATION RESISTANCE.

4. WINDING RESISTANCE.

5. OIL:
   (a) DIELECTRIC STRENGTH AND WATER CONTENT AND OTHER OIL QUALITY PARAMETERS.
   (b) DISSOLVED GAS-IN-OIL ANALYSIS (DGA). THESE WILL BE BENCHMARK READINGS.

6. OPERATIONAL CHECKS ON FANS AND PUMPS.

7. CONTROL AND PROTECTIVE CIRCUIT CHECKS.

8. LTC: (a) DIVERTOR CONTACTS THICKNESS.
   (b) RESISTANCE OF TRANSIENT RESISTORS.

9. POWER FACTOR (DOBLE TEST).

FIRST ENERGIZATION

(a) PRECAUTIONS:

(1) AMBIENT TEMPERATURE (IF VERY LOW FOLLOW COLD START INSTRUCTIONS IN THE MANUAL).
(2) LTC TAP POSITION (SHOULD BE SUCH TO PRODUCE MINIMUM IN-RUSH CURRENT).
(3) ENERGIZE ON NO-LOAD ONLY.
(4) MIN. 24 HOUR WAIT PREFERRED BEFORE LOADING THE TRANSFORMER.
(5) LOAD SLOWLY.

(b) OBSERVATIONS:

(1) TRANSFORMER NOISE LEVEL.
(2) LTC SOUND DURING OPERATION.
(3) FANS AND PUMPS VIBRATIONS.
(4) OIL LEAKS.
(5) HOT SPOTS ON TANK AND BUSHINGS (THERMOVISION).
(6) ABNORMAL NOISES (DISCHARGES).

(C) CHECKS AND RECORD THE FOLLOWING BENCH MARK READINGS:

(1) OIL LEVEL GAUGES.
(2) AMBIENT TEMPERATURE.
(3) OIL TEMPERATURE INDICATOR.
(4) WINDING TEMPERATURE INDICATOR.
(5) GAS RELAY.
(6) NO-LOAD CURRENT.

POINTS CRITICAL TO EFFECTIVE MAINTENANCE

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1. SAFETY: MOST IMPORTANT AS MUCH OF MAINTENANCE IS DONE WHEN TRANSFORMER IS STILL ENERGIZED. MAINTENANCE STAFF SHOULD BE COMPETENT AND TRAINED.

2. HISTORY: KEEP RECORDS OF EVERYTHING DONE ON THE TRANSFORMER AND EVERYTHING THAT HAPPENS TO THE TRANSFORMER.

3. CONSISTENCY: TO DO THINGS THE SAME WAY AT THE SAME TIME. DEVELOP WORK PROCEDURES FOR ROUTINE INSPECTIONS AND FOR EMERGENCY SITUATIONS

4. ACCURACY: DATA COLLECTED SHOULD BE REPEATABLE AND RELIABLE. AN INCONSISTANT DATA COULD BE INDICATIVE OF A PROBLEM.

5. QUALITY: VERY IMPORTANT TO AVOID AN OUTAGE/FAILURE.

6. FOLLOW INSTRUCTION MANUALS.

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DAILY (after energization)

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IN THE FIRST WEEK AFTER ENERGIZATION:

(A) CHECK AND RECORD THE READINGS.

(1) LIQUID LEVEL GAUGES.
(2) AMBIENT TEMPERATURE.
(3) WINDING TEMPERATURE INDICATOR.
(4) OIL TEMPERATURE INDICATOR.
(5) GAS DETECTOR RELAY.
(6) VOLTAGE AND CURRENT.

(B) CHECK.

(1) FANS AND PUMPS OPERATION.
(2) NUMBER OF LTC OPERATIONS.
(3) OIL LEAKS.
(4) ON-LINE MONITORS READINGS (HYDRAN ETC.).
(5) HOT SPOTS AT BUSHINGS AND ON TANK.

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WEEKLY (after energization)

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CHECK:

1. OIL LEVEL GAUGES ON BUSHINGS.
2. BOTTOM OF ALL RADIATORS SHOULD BE MORE OR LESS OF SAME TEMPERATURE, IF BOTTOM OF ANY RADIATOR IS HOT THEN THERE COULD BE BLOCKAGE IN THAT RADIATOR.
3. GEL COLOUR IN DEHYDRATING BREATHER.
4. OIL TEMPERATURE INDICATOR.
5. WINDING TEMPERATURE INDICATOR.
6. OIL LEAKS.
7. SUSPECIOUS NOISES IN-SIDE THE TANK.

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MONTHLY (after energization)

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CHECK AND RECORD:

1. LIQUID LEVEL GAUGES.
2. OIL TEMPERATURE INDICATOR (PRESENT AND DRAG HAND MAXIMUM READINGS).
3. WINDING TEMPERATURE INDICATOR (PRESENT AND DRAG HAND MAXIMUM READINGS).
4. LTC POSITION (PRESENT, MAXIMUM AND MINIMUM).
5. LTC OPERATIONS COUNTER.
6. OIL LEAKS.
7. DEHYDRATING BREATHER.
8. PUMPS AND FANS OPERATION.
9. GAS DETECTOR RELAY.
10. ANTI CONDENSATION HEATERS.

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SIX MONTHS (after energization)

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A. TAKE AN OIL SAMPLE FOR DGA PER INSTRUCTION MANUAL.

B. PERFORM LTC INTERNAL INSPECTION (On in-tank tap changers inspect diverter only).

C. CLEAN BUSHINGS PORCELAIN IF NEEDED.

D. CLEAN RADIATORS AND TANK SURFACES IF NEEDED.

E. **CHECK:**

1. DIELECTRIC STRENGTH OF OIL IN THE MAIN UNIT.
2. WATER CONTENT OF OIL IN THE MAIN UNIT.
3. OIL LEVELS ON BUSHINGS.
4. PAINT FINISH FOR RUST.
5. DEHYDRATING BREATHERS.
6. OIL LEAKS.
7. GAS RELAY.

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ONE YEAR (after energization)

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A. CHECK:

1. TRANSFORMER POWER FACTORS.
2. BUSHINGS POWER FACTORS AND CAPACITANCE (REQUIRED IF TRANSFORMER POWER FACTORS ARE HIGH).
3. GAS DETECTOR RELAY OPERATION (PER INSTRUCTION MANUAL).
4. CONTINUITY OF TANK AND NEUTRAL GROUNDS.
5. PROTECTIVE RELAY OPERATIONS.
6. OIL LEAKS.
7. OIL AND WINDING TEMPERATURE INDICATORS.
8. LTC DIVERTORS (OVERHAUL AND MEASURE CONTACTS WEAR).
9. CORE AND CLAMP GROUNDS.
10. NEUTRAL GROUNDING RESISTOR CONTINUITY.
11. HEATERS AND LIGHT IN CONTROL BOX.
12. PRESSURE RELIEF DEVICE.

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ONE YEAR (after energization) (CONTINUED)

B. TAKE OIL SAMPLES AND CKECK THE FOLLOWING.

1. DGA.
2. DIELECTRIC STRENGTH (FOLLOW THE SAME METHOD USED BEFORE ENERGIZATION).
3. NEUTRALIZATION NUMBER.
4. INTERFACIAL TENSION.
5. POWER FACTOR.
6. WATER CONTENT.

C. CLEAN, PRIME AND PAINT RUSTED AREAS.

D. CHECK AND CORRECT OIL LEAKS (PAUWELS DO PRESSURE TESTS AT THE FACTORY TO CHECH LEAKS).

E. CHECK BUSHING CURRENT TRANSFORMER TERMINALS FOR LOOSENESS.

F. OPERATE LTC AND DE-ENERGIZED TAP CHANGER (DTC) TWICE THROUGH THE COMPLETE TAP RANGE TO BREAK THE OXIDE FILM PER THE INSTRUCTION MANUAL.

SECOND, THIRD AND FOURTH YEAR (after energization)

1. CHECK BUSHINGS AND SURGE ARRESTORS FOR POLLUTION ACCUMULATION, CHIPS AND CRACKS.
2. TEST OIL SAMPLE FOR:

   (a) DIELECTRIC STRENGTH.

   (b) WATER CONTENT.
3. CHECKFOR OIL LEAKS.
4. CHECK TANK AND RADIATORS FOR RUST.
5. OPERATE LTC AND DTC TWICE THROUGH THE COMPLETE TAP RANGE PER INSTRUCTION MANUAL.

EVERY FIVE YEARS

A. LTC DIVERTOR INSPECTION.

B. TEST OIL IN MAIN TANK AND IN BUSHINGS FOR:
1. DIELECTRIC STRENGTH.
2. INTERFACIAL TENSION.
3. POWER FACTOR.
4. WATER CONTENT.
5. VISUAL CONDITION.
6. SPECIFIC GRAVITY.
7. COLOUR.
8. INHIBITOR CONTENT.

C. CHECK SURGE ARRESTORS AND BUS INSULATORS.

D. GAS DETECTOR RELAY OPERATION.

E. CONTINUITY OF TANK AND NEUTRAL BUSHING GROUNDS.

F. POWER FACTOR TESTS. IF THE RESULTS ARE SUSPICIOUS CHECK BUSHINGS POWER FACTOR AND CAPACITANCE.

G. DGA.

H. OPERATION OF PROTECTIVE RELAYS AND GAUGES.

DISSOLVED GAS-IN-OIL ANALYSIS (DGA)

A. KEY GASES ARE: HYDROGEN (H2)
METHANE (CH4)
ETHYLENE (C2h4)
ETHANE (C2H6)
ACETYLENE (C2H2)
CARBON MONOXIDE (CO)
CARBON DIOXIDE (CO2)

B. SOME GUIDE LINES FOR DIFFERENT GAS CONTENT ARE:
1. METHANE AND ETHANE WITH SOME ETYLENE AND HYDROGEN.
—LOW TEMPERATURE OVERHEATING.
2. ETHYLENE WITH SOME METHANE AND HYDROGEN:
—HIGH TEMPERATURE OVER A SMALL AREA.
3. HYDROGEN AND ACETYLENE:
—ARCING.
4. HYDROGEN:
—CORONA.
5. CARBON MONOXIDE AND CARBON DIOXIDE.
—PAPER DEGRADATION.

C. ROGERS RATIOS AND OTHER GUIDES ARE GOOD ANALYSING TOOLS

Roger's gas ratio method (see IEEE Standard C57.104)

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$\frac{CH_4}{H_2}$	$\frac{C_2H_6}{CH_4}$	$\frac{C_2H_4}{C_2H_6}$	$\frac{C_2H_2}{C_2H_4}$	Diagnosis
0	0	0	0	Normal Deterioration
5	0	0	0	Partial Discharge
1/2	0	0	0	Slight Overheating – below 150°C (?)
1/2	1	0	0	Overheating – 150 – 200°C (?)
0	1	0	0	Overheating – 200 – 300°C (?)
0	0	1	0	General Conductor Overheating
1	0	1	0	Winding Circulating Currents
1	0	2	0	Core and Tank Circulating Currents, overheated joints
0	0	0	1	Flashover without Power Follow Through
0	0	1/2	1/2	Arc with Power Follow Through
0	0	2	2	Continuous Sparking to Floating Potential
5	0	0	1/2	Partial Discharge with Tracking (note CO)

Gas Ratio	Range		Code
$\frac{CH_4}{H_2}$	Not greater than 0.1	(≤ 0.1)	5
	Between 0.1 and 1.0	(> 0.1, < 1)	0
	Between 1.0 and 3.0	(≥ 1, < 3)	1
	Not less than 3.0	(≥ 3)	2
$\frac{C_2H_6}{CH_4}$	Less than 1.0	(< 1)	0
	Not less than 1.0	(≥ 1)	1
$\frac{C_2H_4}{C_2H_6}$	Less than 1.0	(< 1)	0
	Between 1.0 and 3.0	(≥ 1, < 3)	1
	Not less than 3.0	(≥ 3)	2
$\frac{C_2H_2}{C_2H_4}$	Less than 0.5	(< 0.5)	0
	Between 0.5 and 3.0	(≥ 0.5, < 3)	1
	Not less than 3.0	(≥ 3)	2

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DGA – gas generation patterns

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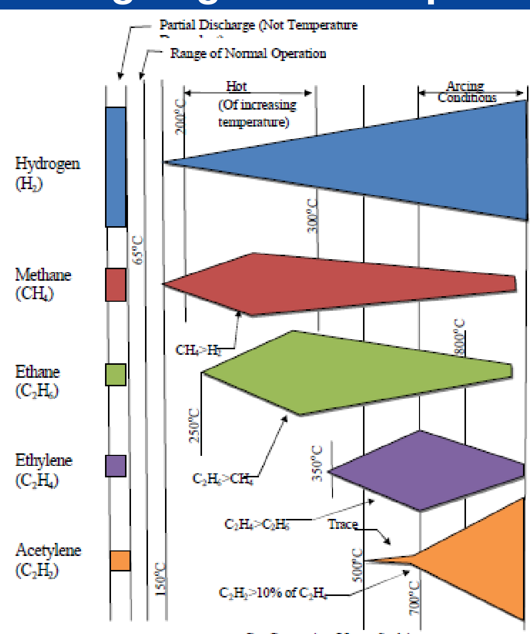

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OIL TESTS

SOME GUIDELINES ON OIL TESTS RESULTS ARE GIVEN BELOW:

1. DIELECTRIC BREAKDOWN.
   —INDICATES OIL QUALITY.

2. INTERFACIAL TENSION.
   —MEASURE OF CONTAMINANTS LEVEL.

3. VISUAL CONDITION.
   —PRESENCE OF FREE FLOATING CONTAMINANTS, SIGNS OF FREE WATER

4. NEUTRALIZATION NUMBER.
   —DEGREE OF OXIDATION.

5. COLOUR.
   —QUALITATIVE ASSESSMENT OF FAILING CHEMICAL PROPERTIES.

6. SPECIFIC GRAVITY.
   —INDICATES IF OIL HAS BEEN CHEMICALLY ALTERED.

OIL TESTS (CONTINUED)

7. INHIBITOR CONTENT.
   —IT SIGNALS THAT OIL QUALITY WILL DECAY

8. WATER CONTENT.
   — CAUTION WITH INSULATION STRENGTH REDUCTION.

9. POWER FACTOR.
   — INDICATION OF CONTAMINATION FROM WATER OR OXIDATION BY-PRODUCTS.

10. PCB CONTENT.
    — TO CHECK THAT PCB CONTENT IS BELOW REGULATORY GUIDELINES.

11. FURAN CONTENT.
    — SUPPORTS DGA AND INDICATES PAPER QUALITY.

12. METALS CONTENT.
    — SUPPORTS DGA AND FURAN CONTENT TEST

Common problems

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(a) No outage permitted

—If safe, operate the transformer with a safety radius (Some users use 50 feet radius based on their internal policies).

—If problem is on a few taps, leave LTC on a safe fixed tap.

—If problem is load related, reduce the load to a safe value.

—If problem is related to insulation and if safe, operate with insulation loss of life.

—If problem is related to gassing and if safe, operate with gassing.

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Common problems (cont'd…)

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(b) Shorts by animals/birds

—Protect the live terminals, buses, etc., that can be shorted or grounded by animals/birds by insulated covers.

—Check gas relay for gas accumulation.

—Check core ground and clamp ground.

—Measure windings insulation resistance.

—Check ratio of windings.

—Do a DGA.

—Check which protection has operated, this will give a clue on the healthiness of the transformer..

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Common problems (cont'd…)

Gassing

—Check the age of the transformer to determine that gas levels are in line with the age.

—Check the load. Load may be more than the safe designed value.

—Check the voltage. High voltage will cause over fluxing and saturation problems.

—Check the tap changer operation.

—Reduce load if gassing is load related.

—Do a DGA at regular intervals to determine the rate of gassing.

Common problems (cont'd…)

(d) Oil leaks

—If possible do temporary fixing and correct at the proper time.

—Based on the age of the transformer, amount of leaks etc., re-gasketting is a good idea.

—Clean the rust in time and prevent further rusting.

Common problems (cont'd…)

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(e) Bushing failure

—Clean dust and salt coating on porcelains at regular intervals.

—Based on how old the bushing is, monitor capacitance and power factor at regular intervals.

—Do not neglect bushing problems. Bushing problems could lead to catastrophic failure.

—If bushings are in bus ducts or cable boxes, maintain proper ventilation.

—Based on the top oil temperature and the maximum current check that the draw lead size is adequate.

—During regular intervals of power factor measurements on the transformer (windings and bushings together) if any readings are suspicious then isolate the bushings and measure power factor and capacitance of the bushings and compare with bench mark readings.

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Common problems (cont'd…)

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(f) Malfunction of lightning arrestors and grounds

— perform checks at regular intervals.

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Common problems (cont'd…)

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(g) Overloading

—Check the limitations with the transformer manufacturer.

—Items to be checked for overload are:

- Windings.
- Leads.
- Oil temperature.
- Tap changer.
- Bushings and bushing turrets.
- Internal magnetic shields.
- Over heating of parts due to increase in leakage flux at higher loads.

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Common problems (cont'd…)

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(h) Moisture

—Maintain the gel in the breather properly.

—Check at regular intervals the water content in the oil.

—Check power factor at regular intervals.

—Check for cracks on the tank through which water can go in to the tank.

—Check for damages in gasket joints through which water can go in to the transformer.

—Check for water content in top-up oil.

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Major Problems

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(a) Hot joints

—At design review stage user should check the design of all current carrying parts and the shop practices to avoid potential problems during the life of the transformer.

—User should specially check the joints during the manufacture so that no hot joints will be developed during the operation.

—Special attention should be given to bolted joints so that they will not become loose during the operation.

—Take precautions to avoid oxide film formation on the surfaces of current carrying parts.

—Monitoring DGA at regular intervals will aid the detection of hot joints.

—At regular intervals check gas relay for gas accumulation.

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Major Problems (cont'd…)

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(b) Loose connections

—During manufacture, specially before tanking, all the bolted connections should be checked for looseness.

— The crimped connections need to be checked for full engagement of the lead with the connector,

—DGA at regular intervals is a good tool in detecting loose connections.

—At regular intervals check the gas relay for gas accumulation.

—Measure windings resistances and compare with bench mark readings.

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Major Problems (cont'd…)

c) Insulation degradation/failure

—During design review user should go through the insulation design to avoid problems during the operation.

—During the design review user should also check the voltage stress verses strength during operation and also during factory testing in all the insulating materials (pressboard, paper etc,).

—Temperature rise of parts in contact with insulation should be limited to the safe values stated in ANSI.

—All current carrying parts, specially the leads should have proper cooling to avoid hot spots.

—Avoid moisture entering the transformer.

—Power Factor and other similar tests at regular intervals will indicate the degradation of the insulation.

Major Problems (cont'd…)

(d) Failure of bushing current transformers (CTs)

—Check that the CTs have adequate cooling.

—Bushing turrets should be properly designed with non-magnetic inserts or with non-magnetic steel where necessary to avoid hot spots. Hot spots on bushing turrets will deteriorate the insulation on the CTs fast.

—Check the type of insulation materials in the CTs that their safe temperature limit is well above the temperatures the CTs experience during the operation.

—Check terminal boards used to bring-out CT leads that no leaks will be developed.

—Check that the insulation used on the CT leads inside the transformer is compatible with hot transformer oil.

Major Problems (cont'd…)

(e)Hot spots on tank etc.

—Do thermo-vision scan regularly on the tank and at the bushing connections.

—During manufacture of the transformer user to check that tank shields are properly designed and installed.

—Based on the current, the bushings turrets should be correctly designed to avoid hot spots during the operation. Where
necessary correct length of non-magnetic material inserts should be placed in the turrets or if needed the bushing turrets
should be made with non-magnetic material.

—Bushing connections to have proper hardware, specially if two different materials (copper and aluminum) are bolted together..

Major Problems (cont'd…)

(f) Design and workmanship

—Purchase the transformers from the proven companies.

—Order should not be based on the price alone.

—User to have tender review and design review meetings with the manufacturer.

—User to inspect at different stages of the manufacturing and during testing.

—Availability of immediate and quality service is a big factor in transformer life cycle cost.

Major Problems (cont'd…)

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(g) Oil aging

—Check the oil quality at regular intervals.

—Take timely corrective action to restore oil quality.

—Have a policy to grade the oils. Based on the transformer highest voltage use a specific grade of the oil.

—Top-up oil must meet all the requirements of the oil during the first filling.

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Thank you