INTERPLANT STANDARD - STEEL INDUSTRY		
IPSS	**CODE OF PRACTICE FOR MAINTENANCE OF OIL FILLED POWER TRANSFORMERS**	**IPSS:1-04-047-08**
	Corresponding IS does not exist	

0. FOREWORD

0.1 This Inter Plant Standard has been prepared by the Standards Committee on Switchgear and Controlgear, IPSS 1:4 with the active participation of the representatives of the steel plants & reputed consulting organizations and was adopted in March 2008.

1.0 SCOPE

The idea of this document is to give guidelines to the Maintenance personnel of steel plants on carrying out proper maintenance in oil filled power transformer of high voltage and extra high voltage grades.

In this document, various maintenance schedules to be adhered to (hourly, daily, monthly, half yearly, yearly, once in five years and once in ten years) are given to enable the maintenance personnel to carry out the maintenance and inspection jobs and to ensure long life to equipment, safety to men and material and also to achieve trouble-free service and un-interrupted power supply to the plant. Though most of the maintenance activities and tests can be conducted in-house, we can make use of **Central Power Research Institute and National Power Grid Corporation,** etc. for certain tests like dissolved gas analysis and furan analysis.

1.1 Reference

Sl No.	INDIAN STANDARD No.	TITLE
1.	10028-Part 3:1981	Code of practice for selection, installation and maintenance of transformers : Part 3 Maintenance (superseding IS:1886)
2.	1866.2000	Method for determination of electric strength of insulating oils (First Revision)
3.	335:1993	New insulating oils (Fourth Revision)
4.	2362:1993	Determination of water by Karl Fisher Method –Test Method (Second Revision)
5.	6103:1971	Method of tests for specific resistance (resistivity) of electrical insulting liquids

6.	1866:2000	Code of practice for electrical maintenance and supervision of mineral insulating oil in equipment (Third Revision)
7.	1448(p21):1992	Petroleum and its products – methods of test – Part 21 : Flash point (Closed) by Pensky Martens Apparatus (Second Revision)
8.	6104:1971	Method of test for interfacial tension of oil against water by the ring method
9.	6262:1972	Method of test for power factor and dielectric constant of electrical insulating liquids

2.0 GENERAL

As is generally known, a transformer consists essentially of the magnetic core built-up of insulated silicon steel lamination upon which are wound two distinct sets of coils suitably located with respect to each other and termed as primary and secondary windings. Such a combination may be used to step up or step down the voltage.

The techniques used in the design and construction of high voltage transformers vary from supplier to supplier. The active parts of a transformer consist of core and windings.

2.1 CORE

Core is made from lamination of cold rolled grain oriented silicon steel. The specific loss at operating flux densities in silicon steel is very low.

2.2 WINDINGS

Paper insulated copper conductor is used for windings. The conductors are transposed at regular intervals for ensuring equal flux linkage and current distribution.

2.3 COOLING

Core and windings are immersed in an oil filled tank. Normally, oil flows through winding and enter cooler or radiator by thermosyphonic effect.

Depending upon the rating, the transformer employs ONAN, ONAF, OFAF and OFWF types of cooling.

ONAN - Oil Natural Air Natural
ONAF - Oil Natural Air Forced
OFAF - Oil Forced Air Forced
OFWF - Oil Forced Water Forced

2.4 TANK AND COVER

Steel plates are used for fabricating transformer tanks and covers. They are designed to withstand full vacuum and a positive pressure of 0.3 kg/cm^2 above the normal oil head.

2.5 CONSERVATOR

Conservator takes care of the expansion and contraction of transformer oil, which takes place due to loading and releasing of load. Modern transformers are provided with separate air shell in the conservator which prevents direct air contact with the transformer oil.

A separate conservator is provided for the on-load top changer diverter switch. Magnetic oil level gauges are provided in the conservator tanks which can give alarm to the operators and isolate the transformer in the event of oil level falling below a preset value.

2.6 PRESSURE RELIEF DEVICE

A pressure relief device is provided with an alarm and trip contacts. When excessive pressure is built inside the transformer in the event of severe fault, the pressure relief device releases the excess pressure.

For smaller transformers, an explosion vent is provided with a lighter diaphragm which breaks in the event of increasing internal pressure.

2.7 BUCHHOLZ RELAY

This gas and oil actuated relay is provided in the oil pipe which connects the conservator and the main tank. For any internal fault inside the transformer, this relay is actuated. This relay operates on the well-known fact that every type of electric fault in an oil-filled transformer gives rise to gas. This gas is collected in the relay to actuate the alarm and trip contacts.

2.8 SILICA GEL BREATHER

Expansion and contraction of oil due to loading causes breathing. External air gets in during the time of contraction. Silica gel absorbs the moisture in the air and prevents moisture entry into the oil.

2.9 TEMPERATURE INDICATORS

For continuous measurement of oil and winding temperatures, separate meters are used. These meters have alarm and trip contacts.

2.10 BUSHINGS

High voltage connections from the windings pass to the terminal bushings. These bushings are hermitically sealed and filled with oil for EHV transformers. This oil does not communicate with the main transformer oil. A separate oil level gauge is provided for monitoring the oil level in the bushings.

2.11 TAP CHANGER

There are two types of tap changers viz., on load and off load. In on load tap changer, tap position changes, when the transformer is energized either through manual mode or auto mode. The OLTC diverter switch has separate oil which needs periodical changing as some amount of arcing takes place during tap changing operations. This has a separate conservator and a Buchholz relay.

2.12 PROTECTIONS FOR TRANSFORMER

The following protections are provided normally for a transformer.

(i) Over current protection
(ii) Restricted Earth fault protection
(iii) Over voltage protection alarm
(iv) Over fluxing (generator transformers)
(v) Surge protection
(vi) Differential protection (above 5 MVA)
(vii) Oil temperature high protection
(viii) Winding temperature high protection
(ix) Oil level low protection
(x) Buchholz protection
(xi) Pressure relief device

The relays checking and calibration procedures are not covered in this document.

3 MAINTENANCE

It is essential to carry out regular and careful inspection on the transformer and associated components/equipment and carry out maintenance activities to provide long life to the equipment and achieve trouble-free service.

IN ORDER TO CARRY OUT THE NECESSARY INSPECTION AND MAINTENANCE WORKS, NECESSARY SAFETY PROCEDURES SUCH AS LINE CLEARANCE/EQUIPMENT SHUTDOWN ETC., WILL BE STRICTLY ADHERED TO, WHEREVER NECESSARY.

The frequency of inspection depends on climate, environment, load conditions and also the age of the transformer. The inspection cum maintenance schedule starts with every hour and continues as given below.

3.1 HOURLY

The following parameters are to be checked every hour and recorded. If the observed value exceeds the value given by the supplier, immediate remedial action should be taken.

(i) winding temperature
(ii) oil temperature
(iii) load current
(iv) terminal voltage

Normally, maximum allowed winding temperature is 55º C above ambient and oil temperature is 45º C above ambient (actual allowed value may vary from supplier to supplier).

3.2 DAILY

(i) Oil level in main conservator
(ii) Oil level in OLTC
(iii) Oil level in bushing
(iv) Leakage of water into cooler (OFWF)
(v) Water temperature (OFWF)
(vi) Water flow (OFWF)
(vii) Colour of silica gel

3.3 QUARTERLY CHECKING/ REPLACEMENT

Reconditioning of silica gel breather.
Checking of water cooler functioning
Checking of cooling fans functioning
Gear oil for tap changer mechanism
Checking of cooling pumps and motor functioning

3.4 HALF YEARLY

(i) Inspection of all gaskets and joints

3.5 ANNUALLY

- (i) Protective relays, alarms, meters and circuits to be checked and calibrated
- (ii) IR value and Polarisation Index
- (iii) Tan delta and capacitance of bushings
- (iv) BDV of transformer oil.
- (v) Oil resistivity
- (vi) Power factor of oil
- (vii) Interfacial tension of oil
- (viii) Acidity and sludge of oil
- (ix) Flash point of oil
- (x) Water content of oil
- (xi) Dissolved gas analysis
- (xii) Replacing of OLTC oil
- (xiii) Thermo vision scanning
- (xiv) Earthing measurements
- (xv) Tan delta and capacitance of winding

3.6 ONCE IN FIVE YEARS

- (i) Furan analysis (Once in a year after the first 5 years)
- (ii) Overhauling of OLTC diverter switch (once in 5 years or after completion of 50,000 operations whichever is earlier)

3.7 ONCE IN TEN YEARS

Overhaul, inspection including lifting of core and winding.

4.0 MAINTENANCE GUIDELINES

4.1 BDV OF TRANSFORMER OIL (As per IS 6792:1992)

The oil sample is subjected to a steadily increasing alternating voltage until breakdown occurs in a BDV test kit. The breakdown voltage is the voltage reached at the time of the first spark appears between the electrodes. The test is carried out six times on the same cell filling and the electric strength of the oil is the arithmetic means of the six results obtained. The electrodes are mounted on a horizontal axis with a test spacing of 2.5 mm. The value should be

1	Electric Strength (BDV) IS 1866:2000	50 KV (Min) 40 KV (Min) 30 KV (Min)	Above 170 KV to 420 KV Above 72.5KV to 170KV Upto 72.5KV

4.1.1 SPECIFICATION FOR UNINHIBITED MINERAL INSULATING OIL-NEW/ UNUSED BEFORE FILLING IN TRANSFORMER/ SWITCHGEAR

Sl.No.	CHARACTERISTICS/PROPERTY	IS 335:1983
1	Appearance	Clear & transparent Free from suspended matter or sediments
2	Density at 29.5º C, Max.	0.89 g/cm^3
3	Kinematic Viscosity at 27º C, Max.	27 cst
4	Interfacial Tension (IFT) 29.5º C, Min.	0.04 N/m
5	Flash point, Pensky Martin (Closed), Min.	140º C
6	Pour point, Max.	-6º C
7	Acidity, Neutralisatin Value	
a	Total Acidity, Max.	0.03 mg KOH/g
b	Inorganic acidity/Alkalinity	NIL
8	Corrosive Sulphur	Non-corrosive
9	Di-electric Strength (Breakdown Voltage) Min.	
a	New unfiltered oil	30 KV, rms
b	After filtration	60 KV, rms
10	Dielectric Dissipation Factor (Tan δ) DDF at 90º C, Max.	0.002
11	Specific Resistance (resistivity)	
a	At 90º C, Min.	35 x 10^{12} ohm -cm
b	At 27º C, Min.	1500 x 10^{12} ohm-cm
12	Oxidation Stability	
a	Neutralisation value after oxidation, Max.	0.40 mg KOH/gm
b	Total sludge after oxidation, Max.	0.10% by weight
13	Ageing Characteristics after accelerated ageing (Open Breaker method with copper catalyst)	
a	Specific Resistance (resistivity)	
i	At 27º C, Min.	2.5 x 10^{12} ohm -cm
Ii	At 90º C, Min.	0.2 x 10^{12} ohm -cm
b	DDF at 90º C, Max.	0.2
c	Total Acidity, Max.	0.05
d	Total Sludge Value, Max. % by weight	0.05
14	Presence of Oxidation Inhibitor	Max. 0.05% treated as absence of oxidative inhibitor
15a	Water content-New unfiltered oil	50 ppm
b	After filtration	15 ppm
16	PCB Content	< 2 ppm
17	SK Value	4 to 8%
18	Dissolved Gas Analysis (DGA)	Not applicable

4.1.2 RECOMMENDED LIMITS OF UN USED MINERAL OIL IN NEW POWER TRANSFORMERS AS PER IS 1866:2000

Sl.No	Property	Power transformer upto 72.5 KV	Power transformer above 72.5 KV To 170 KV	Power transformer above 170 Kv
01	BDV	30 KV	40 KV	50 KV
02	Flash point	140° C	140° C	140° C
03	Pour point	- 6 ° C	- 6 ° C	- 6 ° C
04	Water content	20 ppm	15 ppm	10 ppm
05	Neutralisation value (mg KOH/ g)	0.03	0.03	0.03
06	Di – electric dissipation factor at 90° C	0.015	0.015	0.010

5.0 MEASUREMENT OF INSULATION RESISTANCE

5.1 RECOMMENDED VALUES

Related Voltage Class of Winding	Min. IR value at one minute
11 KV	300 Meg. Ohm
33 KV	400 Meg. Ohm
66 KV and above	500 Meg. Ohm

5.2 MEASUREMENT OF POLARISATION INDEX

If moisture is present in a system, the leakage current increases at a faster rate than the absorption current and the mega ohm readings will not increase with time as fast with insulation in poor condition as with insulation in good condition. This results in a lower PI.

PI = 10 minutes IR value/1 minute IR value

Polarisation Index	Insulation Co-ordination
< 1	Dangerous
1.0 to 1.1	Poor
Above 1.1 to 1.25	Questionable
Above 1.25 to 2.0	Fair
Above 2	Good

6.0 DRYING OUT OF TRANSFORMER

Deterioration of insulation resistance value of transformer is mainly due to ingress of moisture into the windings and insulating materials. In order to improve the insulation resistance at site, following methods are available:

(i) **Hot Oil Spraying**: In this method about 7% of quantity of oil is heated up to 90-95º C separately and the hot oil is sprayed on to core and windings by means of nozzles in the form of fine spray and simultaneously the transformer is subjected to a high degree of vacuum say less than 5 m bar. The hot oil is collected at the bottom sent through a filter and reheated and sprayed. This process removes moisture from the core and windings. The oil used for spraying should be discarded.

(ii) **Flushing Method:** In this method, the transformer is put under hot oil circulation up to 60º C. After reaching steady temperature, the entire oil is drained quickly into a separate tank. Immediately after draining the oil, the transformer is subjected to a vacuum as per the guidelines of the manufacturer for 12 hours. During this period of application of vacuum, the transformer oil drained can be filtered to improve the quality. After 12 hours of vacuuming of the transformer, break the vacuum by means of dry nitrogen. Fill the transformer with filtered oil under vacuum. Now the oil in the transformer can be again circulated to raise the temperature of oil to 60º C. Again drain the oil, apply vacuum and repeat the process till you get a good IR value.

Precautions

The diverter switch tank and the main tank should be inter-connected before the above works to equalize the pressure. Otherwise the diverter switch tank may be damaged when the vacuum is applied.

7.0 BUCHHOLZ RELAY FUNCTIONAL TEST

Tools and materials required:

Cycle pump or Nitrogen cylinder with 4 kg/cm^2 pressure and connecting tubes.

Procedure:

- Transformer shall be isolated.
- Connect Nitrogen cylinder or cycle pump to the top petcock of Buchholz relay
- Open the other petcock
- Allow gas to enter the relay
- Check and confirm alarm signal is received
- Close petcock on gas supply side and release all gases trapped in relay casing
- Increase the gas pressure to approx. 2 kg/cm^2
- Open the test petcock and allow full surge of gas to enter the relay casing
- Check and confirm in control room that the Trip signal has been received
- Close Buchholz relay petcocks and normalize

7.1 BUCHHOLZ GAS ANALYSIS

This is to be done only when the transformer has tripped on account of Buchholz fault or Buchholz alarm has been initiated.

The following procedure should be adopted for testing of gas accumulated in Buchholz relay of power transformers.-

(i) Switch off the transformer when the Buchholz relay alarm rings, indicating the development of an internal fault in the transformer.

(ii) Through the lateral sight hole of the Buchholz relay, the colour and quantity of the gas may be determined.

(iii) Collect a portion of the gas in the test tube and apply a lighted match stick to the test tube to test the combustibility of the gas.

If gas is not combustible, it is mere air.

(iv) Then proceed to carry out the chemical test with a simple gas tester as follows:

The gas tester consists of two glass tubes containing two different silver nitrate solutions which through passage of decomposed gases form two distinguishable precipitates. The tubes must be assembled as indicated in the sketch and tube 1 should be filled with solution prepared by dissolving 5 grams of silver nitrate (Ag NO_3) in 100 cc of distilled water.

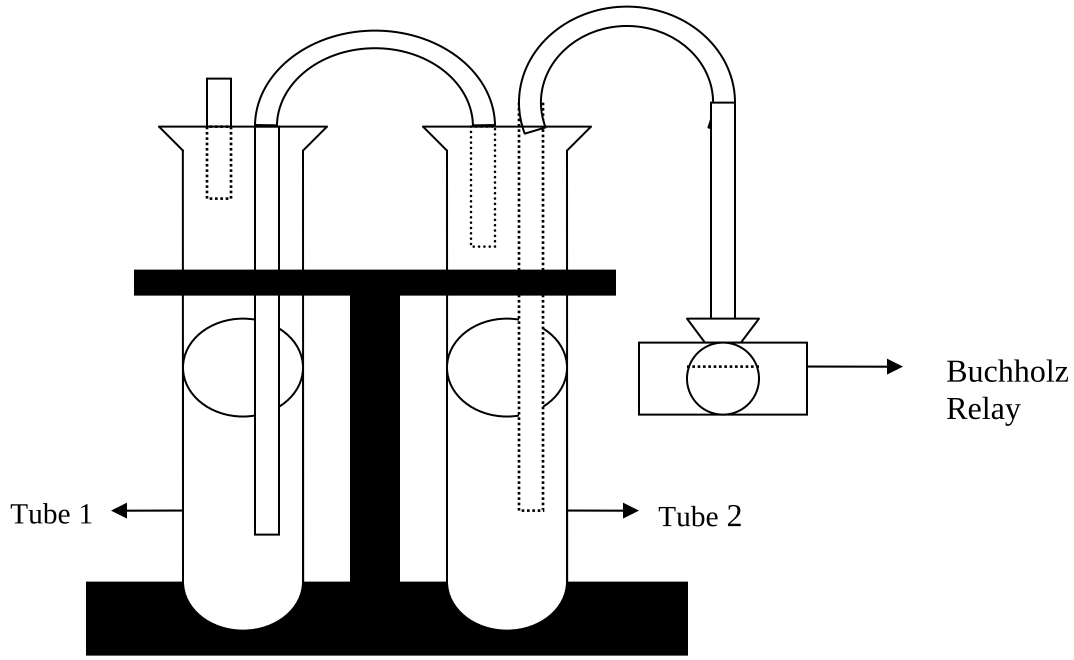
Tube 2 should be filled with solution prepared by dissolving five grams of silver nitrate (Ag NO_3) in 100 cc of watery ammonia solution.

Use of the gas tester is quite simple. Each of the two glass tubes should be filled with corresponding solutions upto the marks. They should be closed by corks fitted with the connecting tubes. Then the gas tester should be screwed on to the test cock of the Buchholz relay. After opening the test cock the collected gas would flow through the solution which would indicate the nature of the fault.

If the gas causes a white precipitate in tube 1 which turns brown under the influence of light, it means the oil has decomposed. Probably a flashover has occurred between bare conductors or between one bare conductor and an earthed part of the transformer.

If the gas causes a dark brown precipitate in the solution in tube 2 it means that solid insulating material like wood, paper, cotton, etc., had decomposed producing carbon monoxide (CO). In this case a leakage in the winding causing an internal short has occurred.

If there is no sedimentation at all the gas is mere air.


Buchholz
Relay
Tube 1
Tube 2

8.0 TAN DELTA AND CAPACITANCE MEASUREMENT OF TRANSFORMER BUSHING

These measurements of bushing provide an indication of the quality and soundness of the insulation of the bushing.

For getting accurate results of Tan Delta and capacitance for oil filled bushing without removing the bushing from the transformer, a suitable test kit of ungrounded specimen test shall be used. Portable standard kit is to be used and the measuring instruction of the meter manufacture is to be followed. The value obtained after the test is to be compared with the value given by the supplier or the value obtained at the time of commissioning. An increase of dissipation factor (Tan Delta) by a marked increase in capacitance indicates excessive moisture in the insulation. Increase of Tan Delta value alone may be caused by thermal deterioration or by contamination. Maximum value Tan Delta for Class "A" insulation (paper insulation, oil impregnated) is 0.007 at 20ºC. Rate of rise of Tan Delta per year of service is 0.001 (max) and the rate of rise of capacitance value per year of service is ±1% (max). Rate of change of Tan Delta and capacitance is very important. Capacitance value may vary from -5% to +10%. If Tan Delta is not measured at 20ºC, the following correction factor is to be applied.

Ambient Temperature (in ºC)	Correction Factor
15	0.90
20	1.00
25	1.12
30	1.25
35	1.40
40	1.55
45	1.75
50	1.95
55	2.08
60	2.42

8.1 Capacitance and Tan Delta Measurement of Winding Insulation of Transformer

The above measurement is carried out to ascertain the general condition of the ground and inter – winding insulation of transformers. Portable capacitance and tan delta bridge from any reputed manufacturer may be used for carrying out this test. All safety instructions as per utility practice and isolation required may be followed before the commencement of this test.

Following precautions need to be taken:

1. Never connect the test set to energized equipment.
2. The ground cable must be connected first and removed last.
3. Heart patients should not use this equipment.
4. The ground terminal of the input supply card (green lead) must be connected to the protective ground (earth) terminal of the line power source.
5. Keep the high voltage plugs free from moisture, dust during installation and operation.
6. Adequate clearance (Min 1 foot i.e. 30 cms) are maintained between energized conductor and ground to prevent any arc over.
7. It should be ensured that test specimen is de –energised and grounded before making any further connection and no person may come in contact with HV output terminal or any material energized by the output.

Testing Procedure

For the purpose of this test, the voltage rating of each winding under test must be considered and test voltage selected accordingly. If neutral bushings are involved, there voltage rating must also be considered in selecting the test voltage. Measurement should be made between in each inter winding combination (or set of 3 phase winding in a 3 phase transformer) with all other windings grounded to tank or ground all the other windings guarded. In the case of 2 winding transformer measurement should be made between each winding and ground with the remaining winding grounded. For 3 winding transformer measurement should be made between each winding and ground with 1 remaining winding guarded and second remaining winding grounded. Finally measurement should be made between all winding connected together and grounded tank.

9.0 DISSOLVED GAS ANALYSIS

Dissolved gas analysis is a powerful diagnostic technique for detecting incipient faults in oil filled transformers long before they develop into major faults. The transformer in operation is subject to various stresses like thermal and electrical resulting in liberation of gases from the hydrocarbon mineral oil, which is used as an insulant and coolant. The components of solid insulation also take part in the formation of gases, which are dissolved in the oil. An assessment of these gases, both qualitatively and quantitatively, would help in diagnosing the internal faults.

9.1 PERMISSIBLE LIMITS OF DISSOLVED GASES IN A HEALTHY TRANSFORMER

Gas	Less than 4 years in service	4-10 years in service	More than 10 years in service
Hydrogen (H_2)	100/150 ppm	200/300 ppm	200/300 ppm
Methane (CH_4)	50/70 ppm	100/150 ppm	200/300 ppm
Acetylene(C_2H_2)	20/30 ppm	30/50 ppm	100/150 ppm
Ethylene (C_2H_4)	100/150 ppm	150/200 ppm	200/400 ppm
Ethane (C_2H_6)	30/50 ppm	100/150 ppm	800/1000 ppm
Carbon Monoxide (CO)	200/300 ppm	400/500 ppm	600/700 ppm
Carbon-di-oxide (CO_2)	3000/3500 ppm	4000/5000 ppm	9000/12000 ppm

- DGA is done in CPRI, Bangalore and their recommendations are furnished to their customers, based on the actual contents of the gases mentioned above for remedial action.

9.2 GAS ANALYSIS AND CORRESPONDING FAULTS

Gases	Possible faults	Findings
All the gases and Acetylene present in large amounts.	High energy electrical arcing 700º C and above.	Same as above with metal discoloration. Arcing may have caused a thermal fault.
H_2, CO, CH_4, C_2H_6 and C_2H_4	Thermal fault between 300º C and 700º C.	Paper insulation destroyed. Oil heavily carbonized.
H_2, CO	Thermal faults less than 300º C in an area close to paper insulation (Paper is being heated).	Discoloration of paper insulation. Overloading or cooling problem. Bad connections. Stray current path and/or stray magnetic flux.

H_2, CH_4, C_2H_6, C_2H_4 and C_2H_2 present in large amounts. If C_2H_2 is being generated, it indicates continuance of arcing CO will be present if paper is being heated.	High energy discharges (arcing)	Metal fusion, (poor contacts in tap changer or lead connections). Weakened insulation, from ageing and electrical stress. Carbonised oil. Paper overhauling/ destruction if it is in the arc path.
H_2, CH_4 (CO if discharges involve paper insulation). Possible trace of C_2H_6	Low energy discharges (sparking)	Pinhole puncture in paper insulation with carbon and carbon tracking. Possible carbon particles in oil. Loose grounding of metal objects.
H_2 possible traces of CH_4 and C_2H_6 possible CO.	Partial discharge (Corona)	Weakened insulation from ageing and electrical stress.

9.3 DISSOLVED GAS ANALYSIS USING GAS RATIOS

(Ratios are to be calculated only if the concentrations of both the gases are above the detection levels)

Sl.No.	Ratio & Value	Remarks
1	$\frac{C_2H_2}{C_2H_6}$ More than 1	Indicates fault
2	$\frac{H_2}{CH_4}$ More than 10	Indicates problem
3	$\frac{C_2H_4}{C_2H_6}$ More than 1	Thermal fault
4	$\frac{CO_2}{CO}$ More than 10	Thermal overheating
5	$\frac{C_2H_2}{H_2}$ More than 2	Possibly tap changer oil leaks into the main oil

10.0 FURAN ANALYSIS

This is a powerful diagnostic test carried out to detect the healthy conditions of the solid insulating materials used in a transformer. Furans are a family of organic compounds, which are formed by degradation of paper insulation. Quality of paper, moisture and oxidation can cause furan formation. The following table indicates the condition of the transformer in the presence of furan.

Total Furan (ppb)	Condition of the transformer
0-100	Normal
101-250	Questionable
251-1000	Deteriorated
1001-2500	Low reliability
> 2500	Rewind/replace solid insulation

The above test is done at CPRI.

11.0 THERMO VISION SCANNING

Thermo Vision Scanning is one of the most valuable diagnostic tools used for predictive maintenance. Thermo vision scanning is used for electrical inspections. When excess heat is generated in an equipment thermo vision scanning can locate the spot of excess heat and action in time can avoid break downs and failures. Since thermo vision scanning is done with a non – contact type thermo vision camera, equipment need not be isolated form power supply and load conditions. Portable infrared imaging systems are available which convert the thermal images to visible pictures for quantitative temperature analysis.

Using this, transformer on load can be scanned and the transformers subject to higher temperatures are identified.

12.0 AUXILIARY EQUIPMENT

Cooling equipment, fans, motors, pumps, control wiring etc., should be checked once in a year. It is also necessary to check both the LT and HT side terminations once in a year.