IS 10028-3 (1981): Code of practice for selection, installation and maintenance of transformers, Part 3: Maintenance [ETD 16: Transformers]

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IS : 10028 (Part III) - 1981
(Reaffirmed 2003)

Indian Standard

CODE OF PRACTICE FOR SELECTION, INSTALLATION AND MAINTENANCE OF TRANSFORMERS

PART III MAINTENANCE

Fourth Reprint APRIL 1997
(Incorporating Amendment No. 1)

UDC 621·314·21—7

BUREAU OF INDIAN STANDARDS
MANAK BHAVAN, 9 BAHADUR SHAH ZAFAR MARG
NEW DELHI 110002

Gr 6 May 1982

Indian Standard
CODE OF PRACTICE FOR SELECTION, INSTALLATION AND MAINTENANCE OF TRANSFORMERS
PART III MAINTENANCE

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Indian Standard

CODE OF PRACTICE FOR SELECTION, INSTALLATION AND MAINTENACE OF TRANSFORMERS

PART III MAINTENANCE

0. FOREWORD

0.1 This Indian Standard (Part III) was adopted by the Indian Standards Institution on 25 November 1981, after the draft finalized by the Code of Practice for Power Installation and Maintenance Sectional Committee had been approved by the Electrotechnical Division Council.

0.2 The code of practice on installation and maintenance of transformers was originally published in 1961 as IS : 1886, intended as a guide to installation engineers, contractors and others engaged in the installation and maintenance of power and distribution transformers. It was made up to date subsequently in 1967, with additional details regarding internal inspection of transformers. Apart from the information concerning transformers themselves, the code covered ancillary work, such as ventilation, cabling and isolation of transformers.

0.3 The present version of the code is being brought about to include additional details on criteria for selection of transformers, transportation to the point of installation, taking into view also the latest thinking on the methods of supervision and maintenance of insulating oils in service. Specific details on maintenance aspects of special purpose transformers are intended to be added at a later date.

0.4 This standard closely follows the earlier version thougn currently being presented in three parts mainly in order to identify information and to consolidate them in functionally coherent sections. This standard is hence brought out in three parts, viz:

Part I Selection (*under preparation*)

Part II Installation

Part III Maintenance

These parts shall be read in conjunction with each other. This standard (Part III) partly supersedes the provisions of IS : 1886-1967* which will be withdrawn when all the parts are made available.

*Code of practice for installation and maintenance of transformers (*first revision*).

0.5 In view of the consideration of this code required to be in conformity with the prevailing statutory regulations in the country, reference to the relevant provisions of the Indian Electricity Rules, 1956 has been made at the appropriate places.

0.6 In the preparation of this standard, considerable assistance has been derived from the following:

IS : 6600-1972 Guide for loading of oil-immersed transformers

IS : 8478-1977 Application guide for on-load tap-changers

IS : 4146-1967 Application guide for voltage transformers

IS : 4201-1967 Application guide for current transformers

Specification for Power and Distribution Transformers, Section K, Erection, Maintenance and Commissioning Manual, issued by the Central Board of Irrigation and Power.

0.7 For the purpose of deciding whether a particular requirement of this standard is complied with, the final value, observed or calculated, expressing the result of a test or analysis, shall be rounded off in accordance with IS : 2-1960*. The number of significant places retained in the rounded off value should be the same as that of the specified value in this standard.

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1. SCOPE

1.1 This standard (Part III) covers guidance on maintenance of distribution and power transformers covered by IS : 1180-1964† and IS : 2026 (Parts I to IV)-1977‡ respectively.

1.2 Special purpose transformers, such as gas cooled, synthetic, liquid insulated, dry type and mining transformers and instrument transformers are excluded from the scope of this code and in all such cases, the manufacturer's instructions shall be followed.

2. TERMINOLOGY

2.1 For the purpose of this code, the definitions given in IS : 1180-1964† and IS : 2026 (Part I)-1977‡, shall apply.

*Rules for rounding off numerical values (*revised*)

†Specification for outdoor type three-phase distribution transformers up to and including 100 kVA 11 kV (*revised*).

‡Specification for power transformers :

Part I General (*first revision*).

Part II Temperature-rise (*first revision*).

Part III Insulation level and dielectric tests (*first revision*)

Part IV Terminal marking, tappings and connectors (*first revision*).

3. GENERAL INFORMATION

3.1 As compared with most electric apparatus, transformers require relatively little attention The extent of the inspection and maintenance required will be governed by the size, importance of service continuity, the location on the system, and operating conditions, such as ambient temperature, unusually dirty atmosphere, heavy fogs and water supply (in the case of water-cooled units). The supply authority shall be consulted if heavy loads on single phase or unbalanced loads are to be connected.

3.2 Distribution transformers and small power transformers ordinarily require and receive less attention than large transformers which represent a much greater investment However, small transformers sometimes supply power to industrial loads where continuity of service is of the utmost importance. In these cases, a greater degree of attention is justified.

3.3 The suggestions in the following pages should prove helpful to operators. Full information on installation and operation are contained in the instructions sent with each transformer and are referred to on the transformer nameplate.

3.4 Generally the causes of breakdown of transformers may be classified as follows:

a) Faulty design or construction,

b) Incorrect installation or use,

c) Overload and peculiarity of loading conditions,

d) Neglect,

e) Wear and tear and other deterioration,

f) Accidents, and

g) Failure of auxiliary equipment.

3.4.1 A rigid system of inspection and preventive maintenance will ensure long life, trouble-free service and low maintenance cost. Maintenance shall consist of regular inspection, testing and reconditioning, where necessary. The amount of attention and maintenance vary with the service conditions and load cycle of the transformers.

3.4.2 Records shall be kept of each transformer giving details of all inspections and testing made and of unusual occurrences.

3.4.3 The principal object of maintenance is to maintain the insulation in good condition. Moisture, dirt and excessive heat in contact with oxygen, are the main causes of insulation deterioration and avoidance of these will, in general, keep the insulation in good condition. The limiting factor is the ageing of the insulation and decline in the quality of the insulation during the ageing process due to chemical and physical effects. The decay of the insulation follows the chemical reaction rate, and in case of oil-immersed transformers, if the sustained operating temperature of the insulation exceeds the normal operating temperature of 98°C, there will be a shortening of the life of the transformer.

4. FACTORS AFFECTING THE LIFE OF A TRANSFORMER

4.1 Effect of Moisture — Transformer oil readily absorbs moisture from the air. The effect of water in solution in the oil is to decrease the dielectric strength of the oil as well as of the insulating paper which absorbs and stores the moisture due to higher affinity of water to paper over oil. All possible preventive steps should, therefore, be taken to guard against moisture penetration to the inside of the transformers. This will include blocking of all openings for free access of air in storage and frequent reactivation of breathers in service.

4.2 Effect of Oxygen — Oxygen may be present inside the transformer due to air remaining in oil, air pockets trapped in the windings, etc. The oxygen reacts on the cellulose of the insulation and the decomposition products of the cellulose lead to the formation of organic acids soluble in oil and sludge which blocks the free circulation of the oil. The adverse effect of oxygen, which may be aggravated by catalytic action between hot oil and bare copper, increase the operating temperature.

4.3 Effect of Solid Impurities — The dielectric strength of oil is diminished appreciably by minute quantities of solid impurities present in the oil. New transformers may contain particles of insulating materials and other solid impurities. It is, therefore, a good practice to filter the oil after it has been in service for a short time, especially for the units of higher voltage class.

4.4 Effect of Varnishes — Some varnishes particularly of the oxidizing type, enter readily in reaction with transformer oil and precipitate sludge on the windings. Synthetic varnishes having acid inhibiting properties generally delay the natural formation of acid and sludge in the oil. This should be borne in mind by the maintenance engineer when rewinding and replacing the coils during repairs to transformers.

4.5 Effect of Slackness of Windings — Slackness of windings may cause a failure due to repeated movement of coils which may wear the conductor insulation at some places and lead to an inter-turn failure. The coils may also get displaced under load conditions or momentary short circuit which may cause electric and magnetic unbalance and produce even greater displacement. It is, therefore, a good practice to lift the core and windings of a transformer and take up any slackness which may have developed by tightening the tie-rods or pressure screws where provided for this purpose at the first inspection. In all cases the instructions given by the manufacturers should be followed closely. However, the maintenance schedules given in Tables 1 and 2 are recommended to serve as a general guidance. Additional maintenance attention should be given where transformers are working under abnormal conditions.

5. MAINTENANCE PROCEDURE

5.1 Safety Precautions — Arrangements shall be made to carry out the maintenance of transformers in safety. Before starting any maintenance work the transformers shall be isolated from the supply and the terminals earthed. Oil level shall always be borne in mind when undoing nuts and bolts and before unsealing the tank. No fire shall be kept near the transformer while maintenance work is going on.

5.2 Oil

5.2.1 Transformer oil is subject to deterioration or contamination in storage and in service. Accordingly, a periodic treatment to maintain it in fit condition is required, and eventually, it may have to be replaced by new oil. The causes of oil deterioration and recommendations for various tests are comprehensively covered in IS : 1866-1978*. Reference shall be made to the same regarding the maintenance of quality of oil in service. The few short tips given below may serve as ready reference.

5.2.2 The oil level should be checked at frequent intervals and any excessive leakage of oil investigated. There may be slight loss of oil by evaporation, this need cause no concern if the tank is topped up at regular intervals.

5.2.3 All leaks should be repaired as quickly as possible so as to avoid possible trouble caused by low oil level.

5.2.4 Oil for toppling up should comply with IS : 335-1972† and should preferably be from the same source as the original oil because the oil refined from different crudes may not be completely miscible and may separate into layers. Furthermore, there may be a greater tendency to form acidity or sludge in a mixture than in an oil from a single source of supply. Used oil shall not be mixed. New oil may be added as make up only, not exceeding about 10 percent. It is desirable not to mix oil taken from a transformer with that from switchgear equipment.

5.2.5 Samples of the oil should be taken at regular intervals and tested.

5.2.6 It may be mentioned that the dielectric strength does not give a true indication of the deteriorated condition of the oil. Even an oil which is highly deteriorated may give a high dielectric strength, if dry. Normal method of oil purification only maitain the dielectric strength, but do not give indication of the deteriorated condition of the oil. It is, therefore, inadvisable, to rely solely on the dielectric strength of the oil by periodic tests. In addition to chemical tests other tests as given in IS : 1866-1978* should also be carried out.

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*Code of practice for maintenance and supervision of insulating oil in service (*first revision*).

†Specification for new insulating oils for transformers and switchgear (*second revision*).

5.2.7 It is recommended that the oil be kept under observation for acidity. If the acidity is increasing rapidly, or exceeds limits the cover should be removed to ascertain the condition of the interior of the tank and of the core and windings. Oil should be treated or discarded, if sludge or corrosion is evident. Advice should be obtained from the manufacturer.

5.2.8 It may be noted that reconditioning by centrifugal separation of filtration does not remove the acidity from the oil but will remove sludge, dust, dirt, etc, and will tend to retard the process of deterioration.

5.2.9 Filters with fullers earth will help to reduce acidity in the oils and in addition improve the resistivity.

5.3 Rollers

5.3.1 After a transformer has been in service for a long period, rollers should be examined carefully. They should be greased.

5.4 Transformer Body

5.4.1 The transformer tank and other parts should be inspected periodically for any rust or leak. Rusted portions, if any, should be cleaned thoroughly and repainted with proper paints. Transformer should be completely painted at proper intervals. If any leak is found, it should be investigated. If it is due to defective welding, the same should be rectified after consulting the manufacturers. Leaking joints can be rectified by tightening the bolts to the correct pressure or by replacing the gaskets.

5.4.2 *Internal Inspection*

5.4.2.0 The core and windings should be lifted from the tank, only if necessary, in suitable conditions.. The surrounding atmosphere should not be humid and should be free from dust, dirt, etc. Suitable lifting device depending on the weight of the core and coil should be arranged. Before disturbing anything, the insulation resistance of the transformer should be measured.

5.4.2.1 *Opening the Transformer* — The tank contains oil with oil vapour and therefore care should be taken to prevent a fire. Naked lights and flames should be kept well away while the tank is open. If an inspection lamp is required, only a protected electric lamp, preferably an extra low voltage lamp should be used. The lamp should be kept off when not in use.

Before opening the tank cover, it should be properly cleaned removing any dust, moisture, etc, from the top. The persons opening the tank cover should not have anything in their breast pocket and should not wear a watch or ring. The spanner should be clean of all metal fillings and should be held by a cotton strap or string tied securely round the waist or wrist of the person opening the tank cover. Cast iron spanners should not be used as they may break and fall inside the tank. All nuts and bolts, etc, should be removed from top of the cover before removing it.

5.4.2.2 *Removing the Cover* — The method of removing the cover depends on the construction of the transformer. If the core and windings are separate from the cover and if there are bushings mounted on top, then first bushings should be dismounted and stored carefully and then the cover should be carefully removed. If however, the core and windings are suspended from the tank cover, substantial lifting lugs, usually in the form of eye bolts, are provided on the cover. While lifting the cores from the eye-bolts care should be taken that the core is removed vertically. It should also be ensured that spanners or other tools used in connection with the work are not dropped into or left inside the tank.

5.5 Core and Winding

5.5.1 *Lifting the Core and Coils* — The core and coils, if not suspended from the cover, are held in the tank by a bolt or other suitable fixing devices at each end near the top. These should first be removed. If there are bushings provided on the tank walls, these should also be removed by undoing the connection Mechanical connection to the tap changing switch handle, if provided, should be removed.

5.5.1.1 The core and coils should then be lifted vertically by slinging it from the lifting lugs provided on the core, making sure that the sling does not foul against bushing connections, tapping switch, etc, as it pulls tight.

5.5.1.2 After allowing the core and coils to drain into the tank, for some time, they should be lowered preferably on beams placed in a metal tray filled with saw dust or sand.

5.5.2 *Inspection* — After removing the core and coils from the tank, the following should be carefully checked making sure that nothing is disturbed unnecessarily and that the leads are not pulled out of their places unless they are unsatisfactory:

a) All bolts and nuts should be adequately tight. If they are too tight clamps, etc, may bend.

b) The coils should be clean and free from sludge. Slight traces of sludges should be cleaned by transformer oil. But if there are heavy deposits, it is likely that the ducts are blocked. In such a case the matter should be referred to the manufacturer.

c) The windings should be firmly clamped without any movements. There should be no loose spacers or end blocks. If loose windings or spacers are noticed, the vertical tie-bars which put pressure on the coil stacks should be adjusted. Special coil adjustment bolts if provided should also be tightened properly.

d) Proper operation of tap changing switch may also be checked.

e) All connections should be tight and clear.

f) If the insulation resistance tests done before untanking gave low value, it should be repeated. If now the test gives satisfactory value, the low value is attributed to some other cause. However, if the test still gives low value, the manufacturers should be informed.

g) If there is sludge deposition at the bottom of the tank, it should be removed while filtering the oil.

5.5.3 It is recommended that the core and winding be removed from the tank for visual inspection as per time schedule given in the inspection table. The windings should be examined to ensure that no sludge has been deposited blocking the oil ducts. Any loose nuts and bolts should be tightened.

5.5.4 Before lifting the core and winding from the tank, it is usually necessary to disconnect the windings from the bushings are cable boxes inside the tank to disconnect the off-circuit tap switch handle or leads of the on-load tap changer and to remove any earthing strips between the core clamps and the tank.

5.5.5 The core and windings shall be removed with great care. It should be placed under cover and in a dry place.

5.6 Bushings

5.6.1 Clean the bushing porcelains and examine them for cracks and chips. Very slight chips may be ignored but any serious damage will require a new porcelain which must be obtaind from the manufacturer. It is recommended to have a spare in stock.

5.6.1.1 In some cases the porcelain only may be changed while in other cases the conducting rod is cemented into the porcelain and the complete bushing requires to be changed.

5.6.1.2 If the bushing is below oil level, the oil should be lowered until it is below the bushing hole.

5.6.1.3 If only the porcelain is supplied it may not be necessary to undo the internal bushing connection, for, in some cases the bushing stems are joined by an insulated bar to prevent them from turning when the nuts are undone. All the nuts at the top of the bushing should be removed and the old porcelain lifted straight up over the central stem which remains in place. Slide the new porcelain down over the stem and replace the nuts. Too much strain on the porcelain should not be applied when tightening the connections. Change only one porcelain at a time, replacing the nuts at the top of the stem befor removing those on the next bushing. If the insulated bar between the bushing stems is not provided, the internal connections should be undone and the whole bushing removed before the porcelain is changed.

5.6.1.4 When a complete bushing is supplied the internal connection to the bushing should be undone. If the replacement bushing has a socket at the bottom end, the old bushing should be unclamped and withdrawn from the tank, the internal lead being flexible and long enough to allow this. This lead may now be unplugged from the old bushing and plugged into the new one, which is then lowered into the hole in the tank and reclamped firmly but not too tightly.

5.7 Cable Boxes

5.7.1 The seating arrangements for filling holes should be checked each year. When screwed plugs are seated with a bituminous compound, the compound should be examined for cracks. If the compound has cracked it should be replaced as the cracks may lead to an accumulation of water around the plug. Gasketed joints should be examined and tightened whenever required.

5.8 External Connections

5.8.1 All connections should be tight. If they appear blackened or corroded, undo the connection and clean down to bright metal with emery paper. Remake the connection and give it a heavy coating of grease. It is particularly important that heavy-current carrying connections should be properly maintained. If the metal has the characteristic bluish tinge which indicates that it has been hot, then in most cases the connection shall not be considered satisfactory. Either it has become loose or dirty, or the conductor is not suitable for carrying the current.

5.8.2 The earth connections shall be properly maintained. A small copper loop to bridge the top cover of the transformer and the tank may also be provided to avoid earthfault-current passing through the fastening bolts when there is a lightning surge, high-voltage surge or failure of bushings.

5.9 Conservator and Magnetic Oil Gauge

5.9.1 Conservators are so arranged that the lower part acts as a sump in which any impurities entering the conservator will collect. A valve/plug is fitted at the lowest point of the conservator for draining and sampling. The inside of the conservator should be cleaned or flushed with oil every two to three years. A removable end is generally provided for this purpose.

5.9.2 The oil level indicator should be kept clean. Generally the oil level is visible through a transparent material. In case of breakage immediate replacement is essential. When conservator is stripped for cleaning, the mechanism of the oil gauge should be inspected and cleaned.

5.10 Breather

5.10.0 There are generally two types of breathers used on a transformer:

a) plain breather, and

b) silicagel breather.

5.10.1 The end of the plain breather should be kept clean and the ventilation holes free of dust. If an oil seal has been provided, the oil should be wiped out and replaced to the correct level.

5.10.2 Silicagel dehydrating breathers are fitted with a sight glass so that the colour of the crystals may be seen. The colour changes from blue to pink as the crystals absorb moisture. When the crystals get saturated with moisture they become predominantly pink and should therefore be reactivated. The body of the breather should be removed by undoing the nuts. If the crystals have been kept in an inner container, the container should be removed, but if they are not, the crystals should be removed into a shallow tray. The crystals should be backed at a temperature of about 200°C until the whole mass is at this temperature and the blue colour has been restored. Clean the breather and replace the dry crystals and renew the oil in the sealing cup at the bottom.

5.11 Buchholtz Relay

5.11.1 Routine operation and mechanical inspection tests should be carried out at one and two yearly intervals respectively.

5.11.2 During operation if gas is found to be collecting and giving alarm, the gas should be tested and analysed to find out the nature of fault. Sometimes, it may be noticed that the gas collecting is only air. The reasons for this may be that the oil is releasing any absorbed air due to change in temperature or due to leakage on the suction side of the pump. The absorbed air is released in initial stages only when no vacuum is applied during filling of oil The internal faults can be identified to a great extent by a chemical analysis of gas.

5.11.3 Buchholtz may also give alarm/trip due to the oil level falling below the Buchholtz level.

5.12 Explosion Vent

5.12.1 The diaphragm, which is fitted at the exposed end of the vent should be inspected at frequent intervals and replaced, if damaged. Failure to replace the diaphragm quickly may allow the ingress of moisture which will contaminate the oil. If the diaphragm has broken because of a fault in the transformer, an inspection shall be carried out to determine the nature and cause of the fault.

5.13 Gaskets

5.13.1 Gaskets sometimes shrink during service. It is, therefore, necessary to check the tightness of all bolts fastening gasketed joints. The bolts should be tightened evenly round the joints to avoid uneven pressure. Leaking gaskets should be replaced as soon as the circumstances permit.

5.14 Small Pipe Work

5.14.1 The pipe work should be inspected at least once a year. Leaks may be due to slack unions, which should be tightened or to badly seated joints caused by a misalignment. In the latter case, the pipes should be aligned and joints remade.

5.15 Temperature Indicators

5.15.1 At each yearly maintenance inspection, the level of oil in the pockets holding thermometer bulbs should be checked and the oil replenished, if required. The capillary tubing should be fastened down again if it has become loose. Dial glasses should be kept clear and if broken, replaced as soon as possible to prevent damage to the instrument. Temperature indicators should be calibrated with standard thermometer immersed in hot oil bath if found to be reading incorrectly.

5.16 Coolers and Cooling Fans

5.16.1 There is a variety of coolers. For radiator type coolers, maintenance primarily consists of replacing damaged elements, cleaning the outer surface to remove settled dust, repainting, etc.

5.16.2 Fan blades are cleaned to remove dust. Bearings of the fan motors should be lubricated occasionally. Grease should not be added while the motor is running. For other coolers, manufacturers, instructions should be followed. Other precautionary measures, such as checking of correct operation of pumps, gauges, indicators and differential pressure between oil and water (in case of water-coolers) shall be taken.

5.17 On-Load Tap Changer

5.17.1 Since all on-load tap changers are not of the same design and construction, special instructions of manufacturer's should be followed. However, a few points are enumerated:

a) *Diverter Switch* — The maintenance primarily consists of servicing of diverter switch contacts, checking the oil level in the diverter switch chamber, and replacement of diverter switch oil when the same becomes unsuitable for further service.

b) *Motor Driving Mechanism*

1. Do not allow dirt to accumulate between contact rings of notching controller.
2. Do not use oil/grease on contacts rings on notching controller.
3. Check the operation of anti-condensation heater.
4. If the contacts of contactors are silver faced, no touching up shall be done, but should be replaced when they are worn out. Copper contacts may be lightly touched up with a file when they become rough. The pole faces of electromagnet shall be kept clean.
5. Do not oil/grease the contact surface of radial multi-contact switches, unless a special contact lubricant is used The space between the rings should be cleaned occasionally. If necessary, a few drops of benzine be used.

c) *Selector Switch* — The contacts do not make/break current. As such, the wear is only due to mechanical movement of moving contacts. These may be inspected once in 2/3 years.

5.18 Spares

5.18.1 It is a healthy practice to have essential spares like one member of each type of bushings, one spare limb winding, one thermometer, one cooling fan, etc, for each group of similar transformers. Suppliers' recommendations may be followed in this connection.

6. MAINTENANCE SCHEDULE

6.1 Recommended maintenance schedules for all types of transformers of rating less than 1 000 kVA and for ratings of 1 000 kVA and above are given in Tables 1 and 2 respectively. The hourly and daily inspection recommended are applicable for attended substations only. However, for unattended substations, these items should be inspected as frequently as possible.

6.2 In addition to the schedule recommended in Tables 1 and 2, it may be necessary to inspect for other details in the case of specific types of transformers. In all such cases, the manufacturers instructions shall be followed.

7. TROUBLE-SHOOTING IN TRANSFORMERS

7.1 Faults observed during the periodic maintenance schedules are to be rectified as per the suggested action required. However, certain chance troubles and major faults in performance of the transformer shall have to be attended to in a desired sequence, as per manufacturer's instructions or ready reference manuals. Guidance to manage electrical and mechanical troubles normally encountered in all types of transformers are provided in Table 3.

TABLE 1 RECOMMENDED MAINTENANCE SCHEDULE FOR TRANSFORMERS OF CAPACITIES LESS THAN 1 000 kVA

(*Clauses* 4.5, 6.1 *and* 6.2)

SL No.	INSPECTION FREQUENCY	ITEMS TO BE INSPECTED	INSPECTION NOTES	ACTION REQUIRED IF INSPECTION SHOWS UNSATISFACTORY CONDITIONS
(1)	(2)	(3)	(4)	(5)
1.	Hourly	i) Load (amperes)	Check against rated figures	—
		ii) Temperature	Oil temperature and ambient temperature	—
		iii) Voltage	Check against rated figures	—
2.	Daily	Dehydrating breather	Check that air-passage are clear. Check colour of active agent	If silicagel is pink, change by spare charge. The old charge may be reactivated for use again.
3.	Monthly	i) Oil level in transformer	Check transformer oil level	If low, top up with dry oil. Examine transformer for leaks.
		ii) Connections	Check tightness	If loose, tighten.
4.	Quarterly	Bushings	Examine for cracks and dirt deposits	Clean or replace.
5.	Half yearly	i) Non-conservator transformer	Check for moisture under cover	Improve ventilation, check oil.
		ii) Cable boxes, gasketed joints, gauges and general paint work	Inspect	
6	Yearly	i) Oil in transformer	Check for dielectric strength and water content. Check for acidity and sludge	Take suitable action to restore qulity of oil.
		ii) Earth resistance	—	Take suitable aactions if earth resistance is high.
		iii) Relays, alarms their circuits, etc	Examine relay and alarm contacts, their operation, fuses, etc. Check relay accuracy, etc	Clean the components and replace contacts and fuses if necessary. Change the setting, if necessary.
7.	2 yearly	Non-conservator transformers	Internal inspection above core	Filter oil regardless of condition.
8.	5 yearly	—	Overall inspection including lifting of core and coils	Wash by hosing down with clean dry oil.

NOTE — When inspection of core and coils are to be done, it is recommended the manufacturer be consulted.

TABLE 2 RECOMMENDED MAINTENANCE SCHEDULE FOR TRANSFORMERS OF CAPACITIES OF 1 000 kVA AND ABOVE

(*Clauses* 4.5, 6.1 *and* 6.2)

Sl No.	Inspection Frequency	Items to be Inspected	Inspection Notes	Action Required if Inspection Shows Unsatisfactory Conditions
(1)	(2)	(3)	(4)	(5)
1.	Hourly	i) Ambient temperature	—	—
		ii) Winding temperature iii) Oil temperature	Check that temperature rise is reasonable	Shut down the transformer and investigate if either is persistently higher than normal.
		iv) Load (amperes) v) Voltage	Check against rated figures	—
2.	Daily	i) Oil level in transformer	Check against transformer oil level	If low, top up with dry oil, examine transformer for leaks.
		ii) Oil level in bushing	—	—
		iii) Leakage of water into cooler	—	—
		iv) Relief diaphragm	—	Replace if cracked or broken.
		v) Dehydrating breather	Check that air-passages are free. Check colour of active agent	If silicagel is pink, change by spare charge. The old charge may be reactivated for use again.
3.	Quarterly	i) Bushing	Examine for cracks and dirt deposits	Clean or replace.
		ii) Oil in transformer	Check for dielectric strength and water content	Take suitable action to restore quality of oil.
		iii) Cooler fan bearings, motors and operating mechanisms	Lubricate bearings. Check gear box. Examine contacts. Check manual control and interlocks	Replace burnt or worn contacts or other parts.
		iv) OLTC	Check oil in OLTC driving mechanisms	
		v) Indoor transformers	Check ventilation	

(*Continued*)

TABLE 2 RECOMMENDED MAINTENANCE SCHEDULE FOR TRANSFORMERS OF CAPACITIES 1 000 kVA AND ABOVE — *Contd*

Sl No.	Inspection Frequency	Items to be Inspected	Inspection Notes	Action Required if Inspection Shows Unsatisfactory Conditions
(1)	(2)	(3)	(4)	(5)
4.	Half Yearly	Oil cooler	Test for pressure	—
5.	Yearly (or earlier if, the transformer can conveniently be taken out for checking)	i) Oil in transformer	Check for acidity and sludge	Filter or replace.
		ii) Oil filled bushings	Test oil	Filter or replace.
		iii) Gasket joints	—	Tighten the bolts evenly to avoid uneven pressure.
		iv) Cable boxes	Check for sealing arrangements for filling holes. Examine compound for cracks	Replace gaskets, if leaking.
		v) Surge diverter and gaps	Examine for cracks and dirt deposits	Clean or replace.
		vi) Relays, alarms, their circuits, etc	Examine relay and alarm contacts, their operation, fuses, etc. Check relay accuracy, etc	Clean the components and replace contacts and fuses, if necessary. Change the setting, if necessary.
		vii) Earth resistance	—	Take suitable action; if earth resistance is high.
6.	(a) 5 yearly	1 000 to 3 000 kVA	Overall inspection including lifting of core and coils	Wash by hosing down with clean dry oil.
	(b) 7-10 yearly	Above 3 000 kVA	do	do

NOTE 1 — With respect to on-load tap changers, the manufacturer's recommendation should be followed.

NOTE 2 — The silicagel may be reactivated by heating it to 150 to 200° C.

NOTE 3 — Every time the drying medium is changed, oil seal should also be changed.

NOTE 4 — No work should be done on any transformer unless it is disconnected from all external circuits and the tank and all windings have been solidly earthed.

NOTE 5 — In case of anything abnormal occurring during service, maker's advice should be obtained, giving him complete particulars as to the nature and the extent of occurrence, together with the name plate particulars in order to assist identification.

TABLE 3 TROUBLE-SHOOTING CHART FOR ALL TRANSFORMERS
(*Clause* 7.1)

TROUBLE	CAUSE	REMEDY
(1)	(2)	(3)
Rise in Temperature		
High temperatures	Overvoltage	Change the circuit voltage or transformer connections to avoid overexcitation.
	Overcurrent	If possible, reduce load. Heating can often be reduced by improving power factor of load. Check parallel circuits for circulating currents which may be caused by improper ratios or impedances. *See* Electrical Troubles, below.
	High ambient temperatures	Either improve ventilation or relocate transformer in lower ambient temperature.
	Insufficient cooling	If unit is artificially cooled, make sure cooling is adequate
	Lower liquid level	Fill to proper level.
	Sludged oil	Use filter press to wash off core and coils Filter oil to remove sludge.
	Short-circuited core	Test for exciting current and no-load loss. If high, inspect core and repair. *See* Electrical Troubles, below.
Electrical Troubles		
Winding failure Core failure	Lightning. Short-circuit Overload Oil of low dielectric strength Foreign material Core-insulation breakdown (Core, bolts, clamps, or between laminations)	Usually, when a transformer winding fails, the transformer is automatically disconnected from the power source by the opening of the supply breaker or fuse. Smoke or cooling liquid may be expelled from the case, accompanied by noise. When there is any such evidence of a winding failure, the transformer should not be re-energized at full rated voltage, because this might result in additional internal damage. Also it would introduce a fire hazard in transformers. After disconnection from both source and load, the following observations and tests are recommended . a) External mechanical or electrical damage to bushings, leads, potheads, disconnecting switches, or other accessories

(*Continued*)

TABLE 3 TROUBLE-SHOOTING CHART FOR ALL TRANSFORMERS — *Contd*

TROUBLE (1)	CAUSE (2)	REMEDY (3)
		b) Level of insulating liquid in all compartments. c) Temperature of insulating liquid wherever it can be measured. d) Evidence of leakage of insulating liquid or sealing compound.
Electrical Troubles		
High exciting current	Short-circuited core	Test core loss. If high, it is probably due to a short-circuited core. Test core insulation. Repair if damaged. If laminations are welded together, refer to manufacturer.
	Open core joints	Core-loss test will show no appreciable increase. Pound joints together and retighten clamping structure
Incorrect voltage	Improper ratio	Change terminal-board connection or ratio-adjuster position to give correct voltage.
	Supply voltage abnormal	Change tap connections or readjust supply voltage.
Audible internal arcing and radio interference	Isolated metallic part	The source should be immediately determined Make certain that all normally grounded parts are grounded, such as the clamps and core.
	Loose connections	Same as above Tighten all connections.
	Low liquid level, exposing live parts	Maintain proper liquid level.
Bushing flashover	Lightning	Provide adequate lightning protection
	Dirty bushings	Clean bushing porcelains, frequency depending on dirt accumulation.
Mechanical Troubles		
Leakage through screw joints	Foreign material in threads Oval nipples Poor threads Improper filler Improper assembly	Make tight screw joints or gasket joints.
Leakage at gasket	Poor scarfed joints Insufficient or uneven Compression Improper preparation of gaskets and gasket surfaces	Make tight screw joints or gasket joints.

(*Continued*)

TABLE 3 TROUBLE-SHOOTING CHART FOR ALL TRANSFORMERS — *Contd*

TROUBLE (1)	CAUSE (2)	REMEDY (3)
Mechanical Troubles — Contd		
Leakage in welds	Shipping strains, imperfect weld	Repair leaks in welds.
Pressure-relief diaphragm cracked	Improper assembly. Mechanical damage	Replace diaphragm. Inspect inside of pipe for evidence of rust or moisture. Be sure to dry out transformer if there is a chance that drops of water may have settled directly on windings or other vulnerable locations, as oil test may not always reveal presence of free water.
Pressure-relief diaphragm ruptured	Internal fault	
	In conservator transformer — obstructed oil flow or breathing	Check to see that valve between conservator and tank is open and that ventilator on conservator is not blocked.
	In gas-seal transformer — obstructed pressure relief valve	Make certain that relief valve functions and that valves in discharge line are open.
	In sealed transformer —liquid level too high	Liquid level should be adjusted to that corresponding with liquid temperature to allow ample space for expansion of liquid.
Moisture condensation in open-type transformers and airfilled compartments	Improper or insufficient ventilators	Make sure that all ventilator openings are free.
Moisture condensation in sealed transformers	Cracked diaphragm	*See* remedies above for cracked and ruptured diaphragms.
	Moisture in oil	Filter oil.
Audio noise	Leaky gaskets and joints. Accessories and external transformer parts are set into resonant vibration giving off loud noise	Make certain all joints are tight. Tighten loose parts. In some cases parts may be stressed into resonant state. Releasing pressure and shimming will remedy this condition.
Rusting and deterioration of paint finish	Abraded surfaces and weathering	Bare metal of mechanical parts should be covered with grease.
Fractured metal or porcelain parts of bushings	Unusual strains placed on terminal connections	Cables and bus-bars attached to transformer terminals should be adequately supported. In the case of heavy leads, flexible connections should be provided to remove strain on the terminal and bushing porcelain.

(*Continued*)

TABLE 3 TROUBLE-SHOOTING CHART FOR ALL TRANSFORMERS — *Contd*

TROUBLE	CAUSE	REMEDY
(1)	(2)	(3)
Oil Troubles (*see also* IS : 1866-1978*)		
Low dielectric strength	Condensation in open-type transformers from improper ventilation	Make certain that ventilating openings are unobstructed†.
	Broken relief diaphragm	Replace diaphragm†.
	Leaks around cover accessories	Regasket, if necessary†.
	Leaky cooling coil	Test cooling coil and repair†.
Badly discoloured oil	Contaminated by varnishes	Retain oil if dielectric strength is satisfactory.
	Carbonized oil due to Switching	
	Winding or core failure	
Oxidation (sludge or acidity)	Exposure to air	'Wash down' core and coils and tank. Filter and reclaim or replace oil.
	High operating temperatures	Same as above. Either reduce load or improve cooling.

*Code of practice for maintenance and supervision of insulating oil in service (*first revision*).

†In any event, filter oil or dry transformer by heating, or both, to restore dielectric strength.

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Printed at Dee Kay Printers New Delhi India