TAMILNADU ELECTRICITY BOARD

CODE OF TECHNICAL INSTRUCTIONS

FORE WORD

Electricity Board makes large investments in terms of Crores of Rupees in its Plants and Machinery, Equipments, Transmission Lines and Distribution net-works. It is absolutely necessary that these infrastructural constituents for transport of power from generation sources to load centres are maintained in healthy operational conditions at all times. With increasing demand for power and greater and greater expectations from the electricity consuming public for better service, reliability of supply and service assume great significance. This can be ensured only by effective and efficient maintenance of all the equipments connected with Sub-Stations and lines. The state of the Art of Technology of the design and manufacture of equipments in the field of power development has been changing at a rapid pace in the recent years and, hence, it is ncessary to update the maintenance manual from time to time.

I am happy to find that the Code of Technical Instructions has been thoroughly reviewed and revised to cover the recently added new type of equipments such as SF6 Breakers, Vacuum Circuit Breakers, Gapless Surge Arresters, Static Var Compensators, etc.

The revision of Code of Technical Instructions (Transmission and Distribution) has been carried out under the direction of:

Thiru S. Sellaratnam,
Member / Distribution

by a team comprising the following Engineers :

1.	**Thiru B.N. Marimuthu**	*CE/NMTPP*
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Thiru E.S. Narayanan, Chief Engineer (Retd.) worked as Consultant in bringing out the revised Code of Technical Instructions.

I wish to congratulate the team of Engineers for their excellent effort in bringing out this revised edition. I have the hope that all Engineers and staff will be greatly benefited by making full use of this revised code.

Madras – 600 002
March, 1990

T.V. Antony,
Chairman
Tamil Nadu Electricity Board

INTRODUCTION

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Introduction

1. The age old proverb "a stitch in time saves nine" amply illustrates the importance of maintenance. In a service utility like the Electricity Board, maintenance management has far reaching technical and economic implications.

2. The primary responsibilities of the State Electricity Board are (a) to generate adequate electricity to met the growing needs of the State and (b) to maintain uninterrupted power supply to its consumers. The Electricity Board has made huge investments to install a large number of generating plants and machinery and to lay a widespread transmission and distribution network. In order to achieve consumer satisfaction, it is essential to operate and maintain the plants and machinery, transmission and distribution lines and equipments, in an efficient manner. The objectives for maintenance management of Electricity Board can be broadly defined (i) to ensure safety (ii) to ensure maximum availability and high reliability to (iii) to reduce maintenance cost.

3. To achieve the above objectives, it is essential to have rigid standards, prescribe periodic inspections, evolve proper procedures for preventive, planned and breakdown maintenance works. In addition, the workers, staff, officers and engineers have to be educated on the various procedures and systems.

4. Preventive maintenance is extremely important in the reduction of maintenance costs and improvement of equipment reliability, where, as a result of breakdown, the damage to an equipment is high, preventive maintenance is a must. Preventive maintenance should be done more specifically to the parts which normally need repairs or replacements often. The success of preventive maintenance will depend largely on the alertness of the operation and maintenance staff who should be continually on the watch for loose bolts, vibration, leaks, wear, unusual noise, odour, heating etc.

5. Planned maintenance work should be done in accordance with prearranged schedules to coincide with periods in which shutdowns on equipments could be easily had and as far as possible when the weather is favourable. It would also be desirable to spread the maintenance works to be done over the entire year. Maintenance work should also be divided into groups which can be done when the equipment is in service and that which can be done only at times when the equipment can be taken out of service.

6. Time is the essence of breakdown maintenance. The work force and work methods should be organised such that the downtime is cut down to the minimum. But on no account, quality of work should be compromised.

7. Each piece of equipment should be inspected at the specified intervals. The routine checks and inspections are intended to detect troubles in their early stages so that corrective measures can be taken before serious trouble develops. Anything unusual found on such inspections, should be promptly referred to the superior officers for proper action. The inspecting officers at all levels should perform purposive inspections to bring out deficiencies, slippages etc., and guide the subordinate officers for the effective execution of maintenance work. They should also verify whether the safety regulations are followed or not.

8. Maintenance registers to be kept should give the following details :

   i) Routine maintenance work to be carried out on each equipment.

   ii) Periodicity of the various items of maintenance works to be done on each equipment.

   iii) The dates on which the various items of maintenance work were carried last on each equipment.

   iv) Results of periodical inspection of tests carried out on each equipment.

   v) Any special maintenance work or repair carried out on each equipment.

   The register should be maintained by the section officer, checked by the Assistant Executive Engineer every month and reviewed by the Executive Engineer every two months and submitted to Superintending Engineer during their inspections or should be sent to them for review whenever required. The Assistant Executive Engineer should ensure that periodical inspections and maintenance are carried out systematically and thoroughly.

BATTERIES

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Batteries

CONTENTS

2. INSPECTION AND MAINTENANCE OF BATTERIES

2.01 Importance

The storage battery in a power house or sub-station is the most vital equipment since the operation of the protective, isolating devices for all equipments depend on the availability of the D.C. power from the battery. There have been instances of major fires in transformers owing to associated circuit breakers not clearing the fault due to the defective conditions of the battery. At power stations the battery is the emergency source to run essential lubricating oil system and provide minimum lighting when there is a total station shutdown. On no occasion, should the condition of the battery be assumed as satisfactory from the voltage indication at no-load.

> **Important**
>
> All measurement of voltages and currents in battery circuits shall be made only with moving coil instruments and not with AC/DC moving iron instruments, as polarity errors will not be readily indicated if AC/DC instruments are used.

2.02 Capacity

The capacity of the battery is expressed in terms of ampere hours, on a 10 hour rating or a 3 hour rating. If 'Q' is the capacity on a 10 hour rating, it implies that a current equal to Q/10 could be continuously drawn for 10 hours without the voltage falling below 1.85 volts/cell. The amperes a battery could deliver for a short duration is much higher and is limited purely by the internal resistance of the battery and the resistance of the load. As a thumb rule the one hour rating in ampere hours of the battery is equal to half the magnitude of the 10 hour rating.

2.03 Preferred Ratings

Batteries are now being ordered by the Board with the following ratings:

i)	33 KV sub-stations without remote control	30V/60 ampere hour
ii)	110 KV sub-stations without remote control	2 Nos. 30V-60 ampere hour battery. (One for 110kv group control OCB and transformer OCBs. The other for feeder control OCBs)
iii)	Sub-stations with remote control	110 V 300 A.H. in case of smaller stations and 220 V in case of bigger stations

iv)	Carrier equipment	48V/64 AH, 128 AH, 250 AH, 400 AH batteries.
v)	VHF equipment	12V batteries.

The ampere hour capacity of 110V and 220 V batteries especially in power stations is to be determined with reference to emergency D.C. motor loads and D.C. lighting to be fed by the battery in case of failure of station A.C. supply.

2.03.01 Battery Room

Batteries should be housed in a separate room well ventilated and free from fumes to come into contact with any electrical plant. A cut-out should be provided near the battery terminals to protect the batteries from short circuit and damage to the cables between the battery and the D.C. Switch Board.

The instructions sheet (normally in one page) given by the manufacturers should be framed and hung inside the battery room.

2.03.02 Accessibility

The arrangement of the cells should be such that each cell can be properly inspected and tested.

2.03.03 Stand

Wooden racks or stillage are provided for raising the battery to a convenient level for battery inspection and also serve as insulation for the battery.

2.03.04 Insulators

Glass or Porcelain insulators are inserted between the stand and the battery to prevent leakage of current from the cells. The insulators should be cleaned and dried so that their insulating properties are not diminished. In addition it is advisable to have insulators fixed between the stand and the flooring, in the case of 110 V and 220 V battery.

2.03.05 Cleanliness

This factor is very important. If the cells are dirty, they cannot be properly inspected. Any moisture will lead to collection of dirt. Dirt and moisture affect the insulation of the battery after which it cannot retain the charge on open circuit as the charge will be dissipated as leakage to ground.

2.03.06 Illumination

It is very important that all cells are thoroughly examined at all times and the battery room should be well illuminated to enable this. No naked light should be permitted into the battery room. Exhaust fans shall be provided for proper ventilation. No naked light is permitted especially during charging since Hydrogen may be released causing an explosion if ignited by heat.

2.03.07 Protection

All wood work and metal work in the battery room should be effectively protected from acid spray and fumes by means of acid proof paint and lamps or fittings should never come directly over a row of cells. The flooring and walls of the Battery room shall be provided with acid proof tiles upto a height of 2 meters in sub-stations where 110 or 220 V Batteries are used; For Battery rooms in other stations, two coats of acid resistant paint may be given for the flooring and the walls upto a height of 2 metres.

2.03.08 Temperature

An even temperature should be maintained in the battery room, as the effect of temperature on the working of the battery is appreciable. The effects of continued high temperature are to make the plates distort, deteriorate, and become brittle and to cause excessive evaporation of the water content in the electrolyte. when the temperature of electrolyte varies appreciably, it is necessary to convert the readings observed in the Hydrometer to an equivalent specific gravity at 27°C by adding 0,0007 to the Hydrometer readings for every 1°C temperature rise above 27°C of the electrolyte.

2.03.09 Equipment

Battery room equipment should include acid, hydrometers, thermometers, inspection lamp, cell testing volt-meter, and other accessories.

Hydrometers of reputed make calibrated to read second decimal place should only be used. Small hydrometer floats of the motor car battery type should not be used with large station batteries as accurate readings cannot be obtained with them. For most station batteries, hydrometers 30 cm. long are necessary to give full range accuracy. Always two hydrometers should be kept in a station and they should be periodically checked to see that they read alike. Spare hydrometers should be kept in a safe place and not issued for use except to replace breakage. Hydrometers meant for alkaline batteries should not be used for lead acid batteries.

The cell testing voltmeter in use should be periodically checked and recalibrated if necessary. When not in use it should be kept in a safe place.

In addition, the following protective equipments should be available to the personnel who perform battery maintenance work;

(i) Goggles and face shields (ii) Acid resistant gloves (iii) Protective aprons (iv) Water facilities for rinsing eyes and stain in case of acid spillage (v) Bicarbonate of soda 0.5 kg. mixed to 5 litres of water.

2.03.09.01 Pilot Cells

Three cells shall be selected as pilot cells; Voltage and specific gravity reading should be taken on the three cells, on one cell in every shift to indicate its state of discharge and charge and this will thus serve as a guide in the operation of the battery as a whole. These pilot cells shall be changed every year.

2.03.10 Preparation of electrolyte

The preparation of the electrolyte at site arises only for the initial charging at the time of installation of the batteries, when ready mixed acid is not supplied.

One volume of pure sulphuric acid of specific gravity 1,843 with five volumes of distilled water makes a dilute acid of specific gravity 1,200. Glass or earthernware vessels may be used for mixing and necessary utensils like spoons, funnels, rods, etc., should also be non-metallic in character. The vessel in which the solution, is being made should stand in a bucket or tub of water to keep it cool and the solution well stirred before using the hydro-meter. It should be remembered that the acid should be poured into the water slowly.

Caution

Water should never be poured in concentrated acid as this will lead to chemical explosion.

NB The specific gravity of the acid while filling in new cells should be 1180 at 27° C or as directed by manufacturer.

2.04 Charging Operations

The charging of the battery can be classified into the following five categories:

1. Initial charging
2. Trickle charging
3. Routine charging
4. Quarterly Equalising charge
5. Special charging.

2.04.01 Initial charging

The performance of the battery is affected to an incredible extent by the way in which the initial or first charge is carried out, when the battery is erected at the installation. It is not practicable to supply from the factory an assembled battery in a fully charged state. The positive plates may lose much of the charges in transit and fully charged negative plates lose their charge due to heating when exposed to atmosphere. Hence in most cases, the battery plates are delivered in a formed state, i.e., treated until they are capable of retaining the charge, but lacking the actual charge which will enable them to yield their rated output. After assembly at site and filling up of the electrolyte into the cell, initial charge is to be given to the battery as per the maker's instructions, which should be followed very strictly. After initial filling, the cell should be at rest for 12 to 24 hrs. before initial charging is done.

During initial charge, the level of the electrolyte may fall down and should be compensated for by addition of distilled water. Some times, absorption by the plates could call for addition of more acid and this should be done in accordance with the maker's instructions. It should be ensured that every cell is properly and thoroughly charged. After the initial charge, the level of the acid should be identical in each cell and the specific gravity of the cell should not vary more than two points plus or minus from the average for the whole battery. The connections should also be remade tight after the charge and be covered with a coat of vaseline.

The newly charged battery should not be allowed to be idle for several days.

The voltage, current, temperature and specific gravity readings taken during the initial charge and discharge of the batteries should be kept as a permanent record of the battery during its lifetime.

When new batteries are charged the chemical reaction in all the cells will not be uniform; it is necessary to condition the constituent cells of the Battery for trickle charging. Hence after assembling at site and initial charge the Battery shall be subjected to charge and discharge cycles-atleast three charges and two discharges.

The charging and discharging operations shall be carried out in accordance with manufacturer's instructions. The readings taken during the initial commissioning of the battery (Voltage, Current, Temperature and Specific gravity) shall be carefully recorded so that they can provide bench mark values for performance trend-monitoring of the various cells in service.

2.04.02 Trickle Charging

All lead storage batteries shall be operated at a floating voltage as near as possible to 2.15 volts at the cell terminals by switching on the charging rectifier. The rectifier shall be set to take the continuous D.C. load of the system by way of indication lamps and coils in continuous operation and in addition, feed a fraction of an ampere into the battery. This is called Trickle Charging. This helps to maintain a charged battery without deterioration and increase the interval between routine recharging. If the floating voltage is set too high, appreciable gassing of the plates will occur and topping up will be required too frequently. If the voltage is set too low, the specific gravity of the electrolyte will fall gradually over a period and the plates may assume an unhealthy appearance. Should the battery get discharged suddenly due to any cause whatsoever, it is necessary to give a recharge before putting it on trickle charging.

The floating voltage of a 55 cell battery will be 118.25 volts and in a 110 cell battery 236.5 volts. The voltage should not vary by more than +0.5%.

When the battery is being properly floated very small gas bubbles about the size of the pin head rise slowly from the plate to the surface of the electrolyte. In batteries that are being over-charged the bubbles are much larger and reach the surface at a higher speed.

Trickle charging for batteries of carrier communication equipment.

Carrier equipment: Batteries are provided with "Automatic float charger" to the full load current of the communication equipment plus the trickle charging current. Hence current adjustment should not be attempted to vary the charging current. Only the terminal voltage of the battery should be adjusted. For 48V battery the terminal voltage should be 51.5V. Correct status of the battery can be ascertained from the specific gravity of the acid and the gassing condition in the battery as described in the following paragraph.

At present in C.C battery charging circuits, a milli ammeter is provided with push button and suitable protection, so that the battery charging current can be correctly adjusted.

2.04.03 Routine Charging

The specific gravity and voltage of pilot cell are noted and if the condition warrants, routine charge is given to the battery. A charge may be commenced at any rate of current within the limit of the charging apparatus, wiring and connections; but a value which is found to be satisfactory in service is the normal rate or starting rate specified by the makers. At a certain point during the charge, the plates start gassing and after that point, the charging current should never exceed the finishing rate which is usually half the normal or starting current. The charge may be discontinued, if the specific gravity in the pilot cell is within five points of the maximum reading.

If the battery is kept idle, it runs the risk of sulphation caused by the acid combining with the lead in the active material of the plates to form lead sulphate, an unhealthy condition. To counteract this possibility, it is better to give a freshening charge at half to full normal rates at regular intervals. The final specific gravity may be kept at 1,215 or as per manufacturer's instructions.

2.04.04 Equalising charge

Experience has shown that the greatest single factor in reducing the life of a lead storage battery is consistent under-charging. On floated batteries this is caused by the floating voltage being held too low, as a result of the voltmeter being out of calibration or due to lack of attention. To prevent the ill effects of any under-charging that may have occured a quarterly equalising or freshening charge is given. This charges up the low cells before they become sulphated and also arrests any tendency of the heavy acid to sink to the bottom of the cell.

A quarterly equalising charge shall be given to all floating batteries at attended stations. This consists of raising the voltage above the floating value and maintaining it for the time shown in the following table:

Charging voltage per cell	Length of charge
2.48	3 to 8 hours
2.39	4 to 12 "
2.36	6 to 16 "
2.33	8 to 24 "
2.30	11 to 34 "
2.27	16 to 48 "

The charging voltage selected from this table will depend on the safe voltage limit of the control coils connected to the D.C. bus. It is preferable to use a short high voltage charge. Whichever voltage is selected, however, the longest time shown for that voltage should be used, provided this is convenient. Thus if 2.36 volts per cell is used (129.8 volts for 55 cells) it should be held for 16 hours. This voltage shall be approached slowly to prevent overloading the charging equipment.

It is desirable not to resort to charging voltages over 2.30 V per cell and whenever this charging voltage is reached, the charging current shall be limited to half that of 10 hour charging rate.

This equalising charge shall be stopped when the original final specific gravity is reached or the specific gravity reading for three consecutive half hourly reading remains constant. However manufacturer's specific recommendations shall over-ride these instructions.

2.04.05 Special charging

If after an interruption to the station or a breakdown of the charging equipment, the battery has been discharged to cause a drop of 5 points or more in sp. gravity as indicated by pilot cells, it shall be re-charged as soon as possible. The charge should be as given under "Equalising charge" in paragraph 2.04.04.

2.0.4.06 Inter-changing of Batteries

In substations with two 30V batteries, one for power transformer breakers and the other for feeder breakers, the battery may be interchanged annually, so that both the batteries may be subjected to same duty cycle to get maximum life out of both the batteries.

2.04.07 Drop in capacity due to climatic change

An acid battery has a tendency to drop down in its capacity whenever there is a very high fluctuation in the atmospheric temperature, that is, the battery may show low capacity during night hours when the temperatures is very low and become normal during day time when the temperature rises.

This may result in the non-tripping of circuit breakers and non action of alarm relays during the low temperature periods and cause distress to the main equipments. Hence, whenever small capacity acid batteries are used in sub-stations located in hill areas, it is very necessary to keep the charging at high level during night hours or during very low temperature conditions and switch back to trickle charge when the temperature conditions return to normal.

2.04.08 C.C. Equipment Batteries

The automatic float charger provided for the carrier battery can meet the full equipment load plus ten hour charge rate of the battery. Whenever there is A.C. supply failure, the full load of the carrier equipment are met by the battery. When the A.C. supply is resumed, the charger starts supplying the load current as well as recharging the battery. If the A.C. supply interruption is brief say half an hour, the battery will be fully charged back with the float voltage itself. After an hour or two after the resumption of A.C. supply the specific gravity should be checked. If the battery is still being charged (noticing the increase in ammeter reading over the normal load current) the charging may be allowed to be continued. If at the end of the charge the specific gravity has not reached the normal level, the charger may be switched to boost condition and increase the terminal voltage such that the battery is charged at the 10 hour rate. In some of the chargers, there is no separate boost switch. In such a charger simply rotate the knob to increase the terminal voltage. As the charge getting stored in the battery increases, the charging current decreases with the increase in the terminal voltage. At the same time watch the voltage per cell. When it reaches 2.3 volts, decrease the charging current to 50% of normal 10 hour rate or maximum charging current rate as per the instructions of the manufacturer. When the battery is fully charged (refer manufacturer's instructions) the terminal voltage should be reduced to the original level.

When the battery is under boost charge the terminal voltage will be much higher than 52 V. The terminal voltage to the carrier equipment should not be more than 54 V. The terminal voltage can be brought down by inserting resistance or dropper diodes. The switches provided for the purpose should be cut in and the equipment terminal voltage is observed for correct adjustment. When the terminal voltage is reduced back to float level, this switch should be cutout.

2.05 Measurement of voltage

The two important parameters to be measured in a cell are the voltage and specific gravity.

2.05.01 Measurement of voltage

The voltage of each cell should be measured with an accurate voltmeter reading in hundredths as 2.17, 2.23. If the difference between the highest reading and the lowest reading is more than 0.1 take a check set of readings and record results.

Sulphated plates, short-circuits due to cracked separators and other defects of a lead cell cause a noticeable drop in the terminal voltage with current flowing in the cell. This drop varies with the amount of current flowing, and in order to get voltages that can be compared from month to month the voltages should be taken with the same current flowing in the cell.

Cell voltages shall, therefore, always be taken with the normal current flowing in the battery with the trickle charger switched off. At the time of the equalising charge they shall be taken at the end of the charge and with the battery in the normal floating condition.

NOTE: It is no use testing a cell on open circuit (i.e) idle with no current passing and such readings have no value or meaning.

A weak cell will often give as high a voltage reading as a healthy one on open circuit. It is the cell voltage while delivering load that matters.

Voltage after charging

The voltage of a cell at the end of a charge is not a fixed value but will vary depending on the age of the battery, the temparature, specific gravity of the electrolyte and charging rate. The voltage of a new cell at the end of an over-charge will be about 2.5 to 2.75 volts. This gradually decreases as the age of the battery increases. With normal temperatures and charging rate this may come down to 2.4 volts.

Voltage during discharge

During discharge, the voltage will be between 1.95 and 2.05, depending on the rate of discharge and will remain constant till the battery capacity is nearly fully utilised, when there will be a rapid drop in voltage. The discharge of the battery should be stopped at that level and the battery should be recharged before further use. During normal service with a floating charge arrangement, the battery is not likely to get discharged to this extent. But, such situations may arise in power stations during emergency when D.C. power is drawn for driving motor and other auxiliaries.

Minimum safe voltage

No cell should be discharged further when the voltage reading falls to 1.85 volts.

2.05.02 Specific Gravity

Measurement of specific gravity of the electrolyte shall be taken with the

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hydrometer. The readings shall be taken only when the battery has ceased gassing since hydrometer readings taken when a cell is freely gassing gives the specific gravity of the mixture of gas bubbles and the electrolyte and not the true specific gravity of the electrolyte.

At the end of the equalising charge the specific gravity shall be taken 15 minutes after the battery has been returned to the normal float condition.

Permissible values of Specific gravity in Tropics:

Fully charged condition	...	1195 corrected to 15.6°C or 1183 at 32.2°C
Deviation of any cell from average	...	10 points
Variation in value for temperature rise	...	0.0007 for 1°C
Discharge limit	...	Fall by 40 points below value noted at end of previous extended charge.

NOTE: Specific gravity of acid as measured by hydrometer falls with increase in temperature.

2.05.03 I.R. Values

In view of numerous and long parallel paths connected to the D.C. system, the overall I.R. value of D.C. circuits especially in power stations when measured with a megger may be low. One of the methods of measuring the I.R. value of the D.C. circuit is to use a high resistance voltmeter and measure the following voltages with the same voltmeter.

1.	+Ve to earth	...	Vp
2.	-Ve to earth	...	Vn
3.	+Ve to -Ve	...	V
4.	Resistance of voltmeter	...	Rv
5.	I.R. value of +ve to earth	...	Rp
6.	I.R. value of -ve to earth	...	Rn

$$R_p = \frac{V-(V_p + V_n)}{V_n} \times Rv$$

$$R_n = \frac{V-(V_p + V_n)}{V_p} \times Rv$$

NOTE: The values of voltage obtained in a D.C. unearthed circuit, as measured by a voltmeter connected +ve to earth or - ve to earth will vary substantially from voltmeter to voltmeter, depending on the resistance of the voltmeters.

The sum of V_p and V_n will not be equal to V. The difference between V and $(V_p + V_n)$ again depends on the resistance of voltmeter.

2.06 Maintenance of Batteries

The battery should be inspected daily. In open type cells with transparent containers, the following points shall be observed during inspection:

i) Colour and touch of plates. (The positive should have a smooth, greasy feel and the negative a smooth feel; neither should be harsh nor metallic unless brand new).

ii) Condition of plates, such as cracks, distortion, accumulations etc. (As distortion of plates caused by growth sideways or downward are likely to burst the container it cannot be ignored)

iii) Colour of cell deposits and clearance between deposit and bottom edge of plate. The deposits in the cells should be brown and not white.

The active material in the positive plates in healthy cells in use for more than 12 months when fully charged should be chocolate in colour and that of negative plate light or bluish grey according to age. A weak cell affects the useful work done by the battery. The chief indications of weak cells are bad colour of plates, irregularity in gassing or entire failure to gas and a fall in voltage and specific gravity below that of other cells.

2.06.01 Plante Type Batteries

In new 'Plante' type batteries flakes of brown scale will be seen getting detached from edges of positive plates. This formation of scale is normal. Untill all this scale is dispersed, the plates cannot be considered stabilised. Sometimes pieces of this scale may lodge across adjacent negative plates and cause a partial short circuit. Such pieces should be gently dislodged with a thin piece of wood and allowed to fall to the bottom of the cell. This scaling occurs only on the edge of the plates and therefore on no account should scaling sticks be passed down the middle of the plates. The removal of scales should be done very carefully, so that the plates are not damaged.

2.06.02 Maintenance Common to all batteries

i) Checking for D.C. leakage once a shift.

ii) Daily check of specific gravity and voltage of pilot cell.

iii) Intercell connector joints:

The inter-cell connections of the battery should be examined to ensure that they are clean and tight and that no corrosion is present on the connectors. Any signs of copper sulphate corrosion should be cleaned up. Acid proof paint or enamel should be applied to all exposed copper work in the Battery Room and any flaking of paint is to be given prompt attention.

2.06.03 Electrolyte Level

The level of the electrolyte should always be maintained above the top of the plates.

A line indicating the normal level of the electrolyte should be painted on each side for guidance.

2.06.04 Evaporation

Evaporation takes place in all storage cells. Water in the electrolyte evaporates and leaves the sulphuric acid intact. The effect of evaporation is to cause the level of the electrolyte to become lower and the specific gravity of the electrolyte will become higher. To compensate for evaporation it is only necessary to add distilled water.

2.06.05 When to add distilled Water

The addition of distilled water should be made at sufficiently frequent intervals preferably whenever the fall in level is about 3mm to maintain the height of the electrolyte at the correct level. Under unavoidable circumstances the limit of difference in levels between the two additions of distilled water may be half normal cover to prevent top of the plate becoming exposed to atmosphere. Though it may appear small, it represents quite a wide difference in the specific gravity of the electrolyte before and after the addition of distilled water. As specific gravity of water is lower than acid in the cell, if distilled water is poured very slowly, there will be a tendency for the water to lie on the surface. It is therefore advisable to introduce distilled water into the bottom of the cell by means of a glass tube or rubber syringe well below the level of the acid near the bottom of the cell. Distilled Water is best added when the specific gravity of the acid in the cell is in the lower limit, i.e. just before commencing charge. When introducing distilled water, care should be taken not to disturb the deposits at the bottom of the cell. Only distilled water should be added to the cells. Acid should not be added to the battery, normally. If the specific gravity of the cell comes too far down, cannot be improved by cycles of charge and discharge, the addition of acid may be inevitable, but this should be done only after obtaining expert advice from the manufacturer.

2.06.06 History

History of each cell should be recorded and reviewed periodically. Weekly battery readings should be taken and recorded in the appropriate form. Note should be made of weak cells.

2.06.07 Weak Cells

Weak cells should be immediately examined for any possible short circuit or metallic contact between positive and negative plates. Short circuit should be removed and the cell should then be given special additional charge by taking it out of circuit and putting back again after recharging. Continuous presence of a weak cell in battery may sometime cause the individual cell to reverse its polarity. Rectification of weak cells in time is therefore important. The replacement of a weak cell or any maintenance of the station battery requiring disconnection of the cell should always be done by availing a total shutdown or suitable bypass clip on connection to short circuit the cell should be established before attempting to cutout the cell.

2.06.08 Problems in Batteries

Problems in batteries could be classified under the following categories:

A. Positive:

Buckling
Sulphating
Disintegrating
Corroding
Breaking up

B. Negative:

Paste blowing
Premature gassing
Paste shedding
Paste sulphating
Paste contracting
Reverse polarity
Hydration

C. Positives and Negatives:

Sulphation
Hydration
Bad colour
Sluggishness through-
(a) Insufficient work, (b) Insufficient charge
Local action

D. Electrolyte:

Lower specific gravity
Stratification
Irregular specific gravity
Impure Water
Discolouration

E. Connections:

End or regulating cells
End cell lower in voltage than the remainder
Inadequate Insulation
Internal short circuits
Weak cells
Reversed cells
Reversed Batteries

Any major problem in the battery is best attended to in consultation with the manufacturers; but following are the causes for some of the problems developing:

i) *Buckling:* This is due to too much charging resulting in unequal expansion of positive plates.

ii) *Sulphating:* This is due to too little charging. If the battery is not sufficiently worked, abnormal sulphation results.

iii) *Hydration:* Hydration is the action of water on the Lead plates. If a battery is exhausted to a point where the electrolyte is practically water and charging is not given at once, or if the plates are not entirely immersed continuously in the electrolyte, hydration will set up as a white creamy substance spreading regularly over the plates and reaching into the pores of the active material
As soon as charging is given, acid liberated from the plates attacks the Lead Hydrate forming Lead sulphate in a condition difficult to recover even by very prolonged charging.

iv) *Stratification:* In this case a layer of strong acid lies at the bottom of the cell for lack of circulation. Strong acid is liberated from the plates under the action of the charging current and, being heavier than the weak electrolyte, it falls by gravity to the bottom of the cell where eventually a layer of acid with specific gravity as high as 1.4 may gradually build up. Stratification causes the hydrometer readings to be misleading. It tends to very irregular working of the plates. It could be overcome by circulation either through stirring up with a paddle or blowing up with an air pump. It is not experienced with a normally working battery.

2.06.09 Water

Only distilled water should be used for topping up. Contamination of electrolyte by adding impure water is a very common problem. If the water contains lime, this will crystalise some of the acid and reduce the specific gravity with a characteristic formation of lime crystals. If the water contains chlorine, this has a formation effect on the positive with abnormal depreciation. If the water contains iron, this causes local action resulting in self discharging of plates even when not doing useful work.

2.06.10 Reversed Cells

A more common cause of reversal is to allow a cell to go weak without giving it special attention. Its capacity consequently falls lower and lower until its voltage touches zero early on discharge; for the remainder of the discharge it is receiving as charge in the wrong direction the current in amperes discharging from the rest of the battery. For example, if a battery be discharging at 20 amperes, and one cell falls to zero volts, the cell will be charged for the rest of the discharge at 20 amperes in the wrong direction.

i) *Reversed Polarity* : The polarity of a battery can only become reversed if it be charged in the wrong direction, that is to say, if the negative instead of the positive terminal of the battery is joined to the positive pole of the charging source. Another possibility is the wrong coupling together of the rows of cells forming the complete battery. The rule is, negative terminal of the one cell joined to the positive terminal of the next cell throughout the battery. The effect of reversal is one of degree, but in most cases the plates are ruined. If the initial charge of a battery is commenced in the wrong direction and the fault is discovered within the first twelve hours, the plates may be recovered, but a longer period-say, 50 hours-will usually wreck the negatives and depreciate the positives.

ii) *Remedy for Reversed Polarity* : It should be difficult to commence the initial charge of a battery in the wrong direction, but if this has been done some difficulty may also be experienced in charging the cells in the right direction again.

The first step is to discharge the reversed battery through a water resistance. An ammeter should be inserted in the circuit, and the current should be adjusted to the normal rate of discharge by adding a little sulphuric acid to the water and altering the distance between the lead plates. When the voltage has fallen to zero, the circuit must be broken and rearranged. The waterbath must now be coupled between the charger and the battery, and the resistance made high by moving the lead plates well apart and using a fresh supply of water without any acid at all to start with. The charging may then be commenced after altering the connections, so that the positive terminal of the battery is connected to the positive pole of the dynamo, and that all the cells are correctly connected-positive to negative. (If only a portion of the battery has been charged up wrongly, that portion only should be dealt with throughout this process. Those cells correctly charged should not be discharged or charged until the other portion has been rectified)

The last switch of the circuit (assuming that there is no automatic cut in and cut out switch on the switchboard) should be closed only when the voltage of the dynamo is equal to the number of cells multiplied by 2.1. It will be found difficult to pass any current at all from the dynamo into the battery because of the high resistance of the water-bath, even though the dynamo voltage has been adjusted to 2.1 multiplied by the number of cells. This resistance acts as a trap to prevent the battery from feeding back on to the dynamo, and as soon as the resistance is reduced the charging current will increase. It is as well to leave the water-bath in circuit until the charge is completed but the lead plates may be clamped together if it is found hard to maintain the proper rate of charge otherwise.

It is quite impossible to pre-determine the duration of the charge required to recover the cells fully. One must be guided by the appearance and behaviour of the plates, a rise in specific gravity and voltage to a maximum stationary value.

2.06.11 End Cells

Wherever the end cells of batteries, in any substation are found surplus, the following procedure should be adopted regarding cutting out and storage of the end cells:

i) Therefore extended charge must be given from the MG set and continued at rated charging current until all 10 cells gas freely and the sp. gr. and cell voltage have reached maximum and remain constant for 5 hours.

ii) The 10 cells should then be dis-connected from the battery circuit and inter-cell connecting bolts removed.

iii) A spare glass box should be cleaned and half filled with distilled water.

iv) Each of the 10 cells concerned should then be dismantled individually and in rotation as follows:

   a) Remove lead and buffer springs.

   b) Remove wood separators.

   c) Lift the negative group and place it in the spare glass box immersed in distilled water. It is important this is done quickly as the plates will heat up and suffer damage from oxidation if exposed more than a few minutes to the atmosphere.

   d) Lift the positive group taking care to support both the group bar and plate ribs to prevent bending. The positive group may be placed vertical on the floor and allowed to drain dry.

e) The glass box from which the above were removed should be emptied of acid, cleaned out and filled with distilled water in readiness.

f) The process of plate removal should then be continued as above from the remaining cells. Two negative groups can be accommodated in one glass box.

The negative groups must be kept immersed in distilled water for at least 48 hours and if any sign of heating takes place on removal, they must be re-immersed in the water until such time as no heating is observed over 30 minutes exposure to the atmosphere.

The negative groups may then be allowed to drain dry before storage.

The wood separators cannot be used again and should be discarded.

The positive groups should be interlaced into five pairs and any interplate wood packing should be covered with grease-proof paper to prevent acetic acid contamination. This also applies to the negative groups.

Both positive and negative groups should be packed in separate cases and stored in a warm and dry location pending recommissioning at a later date.

2.06.12 Overhaul of Cells

For individual cells where flakes have been found to short the plates adopt the dismanting procedures detailed in para 2.06.11 End Cells. After thoroughly cleaning the container and after discarding flakes on plates, the dismantled parts may be reassembled in the reverse sequence, filled back with electrolyte and put into service if necessary with a short quick charge.

2.06.13 Charging Apparatus

In older stations motor generator sets have been provided for charging the battery. But, later only a rectifier is provided with arrangement both for trickle charging the battery as well as for quick charging the battery.

A general overhaul of the charging apparatus should be done with particular attention to testing of reverse current relays, overload feature of breakers and general examination of fuses.

Float charger for CC equipment:

This is a fully solid state electronic equipment and normally does not require any maintenance except cleaning of dust particles with a blower. The periodicity may be different for different locations and has to be decided by station staff.

2.06.14 Precaution against Acid

The electrolyte of the battery and the spray containing the electrolyte are corrosive and contact with body or clothes with the electrolyte should be avoided. Acid left on cloth may be neutralised with dilute Ammonia and the stains, will disappear.

If any acid is spilt on the wood stand or on the insulators, they should be wiped clean and dry.

If acid spills on the floor, it should be dried by putting saw dust. Acid spilt in large quantity could be neutralised with whiting or powdered chalk. No Blancol oil film should be used on the surface of the electrolyte of the cell.

2.06.15 Accidents

i) *Acid splash:* If acid is splashed in the eyes, immediately flush eyes with water followed by Olive oil, If irritation does not subside bathe the eyes with Zinc and rose water lotion in eye glass.

ii) *Drink:* If acid is consumed by mistake, take a drink of soap suds and baking soda in a glass of water and get medical advice as soon as possible.

2.07 Responsibility

The Section Officer (Maintenance) in charge of batteries will be responsible for the maintenance of battery as per the instructions given in this book together with maker's instructions. The Assistant Executive Engineer supervising the work of the Section Officer in charge of the battery shall carryout a personal inspection of the battery once in six months, including taking up the voltage and specific gravity readings of each cell and attend to other aspects. The Executive Engineer will carryout a similar personal inspection once a year.

The following salient features of the batteries shall be exhibited in all sub-stations and power stations.

1. Name of the battery
2. Type
3. Capacity
4. Date of installation and first commissioning
5. Room temperature
6. No. of Cells
7. Pilot cell No.
8. Voltage of pilot cell
9. Specific gravity
10. General condition

11. Trickle charge
12. When extended charge given

2.08 What to guard against

- Failing to give the battery a proper initial charge.
- Failing to give a new battery plenty of work and liberal charging.
- Charging the battery too little.
- Charging the battery too much.
- Working the battery too little.
- Running the battery too low in voltage and specific gravity between charges.
- Running the battery too long between charges irrespective of the amount of work done.
- Charging the battery at too high rates, especially towards completion of charge.
- Charging the battery at too low rates (less than normal)
- Having the battery room too hot, or letting too strong a breeze blow through the room, both of which cause an increase in the rate of evaporation.
- Using unsuitable water to compensate for evaporation.
- Not adding water sufficiently often to keep the plates covered always with electrolyte.
- Adding any acid unwarranted by the condition of the plates or working conditions.
- Using acid unsuitable in strength or purity.
- Neglecting to observe the indications of irregular treatment.
- Neglecting to attend the weak cells promptly.
- Failing to clear internal short circuits.
- Allowing individual cells to be thoroughly exhausted (volts run down to zero)

— Allowing individual exhausted cells to receive charge in the wrong direction, by leaving them joined up in series with the rest of the cells on discharge.

— In bolted-up batteries, allowing the connections to become dirty, corroded or slack (which sets up heating and melting of the lead lugs)

— Omitting to keep the vent plug holes clear in sealed cells.

— Bringing a naked light near the cells (sealed in cells in particular) especially during charge.

2.09 Dont's

— Don't over charge the battery

— Don't under charge the battery

— Don't keep the battery idle

— Don't discharge at a rate higher than the permissible one.

— Don't discharge when the voltage comes down to 1.85 volts per cell or specific gravity falls down to 1160. This does not apply to initial charge and discharge cycle.

— Don't take open flame near the battery especially while it is being charged.

— Don't allow the level of the electrolyte to fall below a mark 10 mm above the top of the plates.

— Don't be carried away by open circuit voltage of the battery.

2.10 Renewal of Electrolyte

The following procedure may be adopted for renewal of the electrolyte of NIFE cells:

1. The voltage and specific gravity of the electrolyte in all alkaline batteries should be checked and re-recorded monthly.
2. The electrolyte of the cell should be renewed once in 18 months or when the specific gravity reaches the lower limit of 1160 at 15.6°C whichever is earlier.
3. The following precautions should be taken in determining the specific gravity:

   a) The electrolyte must be adjusted to the proper level and thoroughly mixed by giving the battery a full charge before a sample is taken for determining specific gravity.

b) The sample taken must be free from gas bubbles at the time of measuring the specific gravity.

c) The sample may be taken in a test tube of suitable size and an immersion hydromotor used to measure the specific gravity.

d) Correction should be made for temperature if readings of specific gravity are taken at temperatures other than of 15.6°C. To correct the observed results at any temperature to the standard temperature of 15.6° C one unit in the third decimal place is to be added for each two degrees Centigrade if the temperature is above the standard temperature, and substracted if below it. These corrections are approximately the same as for acid electrolyte used in lead acid cells.

e) The field officers should take every care to ensure that specific gravity readings are taken carefully and correctly.

2.11 Motor Generator Sets

Dampness or excessive temperature and humidity will,in time deteriorate the insulation of motor winding and grounds and short circuits will occur. All rotating machines should be kept clean and properly lubricated and a regular inspection schedule should be kept up. Normal schedule of inspection and maintenance of motor generators is given in Annexure-III.

2.11.01 Cleaning of Windings

Light, comparatively harm-less dust can be blown out with low pressure dry air, Grit, iron dust, carbon dust etc., should be removed by suction. Hose tips for either pressure or suction should not be of metal. Grease and oil can be removed by the conservative use of a solvent like carbon tetrachloride, which evaporates quickly. After cleaning, dirt can be blown out.

2.11.02 Drying of Windings

Dampness will be indicated by low insulation resistance. External heat can be applied under a canvas cover well ventilated. Heating should not go beyond 90°C. Current may be circulated through the windings by applying low voltage to the windings. This should be only a fraction of full load current and the temperature should not exceed 90°C.

2.11.03 Commutators

It is important that the commutator must be mechanically true, the unit in good balance and the brushes free to move up and down in the holders. The following mechanical features should be checked:

i) All connections should be tight.

ii) The brush spacing and alignment should be correct. The more accurate the brush spacing, the more uniformly good will be the commutation.

iii] There should be no burning or toughness of the contact surface.

iv) Correct brush pressure should be applied. Brush springs that have lost their tension should be replaced.

v) Check the centering of the commutator poles between the main poles and check both the main and commutating pole air gap.

The commutator surface should be clean and smooth and have a high polish. Oil, grease, etc., will create a motley appearance on the commutator surface film. The commutator surface should be wiped clean at regular intervals with a canvas wiper.

Detailed instructions for maintenance of commutator, brush and bearings of generators are given in Technical Instructions for the maintenance of electrical equipment. These instructions are applicable for motor generators also.

2.12 DC Leakage

The DC distribution system from the station battery which is unearthed caters to protective relays, breaker trip and close coils, remote operation of isolators, indication and alarm circuits. Since this system is the vital part of a substation, it is necessary to provide means for early detection and indication of earth fault in the DC system since a second earth fault may affect the DC system.

In old stations either the lamp system or the two voltmeter system for detecting the earth fault are adopted. In both the above cases, the operator on duty has to check for DC leakage in every shift. Continuous monitoring of the DC system of the battery is very essential and battery earth fault relays are now being provided in each substation which detect earth fault on either pole and initiate an alarm. The three types of battery earth fault relays which are now used are described below:

Scheme 1: (Fig. 2.1)

The scheme consists of a centre tapped resistor connected to battery terminals of an attracted armature relay with its relay coil connected between the centre point of the resistor and earth. When an earth fault occurs on the battery terminals or at any point on the auxiliary wiring, the fault current passes through the relay which operates and sounds an alarm.

The relay is of fixed setting and the value of the centre tapped resistor depends upon the battery voltage and operating current chosen. If the relay is made too sensitive, frequent operation in case of complicated DC auxiliary wiring, cannot be avoided.

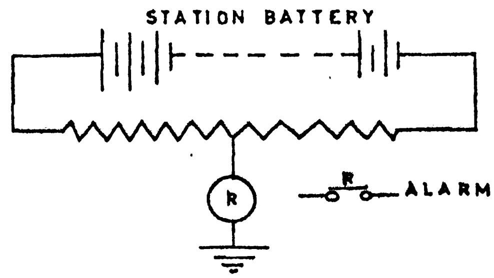


Fig. 2.1

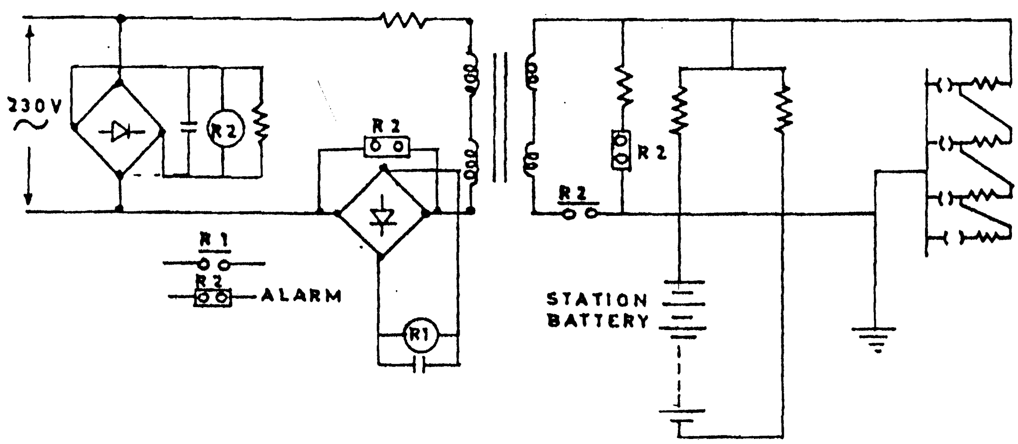


Fig. 2.2

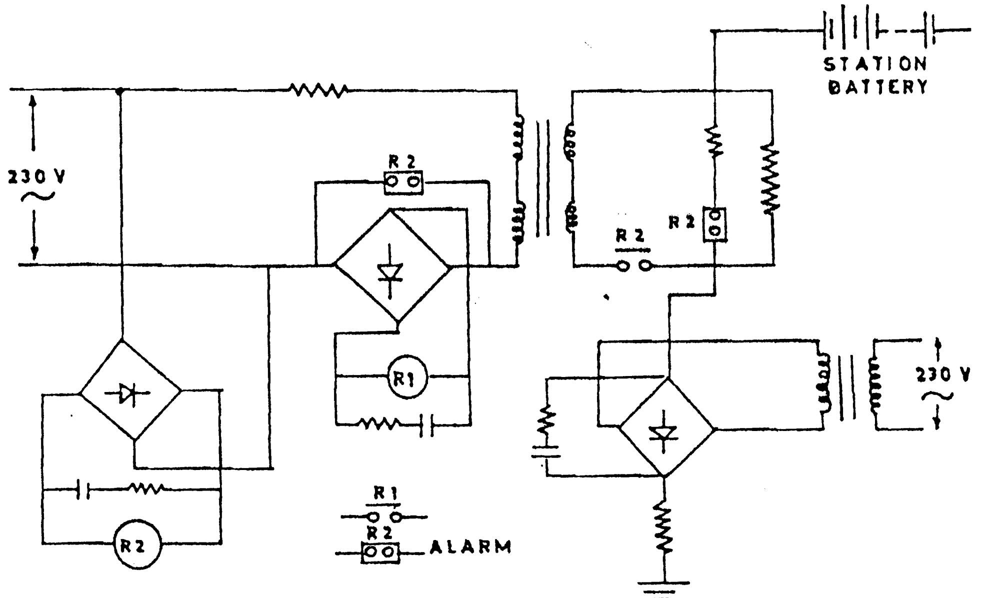


Fig. 2.3

Scheme 2: (Fig 2.2)

In another version various sensitivities are provided by means of plug bridge so that pick up current can be selected. This scheme operates with a transductor principle; under healthy condition no current flows through the DC windings and the AC windings which are connected in opposition present a high impedance and maximum voltage drop takes place across the A.C. windings as they are matched and connected in opposition, current or voltage on the AC side is not reflected on the DC side. In the event of an earth fault on any pole of the battery or wiring insulation failure, current flows on the DC winding. The core gets saturated and the impedence of the AC winding goes down, energising an auxiliary relay and sound an alarm.

Scheme 3: (Fig 2.3)

This scheme is based on the negative potential biasing principle which provides complete protection against corrosion. It enables both wires to be monitored and limit the earth fault current. Since in an insulated battery system if the coil of a protective relay is at a positive potential with respect to earth it results in electrolytic corrosion.

This scheme consists of a transductor, a transformer and a rectifier bridge for providing biasing, limiting resistor and auxiliary relays for alarm purpose.

The positive pole of the battery is earthed via the biasing circuit and limiting resistor. The AC windings of the transductor are matched and current or voltage on the AC side will not be reflected on the DC side. Under normal condition the DC system is biased below earth potential and high insulation resistance of the system prevents any significant current flowing on the DC side of the transductor. In the event of an earth fault or deterioration of insulation resistance to the appropriate level current flows in the DC winding of the transductor. This results in the saturation of the core which reduces the impedance of the AC winding and the auxiliary relay picks up and sounds an alarm.

2.13 Battery chargers

Normally two battery chargers are required one acting as stand by. In case of two sources of DC supply as is the case in 400 KV substations or thermal power stations, three battery chargers are provided. Battery chargers, being static normally require no maintenance except periodical cleaning of dust with blower.

2.14 Capacity Testing

Capacity test at the time of acceptance or within the first two years of service and once in 5 years thereafter are suggested to ensure that batteries are replaced at the appropriate time. Where there are two sets of batteries in a substation, this test can be done on one, putting the other to take care of the extra load, if possible. Where there is only one battery in a substation, this test is recommended in case of doubts about the usefulness of the battery after installing a standby battery. Generally, the schedule of capacity testing shall be followed only at stations having two Batteries.

2.14.01 Capacity Test Schedule

The following schedule of capacity tests is used to (1) determine whether the battery meets its specification or the manufacturer's rating, or both: (2)periodically determine whether the performance of the battery, as found, is within acceptable limits; and (3) if required, determine whetherthe battery as found meets the design requirements of the system to which it is connected.

2.14.02 Acceptance

An acceptance test of the battery capacity should be made either at the factory or upon initial installation as determined by the user. The test should meet a specific discharge rate and duration relating to the manufacturer's rating or to the purchase specification's requirements.

NOTE: Batteries may have less than rated capacity when delivered. Unless 100% capacity upon delivery is specified initial capacity can be as low as 90% or rated. This will rise to rated capacity in normal service after several years of float operation (vide ANSI/IEEE Std. 485.1983/4/).

2.14.03 Performance

i) A performance test of the battery capacity should be made within the first 2 years of service. Initial conditions shall be as described 2.14.05 omitting requirements. (a) and (b). Results of this test reflect all factors, including maintenance, that determin the battery capability. It is desirable for comparison purposes that the performance tests be similar in duration to the battery acceptance test. If on a performance test the battery does not deliverits expected capacity, the test should be repeated after the requirements of 2.14.05 has been completed.

ii) Additional performance tests should be given to each battery at 5 year intervals until it shows signs of degradation.

iii) Annual performance tests of battery capacity should be given to any battery that shows signs of degradation or has reached 85% of the service life expected for the application. Degradation is indicated when the battery capacity drops more than 10% of rated capacity from its capacity on the previous performance test, or is below 90% of the manufacturer's ratng:

iv) When a service test is also being used on a regular basis it will reflect maintenance practices, so the performance test can be modified to include the requirements of 2.14.05 (a) & (b). However, when the performance test is used in lieu of a service test, eliminate (a) & (b) of 2.14.05 so as to provide maintenance factors.

2.14.04 Procedure for Battery Capacity Tests

This procedure describes the recommended practice of capacity testing by discharging the battery.

2.14.05 Initial Conditions

The following list gives the initial requirements for all battery capacity tests. For performance tests when the results should reflect maintenance practices, omit requirements (a) & (b) below. The most stringent performance and service test conditions will be just proof to the scheduled equalizing charge.

(a) Verify that the battery has had an equalizing charge completed more than 3 days and less than 7 days prior to the start of the test.

(b) Check all battery connections and make sure that all connectors are clean, tight and free of corrosion.

(c) Read and record the specific gravity, and voltage of each cell just prior to the test.

(d) Read and record the temperature of the battery electrolyte for an average temperature (suggested every sixth cell)

(e) Read and record the battery terminal float voltage.

(f) Disconnect the charger from the battery.

(g) Take adequate precautions (such as isolating the battery to be tested from other batteries and critical loads) to ensure that a failure will not jeopardize other systems or equipment.

The practice recommended by ANSI/IEEE for capacity testing of Batteries is extracted in Annexure I

7. Replacement Criteria

The recommended practice is to replace the battery if its capacity as determined in para 4 is below 80 percent of the manufacturer's rating. The timing of the replacement is a function of the sizing criteria utilized and the capacity margin available, compared to the load requirements. Whenever replacement is required, the recommended maximum time for replacement is 1 year. A capacity of 80 per cent shows that the battery rate of deterioration is increasing even if there is ample capacity to meet the load requirements. Other factors, such as unsatisfactory battery service test results (see Para 5) require battery replacement unless a satisfactory service test can be obtained following corrective actions.

Physical characteristics, such as plate condition together with age, are often determinants for complete battery or individual cell replacements. Reversal of a cell as described in Para 3 (d) is also a good indicator for further investigation into the need for individual cell replacement. Replacement cells, if used, should be compatible with existing cells and should be tested prior to installation. Replacement cells are not usually recommended as the battery nears its end of life.

Failure to hold a charge, as shown by cell voltage and specific gravity readings, is a good indicating for further investigation into the need for replacement.

8. Records

Data obtained from inspections and corrective actions are important to the operation and life of the batteries. Data should be recorded at the time of installation and as specified during each inspection. Data records should also contain reports on corrective actions and on capacity and other tests indicating the discharge rates, their duration, and results.

TABLE 1
Discharge Current Correction Factor K (for Temperature)

Initial (°C)	Temperature (F)	Factor K
-3.9	25	1.520
-1.1	30	1.430
1.7	35	1.350
4.4	40	1.300
7.2	45	1.250
10.0	50	1.190
12.8	55	1.150
15.6	60	1.110
18.3	65	1.080
18.9	66	1.072
19.4	67	1.064
20.0	68	1.056
20.6	69	1.048
21.1	70	1.040
21.7	71	1.034
22.2	72	1.029
22.8	73	1.023
23.4	74	1.017
23.9	75	1.011
24.5	76	1.006
25.0	77	1.000
25.6	78	0.994
26.1	79	0.987
26.7	80	0.980
27.2	81	0.976
27.8	82	0.972
28.3	83	0.968
28.9	84	0.964
29.4	85	0.960
30.0	86	0.956
30.6	87	0.952
31.1	88	0.948
31.6	89	0.944
32.2	90	0.940
35.0	95	0.930
37.8	100	0.910
40.6	105	0.890
43.3	110	0.880
46.1	115	0.870
48.9	120	0.860
51.7	125	0.850

NOTE: This table is based on nominal 1.210 specific gravity cells. For cells with other specific gravities refer to the manufacturer. The manufacturers recommend battery testing be performed between 65°F and 90°F.

ANNEXURE - I

ANSI/IEEE
Std. 450-1987

Recommended practice for capacity testing of batteries

1. Test Length

The recommended procedure is to make a capacity test for approximately the same length of time as the critical period for which the battery is sized. See para 5 for test length of the service test.

2. Discharge Rate

The discharge rate depends upon the type of test selected. For the acceptance test or performance test the discharge rate should be a constant current load equal to the manufacturer's rating of the battery for the selected test length. See para 5 for the test discharge rate of the service test.

Note that the test discharge current is equal to the rated discharge current divided by K, where K is the discharge current correction factor for the initial electrolyte temperature. See Table I.

3. Acceptance and Performance Test

Set up a load with an ammeter and a voltmeter with the provisions that the load be varied to maintain a constant current discharge equal to the rating of the battery at the selected rate (see para 2)

(a) Connect the load to the battery, start the timing, and continue to maintain the selected discharge rate.

(b) Maintain the discharge rate until the battery terminal voltage decreases to a value equal to the specified average voltage per cell (usually 1.75 V) times the number of cells.

(c) Read and record individual cell voltages and the battery terminal voltage. The readings should be taken while the load is applied at the beginning and the completion of the test and at specified intervals. There should be a minimum of three sets of readings.

NOTE: Individual cell voltage readings should be taken between respective posts of like polarity of adjacent cells, so as to include the voltage drop of the intercell connectors.

(d) If an individual cell is approaching reversal of its polarity (plus 1 V or less) but the terminal voltage has not yet reached its test limit, the test should be continued with a jumper across the weak cell. Complete the Jumper connection away from the cell to avoid arcing near the cell. The new minimum terminal voltage should be determined based on the remaining cells [(see para 3 (b)]

NOTE: The possibility of a weak cell (s) should be anticipated and preparations made for jumpering the weak cell with minimum hazard to personnel.

(e) Observe the battery for intercell connector heating.

(f) At the conclusion of the test, determine the battery capacity according to the procedure outlined in para 4.

4. Battery Capacity

For an acceptance or performance test, use the following equation to determine the battery capacity:

$$\% \text{ capacity at } 25^{\circ}\text{C } (77^{\circ}\text{F}) = \frac{Ta}{Ts} \cdot 100$$

where

Ta	=	actual time of test to specified terminal voltage [see Para 3 (b)]
Ts	=	rated time to specified terminal voltage.

5. Service

A service test is a special battery capacity test which may be required to determine if the battery will meet the design requirements (battery duty cycle) of the system. The system designer should establish the test procedure and acceptance criteria prior to the test. Recommended procedure for the test is:

(1) The initial conditions shall be as identified in 2.14.05 [omit items a and b]

(2) The discharge rate and test length should correspond as closely as is practical to the design requirements (battery duty cycle) of the dc system.

(3) If the battery does not meet the design requirements of the dc system, review its rating to see if it is properly sized, equalize the battery, and, if necessary, inspect the battery, take necessary corrective actions, and repeat service test. A battery performance test may also be required to determine whether the problem is the battery or the application.

6. Restoration

Disconnect all test apparatus. Recharge, equalize if necessary, and return to normal service.

ANNEXURE - II

Schedule of maintenance-lead acid batteries

S.No.	Item of maintenance work	Periodicity
1.	Earth fault indicating device-check reading of D.C. voltage	Every shift
2.	Pilot cell voltage specific gravity and temperature of electrolyte	Every shift
3.	Battery cell voltages, specific gravity and temperature of electrolyte and cadmium test results	Weekly
4.	Equaliser charge	Quarterly or when the specific gravity falls by 40 points whichever is earlier
5.	Inspection testing of battery, relays, check up of instruments.	Annual
6.	Checking control cables for continuity and insulation resistance.	Quarterly

ANNEXURE – III

Schedule of Maintenance-Motor Generators

S.No.	Item of Maintenance work	Periodicity
1.	Feel ball and roller bearing housing for evidence of vibration and listen for any unusual noise.	Weekly
2.	Examination and cleaning of commutator surface, checking of brushes in holders for fit and free play and examination of brush faces for chipped toes.	Monthly
3.	Check coupling and other drive details. See if belt runs steadily and close to motor edge of pulley, clean inside of chain housing.	Monthly
4.	Field Rheo Movement, I.R. value of winding, cleaning of surface and ventilation passages thoroughly.	Yearly
5.	Inspection of rotors and checking of air gap.	Yearly

MAINTENANCE OF BATTERIES

MONTH	Whether monthly/Weekly* maintenance done (Yes/No)				Reason for slippage	Whether overhaul done as per Schedule (Yes/No)	Reason for slippage
	W1	W2	W3	W4			
April							
May							
June							
July							
August							
September							
October							
November							
December							
January							
February							
March							

* Weekly for Lead Acid Batteries. Monthly for Nife Cells

POWER TRANSFORMERS

3
Power Transformers

CONTENTS

3. INSPECTION AND MAINTENANCE OF POWER TRANSFORMERS

3.01 General

Certain items in a transformer require regular inspection and immediate and prompt remedial action wherever necessary. Failure of regular inspection may lead to conditions which will put the normal life of the transformer into jeopardy. The frequency of inspection and maintenance has to be determined depending on the size and importance of continuity of service. Local environmental conditions like climate, atmospheric conditions such as ambient temperature, pollution etc. shall also be taken into consideration when working out inspection and maintenance schedule.

3.02 Classification of Transformers

Identification of Transformers according to cooling method and permissible temperature rise: There have been major revisions in regard to classification of cooling and permissible temperature rise for transformers between BS 171-1959 and BS 171-1970. There are also variations from BS 171-1970 and IS 2026-1977. As the transformers made according to BS 171-1937 and BS 171-1959 are also in service in the Board, classification and temperature rise limits are furnished as per BS 171-1959 as well as BS 171-1970. The field engineers should adopt appropriate values depending upon the date of manufacture of the transformers as indicated in the name plates.

Important

The Board was placing orders for transformers conforming to BS 171, except with the modification that the maximum ambient temperature is 45°C instead of 40°C specified in BS. As per clause 18 of BS 171 the permissible temperature rise indicated in BS should be reduced by 5°C for taking into account, the higher ambient temperature.

3.02.01 *Classification and Temperature-rise limits as per BS 171-1959*: The classification of transformers according to different methods of cooling and the recognised abbreviation for each class, is given in Table 1. In the table of symbols 'O' is used to indicate mineral oil complying with B.S. 148 applicable to 'Insulating oil for transformers and switchgear'.

TABLE 1 - METHODS OF COOLING

Type of Transformer	Oil circulation	Cooling Method	Abbreviation Mineral Oil
	Natural Thermal head only	Air natural	ON
		Air blast	OB
		Water	OW
Oil Immersed	Forced by Pump	Air natural	OFN
		Air blast	OFB
		Water	OFW

For oil immersed type transformers built with a combination of natural and forced cooling the following are typical additional abbreviations:

ON/OB ON/OFN ON/OFB ON/OFW

TABLE 2 - TEMPERATURE RISE LIMITS FOR OIL IMMERSED TYPE TRANSFORMER AS PER BS 171-1959

1	Cooling Classification 2	Temperature rise centigrade degrees 3
Winding (measured by resistence)	ON,OB,OW	60
	OFN, OFB	65
	OFW	70
Oil (measured by thermometer)	All	50
Cores	Cores shall be designed so that the temperature rise on any part of the external surface does not exceed that of the windings but it is recognised that it is not practical to make measurements during commercial tests.	

3.02.02 Classification and temperature rise limits as per BS 171-1959 are given in Table 2. Transformers shall be identified according to the cooling method employed. Letter symbols for use in connection with each cooling method shall be as given in Table 3.

TABLE 3 - LETTER OF SYMBOLS

Kind of cooling medium	Symbol
Mineral oil	O
Synthetic insulating liquid	L
Gas	G
Water	W
Air	A
Solid insulant	S

KIND OF CIRCULATION	
Natural	N
Forced	F

With the exception of dry-type transformers in protective enclosures, for which the symbols shall be 'AN' or 'AF' as appropriate, transformers shall be identified by four symbols for each cooling method for which a rating is assigned by the manufacturer. An oblique stroke shall be used to separate each group of symbols.
The order in which the symbols are used shall be as given in Table 4.

TABLE 4 - ORDER OF SYMBOLS

1st letter	2nd letter	3rd letter	4th letter
Indicating the cooling medium that is in contact with the windings.		Indicating the cooling medium that is in contact with the external cooling system.	
Kind of medium	Kind of circulation	Kind of medium	Kind of circulation

For example, an oil-immersed transformer with forced oil and air circulation would be designated 'OFAF', whereas a dry type transformer with cooling fans would be designated 'AF'. For oil immersed transformers in which the alternatives of natural or forced cooling are possible, typical designations are:

ONAN/ONAF ONAN/OFAF

For convenience of reference, some of the old classifications according to BS 171-1959 and the corresponding equivalent in BS 171-1970, are indicated below:

BS 171-1959	BS 171-1970
ON	ONAN
OB	ONAF
OFB	OFAF
OFW	OFWF
ON/OB	ONAN/ONAF
OW/OFB	ONWF/OFAF

TABLE 5 - TEMPERATURE RISE LIMITS FOR OIL IMMERSED TYPE TRANSFORMERS AS PER BS 171-1970

Part 1.	Cooling Method 2.	Oil circulation 3.	Temperature Rise deg.C. 4.
Winding temperature	Natural air Forced air water (internal coolers)	Natural	65
Class A (Measured by resistance)	Forced air Water (external coolers)	Forced	65
Top oil (measured by thermometer)			60, When the transformer is sealed or equipped with conservator. 55, When the transformer is not so sealed or equipped, with conservator
Cores and other parts			The temperature in no case to reach a value that will injure the core itself or adjacent materials.

TEMPERATURE-RISE

NOTE: The temperature rise limits in Table 5 are based on the following temperature of cooling media:-

For oil cooled apparatus, air temperature never exceeding 40° or below 26°C.

For water cooled apparatus, cooling water with temperature not exceeding 25°C at the inlet. In addition, for air cooled apparatus, the air temperature should not exceed 30° average in any one day 20° average in any year.

Reduced temperature rises for transformer designed for higher cooling medium temperatures

If the transformer is designed for service where the temperature of the cooling medium exceeds one of the maximum values shown by not more than 10°C, the allowable temperature rise for the windings, cores and oil shall be reduced:-

- By 5°C, if the excess temperature is less than or equal to 5°C.
- By 10°C, if the excess temperature is greater than 5°C and less than or equal to 10°C.

3.02.03 Classification and Temperature-rise limits as per IS 2026-1962

Temperature-rise of transformer windings, oil and cores shall not exceed the limits prescribed in Table 6 when tested in accordance with 17.13 of IS 2026-1962.

For water cooled transformer, the temperature-rise given is that measured above the inlet water temperature. For other types of cooling, the temperature-rise given is that measured above the temperature of the cooling air.

Combined Cooling of Oil-immersed Transformer

Where combined cooling is specified, the limits of temperature-rise at the ON rating shall be the same as for ON cooling and at the OB, OFN, OFB or OFW rating the same as for OB, OFN, OFB or OFW cooling respectively in accordance with the values given in Table 6.

TABLE 6 – TEMPERATURE RISE LIMITS FOR OIL IMMERSED TYPE TRANSFORMERS

	Cooling Classification	Temp. Rise °C
Windings (measured by resistance)	ON, OB, OW	55
	OFN, OFB	60
	OFW	65
Oil (measured by the thermometer in top oil)	All	45

CORES: Cores shall be so designed that the temp-rise on any part of the external surface does not exceed that of the windings as determined by the formula in 17.13.8. of I.S.2026-1962. It is recognised that it is not practicable to make measurements during commercial tests.

Reference Ambient Temperatures

The reference ambient temperature assumed for the purpose of this I.S. specification are:

a) Max. ambient air temp. 45°C

b) Max. daily average ambient air temp. 35°C

c) Max. yearly average ambient air temp. 30°C

3.02.04 Classification and Temperature-rise limits as per IS 2026-1977

Transformers are classified according to the kind of cooling media adopted and the type of circulation of the cooling media adopted, taking into consideration, the cooling media in contact with the windings and the cooling media in contact with the external cooling system. Letter symbols which are used in connection with the cooling method are given in Table 7.

TABLE 7 - LETTER SYMBOLS

			Symbol
(i)	Kind of cooling Medium		Symbol
	a)	Mineral oil or equivalent flammable synthetic insulating liquid	O
	b)	Non-flammable synthetic insulating liquid.	L
	c)	Gas	G
	d)	Water	W
	e)	Air	A
(ii)	Kind of circulation		
	a)	Natural	N
	b)	Forced (oil not directed)	F
	c)	Forced (directed oil)	D

The transformers could be identified by four symbol for each cooling method for which a rating is assigned by the manufacturers. The order in which the symbols are used shall be as given in Table 8. Oblique strokes shall be used to separate the group symbols for different cooling methods.

TABLE 8 - ORDER OF SYMBOLS

1st Letter	2nd Letter	3rd Letter	4th Letter
Kind of cooling. Medium indicating the cooling medium that is in contact with the windings.	Kind of circulation	Kind of cooling medium indicating the cooling.	Kind of circulation Medium that is in contact with the external cooling system.

Transformers with forced circulation of oil have special baffles provided in the tank to specifically direct the circulation against the windings.

New Classification	Old Classification
ONAN	ON

Limits of Temperature-rise

The limits of temperature-rise for oil immersed type of transformers as per IS 2026-1977 are given in table 9.

The reference ambient temperature assumed for the purpose of specification, are as follows:

a) Maximum ambient air temperature 50°C

b) Maximum daily average ambient air temperature 40°C

c) Maximum yearly average ambient air temperature 32°C

d) Minimum ambient air temperature 5°C

e) When the cooling medium is water, it is assumed that a temperature of 30°C will not be exceeded and the average cooling water temperature will not exceed 25°C in any day. The above temperature-rise limits are for transformers operating at an altitude not exceeding 1000 metres above sea level.

TABLE 9 – TEMPERATURE-RISE LIMITS FOR OIL IMMERSED TYPE TRANSFORMERS

Sl. No.	Part	Temperature Rise External Air	Cooling Medium Water
i)	Windings (Temperature-rise measured by resistance method)	55, When the oil circulation is natural or forced non-directed.	60, When the oil circulation is natural or forced non-directed.
ii)	Temperature class of insulation-A	60, When the oil circulation is forced directed	65, When the oil circulation is forced directed.
iii)	Top Oil (Temperature-rise measured by thermometer)	50, When the transformer is equipped with a conservator or sealed.	55, When the transformer is equipped with conservator or sealed.

Sl. No.	Part	Temperature Rise External Air	Cooling Medium Water
		45, When the transformer neither equipped with a conservator nor sealed.	50, When the transformer is neither equipped with a conservator nor sealed.
iv)	Cores metallic parts and adjacent materials.	The temperature shall in no case reach a value that will damage the core itself, other parts or adjacent materials.	The temperature shall in no case reach a value that will damage the core itself, other parts or adjacent materials.

NOTE: The temperature-rise limits of the windings (measured by resistance method) are chosen to give the same hot spot temperature-rise with different types of oil circulation. The hot spot temperature-rise cannot normally be measured directly. Transformers with forced directed oil flow have a difference between the hot-spot and the average temperature-rise in the windings which is smaller than that in transformers with natural or forced but not directed oil flow. For this reason the windings of transformers with forced directed oil flow can have temperature-rise limits (measured by resistance method) which are 5°C higher than in other transformers.

3.03 Maintenance Procedures

3.03.01 Power Transformer Maintenance Schedule

The Maintenance of the power transformers shall be carried out as per the schedule furnished in Table 10.

TABLE 10 – POWER TRANSFORMER MAINTENANCE SCHEDULE

H-Hourly	PA-Pre-arranged shutdown
SH-Once a shift	M- Monthly
D-Daily	Q-Quarterly
W-Weekly	SA-Semi annually
Y-Yearly	BA-Biannually (once in 2 years)

ITEMS TO INSPECT		SCHEDULE
	Ambient temperature	H
	Winding temperature	H
	Oil Temperature	H
	Check for unusual noise	SH
	Oil level in transformer: Conservator	
i)	Transformer	SH
ii)	OLTC	SH
	Oil level in bushing	SH
	Leakage of water into cooler	SH
	Relief Diaphragm	D
	Colour of silicagel in Breather	D
	Cleaning of Bushing	M/PA
	Reconditioning of Breather	M
	Checking oil level in oil-seal in Breather and renewing if required	M
	Checking temperature and water flow alarm	M/PA
	Check of air release Valve	Y
	Relays, alarms and circuits	Y
	Meggering	M
	Check for gas accumulation	M
	Measurement of Resistance of all earth pits both individual and combined	Q
	Check earth connection	Q
	Surge diverters and gaps in bushings	SA
	Tan delta and capacitance of bushings (where test cap is provided)	Y
	Greasing of motor bearing	PA
	Detailed inspection	A

ITEMS TO INSPECT	SCHEDULE
Automatic Gas Seal Equipment	
1. Pressure Gauge	D
2. Gas cylinder content	D
Water Cooling Equipment	
1. Water temperature	SH
2. Water flow	SH
3. Pressure Test	Y
Forced Air Cooling Equipment	
Fans	M
Radiator core	A
On-load Tap Changer	
1. Oil level in Tap changer conservator	D
2. Diaphragm plate of explosion vent	D
3. Spare heater in driving machanism	D
4. No. of tap-changing operations carried out	D
5. Dielectric strength of oil used in Divertor switch chamber	Q
6. Checking for oil leak in the gasket joints	Y
7. Checking for oil leak from the 'O' rings in the Bevel gear box.	Y
8. Greasing (to prevent rusting) of universal joints and other driving shaft parts which are not painted but in contact with air.	Y
9. Cleaning of gas vent on the conservator	Y
10. Checking for correct working of gas and oil operated relay	Y
11. Cleaning and replacement of auxiliary relays and contacts to prevent chattering and to ensure their proper working.	Y

ITEMS TO INSPECT		SCHEDULE
12.	Checking of time setting of timer relays	Y
13.	Checking of control cable connections	Y
14.	Checking of lubrication oil level in the gear box of driving mechanism.	Y
15.	Electrical resistance of driving mechanism	Y
16.	Checking thickness of arcing contacts in the Divertor switch contact compartment.	After 50,000 operations or every 5 years after commissioning whichever is earlier.
17.	Checking tap selector for electric discharges on the surface of insulators, conditions of fasteners, moving and stationary contacts, smooth operation of gears and other moving parts.	10 years

Oil

For transformers of voltage class 110 Kv and above.

Oil samples from Main tank will be tested.

(i)	B.D.V. of Transformer oil	Q
(ii)	Resistivity	Y
(iii)	Power factor of oil	Y
(iv)	Interfacial tension	Y
(v)	Acidity and sludge	Y
(vi)	Flash point	Y
(vii)	Dissolved Gas Analysis	Y
(viii)	Water content	Y

OIL IN OLTC: BDV to be checked — Q

(Tap Changer Maintenance Schedule Item 5)

For Transformers of voltage class less than 110 KV

(i) B.D.V. of Transformer oil and oil in O.L.T.C. — Q

NOTE:

(i) Spare transformers should be inspected and maintained in the same manner as transformers in operation.

(ii) Ensure that equalising valve between main tank and conservator is kept in open position. All radiator valves shall also be in open position.

(iii) Oil samples from main tank bottom shall be sent to Transformer oil Testing Lab of R&D Wing Madras in case of Power/Auto Transformers of voltage class 110KV and above and from power/Auto Transformers in Generating Stations.

3.03.02 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.

3.03.03 External cleaning

Keep heat radiating surfaces of the transformer clean. The transformers especially those near the sea coast should be kept painted to prevent corrosion or rusting of metal parts.

Use an oil solvent to thoroughly remove oil that has got on the outside of the tank or on gaskets, in the next available shutdown after the leak occurs. Otherwise, this oil later showing up on the painted surface gives a false impression of a leak.

3.03.04 Breather

There are generally two types of breathers used on a transformer.

a) Plain breather and

b) Silicagel breather

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.

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 into a shallow tray. The crystals should be baked 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. It is a good practice to change the silicagel in the breather when the power transformer is "Breathingout".

3.03.05 Temperature Indicators

The temperature indicators should be calibrated once a year and the operation of the temperature alarms checked. Any variation in temperature of oil or winding temperature from the figures observed earlier in operations should be checked and causes for the variation investigated. Any rise in the operating temperature without corresponding increase in load should also be investigated.

3.03.06 Noise

Unusual noise arising due to electric arcs or oil gurgling or overly loud magnetic noise,if observed should be immediately investigated. Excessive vibration of radiator tubes should be rectified by tightening the loose/vibrating parts.

3.03.07 Oil Level

The oil level varies with the oil temperature. The indicator generally shows the 'cold' level when the oil is at a temperature of about 30°C. To find out the correct oil level therefore, it should be checked when the transformer has been off load for some hours. The transformer should be topped up, when necessary with tested transformer oil. If the level drops appreciably over a short period, the tank should be checked for leaks. A leaking gasket may be remedied by tightening the bolts. If this is not sufficient, the gasket should be replaced. In case the seal on the tapping switch is leaky, the manufacturer should be consulted and in case there is a leak on a welded joint, it should be rewelded.

3.03.08 Gaskets

Check all gaskets. The golden rule for gaskets is when in doubt, install a new one.

However, changing of the gasket is a specialised work, it is necessary that assistance of the territorial special Maintenance or the nearest Transformer-Erection Staff is sought for without any delay.

It is desirable that this is not attempted by the Maintenance staff who may not be trained or acquainted with handling such work.

3.03.09 Bushings

Bushings should be inspected at regular intervals and kept free from dust and dirt. Wherever abnormal conditions like salt deposits, cement dust, acid fumes etc. may pollute the atmosphere and create a special hazard, the bushing should be cleaned regularly to avoid accumulation on the external surface which will result in flash over if unattended. Clean bushings with water or carbon tetrachloride.

Wherever shut down is not feasible, seek the assistance of nearest hot-line staff and have the bushing washed and cleaned under live line conditions since they have hot-line washing kits.

When they are clean, inspect closely for cracks, pin holes or chipping.

Chipped parts have to be repaired by painting or filling up with Litharge cement or glyptol lacquer. It is preferable that this is done by either transformer erection or special Maintenance staff.

If the chipping or cracking is not safe and leakage is observed action should be taken to replace the bushing by the Transformer erection staff.

If this is an EHT Bushing, tan Delta is to be measured to safeguard and ensure satisfactory condition. This is to be got done by the R&D staff.

If the bushing is provided with horn gaps, check the gap setting and ensure that it is kept as per specifications.

3.03.10 Diaphragm

Check that the relief diaphragm is in good condition. The non shattering type of diaphragm should be checked to see that it is not stuck due to rust or paint. The shattering type of diaphragm should be checked to ensure that the material used is not too thick (about 0.4 mm is the normal thickness). Be sure that there is no foreign material or moisture in horizontal diaphragm.

3.03.11 Earth connection

All ground bus and all wiring leads to the ground from arrester, transformer tank and from neutral (if neutral is earthed) must be kept in good condition and periodically checked. All connections must be checked for looseness and tightened where necessary. Climatic conditions will determine the inherent characteristic of the ground. Relay operation in a system depends on the ground resistance being low at all times. A low ground resistance is of such importance that it should be measured quarterly and steps taken to keep it as low as possible.

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

3.03.12 Alarms and indicators: Check oil level indicators and relays for proper operation. Calibrate the temperature indicators and check up operation of temperature alarms.

Check operation of water flow alarm indicator and relays for proper action. Examine and clean relay contacts. Check that the pressure gauges are indicating properly.

Check setting and operation of relays on the transformers.

3.03.13 Circuits and Control Equipments

Inspect monthly the following:

1. Control circuit voltage
2. Excess heating of power contacts as evidenced by discolouration of metal parts, charred insulation or burnt out smell (odour)
3. Free Movement of moving parts.
4. Corrosion of metal parts.
5. Extent of wearing observed on contacts (whether any allowance is available or the contact has to be changed immediately).
6. Loose connections and proper contacts.
7. Condition of shunt resistance used (heated up or colour changed or burnt out etc).
8. General condition of all the moving parts (wornout or broken requiring replacement or satisfactory)
9. Condition of the A.C. contactors.
10. Condition of the air breaking circuits (contact pitting etc)
11. Contamination of the control circuits with oil or water.
12. Operation of timing devices, sequencing devices etc.

3.03.14 Cleaning of Control Equipments

Grease, oil or dirt may be removed with a dirt free cloth moistened in a noninflammable cleaning liquid. But do not soak the parts with a cleaner. But use just enough to remove grease or dirt so that it can be white. For cleaning small parts, a small brush dipped into the cleaning solution is good for getting into the corners and crevices.

3.03.15 Fuses and Control Wiring

Inspect all fuses on all control and alarm circuits and on power supplies to auxiliary and control equipment and devices. Check and tighten wiring connections to all terminal points. Inspect all wirings for open circuit, short circuits and damaged insulation. Check insulation resistance of all wiring to equipment and devices connected.

3.03.16 Power Connections

Check and tighten all main power connections to the transformer. Whenever tube connections are used ensure that there is provision for free thermal expansion of the tube so that stresses are avoided on the bushings.

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 blue tinge which indicates it has been hot, then in most cases the connections shall not be considered satisfactory. Either it has become loose or dirty, or the conductor is not suitable for carrying the current.

3.03.17 Gauge Glass and Vents

Clean the gauge glasses and connection to the tank. Check that screen and baffles in vents and breathers are not obstructed or broken.

3.03.18 Pumps and Motors

Examine all pumps and motors and check for proper operation and control.

3.03.19 Buchholz Relay connections

In the case of power transformers and boosters which are provided with O.C.B.S. for complete isolation, the contacts operated by the upper float of the Buchholz relay should be connected to an alarm signal and the contacts of the lower float to trip the concerned circuit breaker.

For transformers and boosters having no circuit breakers on the supply side, both the upper and lower float contacts should be connected to indicating lamps and alarms as below:

(a) Upper float contact to be connected to an yellow lamp to indicate faults in the incipient stages.

(b) The lower float contact to be connected to a red lamp to indicate major faults inside the transformer.

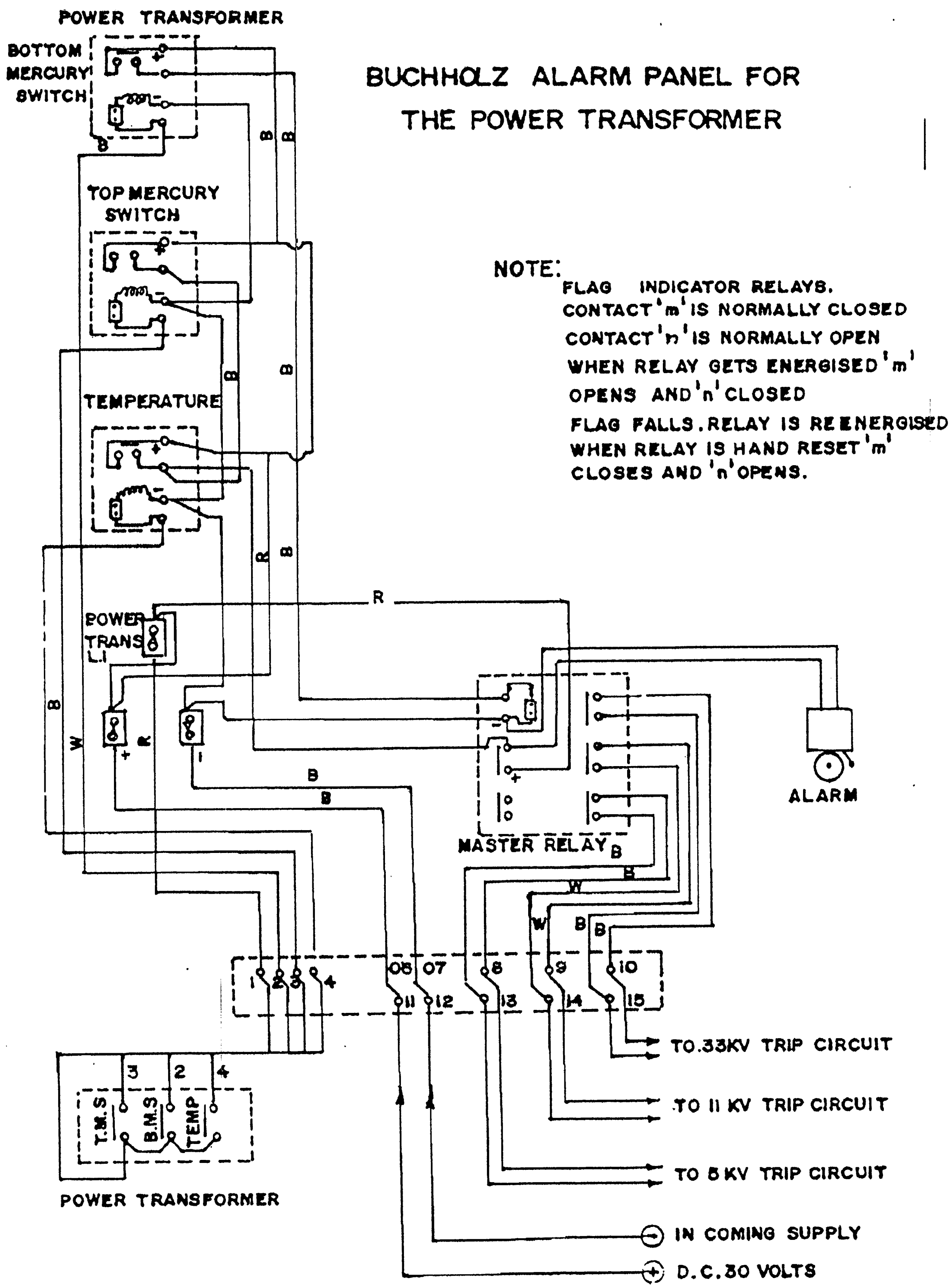

BUCHHOLZ ALARM PANEL FOR
THE POWER TRANSFORMER
POWER TRANSFORMER
BOTTOM MERCURY SWITCH
TOP MERCURY SWITCH
TEMPERATURE
POWER TRANS L.1
NOTE:
FLAG INDICATOR RELAYS.
CONTACT 'm' IS NORMALLY CLOSED
CONTACT 'n' IS NORMALLY OPEN
WHEN RELAY GETS ENERGISED 'm'
OPENS AND 'n' CLOSED
FLAG FALLS. RELAY IS REENERGISED
WHEN RELAY IS HAND RESET 'm'
CLOSES AND 'n' OPENS.
MASTER RELAY
ALARM
TO 33KV TRIP CIRCUIT
TO 11 KV TRIP CIRCUIT
TO 5 KV TRIP CIRCUIT
IN COMING SUPPLY
D.C. 30 VOLTS
T.M.S
B.M.S
TEMP
POWER TRANSFORMER

Fig. 3.1

(c) Both the lamp circuits to be connected in series with an alarm of suitable voltage rating so as to sound if any one of the relay contacts closes.

(d) Two push buttons A & B included in the circuit may be operated once every shift to make sure that the bell and the lamps are sound. This is to ensure that there is no risk of any of the lamps getting fused during the period of the shift as the lamps will not normally be burning-

A schematic diagram of connection is given in fig 3.1.

NOTE: In the event of the alarm device acting where there are no O.C.B.S. on the supply side, the operator should immediately trip off the feeders fed by the transformer and then get in touch with the station having the circuit breakers controlling the supply and get them opened out. He should not isolate the transformer/booster by opening the AB switch on the supply side before the supply to the transformer is cut off.

3.03.20 Buchholz Relay-Examination of Gas

Examine the relay to see if any gas is collected. In case of gas collection note and record the quantity of gas collected. A colourless accumulation usually indicates the presence of air, but always a small quantity should be released and the smell noted.

Follow the instructions for testing of gas accumulated in Buchholz relays. (Annexure IV)

ii. Check operation of Buchholz relay by injecting air at the petcock of the relays.

NOTE: A suitable testing equipment can be rigged up with a small air container with a pressure gauge a length of rubber tubing and a suitable gas thread connection. The air container should be charged to a pressure of 0.35 Kg. per sq.cm. or sufficient to inject air against the head of oil. By opening the petcock slowly air can be bubbled into the gas chamber to check operation of the top float. To check the operation of the surge float, the air container must be charged to a higher pressure and the petcock suddenly opened.

This must be repeated with successively lower pressures to find the minimum operating pressure. After each test, the air accumulated in the gas chamber must be released through the upper petcock to ensure that the chamber is full of oil.

A mechanical inspection of the relay may be made after bringing down the oil to the necessary level and removing the internal assembly of the unit. Check that the floats rise and fall freely and that the switches are in good condition.

Check operation of the Buchholz relay by pumping air at the petcock of the relays. For this purpose, the valve on the conservator side will have to be kept closed. After checking the operation of the relay as above, open the valve on the conservator side and release the air accumulated inside the Buchholz relay by opening the petcock gradually until only oil found to come out of the petcock. The petcock should be closed immediately.

In case the Buchholz relay acts during service conditions, action must be taken as follows:

(a) Immediately on actuation of the Buchholz relay the transformer should be isolated and tested in detail. Any gas available in the Buchholz chamber should be subjected to the chemical tests as per instructions.

(b) Whether gas collection is observed or not the transformer should be tested by the territorial MRT staff and specific comments of the MRT got recorded. The MRT staff should analyse their observations with reference to the pre-commissioning test results and furnish their comments. All the prescribed tests must be conducted by the MRT staff.

(c) The special Maintenance staff should immediately arrange for testing the oil. All the test results must be properly recorded with specific comments.

(d) Every power Transformer should have its History Register available in the sub-stations where it is in service.

Relevant Test reports and the corresponding comments as and when furnished by MRT, GRT, Special maintenance or Transformer Erection Staff should form part of the History Register.

(e) Buchholz relay action should not go without proper intimation and recording. Every occurrence should be recorded in a separate register and maintained properly. Immediate intimation about the occurrence should be given to all concerned.

(f) For every Buchholz action in a Power Transformer, the oil must be got tested for "Dissolved Gas Analysis" and the test values recorded.

(g) Similarly for every Buchholz action, arrangements must be made for the chemical test of the gas (as per instructions) immediately. Otherwise, if the gas is left for a long time in the Buchholz relay, some constituents of the gas may dissolve in the oil modifying the composition of the gas originally collected in the Buchholz Chamber, leading to misconception about the happenings inside the transformer.

(h) In several cases, it is seen that the significance of measurement of magnetising current in power transformers is not appreciated. It is desirable that the measurements are made on both H.T. & L.T. sides on all the phases, and recorded properly whenever there is an occasion for testing the transformer. A comparative study of these values over an extended period will provide a definite pointer to the condition of the core and the windings of the transformer.

3.03.21 Foundation

Check for cracking and settling. Slight shift of transformer may damage the bushing or connecting oil/water piping. Check the rail stops to see that they are firmly in place to hold the transformer in position on the rails.

3.03.22 Oil Piping

Check the piping valves and plugs. Manipulate radiator cut off valves to see that they are in a good operating condition and are secured in the open position. Check that all drain valves which are operated without wrenches are plugged or locked.

See that all valves which are to be kept open during operation of the transformer are given a red paint and that the valves which are to be kept closed are given a Blue paint.

Have all the valves checked by Special Maintenance/Transformer erection wherever possible so that their satisfactory condition is ensured.

3.03.23 C.W. Pipings

Check cooling water and drain piping for leaks. Test cooling coils for leaks by applying air pressure to the coils and observing for bubbles rising in oil. If water scale is present, circulate a solution of 10% hydrochloric acid and water (mixed in the ratio of one litre of acid to nine litres of water) through the coils until they are clean. Then flush out thoroughly and clean external surface of coils.

Ensure always that the pressure of the oil inside the transformer is higher than the cooling water. Usually a positive difference of about 0.5 Kg/Sq.cm. is to be maintained. This is to ensure that cooling water does not enter into the transformer tank under any circumstances.

3.03.24 Fans

Fans should be checked at monthly intervals to clean the blades of any accumulation of dirt. The ball bearings of the motor should be lubricated yearly or earlier if necessary with the appropriate type of grease approved by the manufacturer. Do not add the grease while the fans are running.

If it is necessary to remove the fan blades, a blade puller should be used to prevent damage to the blades. Always ensure that the fans blow air on the transformer radiator.

3.03.25 Heat Exchanger

The Heat Exchanger surface on air blast cooler can be cleaned by directing a stream of water over the surfaces. The fans should be switched off and a stream of water jet directed to the rear side of the radiator to wash any dirt.

3.03.26 Painting

Paint metal work of transformer as needed. As already pointed out repaint all the valves to be kept open with red paint and the valves to be kept closed with blue paint wherever necessary so that the colour is distinctly visible without any fading.

3.04 On-load Tap Changer

On load tap changer facilitates changing of secondary voltage without interrupting the load current. The principle parts of the on-load tap changer are:

i) Diverter switch oil tank.
ii) Diverter switch.
iii) Transition resistors.
iv) Tap selector.
v) Drive mechanism.

3.04.01 Diverter Switch Oil Tank

The diverter switch which performs the function of load transfer from one tap to another is housed in its own oil tank. The oil in this tank is kept separate from the transformer oil owing to the fact that due to arcing that takes place in the diverter switch the diverter oil gets carbonised.

The diverter switch oil tank is made of either paper laminates or fibre glass material. It has to withstand the full working voltage to earth. This oil tank is connected to a small oil conservator to ensure that the diverter switch oil tank is full of oil at all times. A protective surge relay is provided in between the diverter switch oil tank and its conservator to prevent serious damage to diverter switch in case of any fault inside the diverter. The operation of relay isolates the transformer from circuit.

3.04.02 Diverter Switch

This is the most important part of the tap changer. It has a stored energy unit, main contacts, transition contacts and transition resistors. By the high speed snap action of the stored unit, the load transfer takes place from one tap to another from the main contact to another main contact after passing through the transition contacts. The total duration of the switching operation from departure from one main contact to arrival at the other is about 0.04 second (i.e.2 cycles). Since the change takes place by means of the stored energy unit there is remote possibility of the contact being in between the taps once the tap changer operation is initiated it is completed without break.

3.04.03 Transition Resistors

Transition resistors are of high grade nickel-chromium alloy wire wound on porcelain carriers. The resistors are all immersed in oil and therefore they are cooled rapidly when they carry the load current during the transition time.

The on-load tap changer fitted with resistors is an improved version to the tap changer fitted with reactors. The tap change action in case of resistor type can be very fast and the arc extinction is effective since the current through the switch is always in phase with the recovery voltage irrespective of the power factor of the transformer load.

3.04.04 Tap Selector

The function of the tap selector is to prepare the tap change by connecting the diverter switch to the required tap on the transformer. During this stage the contact system of the diverter switch stays in its original position until the tap selector has arrived at the new tap. The change of tap takes place only when the diverter switch operates.

The tap selector contacts which are connected to the transformer winding taps are arranged one above the other. Alternate connection of even numbered and odd numbered tap selector contacts to the diverter switch contacts takes place. With this arrangement the tap selector contacts for each phase are divided into two groups, odd numbered contacts 1,3,5, ... and even numbered contacts 2,4,6,8,....... During tap change the diverter switch only effects the no-break transfer of the current from the odd tap to even or vice versa as per the selection made earlier by the tap selector. The entire tap selector assembly is inside the oil of the main tank of the transformer.

3.04.05 Drive Mechanism

The onload tap changer is operated by a motor drive unit mounted outside the transformer tank. Tap change operation can also be effected by means of a crank handle. When the change is done manually, power supply to the motor is automatically disconnected.

The motor drives a vertical shaft that goes upwards from the drive mechanism box to a bevel gear unit fixed on the edge of the transformer cover. This bevel gear inturn is connected to the tap changer head by means of horizontal shaft. The stored energy unit which effects the tap change is at the tap changer head.

The tap change motor can be operated either from the local drive mechanism box or from the control room through the remote tap change control panel (RTCC Panel).

3.04.06. Precautions

1. Before disconnecting mechanically coupled parts, bring the driving mechanism to tap no.1. The centre of green zone on the tap position indication wheel shall be under the arrow mark. While re-coupling ensure that the tap selector, diverter switch and driving mechanism are on tap I with centre of the green zone against the arrow mark.

   Avoid indiscriminate overhauling. It is advisable not to disconnect the mechanically coupled parts unless it is absolutely necessary. Mating marks shall be made to denote the positions of all moving components with respect to stationary parts before disassembly. Surface of insulation materials shall not be scratched for the purpose of marking.

   In some tap changer a name plate with an arrow mark is fixed inside the mechanism case, for correctly inserting the contact compartment into the diverter switch chamber. The white mark given on the edge of the contact compartment cylinder shall be against the arrow mark while inserting into the diverter switch chamber.

   Whenever a moving part is disconnected, voltage ratio of the transformer on all taps shall be checked after re-assembly,giving special attention that there is no discontinuity at the time of operation of tap selector and diverter switch.

   Voltage ratios shall also be taken whenever the tap lead wires, which are disconnected at the tap selector terminals, are reconnected.

   High voltage to the transformer shall be applied, only if the voltage ratios obtained are correct. Any miscoupling or misconnection will result in wrong ratios.

2. The gases collected in the conservator and the mechanism case are combustible and hence adequate precaution is to be taken to avoid fire hazards while releasing gas during inspection.

3. Before recommissioning the tap changer after inspection ensure that a cushion of air is left on the top of the mechanism case.

4. Whenever possible, inspect coupling pins, bolts, nuts and other fasteners. Tighen the parts which are loose. Replace cracked or rusted or missing components and take action to avoid the recurrence of the same defects. All bolts and nuts used shall be locked whenever a re-assembly is required. Failure to lock fasteners or improper locking may lead to the failure of the equipment itself. All joints of current carrying parts except the spring loaded contact points shall be rigidly connected.

5. Filtering or replacing oil under certain circumstances may cause static charge to build up which may cause explosion. To prevent this, inject nitrogen into the gas space of mechanism case for diluting the explosive gases, before filtering oil.

6. When replacing oil in the diverter switch chamber, thoroughly clean it before re-filling with good oil.

7. If dirt is seen on the insulation materials or on contact points, clean them with soft cloth without leaving scratches on the materials.

8. If abnormal noise is heard during the operation of tap changer, it shall be investigated and remedial measures taken.

9. Eventhough the tap changer is capable of satisfactory operation at the maximum capacity, from one extreme tap to the other at stretch, large amount of heat is generated in the contact compartment due to the switching action. Therefore to reduce thermal stresses it will be better to allow a time gap of a few seconds between successive operations when consecutive operations are required. This is applicable even when the operation is required in an energised but unloaded transformer, in which case switching of circulating current will take place.

10. If the transformer with On-load Tap Changer is kept in the de-energised state for a long time, check the BDV of the diverter switch oil before re-charging the transformer.

11. The power supply voltage to the driving mechanism shall be maintained within 110% and 85% of the nominal voltage, for its satisfactory working. Voltage variations outside this range, will reduce the life of control equipments.

Tap Changer Maintenance Schedule

Sl. No	Inspection Frequency	Inspection Item	Check	Remarks
1.	Daily	Digital counter on the Driving Mechanism	No. of tap changing operations carried out.	Record the cumulative no. of operations carried out from the date of first commissioning of the transformer.
2.	"	Tap changer conservator	Oil level	If low, top up with new dry oil. If the level is going up without adding oil, report the matter to manufacturer.
3.	"	Explosion Vent	Diaphragm Plate	Replace if cracked or broken.
4.	"	Space heater in the Driving Mechanism	–	Switch on the heater if the ambient temperature falls below 20°C. Heater need be switched off only when the ambient temperature goes above 30°C
5.	Half yearly or after every 5000 operations	Oil in the Diverter Switch	Break Down Voltage of oil	Filter or replace if BDV is less than 24 kV at gap of 2.5 mm between spheres of 12.7 mm diameter. (Ref.IS:335) Inspection frequency is to be increased if rate of deterioration of oil is faster.
6.	Yearly	Gasket Joints	Oil leak	Tighten the bolts evenly to avoid uneven pressure or replace the gaskets.
7.	"	"O" rings in the Bevel Gear Box	"	Replace "O" rings if there is leak. Dip the "O" rings in transformer oil before inserting into the "O" ring grooves.
8.	"	Universal Joints and other driving shaft parts which are not painted, but in contact with air.	–	Apply grease to prevent rusting.

Sl. No	Inspection Frequency	Inspection Item	Check	Remarks
9.	Yearly	Gas vent on the conservator	–	Clean if clogged with carbon or dust particles.
10.	"	Gas and oil operated relay	Correct working	Rectify defects if any observed.
11.	"	Aux. relays and contactors	Rusting of core, dirt on contacts chattering etc.	Clean or replace.
12.	"	Timer relays	Time setting	Adjust if the setting is too low or high.
13.	"	Control cable connections	Loose cable connections at the terminals of relays, rotary and push button switches, cam switches, hand operation interlock switch, motor, aux. transformer, terminal blocks etc.	Tighten the terminal screws if found loose.
14.	"	Lubricating oil in the gear box of driving mechanism.	Low oil level	Add or replace oil.
15.	"	Electrical resistance of driving mechanism	The resistance shall be more than 2 M. ohms at 20°C on a 500 V megger	If the reading is too low, investigate and rectify.

Sl. No	Inspection Frequency	Inspection Item	Check	Remarks
16.	"	Feed Back Data	-	Please supply the information sought in the feed back data sheet to manufacturer every year positively.
17.	After every 50,000 operations or every 5 years after commissioning whichever is earlier	Diverter switch contact compartment	Thickness of arcing contacts	Replace all the contacts if thickness of any one of the arcing tips is reduced to 2 mm. This inspection may be carried out in the presence of manufacturer's authorised representative.
18.	Every 10 years	Tap Selector	Electric discharges on the sufrace of insulators, condition of fasteners, moving and stationary contacts, smooth operation of gears and other moving parts.	If anything abnormal is observed, report to manufacturer.

3.05 Loading of Transformers

3.05.01 Life Expectancy

The life expectancy of transformers, regulators, reactors etc. depend upon the rate of deterioration of the insulation. Generally the rate of deterioration of insulation at various operating temperatures doubles with each 6°C temperature rise above 98°C. The deterioration is also proportional to time for any given temperature above 98°C.

Since the actual temperature is the sum of the ambient temperature and temperature rise, it is apparent that the ambient temperature very largely determines the load at which the transformer can be operated in service.

The main factor is the permissible loading of transformers without reducing their overall life expectancy i.e. the deterioration of insulation life with temperature when the hot-spot temperature exceeds 80°C. The relative rate of use of life for various hot-spot temperature is as given in IS 6600-1972 are given below:

°C	Relative rate of use of life
80	0.125
86	0.25
92	0.50
98	1.00
104	2.0
110	4.0
116	8.0
122	16.0
138	32.0
140	128.00

Example:

10 hours at 104°C and 14 hours at 86°C would rate (10x2) plus (14x0.25) or 23.5 hours in 24 hours operation.

It may be noted that below 80°C the use of life is negligible.

There is no way of measuring hot-spot temperature in the transformer. The temperature measurements available are the winding temperature (if winding temperature indicators are provided) and the top oil temperature. In fixing limit for winding temperature and top oil temperature for operation at standard life deterioration, a margin has to be allowed for the difference between Hot-spot and winding temperature or Hot-spot and top oil temperature.

3.05.02 Operation of transformers

The following maximum temperature limits may be taken as a general guide for operation of transformers.

1. Winding temperature ... 85°C
2. Top Oil temperature
   i) For natural cooled ... 75°C
   ii) Water cooled ... 70°C

Wherever winding temperature indicators are provided, the loading of the transformer should be controlled to limit the winding temperature to the above value. If the winding temperature indicators are not available, the top oil temperature may be had as the guidance. But generally the oil temperature is not a reliable guide for loading transformers.

Overloading of Transformers

Transformers may be over loaded only when any sister unit fails, when a spare unit is not available, and when load shedding is not possible. The cooling system in such cases should be made as effective as possible by (i) increasing the cooling water supply if the transformer is of the water cooled type or (ii) by increasing the cooling air supply by blowers. It is, however, important that overloads should not be carried on transformers without an investigation of the various limitations involved. Among these limitations which should be checked in the field are, oil expansion, heating of bushings, leads, soldered connections, tap changers and disconnecting switches, current transformers, heating of the associated equipment such as cables, reactors, circuit breakers etc.

Any one of these may constitute the practical limit in load carrying ability. Rapid wide changes in operating temperatures should be avoided as much as possible since these aggravate the changing effects caused by temperature expansion and contraction of the copper upon the winding insulation.

3.05.03 Basic concepts in Overloading Transformers

As stated earlier the transformer insulation deteriorates when the hotspot temperature exceeds 80°C and the rate of deterioration is taken as one for the hot spot temperature of 98°C. Specific attention is to be drawn to the fact that both BS and IS specify not only the maximum ambient temperature but also the maximum daily average temperature which is lower than the maximum ambient and the maximum yearly weighted average ambient temperature. Even for water cooled transformers, a maximum temperature of 30°C and a maximum average cooling water temperature of 25°C are specified. For convenience, the reference ambient temperatures specified in BS and IS are given below:

Reference Ambient Temperature

		B.S. 171 1959–1970		I.S. 2026 1962–1977	
S.No.	Description	Temperatures in °C			
1.	Maximum ambient air temperature	40	40	45	50
2.	Maximum daily average air temperature	30	30	35	40
3.	Maximum yearly weighted average temperature	20	25	30	32
4.	Water a) Maximum b) Maximum daily average	 25 20	 30 20	 30 25	 30 25

It may be seen that when the transformer operates at the maximum ambient temperature and that the permissible temperature rise specified in BS/IS the maximum winding temperature may reach as per BS 171-1970 and IS 2026-1977, a temperature of 105°C and the corresponding hot-spot temperature may be even 115°C, whereas the permissible temperature of hot-spot for the standard unit rate of deterioration is 98°C. The higher permissible temperature rise takes into account the fact that the transformer may operate even on continuous load at lower ambient for a good portion of the day. The specification of maximum average ambient in addition to the maximum ambient is an important point to be noted. The transformer could therefore be overloaded for short intervals. If the average ambient is less than that specified in BS or IS or if the transformer carried a much lower load than continuous rating for several hours, a corresponding gain in life by the operation at temperatures lower than 98°C hot-spot is offset by operating the transformer at a higher temperature with an overload for a short period.

Special Note

IS 2026 of 1977 stipulates a maximum ambient of 50°C as against a maximum ambient of 45°C specified by the Board in its specification and also by IS 2026, 1962. Both BS 171-1970 and IS 2026-1977 provide for a higher temperature rise for Class 'A' insulation than BS 171-1959 and IS 2026, 1966. The absolute temperature to which the windings and top oil can be safely permitted as per BS and IS are given below. As per the higher ambient of 45°C specified by the Board against 40°C in BS, the permissible temperature rise is lower by 5°C. Hence the permissible absolute temperature of the winding and top oil as per BS will be applicable to Board specification also without any change.

	Windings		Top oil	
	BS 171		BS 171	
	1959	1970	1959	1970
Natural cooled Forced Oil Air blast	100°C 105	105°C 105	90°C 90	100°C 100
	IS 2026		IS 2026	
	1962	1977	1962	1977
Natural cooled Forced Oil Air blast	100 105	105 105	90 90	100 100

3.05.04 Operation of Water cooled Transformers

The following points regarding operation of water cooled transformers are for the guidance:

i. Water from coolers should be discharged in the open air into a small tank specially built for the purpose so that the water can be easily examined and watched for any mixing of oil due to the deterioration of cooler tubes.

ii. In water cooled transformers with forced oil circulation the water pressure in the coolers should be less than the oil pressure to prevent any possibility of water getting into the oil if the cooler tubes fail.

iii. If large water cooled power transformers show excessive heating they should be checked for overload and the oil should be examined for sludge. If the load is all right, then the heating may be due to the water cooling coil becoming partially choked up and reducing the water flow required. There may also be a heavy scale on the outside of the cooling coil. These have to be cleaned.

   a) Scale and sediment can be removed from a cooling coil without removing the coil from the tank. Both inlet and outlet pipes should be disconnected from the water system and temporarily piped to a point quite far away from the transformer where the coil can be filled and emptied safely. All the water should be blown or syphoned from the cooling coils which should be then filled with a solution of hydrochloric acid, specific gravity 1.1 (equal parts of commercially pure concentracted hydrochloric acid and water will give this specific gravity).

   It may be found necessary to force this solution into the cooling coils. When this is done, one end of coil should be partially restricted, so that the solution will not be wasted when the coil is full. After the solution has stood in the coil for about an hour, the coil should be flushed out thoroughly with clean water. If all the scale is not removed in the first time, the operation should be repeated until the coil is clean using new solution each time. The number of times necessary to repeat the process will depend on the condition of the coil though ordinarily one or two fillings will be sufficient. As the chemical action which takes place may be violent and may often force, acid, sediment, etc. from both ends of the coil, it is well, therefore to leave both ends partially open to prevent abnormal pressure.

b) Using a solution of caustic soda and blowing it through the coils.
The outside of cooling coils should be cleaned by using caustic soda solution and steam or using a hand wire brush.

iv) Water cooled transformers should not be run continuously even at load without cooling oil circulation and without water circulating in the coolers. It is essential to maintain proper circulation of oil and cooling water.

v) If water circulation is stopped for any reason, the load should be immediately reduced as much as possible and close watch kept on the temperature of the transformer. When the oil temperature reaches 70°C, the transformer should be cut out of service at once.

3.06 Parallel Operation

If two or more transformers are to operate in parallel, their satisfactory performance requires that they have

a) the same polarity

b) the same phase angle difference between HV and LV windings and the same phase sequence.

c) the same voltage ratio

d) the same per unit (or percentage) impedence

e) the difference in KVA capacity should not exceed the ratio of 3:1

Of these (a) and (b) are absolutely essential (c) must be satisfied to a close degree. There is more latitude with (d), but the more nearby it is true, the better will be the load-division between the several transformers.

When the difference in capacity exceeds the limit of (e) the permissible limit in variation of impedance (d) is exceeded.

The currents carried by two or more transformers will be proportional to their ratings if their ohmic impedances are inversely proportional to these ratings or their per unit impedance are identical. A difference in the quality of the per unit impedance (i.e., ratio of resistance to reactance) of transformers in parallel results in a divergence of phase angle of the two currents shared by the transformers.

The impedance of transformers is small. Even a small percentage difference in open circuit voltage on secondaries causes considerable circulating current when they are in parallel. As a result the combined load will be reduced.

Equal Voltage Ratios

Given the actual impedence values, the load shared by each transformer when two transformers are in parallel will be :

$$S_1 = S \frac{Z_2}{Z_1 + Z_2} \quad \text{and} \quad S_2 = S \frac{Z_1}{Z_1 + Z_2}$$

where

S	is the combined load in KVA
S_1, S_2	are loads in K.V.A. shared by the individual transformers and
Z_1 and Z_2	are ohmic impedence value of the transformers.

If Z_1 and Z_2 are expressed as per unit values or percentage impedance then they are to be converted to a common base before applying the formula.

When three transformers having impedance values Z_1, Z_2 and Z_3 ohms (or per unit values or percentage impedances on a common base) respectively the load shared by each of the transformers is given by

$$S_1 = S \frac{Z_2 Z_3}{Z_1 Z_2 + Z_2 Z_3 + Z_3 Z_1}$$

$$S_2 = S \frac{Z_3 Z_1}{Z_1 Z_2 + Z_2 Z_3 + Z_3 Z_1}$$

$$S_3 = S \frac{Z_1 Z_2}{Z_1 Z_2 + Z_2 Z_3 + Z_3 Z_1}$$

Often the problem is merely to find the maximum common load that can be supplied without overloading any of the transformers in parallel. This can be directly solved from

$$S_{max} = S_1 \frac{Z_{min}}{Z_1} + S_2 \frac{Z_{min}}{Z_2} + S_3 \frac{Z_{min}}{Z_3} \text{ etc.}$$

where S_1, S_2 and S_3 etc., are the rating of the transformers Z_1, Z_2 and Z_3 etc., are per unit or percentage impedance values of various transformers on their respective bases. Z_{min} is the smallest figure among Z_1, Z_2 and Z_3 etc.

In the aforesaid formulae one basic assumption that has been made is that the ratios of resistance to reactance of all the transformers to be parallelled are identical. If the ratios are different and the resistance and reactance values are known separately then all the arithmetic computations are to be made vectorially.

Unequal Voltage Ratios

The problem of parallelling the transformers having unequal voltage ratios can be solved algebrically. A case of two units in parallel may be considered.

E_1, E_2 = no load secondary e.m.f.s (induced emfs)

Z_L = load impedance at the secondary terminals

Z_1, Z_2 = the impedance of the two transformers

I_1, I_2 = their currents

$$E_1 = I_1 Z_1 + (I_1 + I_2) Z_L$$

$$E_2 = I_2 Z_2 + (I_1 + I_2) Z_L$$

$$I_1 = \frac{(E_1 - E_2) + I_2 Z_2}{Z_1}$$

$$E_2 = I_2 Z_1 + \frac{(E_1 - E_2) + I_2 Z_2 + I_2}{Z_1} Z_L$$

$$I_2 = \frac{E_2 Z_1 - (E_1 - E_2) Z_L}{Z_1 Z_2 + Z_L (Z_1 + Z_2)}$$

and $$I_1 = \frac{E_1 Z + (E_1 - E_2) Z_L}{Z_1 Z_2 + Z_L (Z_1 + Z_2)}$$

6.

Circulating current between the windings of the transformers can be found by assigning value for Z as

$$I_2 = \frac{(E_1 - E_2)}{Z_1 + Z_2}$$

and

$$I_1 = \frac{(E_1 - E_2)}{Z_1 + Z_2}$$

A solution for two or more transformers in parallel having unequal voltage ratios can be solved by application of parallel generator, theorem. The case of two transformers in parallel is given below as an example. The method can be adopted to any number of units in parallel.

E_1, E_2 = emfs of two units

I_{1sc}, I_{2sc} and I_{sc} = Short circuit currrents of Individual units and the total short circuit current

Z_1, Z_2 and Z_L = impedances of the two units and load impedance

Z = Combined impedance of load and the two units

V = Terminal voltage

I_1, I_2 = Currrents in the units

$$I_{1sc} = \frac{E_1}{Z_1} \qquad I_{2sc} = \frac{E_2}{Z_2}$$

$$I_{sc} = I_{1sc} + I_{2sc}$$

$$\frac{1}{Z} = \frac{1}{Z_L} + \frac{1}{Z_1} + \frac{1}{Z_2}$$

$$V = I_{sc} Z$$

$$I_1 = \frac{E_1 - V}{Z_1} \text{ and } I_2 = \frac{E_2 - V}{Z_2}$$

It is convenient to solve the unequal voltage ratio problems with actual ohmic impedance values.

Connections for Transformers

The nomenclature for marking transformer terminals has undergone changes from BS 171-1936 and onwards. But however the basic principles have remained the same in most of the cases.

a) The vector diagrams given in the name plates represent induced emfs and not applied voltage; all windings are assumed to be wound in the same direction.

b) Polyphase transformers are allotted symbols giving the type of phase connection and the angle of advance turned through in passing from the vector representing h.v. emf to that representing l.v. emf at the corresponding terminal. The angle may be indicated by a clockface figure, the h.v. vector being 12 o' clock (zero) and the l.v. vector being represented by the hour hand.

c) For multi winding transformers the vector for the high voltage winding remains the reference vector and the symbol for this winding shall be given first. Other symbols shall follow in diminishing sequence of rated voltages of the other windings. For example DY 11 means h.v. winding is connected in delta and lv winding in star. The vector position of lv winding is 30° lead (11 O'clock) with reference to hv winding reckoning phase rotation as anticlockwise.

In practice sometimes the necessity for parellelling DY 11 group unit with DY 1 group unit arises. For this purpose jumper connection for any two phases on h.v. side and for corresponding two phases on the L.V. side for DY 1 group transformer may be interchanged. If there is any mechanical constraint in making change of connections for the DY 1 group unit the same may be carried out for the DY 11 unit. However as majority of units in service are of DY 11 group change of connections to DY 1 group unit may be preferred for the sake of uniformity.

3.07 Transformer Oil - Dissolved Gas Analysis (DGA)

3.07.01 Introduction

(a) Dissolved gas analysis (DGA) is a powerful diagnostic technique for detecting incipient faults in oil filled equipment particulaly power transformers long before they develop into major faults. The Central Board of Irrigation and Power have evolved a guide on this, vide their Technical Report No.62 of April 1988. Also Refer to IS:9434 - 1979.

(b) 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 in the transformers.

Facilities for this test are available only at Research and Development lab. in Madras. It is desirable that this test is conducted (i) on all transformers of 110KV and above once a year (ii) on all generator transformers once a year and (iii) on all new transformers of 25 MVA and above just prior to commissioning so that the test result can be used as a bench mark to compare in future.

3.07.02 Sampling

i) Sampling of Oil from oil/gas filled equipment

The method of sampling is given in Annexure V. For routine sampling on a large scale, the use of bottles or sampling tubes may be most economical. The method described is suitable for large oil-volume equipment such as power transformers. With small oil-volume equipment, it is essential to ensure that the total volume of oil drawn off does not endanger the operation of the equipment.

Sampling of oil from energised transformers should be carried out with caution and conform to the instructions from the manufacturers. If there are any doubts about the presence of vacuum in the transformer, samples should be taken only after the transformer is de-energised.

The selection of points from which samples are drawn should be made with care.

Normally, the samples should be taken from a point where it is representative of the body of the oil in the equipment and where changes in composition due to pump cavitation do not exist. It will some time be necessary however, deliberately to draw samples where they are not expected to be representative, for example in trying to locate the site of a fault. Generally the oil is sampled from both the bottom as well as top valves of the transformer.

The material of the sampling container may be from any one of the following:

1. Stainless steel or glass with two stop cocks or valves and
2. Air tight glass bottles or glass hypodermic syringes or tin cans.

In sampling, where glass bottles are used, preferably brown bottles are to be used, to delay the oxidation process, if any.

While sampling, the oil from transformers, which has definite indication of fault, the sampling container has to be carefully rotated (not agitation) several times before transferring it to the extraction apparatus.

ii) **Labelling of samples**

Oil samples preferably in duplicate should be properly labelled before despatch to the laboratory and the following information is to be sent along with each sample.

a) customer or plant

b) identification of equipment

c) object of sampling

d) date of sampling

e) Load at the time of sampling

f) type of oil (if known)

g) volume of oil in equipment

h) temperature of sample when drawn

i) date of commissioning of the transformer

j) date of last filtration of oil

k) tap changer (if any) - whether it is integral part of the transformer or isolated part

l) details of repairs (if any) carried out since the commissioning of the transformer.

m) Any available data on transformer malfunctioning including date of buchholz relay actuation, if any

n) the date of last DGA of transformer

NOTE: Object of sampling and any available data on transformer may be stated. It may be indicated whether the sampling is consequent to the tripping of the transformer, through protective relays or a normal routine periodic testing.

iii) **Frequency of Sampling for DGA**

The frequency of sampling for DGA will depend on various factors such as the age of the transformers, its operational requirements, the nature of repairs, if any, carried out on it etc. In general, the following broad guidelines are adopted keeping in view that monitoring of the trend of (fault) gas generation rates is essential in the proper interpretation of the incipent faults inside the transformer and healthiness of the transformers in service.

iv) **New Transformers:**

1. The analysis may be carried out on oil after filling inside the transformer at the manufacturers' works. The second analysis of the sample shall also be carried out on the transformer after carrying out the heat run test. The results will form the part of the heat run test certificate (Limits for acceptance, i.e., the acceptable values for new transformers after heat run test are under consideration).

2. At site, the analysis may be carried out on new oil after filling inside the transformer and before charging. This forms the initial bench mark for the transformer for trend monitoring in service. The analysis may be repeated after one month of service to ensure that no abnormality is indicated during the initial period of operation of new transformer after commissioning. Subsequent monitoring may be carried out at regular intervals in service say once a year or at increasing intervals if found necessary.

3. Transformers after overhaul and repair

   3.1. Transformers which have been repaired or internally inspected and overhauled may be subjected to DGA initially as in the case of new transformers. However, subsequent monitoring at regular intervals may be carried out once in 3 months (instead of one year for new transformers) to detect any incipient defects not noticed during repair/inspection and overhaul.

   3.2. In service Transformers:

   a) Periodic routine and special monitoring : As mentioned in the scope of the guide, the analysis should be carried out on all the transformers with voltage rating of 110 KV and above and other critical transformers. The transformers whose results are satisfactory may be subjected to DGA once a year. The frequency can be increased to say once in 3 months on transformers whose gas concentrations approach limiting values.If oil filtration is carried out during routine maintenance of a transformer it is essential to carry out DGA before and after completion of the filtration cycle. While the former reveals the latest data on the trend of DGA, the latter provides a fresh bench mark for future trend analysis. The routine DGA monitoring would also help in planning preventive and predictive maintenance programmes.

b) Another important aspect of DGA on transformer is that it helps to reliably establish the healthiness of a transformer when it has tripped by protective relay action for any reason. Transformers tripped due to suspected mal-operation of protective relays can be returned into service with confidence on the basis of DGA as also other electrical tests to confirm healthiness of the active parts.

3.07.03 Analysis of Dissolved Gases

Table I gives the permissible concentrations of dissolved gases in the oil of a Healthy transformer.

TABLE 1

Gas	Less than 4 years in service	4–10 years in service	More than 10 years in service
Hydrogen	100/150 ppm	200/300 ppm	200/300 ppm
Methane	50/70 ppm	100/150 ppm	200/300 ppm
Acetylene	20/30 ppm	30/50 ppm	100/150 ppm
Ethylene	100/150 ppm	150/200 ppm	200/400 ppm
Ethane	30/50 ppm	100/150 ppm	800/1000 ppm
Carbon monoxide	200/300 ppm	400/500 ppm	600/700 ppm
Carbondioxide	3000/3500 ppm	4000/5000 ppm	9000/12000 ppm

Table II gives the code for evaluating the analysis of Gas dissolved in Mineral oil.

Table II

Ratios of characteristic Gases		Code of range of ratios		
		(Acetylene) C_2H_2 / (Ethylene) C_2H_4	(Methane) CH_4 / (Hydrogen) H_2	(Ethylene) C_2H_4 / (Ethane) C_2H_6
Less than	0.1	0	1	0
	0.1 to 1	1	0	0
	1 to 3	1	2	1
Greater than	3	2	2	2

Case No.	Characteristic Fault	Code of	Range of	Ratios	Typical examples
1.	2	3	4	5	6
0.	No fault	0	0	0	Normal ageing
1.	Partial discharges of low energy density	0 but not significant	1	0	Discharges in gas filled cavities resulting from incomplete impregnation, or super-saturation or cavitation or high humidity.
2.	Partial discharges of higher energy density	1	1	0	As above, but leading to tracking or perforation of solid insulation.

1.	2.	3.	4.	5.	6.
3.	Discharge of low energy (See Note 1)	1–2	0	1 – 2	Continuous sparking in oil between bad connections of different potential or to floating potential breakdown of oil between solid materials.
4.	Discharge of high energy	1	0	2	Discharges with power follow-through. Arcing breakdown of oil between winding or coils or between coils to earth. Selector breaking current.
5.	Thermal fault of low temperature < 150°C (See Note 2)	0	0	1	General insulated conductor over-heating
6.	Thermal fault of low temperature range 150°C to 300°C (See Note 3)	0	2	0	Local overheating of the core, due to concentrations of flux. Increasing hot spot temperatures; varying from small hot spots in core, shorting links, in core, overheating of copper due to eddy currents bad contacts/ joints (pyrolitic carbon formation) upto core and tank circulating currents.
7.	Thermal fault of medium temperature, 300°C to 700°C	0	2	1	
8.	Thermal fault of high temperature greater than 700°C (See Note 4)	0	2	2	

Note 1 For the purpose of this table there will be a tendency for the ratio $\frac{C_2H_2}{C_2H_4}$ to rise from a value between 0.1 and 3 to above 3 and for the ratio $\frac{C_2H_4}{C_2H_6}$ from a value between 0.1 and 3 to above 3 as the spark develops in intensity. The characteristic code of the fault at an incipient stage will be 1.0.1.

Note 2 In this case the gases come mainly from the decomposition of the solid insulation, this explains the value of the ratio $\frac{C_2H_4}{C_2H_6}$.

Note 3 This fault condition is normally indicated by increasing gas concentrations. Ratio $\frac{CH_4}{H_2}$ is normally about 1; the actual value above or below unity is dependent on many factors such as design of oil preservation system, actual level of temperature and oil quality.

Note 4 An increasing value of the amount of C_2H_2 may indicate that the hot-point temperature is higher than 1000°C.

Note 5 Significant values quoted for ratios should be regarded as typical only.

Note 6 Transformers fitted with in-tank on-load tapchangers may indicate faults of Types 3 or 4 of Table II depending on seepage or transmission of decomposition products in the diverter switch tank into the transformer tank oil.

Note 7 Combination of the ratios not included in table II may occur in practice. Evaluation of such combinations is under consideration.

Note 8 Fault gas ratios alone cannot be used to evaluate transformer condition since ratios contain no information regarding severity (A ratio always exists regardless of absolute amounts present). The table should be used to characterise the fault type after other considerations have indicated that an abnormal condition exists.

3.08 Overhauling of Transformers

Overhauling

All power transformers to be overhauled whenever there is a visible deterioration in the parameters of the transformer oil and the transformer insulation beyond the prescribed values.

This is very necessary with the latest concept of Dissolved Gas Analysis (DGA) which shows the condition of the core and winding of the transformer.

3.08.01 Oil circulation

Oil circulation need be done for improving the chemical, thermal and electrical quality of the oil only when the respective prescribed parameters show definite signs of deterioration evidenced by the results of atleast two consecutive detailed tests conducted on the oil.

3.09 Drying out of Transformer

Deterioration of insulation resistance value of transformer is mainly due to ingress of moisture into the windings and other insulating materials in the transformer like oil, press boards etc. The poor insulation values may also be due to very low resistivity of oil.

Before undertaking the drying out of transformer the resistivity and power factor (tan delta) of the oil should be checked. If the values are not satisfactory the oil should also be replaced as otherwise any amount of drying out will not improve the IR values.

Success of drying out is in subjecting the transformer to a fine degree of vacuum than in oil circulation at a high temperature. If the service oil of the transformer is heated above 60°C oil loses its properties rapidly. Therefore hot oil circulation at temperature above 60°C is not desirable. There are four methods of drying out a transformer.

(a) *Vapour phase drying:*

This is a sophisticated method of drying which is not possible at site.

(b) *Hot oil spraying:*

In this method a small quantity of oil (say about 8 to 10% of Quantity of oil in transformer) is heated upto 90°C to 95°C separately and this hot oil is sprayed on to the core and windings by means of nozzles in the form of fine spray. Simultaneously the transformer is subjected to a high degree of vacuum say less than 5m bar. The hot oil collected at the bottom of the transformer tank is sucked by means of a pump. sent through a filter and the hot oil is again sprayed into the transformer through nozzles. In this process the extraction of moisture is continuous and quick drying is achieved. But the disadvantages in this method are:

i) The hot oil used for spraying should be discarded.

ii) Unless the filter or the suction pump is placed in a deep pit it cannot suck the oil collected at the bottom of transformer against the full vacuum applied at the top.

iii) Special fabrication work is necessary for fitment of spraying nozzles.

(c) *Flushing method:*

This method is best suited for drying the transformer at site though it takes longer time than the second method.

In this method the transformer is put under hot oil circulation so as to raise the temperature of the oil to 55°C - 60°C. After obtaining steady temperature, the entire oil in the transformer is drained quickly into a separate tank say within one hour so that the winding temperature does not fall appreciably. Immediately after draining the oil the transformer is subjected to a vacuum of less than 5 mbar for 12 hours. During this period of application of vacuum, the oil drained from the transformer can be filtered to improve the quality of oil by extracting moisture from oil. After 12 hours of vacuum, fill into the transformer the filtered oil under vacuum and then break the vacuum by means of dry nitrogen. Now the oil in the transformer can again be circulated to raise the temperature of oil to 60°C. After reaching steady temperature again drain oil, apply vacuum etc. The cycle of raising the temperature of oil to 60°C, draining oil into auxiliary tanks, application of vacuum to transformer, filling filtered oil into transformer can be repeated until satisfactory results of IR values and PI values are obtained.

Precautions

(i) Before starting the work inter-connect the divertor switch tank of OLTC gear and main tank so as to equalise the pressure, as otherwise diverter switches chamber may be damaged when vacuum is applied.

(ii) Take IR and PI values when the transformer is with oil and not under vacuum.

(iii) Small 33 KV transformers are not normally designed for full vacuum. Therefore it must be ascertained whether the transformer can withstand the vacuum that is going to be applied.

(d) *Hot Oil Circulation*

This is the old method of drying out adopted in the Board, but this method is very inefficient and time consuming. This type of hot oil circulation is suitable only for small transformers where the winding and other solid insulating materials have not absorbed moisture.

Annexure I

Check List for Commissioning of Power Transformers

1. *Foundation*

   a. Whether rail centres have been checked?

   b. Whether height of the Plinths have been checked?

   c. Whether the Plinth have been checked for levels?

   d. Whether rail levels checked with spirit level?

2. *Main Tank*

   a. Has it been checked and cleaned?

   b. Has it been painted?

   c. Whether the name plate has been fixed?

3. *Radiators*

   a. Have they been checked and cleaned?

   b. Are they leak proof?

   c. Whether Gaskets have been renewed?

   d. Whether the fixing bolts are uniformly tightened?

   e. Are radiators valves functioning properly?

   f. Are 'open' and 'close' direction marked clearly and the indications correct?

   g. Are vent plugs and drain plugs having good gaskets and are leak proof?

4. *Valves*

   i) a. Type of valves whether screw or flange type?

   b. Are they leak proof?

   c. Have Gaskets been renewed?

ii) Check valve positions:

a. Conservator to Tank open or closed?

b. Radiators open or closed?

c. Equaliser pipe Open or closed?

d. Drain open or closed?

e. Filter open or closed?

5. *Fan Motor*

a. Whether bearing has been checked?

b. Whether noise and vibration of motor is normal?

c. Whether winding resistance is checked?

d. Whether the motor gets abnormally heated while running?

e. Whether load current is within limits?

f. Whether automatic starting and stopping is satisfactory?

g. Whether direction of rotation is correct?

h. Are all lubricating points, clear and not choked?

i. Is grease or oil filled in bearings?

j. Are the 2 earths of the motor and starter body sound?

k. Are oil gauges indicating correctly?

6. *H.V. Bushings*

a. Classify type of bushings.

b. Whether Gaskets have been renewed?

c. Whether any oil leakage is noticed?

d. Whether the bottom & top connection leads have been checked for tightness?

e. Whether jumper connection is flexible and does not strain the bushings?

f. Whether Bimetallic action has been prevented?

g. Whether the oil level is adequate?

h. Whether the arc-Gap has been checked?

i. Whether all the mounting bolts have been uniformly tightened?

j. Whether the air has been released?

k. Whether Power factor has been checked and test cap replaced?

l. Whether the gap between LV & HV leads are sufficient?

7. *L.V. Bushings*

a. Classify type of bushings

b. Whether Gaskets have been renewed?

c. Whether any oil leakage is noticed?

d. Whether the bottom and top connection leads have been checked for tightness?

e. Are the connections flexible?

f. Is Bimetallic action prevented?

g. Whether mounting bolts are uniformly tightened?

8. *Tap Changer*

a. Classify the type of tap changer ON load/OFF load.

b. Whether connections have been checked?

c. Whether oil level is checked?

d. Whether manual or motor operated?

e. Whether operation checked for i) movements ii) Voltage steps?

f. Whether motor insulation value has been checked?

g. Whether fuse capacity checked?

h. Whether protected against out of steps mal-function. If so whether protection checked?

i. Whether tap changer is in communication with main tank oil or sealed?

j. Whether the air inside is released?

9. *Conservator*

a. Whether there is any leak?

b. Whether the oil level gauge has been checked and compared with the dip stick level?

c. Whether support structures have been checked?

d. Whether the Buchholz piping has been checked?

e. Whether new gaskets have been provided?

10. *Vent pipe*

a. Whether the condition of diaphragm at top has been checked? at bottom has been checked?

b. Whether provided with protection cover or grill?

c. Whether gaskets are renewed?

d. Whether provided with an equaliser pipe?

e. Whether flow of oil checked with the equaliser?

f. Whether the gauge glass is clear and visible?

g. Whether all bolts etc. checked for correctness?

11. *Breather*

a. Classify the type of the breather.

b. Whether free passage of air is available?

c. Whether silica gel is renewed?

d. Colour of gel at the time of energisation?

e. Whether oil seal available at the bottom?

f. Whether oil is renewed?

g. Whether the glasses are clean and clear?

h. Whether the joints in the breather pipe free from leaks?

12. *Buchholz Relay*

a. Whether the position of the relay is correct?

b. Whether the operation of the top float is checked?

c. Whether the operation of the bottom float is checked?

d. Whether the direction of oil flow is checked?

e. Whether there is any leak?

f. Whether gaskets have been renewed?

g. Is there a mechanical plunger to operate the floats?

h. Is the glass window clean and clear?

i. Is the relay in "Service" position?

13. *Thermometer*

a. Classify type and make of Thermometer.

b. Whether the calibration is checked?

c. Whether the movement is checked?

d. Whether the Thermometer is dust proof?

e. Whether the Thermometer is moisture proof?

f. Whether the capillary tubing is provided/checked?

g. Whether the mounting is checked?

h. Whether the setting is checked?

i. Purpose of the Thermometer contacts. Trip or alarm?

j. Whether 'oil' or 'winding' Marked on the Thermometer?

14. *Oil*

i) a. Whether the minimum flash point checked?

b. Whether the acidity (neutralisation value) at max. is checked?

c. Whether the "Water Content" test conducted?

d. Whether B.D.V. Value tested?

e. Whether the resistivity checked?

f. Whether the Interfacial tension checked?

g. Whether the Power factor checked?

ii) Oil Samples:

a. Whether the bottom sample of tank tested?

b. Whether the top sample of tank tested?

c. Whether the conservator oil samples tested?

d. Whether the tap changer oil samples tested?

e. Whether the radiator tank oil samples tested?

f. Whether bushing oil samples tested?

15. *Insulation of Windings*

i) Whether the polarisation index values checked?

ii) Whether the I.R. Value with mains operated megger was tested between
H.V. to Earth
L.V. to Earth
H.V. to L.V.

iii) Whether any hot oil circulation was done and if so the details and the I.R. values obtained at 60°C.

16. *Cables*

a. Whether the I.R. values of the cables have been checked?

b. Whether the un-armoured cables if used have been provided with protective covers?

17. *General*

a. Whether wheels have been provided?

b. Whether stop blocks have been provided?

c. Type of protection available for the transformer?

i) against over load

ii) against earth faults

iii) against over temperature

iv) against internal faults.

d. Whether there are bushing C.Ts?

i) Whether they are used for protection?

ii) Whether the secondaries are shorted if not used?

iii) What are the C.T. ratios available?

e. Earthing

i) Whether the neutral bushing is earthed?

ii) Whether there is double earth?

iii) Is the size of copper strip adequate?

iv) Is the main tank earthed?

v) Is there bonding between top and bottom portions of tanks?

vi) Whether the earth strips are connected to the earth grid?

vii) Whether the neutral bushing connection is given a 'U' bend and made flexible?

f. Surge Arrestors

i) Are there surge arresters on the HV side?

ii) Is it within permissible Electrical distance?

iii) Are there surge arresters on the LV side?

iv) Is it within electrical distance?

v) Whether there is an earth screen?

vi) Do the HV bushings lie within the cone of protection?

g. General

i) What are the clearances from the HV bushing terminals to nearest metal part of Transformer and to the structure? Are these satisfactory?

ii) Are the ratio switches and tap switches locked firmly (to prevent unauthorised operation) in their prescribed positions?

iii) Are all the valves of radiator inlet/outlet, buchholz pipe, equaliser pipes, bushing pipes vents etc. in their correct final positions?

Annexure II

Form of Report on Low Insulation Value in Transformers

1. System Division Sub-station
2. Voltage ratio of the Transformers:
3. Make/Year of Manufacture:
4. Maker's serial No.
5. Capacity
6. No. of such Transformers in service in the S.S.
7. Date of commissioning of each of these transformers.
8. Insulation values at the time of commissioning and winding and oil temperature at which readings were taken-Serial No. wise -
9. Insulation values as observed now-date to be indicated. Serial No. wise-Temperatures to be indicated.
10. Voltage, Make, Sl. No. of megger used now.
11. Hand operated or Power operated.
12. Polarisation Index.
13. Whether the final readings (9) were taken after freeing the transformers of jumpers and after cleaning the bushing insulators.
14. Voltage/Make/Sl.No. of megger used for preparing the insulation drying curve by Transformer Erection staff at the time of commissioning.
15. Insulation values obtained with this megger at each tap portion-Serial No. wise-Temps. to be indicated.
16. Enclose Insulation Drying curve for these transformers.
17. Enclose the monthly megger readings for the entire period of service in this S.S. with Make/voltage of megger used on each occasion. Temperatures to be indicated positively.

18. Frequency of reactivisation of Silicagel in the breather in a week for this Transformer.

19. Cracking test on oil; Score out what is not applicable. Bottom Oil: positive/negative. Conservator oil:positive/negative.

20. BDV test-Bottom Oil :

    Conservator oil

21. If item (19) is positive oil to be tested for and results furnished :

    IFT :

    Water content :

    Acidity :

    Tan delta :

    Resistivity :

22. Quantity of oil in the Transformer:

23. Type of bushings :
    H.V. Sealed or Communicating
    L.V. Sealed or Communicating

24. If sealed, when was oil last tested
    Date :
    Results :

25. Does the system have the facility to remove the bushings and check its condition and condition of winding separately?

26. Does the system have the facility for Hot oil circulation under short circuit/Hot Air Circulation/Vacuum drying of this Transformer (Mention which of these is possible)?

27. Duration of shut down required.

28. How the Station load will be managed without the Transformer Details to be given.

29. If replies to 25 and 26 are negative state the possible period during which the transformer can be shutdown enabling Transformer Erection to carry out the Drying process.

30. Remarks.

AEE/S.S. AEE/Spl. Executive Engineer

Annexure – III

Proforma for Recording Maintenance

Maintenace Due : Power Transformers

Month	Monthly Maintenance done on TR.s			Reason for slippage	Quarterly maintenanc. done on TR.s			Reason for slippage	Half-yearly maintenance done on TR.s			Reason for slippage	Annual maintenance done on TR.s			Reason for slippage
	1	2	3		1	2	3		1	2	3		1	2	3	
April																
May																
June																
July																
August																
September																
October																
November																
December																
January																
February																
March																

Note : Mark ✔ if maintenance is done, otherwise × may be used.

Annexure IV

Instructions for testing of gas accumulated in Buchholz Relays

The following procedure should be adopted for testing of gas accumulated in Buchholz relay of power transformers, boosters, etc:-

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

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

(3) 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.

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

The gas tester consists of 3 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 c.c. of distilled water.

Tube 2 should be filled with solution prepared by dissolving five grams of silver nitrate ($Ag\ NO_3$) in 100 c.c. 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 tube. 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.

Note 1. The re-agents can be used only once and must be renewed after each test. Alkaline silver nitrate is not durable for an unlimited period, not even in case of proper storage. The solution must be prepared periodically and kept in suitable bottles painted white.

Note 2. The gas tester can easily be rigged up, one for each substation, similar to the AEG gas tester ordered and supplied to the important substations.

If the above tests indicate that the accumulation is mere air then energise the transformer without putting on load. If any more gases are developed carry out short circuit test. If however, gases (air) continue to be developed, check for the causes for leakage.

(5) If the gas in combustible and a chemical test reveals the nature of the defect, take out the transformer and proceed with detailed examination.

The chemical test which is positive may be done first and the combustion test done later to confirm if there is sufficient gas available.

Annexure V

Instruction for sampling of oil

A-1. *General remarks*

The general principles are outlined in 3.07.02

A-1.1. The method using sampling vessels is convenient especially, when oils with low dissolved gas contents requiring a large sample volume are involved.

A-1.2. The method using bottle is simple, requires little skill and will be adequate for many purposes. While filling caution may be taken that there may not be any air/gas bubble in the bottle. The oil carrying hose should be at the bottom of the bottle and fill-up upwards without stirring.

A-2.0. *Sampling by sampling tube*

A-2.1. The volume of sampling tube may be 250cm^3 to a litre. It may be closed by suitable valves provided at both ends. Impermeable oil resistant rubber tubing is to be used for transferring the sample to the extraction apparatus.

A-2.2. The sampling tube is connected to the sample point by impermeable oil-resistant rubber tube. The valves on the sampling tube are opened. The free end of the rubber tube is connected to the sampling point of the transformer.

A-2.3. After the sampling tube has been completely filled with oil, about 1 litre to 2 litres are allowed to flow to waste.

A-2.4. The oil flow is then closed by shutting off firstly the outer cock, then the inner one and finally the sampling valve.

A-3.0 *Sampling by bottles*

A-3.1. This method requires the bottles capable of being sealed gas tight, Suitable bottles have screwed plastic caps holding a conical polythylene seal or high vacuum glass stoppers.

A-3.2. The connection to the sample point may be made by oil-proof plastic or rubber tubing of about 5mm diameter.

A-3.3. If the connection is to be made to a drain valve for sampling, it may be made with the help of a blanking plate fitted with a suitable adopter.

A-3.4. The sampling valve is opened and about 1 litre of oil allowed to flow to waste through the tube. The end of the tube is then placed, with the oil, still flowing, at the bottom of the sampling bottle and the bottle allowed to fill. After allowing about one bottle volume to overflow, the sample tube is gently withdrawn with the oil flow continuing. The bottle is then tilted, allowing the oil level to fall to 1 mm to 2 mm from the rim and the bottle cap is placed in position. The sampling valve is then closed.

Annexure VI

Instruction for Testing Acidity, free Moisture, I.F.T. B.D.V., etc.

1.1 *Testing for Acidity*

General : Properly refined insulating oils are free from mineral acids and alkalis. On the other hand, practically all oils contain natural organic substances which are either weak acids or which on oxidation form compounds which are acidic in nature. The proportion of these organic substances present in an oil is referred to as 'organic acidity' while the inorganic acidity gives a measure of the mineral acid and contamination present. The inorganic acidity and the total acidity (which gives a measure of the contained organic and inorganic acidity) are usually determined and the organic acidity is derived by deducting the inorganic acidity from the total acidity.

1.2. *Total acidity*

1.2.1. Preparation of reagent and indicator:

a) Prepare 0.1 N aqueous solution of potassium hydroxide (KOH) by dissolving 1/100th of the molecular weight of KOH in 100 c.c of freshly boiled and cooled distilled water.

NOTE: The molecular weight of KOH is 56.1 and 0.1 N solution may be prepared by dissolving 0.561 gm. of KOH in 100 c.c. of distilled water or a proportionate amount of KOH in a smaller quantity of distilled water.

The standard KOH solution made as above should be stored in a glass stoppered bottle and restandardised periodically with a standard acid solution (say 0.1 N hydrochloric acid or oxalic acid) as reaction with the carbon-di-oxide in the air might result in weakening of the KOH solution.

(b) Prepare phenolphthalein (indicator) solution by adding phenolphthalein to distilled water or alcohol in the proportion of 0.05 gms of phenolphthalein to 100 c.c. of water or alcohol.

1.2.2. Procedure for Testing:

i) Weigh approximately 10 grams of the oil to be tested to the nearest 0.01 gram into a 250 ml. conical flask.

ii) Add 1 ml. of the phenolphthalein solution to 50 ml. of alcohol, heat the mixture to 40 to 50°c with a spirit lamp and neutralize with the standard potassium hydroxide solution.

(iii) Add the neutralized alcohol to the sample and heat the mixture to boiling. Allow to boil for 5 minutes. The mixture should be agitated by swirling in the unstoppered flask to ensure extraction of the acid by the alcohol.

(iv) Add 1 ml. of phenolphthalein solution and cool the mixture to 40 to 50°C and titrate as quickly as possible with the standard KOH solution.

(v) Express the result as the number of milligram of KOH required to neutralize the acidity of one gramme of sample. This should be calculated as follows:

$$\text{Total acidity} = \frac{A \times N \times 56.1}{W} \text{ mg. KOH / gm. of oil}$$

Where A = Quantity of KOH solution in ml. used in titration.

N = Normality of the KOH solution used for titration.

W = Weight of the sample in grammes.

NOTE: As alcohol is costly, rectified spirit may be used instead of alcohol.

1.3 *Inorganic Acidity*

i) Weigh approximately 100 gms of the oil to the nearest 1 gramme into a separating funnel.

ii) Neutralize 100 ml. of warm distilled water using 0.1 ml. of a solution of methyl orange indicator (containing methyl orange in the proportion of 1 gramme to 1000 ml. of distilled water).

iii) Add the warm neutralised water to the oil in the funnel, shake the mixture vigorously for 1 minute and allow to stand for the oil and water to separate.

Run the water layer into a flask add one ml of methyl orange solution and titrate with the standard KOH solution.

iv) Express results in milligram KOH per gram of oil as in 1.2.2.(v) above.

1.4 *Organic Acidity*

Organic acidity is total acidity minus inorganic acidity and may be obtained from tests outlined in 1.2 and 1.3 above.

1.5 The quantity of organic acidity in most oils is negligible and for all practical purposes, it would suffice if tests for total acidity are conducted for maintenance purposes.

1.6 *Limits of acidity*

1.6.1 Transformer oil deteriorate gradually while in service through oxidation with the resultant formation of sludge and other oxidation products. The acids formed promote emulsification of water with oil and thus contribute to lowered dielectric strength. Peroxides are also formed which seriously reduce the mechanical strength of fabric (cellulose) insulation. Acidity in the oil causes rusting of the iron work inside the tank above the oil level and attacks varnish on windings. The acidity in an oil is therefore an important characteristic in assessing its service worthiness and oil of acidity above 1.0 mgm. KOH per gramme of oil should not be retained in service in transformers or other equipment.

1.6.2 The upper limit of acidity to be adopted for oils in power and distribution transformers is 1.0 mgm. KOH/gm of oil.

If the acidity exceeds 0.7 mgm. KOH/gm. of oil the oil should be watched by means of frequent acidity tests (atleast once in a month in the case of power transformers and once in three months in the case of distribution transformers). If the acid content exceeds 1 mgm. KOH/gm. of oil, the oil should be replaced by fresh oil.

1.6.3 The acidity limits laid down under paragraph 1.6.2 above may be taken to be for the 'total acidity' of the oil.

1.6.4 More than the acidity itself, the rate of increase of acidity of oils in service would appear to give a better indication of the condition of the oil and any rapid rate of increase in acidity of oils in service transformers should be investigated in detail.

2.0 *Testing for presence of free moisture*

2.1 The crackle test is a simple test for the detection of moisture in the oil and should be carried out in addition to the standard test for di-electric strength.

The greatest defect of the electric strength test is that it will not detect moisture in otherwise clean oil. It will detect dirt and water but not dirt or water. For this reason, it should invariably be supplemented by the crackle test which should be made compulsory.

A case occurred some while ago of a transformer put into service out of storage which immediately failed between turns. The oil was examined and it easily passed the dielectric strength test withstanding over 45 kv.

However, it failed instantly under the crackle test and subsequent examination showed moisture penetration into the winding insulation.

A compulsory crackle test during maintenance inspection or before being put into service, would show this condition.

2.2 A representative sample of the oil should be taken in a clean dry test tube (about 12.5 cm long and 1.25 cm diameter) to fill the test tube to one quarter of its depth, care being taken to see that the oil is not in an aerated condition. The test tube containing the oil should be heated gently in a silent flame until the oil commences to boil. Audible crackling indicates the presence of moisture.

2.3 Alternatively a metal of about 1/2 inch diameter may be heated to dull redness and plunged into a cold sample of the oil of 600 ml. contained in a clean and dry receptacle. The oil should be stirred with the hot rod thoroughly. Cracking during the stirring process indicates presence of moisture.

2.4 A third method for detection of moisture in oil is to add anhydrous copper sulphate to a sample of oil. If the oil takes a blue tint moisture is present.

3.0 *Resistivity Test*

The resistivity of the oil should be checked. Minimum value is 0.1×10^{12} ohm-cm at 90°C.

4.0 *Power Factor Test*

The power factor of the oil should be measured every year. At 90°C - Max. value is

1.0 for voltages 145 KV and below and 0.2 for voltages 145 KV and above.

5.0 *Interfacial Tension Test*

This test reveals the overall quality of the oil and consists of measuring the INTERFACIAL TENSION of 18 dynes/cm between an oil and water layer. Interfacial tension should be a minimum of 18 dynes/cm. if not the oil should be discarded.

Field test for interfacial tension of oil

The following is the procedure for quick determination by a field test if the interfacial tension of oil sample has fallen below a specified limit. This test will enable a rough determination of the condition of the oil so that corrective measures to prevent sludge formation can be taken at the initial stages of deterioration of oil which is reported to occur if IFT tends to fall below 18 dynes/cm.

Field test for IFT

Centre a piece of rapid filtering filter paper (Whatman No.4 is suitable) on a support so that the paper is held along its circumferential edge. Apply three drops of oil to be tested at the centre of the paper. Two minutes after the oil has been absorbed by the paper, apply one drop of erythrosin indicator solution (prepared by dissolving lg. of commercially available erythrosin dye in 100 ml. of distilled water) to the centre of the oil spot. Measure the time required for the centre of the indicator spot to be completely absorbed by the paper. This time is related to the concentration of the polar contaminants in the oil. By knowing the absorption time of the oils with different IFT values we can judge whether the unknown sample has an IFT value of below or above the specified limit.

Also the shape of the indicator spot gives a good indication of the IFT value of the oil. With oils having an IFT value of 25 dynes/cm. or above the edges of the spot are smooth and the shape is regular. If the IFT falls below this level the edges of the spot become irregular and oils with IFT of below 14-16 dynes/cm. have highly irregular shapes. This test however can be used only as a screening test for lessening the number of samples to be sent to the laboratory, where the exact IFT can be determined with the aid of a tensiometer.

Conclusions

The interfacial tension value of oils can be used effectively to predict the presence of formation of sludge in an oil filled equipment. Sludge formation is imminent if the IFT value falls below 18 dynes/cm. Oils with an IFT value of 18 dynes/cm. or above do not contain sludge. Thus suitable corrective measures, if adopted, when the IFT value is tending to fall below 18 dynes/cm can prevent sludge formation and reduce the maintenance cost to a large extent.

NOTE 1. Erythrosin Indicator solution may be prepared by the Asst. Executive Engineer/Special Maintenance of the system and supplied to all Substations. Power station staff can prepare it at the power station or obtain from the nearest system.

2. Substation staff can determine the condition of oil by the shape of the spot and if it shows deterioration in IFT they may send a sample to A.E.E./Special Maintenance.

3. A.E.E./Special Maintenance may determine the condition of oil through 'absorption time' method and if the oil shows poor IFT values, the sample may be sent to Research Lab. for determination of actual I.F.T.

4. A.E.E./Special Maintenance should use only one brand of paper for testing of oil, as use of different brands of paper may lead to erratic values and cause confusion.

NOTE: The insulation resistance of the transformer varies with winding temperature; the higher the temperature, lower will be the values. In the case of E.H.V. transformers, the values can vary from 600 megohms at 30°C to 75 megohms at 75°C. The exact condition of the insulation is best assessed by operating the values obtained at a certain temperature to the value expected with the temperature according to insulation drying curve of the transformer, plotted during previous drying out operation carried by the transformer erection division. It is desirable that this graph is got by the sub-station staff from the transformer erection and kept exhibited. Whenever, megger readings during routine maintenance are found to be lower than the readings expected as per the chart the IR values should again be checked with the power operated megger after disconnecting all the jumpers from the transformers. The polarisation index should be determined before declaring the transformer to be with a low I.R. value requiring a fresh dry out.

Method for determination of electric strength of insulating oils as per IS 6792/1972

Principle

The test method covered in this standard consists in subjecting the oil, contained in a specified apparatus, to an ac electric field with a continuously increasing voltage till the oil breaks down.

General

Although the test method is intended for the acceptance of new insulating oils at the time of their delivery, it is applicable, in principle to all classes of new and used oils for transformers, circuit-breakers, oil-filled cables and capacitors. Its application, however is restricted to oil having a kinematic viscosity of less than 50 centistokes at 27°.

Sampling

The sampling shall be done in accordance with the procedure laid down in IS:6855.

Condition of the oil

The test is carried out on the oil as received, without drying or degassing.

Test Cell

The cell, made of glass or plastic, shall be transparent and non-absorbant. It shall have an effective volume between 300 and 500 ml. It should preferably be closed.

Two types of cells are illustrated in Figs. 3.2 and 3.3.

Electrodes

The copper, brass, bronze or stainless steel polished electrodes shall be either spherical (12.5 to 13.0 mm diameter) The electrodes shall be mounted on a horizontal axis and shall be 2.5 mm apart.

The gap between them shall be set to an accuracy of ± 0.1 mm by means of thickness gauge. The axis of the electrodes is immersed to a depth of approximately 40 mm.

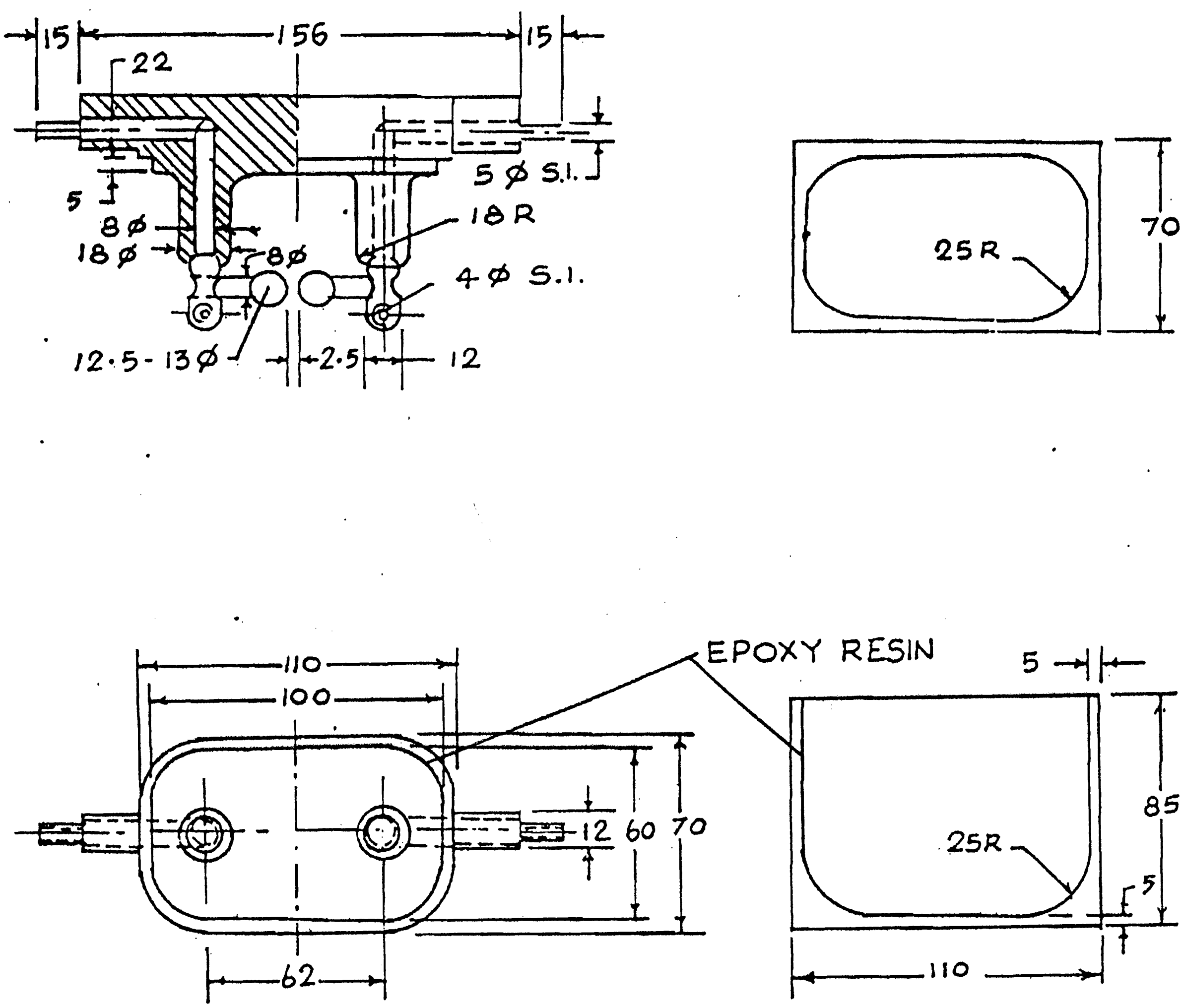
Electrodes shall be replaced as soon as pitting caused by discharges is observed.

Preparation of the cell

Between tests, the oil shall be poured away and the cell left in an inverted position to exclude dirt and moisture, alternatively, the cell shall be filled with oil having high electric strength and suitably covered.

If the cell has not been used for some time, it should be thoroughly cleaned; the electrodes shall be removed, cleaned and finally rinsed with dry clean new oil. Replacement of electrodes should be carried out with the greatest care, avoiding all direct contact with the fingers.

Immediately before use, the cell shall be cleaned by rinsing with the test oil (at least twice) before proceeding to the final filling.



ALL DIMENSIONS IN MILLIMETRES

Fig. 3.2
Test Cell

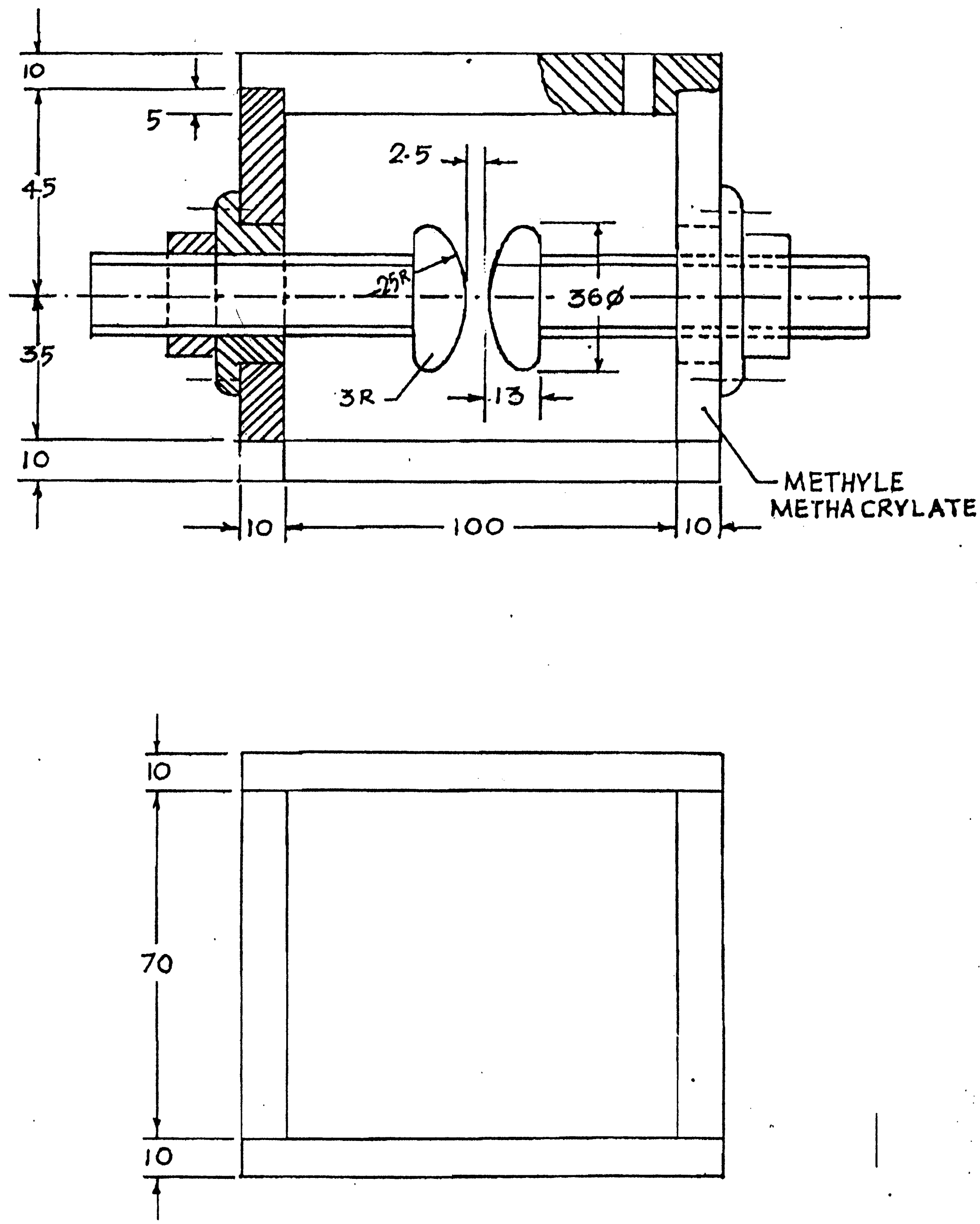


Fig. 3.3
Test Cell

Preparation of the sample

The sampling vessel containing the test oil shall be gently agitated and turned over several times in such a way as to ensure as far as possible a homogeneous distribution of the impurities contained in the oil without causing the formation of air bubbles.

Immediately after this, the sample should be poured down into the test cell, slowly in order to avoid air bubbles forming (for example, by means of a clean, dry glass rod) The operation is carried out in a dry place free from dust.

The oil temperature at the time of the test shall be same as that of the ambient air, preferably in the neighbourhood of 27°C (15°C to 35° C) and noted.

Test method

The test consists in applying to the electrodes, an increasing ac voltage of frequency 40 to 60 Hz., the rate of increase of the voltage being uniform and equal to approximately 2 kv/s, starting from Zero up to the value producing breakdown.

The circuit is opened manually if a transient spark (audible or visible) occurs between the electrodes or automatically if an established arc occurs.

In the latter case the automatic switch shall break the voltage within 0.02 second.

The breakdown voltage is the voltage reached during the test at the time of the first spark, occurs between electrodes, whether it is transient or established.

The test shall be carried out six times on the same cell filling.

The first application of the voltage is made as quickly as possible after the cell has been filled, provided there are no longer any air bubbles in the oil, and at the latest 10 minutes after filling. After each breakdown, the oil is gently stirred between the electrodes by means of a clean, dry glass rod, avoiding as far as possible the production of air bubbles. For the subsequent five tests, the voltage is re-applied one minute after the disappearance of any air bubbles, that may have been formed. If the observation of the disappearance of the air bubbles is not possible, it is necessary to wait for five minutes before a new breakdown test is started.

The electric strength shall be the arithmetic mean of the six results which have been obtained.

Electrical apparatus

General : The characteristics of the electrical apparatus shall comply with the following requirements.

Transformer

The test voltage may be obtained by using a stepup transformer supplied from an ac (40 to 62 Hz) low voltage source. The primary voltage is gradually increased, either manually or by an automatic control device.

The voltage applied to the electrodes of the oil filled cell has an approximately sinusoidal wave-form, such that the peak factor is within 1.34 and 1.48.

The transformer and associated equipment are designed to produce a minimum short-circuit current of 20 mA for voltage higher than 15KV: To avoid damage to the electrodes, the short-circuit current shall be limited to a maximum of 1.0A, if necessary by the addition of external impedance.

Protective gear

The test is carried out so as to prevent high frequency oscillations as far as possible.

To protect the equipment and to avoid excessive decomposition of the oil at the instant of breakdown, a resistance limiting the breakdown current may be inserted in series with the test cell.

The primary circuit of the high-voltage transformer is fitted with a circuit-breaker operated by the current flowing, following the breakdown of the sample, and with a delay not more than 0.02 second. The circuit-breaker is fitted with a no-voltage release coil to protect the equipment.

Voltage regulation

Voltage regulation may be ensured by one of the following methods.

a) Variable-ratio auto-transformer

b) Resistance type voltage divider

c) Generator-field regulation, and

d) induction regulator

Preference is given to an automatic system for increasing the voltage because it is difficult to obtain manually a reasonably uniform rate of voltage rise as a function of time.

Measurement of test voltage

For the purpose of this standard, the magnitude of the test voltage is defined as its peak value divided by $\sqrt{2}$.

This voltage may be measured by means of a peak voltmeter, alternatively by means of another type of voltmeter connected to the input or output side of the testing transformer; or to a special winding provided there-on; the instrument then used shall be caliberated against a sphere-gap up to the full voltage which it is desired to measure.

The ratio of the voltage derived from the sphere-gap to the voltage indicated on the auxiliary instrument may be dependent upon the presence of the test cell or of the sphere-gap and it is important that the test cell (or an equivalent load) should be in the circuit during the calibration.

The sphere-gap may be disconnected during the actual test if its presence is known to have a negligible influence on the voltage ratio.

The accuracy of measurement of voltage shall be better than ±4 percent.

Results

The report of results shall include the following information:

a) Reference to the Indian standard

b) Breakdown voltages obtained during each test

c) Average of the breakdown voltages

d) Type of electrodes

e) Frequency of the test voltage and

f) Oil temperature

Annexure VII

Proforma for transformer oil test results

New Oil

1. Name of supplier:
2. Sample received from:
3. Date of sample:
4. Date of Test

Test Values as per IS 335/1983 for New Oil.

Sl. No.	Characteristic	Permissible limit for satisfatory use	Test results	Remarks
1.	Appearance	The oil shall be clear and transparent and free from suspended matter or sediment.		
2.	Electric Strength (BDV) IS 6792/1972	A. As received 30 KV (Minimum) B. After filtration 60 KV (Minimum)		
3.	Water content IS 2362/1973	30 PPM (max)		
4.	Ressistivity at 90°C IS 6103/1971	35 x 12^{12} Ohm-Cm at 90°C (Min)		
5.	Neutralisation value (total acidity) IS 335/1983 App. A	0.03 mgm of KOH/gm (Max.)		
6.	Flash point IS 1448/P21/1970	140°C (Minimum)		
7.	Interfacial Tension IS 6104/1971	Not less than 40 Dynes/cm		
8.	Dielectric Dissipaction factor (Tan Delta) at 90°C IS 6262, 1971	0.002 (Max)		

Proforma for transformer oil test results

1. Name of S.S. : OIL IN SERVICE
2. Transformer capacity : MVA Auto/Power Transformer
3. Voltage ratio :
4. Make & Sl. No. :
5. Date of first commissioning :
6. Date of last oil filtration :
7. Sample from : Bottom/Top/Buchholz/conservator
8. Date of Sample :
9. Date of test :

Test values as per IS 1866/1983 for oil in Equipments.

Sl. No.	Characteristic	Permissible limit for satisfactory use		Test results	Remarks
1.	Electric Strength (BDV) IS 6792/1972	50 KV (Min) 40 KV (Min) 30 KV (Min)	For use in 230KV & above for use in 110 KV, for use in 66 KV & below.		
2.	Water content IS 2362/1973	25 PPM (Max) 35 PPM (Max)	For voltages above 145KV For voltages below 145 KV		
3.	Resistivity at 90°C IS 6103/1971	0.1×10^{12} (Min)	Ohm-Cm for all volages		
4.	Neutralisation value (Total Acidity) App B IS 1866/1983	0.5 mgm of KOH/gm (Max)	for all voltages		
5.	Flash Point IS 1448 (P 21) 1970	125°C (Min)	for all voltages		
6.	Interfacial tension IS 6104/1971	Not less than 18 dynes/cm	for all voltages		
7.	Di-electric dissipation factor (Tan delta) at 90°C IS 6262/1971	Max. 1.0 Max. 0.2	for below 145 KV for above 145 KV.		
8.	Dissolved Gas Analysis IS 9434/1979	No. of years in service (a) 1–4 yrs. (b) 4–10 yrs. (c) 10 yrs. & above			

	Hydrogen	Methane	Ethane	Ethylene	Acetylene	Carbondioxide
Permissible limits in ppm						
Test values in ppm						

9.	Remarks :

Annexure VIII

Condenser Bushing

This type of bushing is commonly used for the terminals of high voltage transformers and switchgears. Fig. 3.4 shows a conductor which is charged to a high voltage V. This conductor is insulated from the flange B (at earth potential) by a condenser bushing consisting of dielectric material with metalfoil cylindrical sheaths of different lengths and radii embedded in it, thus splitting up what is essentially a capacitor having the high tension conductor and flange as its plates into a number of capacitors in series.

Dielectric loss and power factor

If a steady voltage V is applied to the plates of a perfect capacitor a "charging current" flows from the supply for a short time and gives to the capacitor a certain quantity Q of electricity, which is sufficient to produce a potential difference between the capacitor plates of V volts. When this potential difference has been attained, the current ceases to flow, the quantity of electricity Q which has been supplied being given by $Q = CV$ where C is the capacitance and is of course dependent upon the permittivity of the dielectric. In a perfect capacitor, therefore the dielectric has only electrical property viz. that of permittivity. In all practical dielectrics the current does not cease after a short time but dies away gradually over a long period of time.

A very small 'conduction' current will also flow through the dielectric because of the resistance of the dielectric though very high.

If a sinusoidal voltage is applied to a perfect capacitor, the current which flows in to the capacitor leads the voltage in phase by 90^o Fig. 3.5 (a).

Owing to the dielectric loss the current in the capacitors used in practice leads the voltage by an angle slightly less than 90^o – Fig. 3.5 (b). The angle Ø is the phase angle. The angle delta which is equal to 90 – Ø is called the 'loss angle'. The power factor is equal to cosine of the angle Ø or sine of angle delta. The dielectric dissipation factor is equal to tan delta when Ø is nearing 90^o.

The power factor is a reliable indicator of deterioration of the dielectric in a bushing. The power factor of sealed bushings is low initially and remains low in service if the bushing is in good condition. An increase in power factor is evidence of a change in the characteristics of the dielectric and a continuing trend towards high power factor is evidence that a potentially damaging condition is developing. Persistently stable power factor readings offer assurance that the internal parts of the bushing are in good condition.

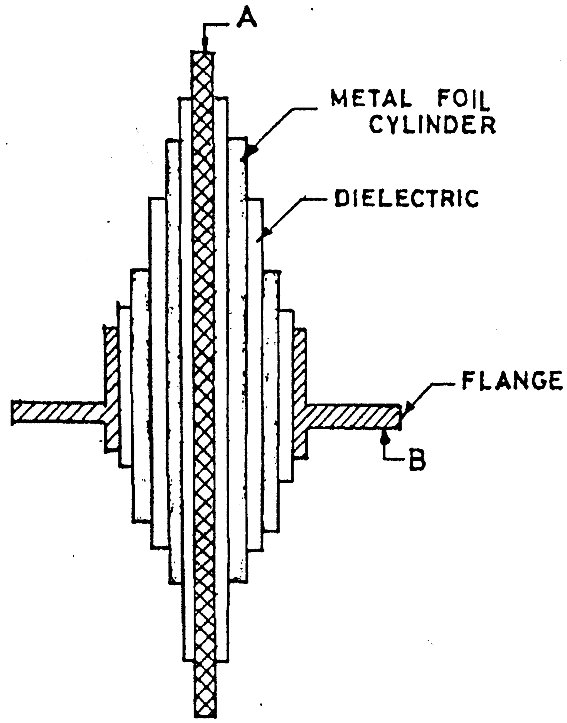


Fig. 3.4

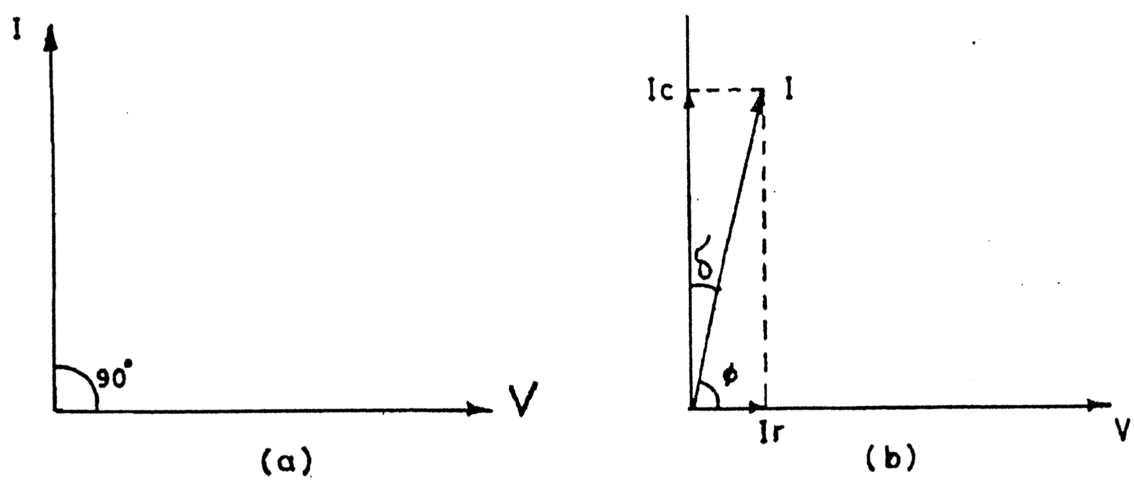


Fig. 3.5

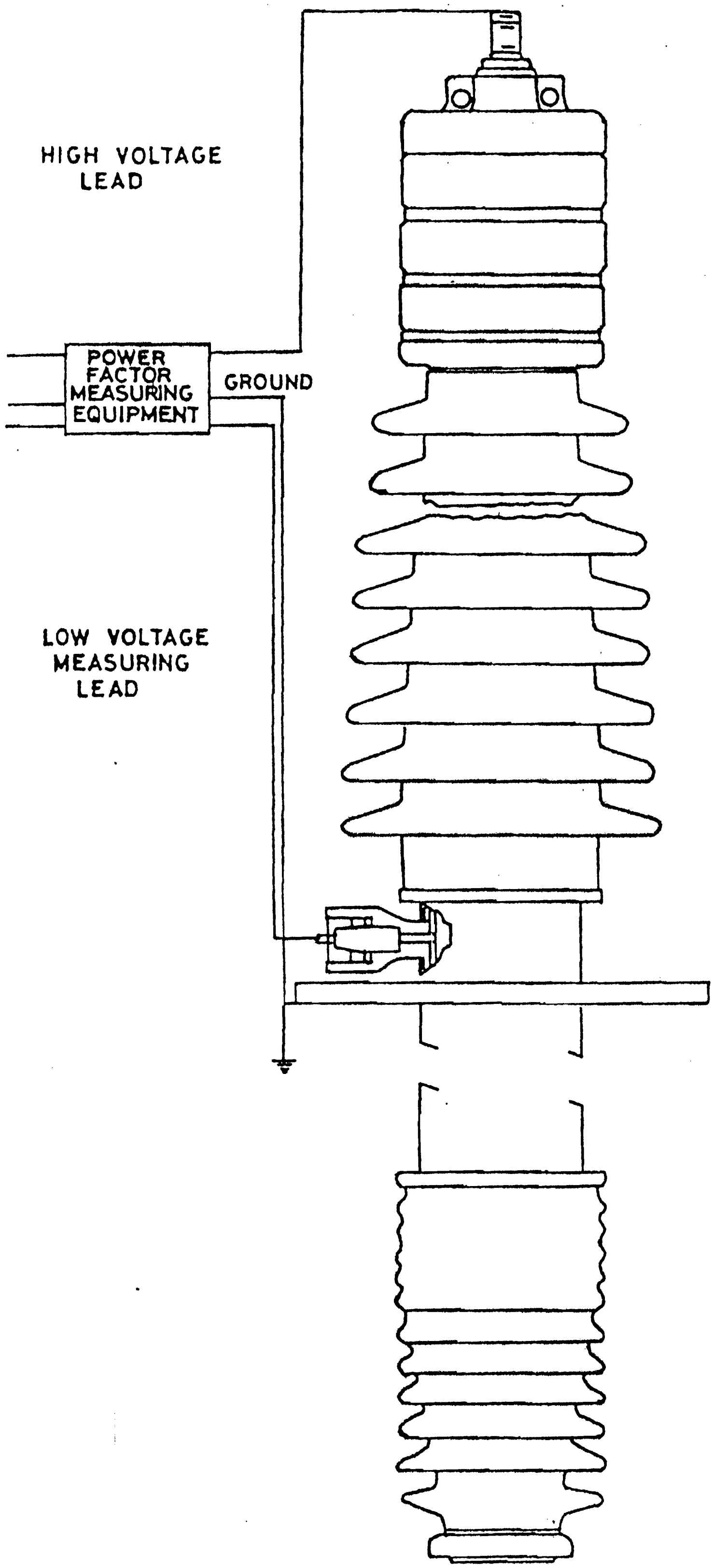


Fig. 3.6
Condenser Bushing

Power Factor Tap

The condenser Bushings are provided with Power Factor tap for conducting tan delta tests. The arrangement is as shown in the Figure 3.6

The maximum values of tan delta, measured at U_n for U_n < 52 KV and at 0.3 U_n for U_n > 52 KV are as follows as per IS.2099/1986:

Condenser bushings	
Resin–impregnated paper Resin–bonded paper	
Cast insulation Composite.	0.015
Oil–impregnated paper	0.007
Non–condenser bushings	
Cast insulation.	0.020

CIRCUIT BREAKERS

4
Circuit Breakers

CONTENTS

4. CIRCUIT BREAKERS

4.01 General

A circuit breaker is a switching device which has to make, carry and break currents under normal and abnormal circuit conditions. The life of a circuit breaker and the service it renders depend to a large extent on proper application, installation and maintenance. Preventive maintenance often averts serious problems.

Major causes for which the circuit breaker need to be attended to

(a) Contact erosion due to short circuit interruption.

(b) Erosion to arc control device.

(c) Deterioration of arc quenching medium.

(d) Deterioration of sealing material (ageing).

(e) Drying of lubricants.

(f) The wear of the sliding surfaces and links.

Inspection, frequency and procedure should be determined by experience under operating conditions. Deciding factors may be the number of fault operations, severity of faults, weather, elapsed time or a combination of these.

If there are unusual noises, discoloration of oil,signs of moisture, or other hazardous conditions, a special inspection is made.

Manufacturer's instruction books are a vital help in maintenance, and should be kept available. The older the breaker, the more maintenance it will need and the harder it will be to get a new manual.

The most frequent mechanical failures are broken lift rods, operating levers, and linkages. Most of these failures result from improper adjustments, infrequent inspections or lack of lubrication.

As each section of the breaker is inspected, make a careful check for worn out or broken parts, loose or missing components, and burnt spots. Clean off all dirty oil, carbon, rust or corrosion. Tighten all nuts, bolts, and mechanical parts. Each component should be checked carefully for evidence of moisture, rust, mildew or low insulation resistance readings. Moisture can usually be minimized by good ventilation. Heaters may be installed to reduce moisture and paint can be touched up to prevent corrosion.

Proper lubrication is equally important. Use oxide-inhibiting oils which contain graphite. Ordinary machine oils and penetrating oils evaporate quickly and frequently gum up or form residues.

Note particularly that all electrical connections should be clean, secure, and make a good electrical contact. Grounds require special attention.

4.02 Safety Precautions

Before starting work on a breaker, be sure you have observed all safety precautions. Be particularly careful when releasing the breaker and when returning it to service. Be sure that:

Breaker is open before opening disconnects.
Line and bus disconnects have been checked open.
There are no backfeeds from potential transformers.
Main fuses at the switchboard have been removed
and d.c. is disconnected from the breaker mechanism.

Tools and equipment are in safe working condition. Finally, work safely. Keep your mind on your work and take no chances.

In breakers rated 46KV or less, work must be done from ladders or platforms along side the breaker. Energised overhead conductors make it dangerous for workmen to stand on these breakers. Essential work may be done from the top of the breakers only if protective barriers have been installed.

Caution

Do not operate the breaker by solenoid or other operating mechanism without oil in the tank as this will damage the breaker mechanism. Hence when working on the mechanism with the breaker closed, wire the trip latch or block the breaker closed so that it cannot be tripped accidentally.

4.03 Operating Mechanisms

4.03.01 Types of Operating Mechanism

1) Spring operated Mechanism.
2) Compressed air Mechanism.
3) Hydraulic operating Mechanism.
4) Solenoid Closing Mechanism.

4.03.02 Spring Operated Mechanisms

i) General description

The operating mechanism consists, in principle, of a battery of springs, which are charged by a motor (by hand cranking also) with gears and a control mechanism for carrying the closing and opening operations.

ii) Maintenance

a) *General:*

Work on operating mechanism should be carried out only when the springs are in discharged condition and the circuit breaker in open position. Clean the operating mechanism whenever required and, if possible, twice in a year. Pay special attention to the auxiliary switch contacts and the terminal blocks for any possible loose contacts etc. The operating mechanism is to be lubricated with recommended lubricants. The brand of lubricants, periodicity of lubrication and the parts that are to be lubricated are to be followed as per the maintenance manual of the circuit breaker. Check I.R. value of the motor and circuits once in a year.

b) *Dash pots:*

Inspect alignment and adjustment of all dash pots, bumpers, and shock absorbers. Be sure dashpots and shock absorbers have the proper amount of suitable fluid and are free from binding. Dashpots, bypasses, and air valves should be free and adjusted so that they check mechanism movement before the opening stroke is complete and allow it come to its proper position without undue impact. Stops must be adjusted to provide the correct overtravel when closing.

c) *Springs:*

Inspect all springs-bumper buffer, closing tail,accelerating, and balance-for breakage, proper size and 'set' replacing any with a permanent loss of tension or compression. See that all spring tops are securely fastened and lubricated. Check for lost or missing springs.

d) *Slow motion Check:*

See that all links and levers move freely. Operate the mechanism slowly by hand to see that all parts move freely and no undue friction is noticeable. Observe mechanism during several closing and tripping operations to see that everything is in working order.

e) *Latch:*

Check all pins, bearings and latches for binding and misalignment. Check latch carefully to see that it is not getting worn so as to unlatch from vibration or stuck and fail to trip.

f) *Electrical Operating Mechanism:*

The first step in checking the electric operating mechanism is to measure insulation resistance of the control cable, trip coil, and closing coil with a 500 V instrument. Clean the DPST control switch and apply a little white Vaseline or oxide inhibiting grease to the control and hinge ends. Be sure that trip solenoid has a little free travel before striking the trip lever and a little over travel after engaging the trip latch. Be sure there is a good connection from the panel to the ground wire. Clean and lubricate all bushings and bearings with oil or grease which will not freeze in winter.

Clean the ground surfaces of all latches. Dirt or corrosion here will increase latch resistance and impede tripping. If the metal surface is uneven, polish with crocus cloth or fine emery but be careful not to alter the angle of the latch. Then coat the surface with a thin film of graphite or gun grease.

Using the manual control lever, operate the electric mechanism slowly to see that all parts move freely. Do this first with the solenoid connected to the life rod linkage, then with it disconnected. The trip-free latch should reset as the mechanism passes the trip-free position. Check travel of the trip plunger, making sure it is long enough to give positive tripping. Compare electrical and mechanical overtravel against values given in the manufacturer's instructions.

g) *Locking pins and plates:*

Check that all pins, locking plates, check nuts etc., are in place and are properly tightened.

h) *Interlocks:*

Check all interlocks for proper action.

i) *Junction boxes:*

Examine all junction and conduit boxes for moisture. If it is present, retape connections with rubber and friction tape and apply a good coat of lacquer. To provide good ventilation, 1/4" holes may be drilled in the bottom of wo or more junction bxes selected to give a natural circulation of air. Conduit covers should be replacd carefully, installing new gasket if needed.

j) *Cabinet heaters:*

Inspect heaters in the mechansm cabinet for loose connections, damaged insulation, or overheating. Turn the power on to see that they are operating correctly. Rust may indicate that they are not working. Heaters should be on at all times to minimise condensation.

k) *Operating counter:*

Check the operations counter to make sure it is operating correctly, that the numbers are in plain view, and that the linkage is properly adjusted. At the beginning and end of the inspection, record the counter reading in the station log book and on the test sheet.

l) *Painting and ventilation of cabinet:*

Clean and paint the inside of the mechanism housing. Excessive rust here may indicate that air vents are blocked, that new vents are blocked, that new vents or heaters are needed. On some old type breakers, a 1/4"hole may be drilled in the web on the bell crank housing to let water out.

4.03.03 Compressed Air Mechanism

(i) General Description:

With suitable air compresser, compressed air is stored in air reservoir. This compressed air is utilised to operate the circuit breaker. A centralised air compressor which feeds compressed dry air for a maximum of about six breakers is installed in a few places. In certain other places unit compressed air plants are provided for each breaker.

ii) Maintenance of compressor:

Daily:

a. Clean the compressor thoroughly.

b. Check the oil level in the crank case. Replenish with the correct grade of oil if required.

c. Check compressor belt tension.

d. Drain water from the air receiver.

Every 125 hours of Operation

(a) Dismantle the suction filter and rinse in petrol or kerosine.

(b) After thorough drying, reassemble on the compressor.

Every 500 Hours of Operation

(a) The breaker valve should be dismantled, cleaned and checked for perfect seating of the valve.

(b) Examine the lubricating oil in the sump-drain the oil if necessary and renew.

(c) Dismantle the delivery unloader valve. All the parts are to be thoroughly cleaned and renew the worn-out parts.

(d) Dismantle the solenoid valve. Examine the plunger, guide and 'O' ring. Renew the spares if required.

4.03.04 Hydraulic operating Mechanism

(i) General Description:

Hydraulic drives are of high pressure, as high as 300 kgs/cm^2. The hydraulic system generally consists of the drive cylinder, main valve, accumulator and control unit. The operating force is produced by differential piston whose, smaller surface area is under constant hydraulic pressure. The larger surface is pressurised for closing and depressurised for tripping.

(ii) Maintenance:

(a) Make a visual leakage check of the hydraulic system daily. Tighten or replace the oil seal wherever necessary.

(b) Check the oil level and its condition every 3 months. Fill in new and correct grade and filtered oil if required.

4.03.05 Solenoid Closing Mechanism

(i) General Description:

The closing energy is obtained from the electro mechanical force due to heavy current in the solenoid. Tripping spring is generally compressed during closing operation. This kind of mechanism is relatively simple in construction.

(ii) Maintenance:

(a) Voltage drop up to solenoid:
Check operating voltage at the solenoid terminals with full operating current flowing to see that it is adequate for correct operation.

(b) I.R. Value:
Check resistance and insulation resistance of the solenoid coil.

(c) Plunger movement:
Check plunger for stickiness in guides.

(d) Fuses:
Examine fuses on solenoid circuit.

(e) Current:
Check closing solenoid current.

(iii) Trip coil Plunger:

(a) Observe operation during electrical tripping. Check that full energetic snappy action of the plunger is obtained.

(b) Check plunger for any stickiness.

(c) Check that the plunger has sufficient travel to assure an adequate impact that will positively release the breaker latch.

(iv) I.R. Value:

Check resistance and insulation resistance of coil.

(v) Fuses:

Examine fuses on trip circuit.

(vi) Control Relay or contactor:

(a) Mechanical movement:
Check mechanical parts for free movements.

(b) Arc chutes:
Clean arc chutes.

(c) Contacts:
Examine contacts and renew where necessary.

(d) Fuses:
Examine fuses on control circuit.

4.03.06 Types of Breakers

The main types of HV circuit breakers in service are as under:

1. Oil circuit breakers.
2. Minimum oil circuit breakers.
3. Air blast circuit breakers.
4. SF6 Circuit breakers.
5. Vacuum circuit breakers (upto 33 KV only).

4.04 Maintenance Schedule for Oil Circuit breakers

4.04.01 General

OCBs are in service in our grid upto 230 KV level. The oil in the tank is utilised to insulate, to provide adequate cooling and arc control.

4.04.02 Tank

(i) *Foundations*:

Check foundations for cracks and setting. A shift of the breaker tanks may break bushings or cause misalignment of contacts or binding of operating mechanism.

(ii) *Tank Lifter:*

Make sure the tank lifter is in good condition before using it. Keep the worm gear and shaft clean, properly lubricated, and adjusted. Be sure all pulleys are well oiled and free of rough surfaces and rust. Do not kink the cable. Keep it clean and well lubricated. When it is not in use, wind it on drums and protect it from the weather. Watch for broken strands. Before lowering the tank, be sure the tank lifter is securely fastened to the frame and that the cable is in the groove of all pulleys. Stand clear of the tank while it is being raised or lowered. Put a couple of planks under tanks of frame mounted breakers before they are lowered to protect the petcock and drain valve.

(iii) *Temperature due to contact heating:*

Note temperature of tank by touch. Some breakers, particularly those carrying heavy currents have a tendency to develop contact heating if left closed for long periods: opening and closing breakers several times at intervals as system operations will permit may alleviate the heating by wiping the oxide from the contact surfaces.

(iv) *Oil Tanks:*

Check oil level in gauges of the tanks. Clean dirty gauge glasses and connections to tank.

Inspect tanks, oil valves, and gauges for leaks. Remove tank hold up bolts, and clean the threads, apply a thin coat of oxide-inhibiting grease, and paint the bolts. Be sure the hole in the top cap of all single connection oil gauges is open. Plugs should be tight enough that they cannot be withdrawn without tools. Replace gaskets and reseat or repack valves.

To locate leaks in the tank cover, first remove all moisture from the bottom. Then build a wall of mud or putty around the outside top of the cover. Fill the enclosure with water and note where it seeps through. Another method is to make the tank airtight, paint the top with soapsuds, force air into the tank, and note where the bubbles form.

Leaks may be repaired by welding, brazing, caulking, or peening. One method of fixing a small hole is to force in metal with a dull cold chisel, then peen the surfaces together with a ball peen hammer. This technique should not be used on cast iron. Another method is to drill and tap the cover and then insert a half inch brass pipe plug which has been painted with shellac or red glyptal. Special kinds of solder will sometimes work. If welding is required, be sure the tank is ventilated.

(v) *Breathers and vents:*

Check for external obstructions to breathers and vents. Check that screens or baffles in vents are not obstructed or broken. Check valves should have a small hole to let out air as the tank is filled. Inspect the screen at the upper end of the vents. Do not remove vents except to clean or replace gaskets. Pipes which extend up and then down over the outside of the tank may not draw off all the gases above the oil: keep flame away from such tanks when the top lid is removed.

(vi) *Oil:*

Sample oil from the bottom of the tank from the drain valve or the sampling plug fitted to the drain valve. In case of small breakers not fitted with drain valves or plugs, sample by means of a glass or brass thief, taking care to take the sample about 1/2 inch above the bottom of the tank. Test the oil for di-electric strength and acidity. Recondition or change oil if results are not satisfactory or if there is noticeable amount of carbon in suspension or in the bottom of the tank.

NOTE: Oil from circuit breakers should be tested for dielectric strength (as per Annexure VI of Chapter 3) once in three months or after six trippings on fault, whichever is earlier. The oil should be reconditioned or renewed as follows irrespective of the operating voltage.

(a) Recondition or renew early, if oil breaks down between 22 KV and 30 KV.

(b) Recondition or renew immediately if oil breaks down at or below 22KV or if there is a noticeable amount of carbon in suspension or deposited at the bottom of the tank.

(vii) *Cleaning of Tank and Refilling:*

Drain oil from the tank. Look for sludge on the bottom of the tank, especially in breakers carrying heavy load or located in confined spaces. Sludge is an indication of overheating, usually from poor contacts or overloading. If sludge is present, determine the cause immediately.

Wipe the inside of the tank with a clean, dry, lint free cloth. Then flush the tank with a little clean oil before refilling. Tanks on frame mounted breakers must be pulled up tight to prevent entrance of moisture.

NOTE: Cotton waste or loosely woven material should not be used for cleaning the inside of circuit breaker tanks, contacts, contact bars, tension rods, etc. Only clean cloth with strong-firm fabric which will not deposit loose fibres should be used.

Clean surface of bushings inside the breaker tank and examine for cracks, chipped or broken porcelain etc.

(viii) *Tank Liners:*

Inspect tank liners visually for burns, holes, warping or carbonized paths in or on the insulation. Check mechanical condition and look for parts that are loose or floating in the oil. Remove all blisters. Remove the liners and clean them thoroughly with oil or by wiping. If liners are too warped, they will interfere with the moving contact. Check the insulation resistance of all liners. If part of the liner is water soaked, it should be baked dry and then varnished.

Remove all rust and scale from the bottom of the cover with a scrapper or wire brush. Oil may be removed by a solvent. Paint the clean surface with an oil resistant paint.

(ix) *Boxing up:*

While replacing the tank cover after completion of inspection and maintenance works, take care to see that the joint packing used, if any, is in proper position and that the tank bolts are uniformly and fully tightened.

(x) *Painting:*

Clean, sand, prime, and spot paint all rusted places on the outside of the tank. If the paint is in bad shape, repaint the breaker. If this cannot be done immediately, record the condition on the inspection report, and the approximate time it should be painted. Clean and paint the top of the tank, bushing flanges and gaskets, bushing caps and all cemented joints.

4.04.03 Bushings

(i) *Fixity:*

Inspect the bushings to make sure that vibrations due to the breaker operation have not caused the bushings to move resulting in misalignment of contacts.

(ii) *External damages:*

Inspect bushings for broken or cracked porcelain, cement breakage, low oil level,foreign matter on petticoats, or loose connections. Look for dried out, improper fittings, or damaged gaskets. Caulking compound may be used to fill cracks around the flanges and on bushings above the oil line. Coat all cracks or breaks with shellac and note them on the inspection report. Coat cement joints between the rain sheds with black paint or lacquer. Paint bushing caps and flanges. On condenser bushings, look for punctured layers at the bottom or for compound leaking from the layers. Repair chipped spots with glyptol lacquer or suitable substitute.

(iii) *Gaskets:*

Inspect bushing gaskets for leaks and tighten bolts.

(iv) *Gauges:*

Check oil level, clean dirty gauge glasses.

(v) *I.R.Value:*

Check insulation resistance of the bushings with contacts closed.

(vi) *Power factor:*

Check power factor of bushings when facilities exist.

(vii) *Bus connections:*

Be sure bus connections are not straining the bushings. If contact pressure on the bottom of the central stud has pushed the stud up into the condenser or if the porcelain condenser layers have been pushed through the flange, install a new bushing.

(viii) *Arc Shields:*

Check porcelain arc shields if provided for cracks, clean the inside and outside of the arc shield and the lower end of the bushing by flushing and wiping with a clean cloth. If there is much oil in the carbon, remove stationary and arc shields and clean thoroughly. Put new oil in the arc shields unless the old oil is clean and has high dielectric.

(ix) *Bushing CTS:*

(a) The insulation resistance of bushing type current transformers should be checked with a 500 V instrument if one is available, if not, use a 1000 V instrument. Include all current transformer circuits upto the switch board. Remove current transformer links at the switchboard and any grounds first. Be sure to replace grounds on the secondary after testing.

(b) Check the copper grounds between the transformer housing and the tank.

Explosive gases may collect in this housing during trip out and then explode when there is another surge.

(c) It is vital that the metal case around the current transformer should not touch the bushing flange. If it does, it will form a short circuiting turn and alter the turns ratio of the unit. Check the insulation resistance of all terminal blocks. Then be sure that any lead removed are reconnected to their proper terminals. Tape any unused taps or fasten them to the terminal board.

(d) Moisture in a current transformer may sometimes be detected by mildew on the leads, by low turns ratio, or by a change in ratio when power is left on a short time. If moisture is present, check conduit cover gaskets for leaks. If the covers are located on the bottom of the conduit, drill two 1/4" holes in the cover.

4.04.04 Contacts

(i) Alignment and Pressure:

Inspect all contacts for proper alignment, uniform pressure, adequate contact area, penetration, and burning. Poor contacts will cause heating, even if they are carrying much less than rated current. The heat in turn will produce sludge and oil deterioration, carbonize the lift rods, soften the copper, or cause a breaker failure.

NOTE: Checking contact surface by inserting a feeler gauge is useless as a guide to the effectiveness of the contact and should be avoided.

(ii) Burning and Pitting:

Examine the main and arcing contacts for burning or pitting. If contacts are burnt or dirty remove and clean them. Large burnt parts on moving contact tips may hit stationary contact and allow or prevent breaker tripping. Remove any beads of fused metal from arcing tips. Clean pitted surfaces with a clean smooth file.

Clean all carbon from contacts of the rod and tulip or socket type and clean all vent holes and orifices. Trim contact surfaces, if necessary.

NOTE:

(a) Where the contacts consist of separate main and arcing contacts, the main contacts generally require little maintenance but should be inspected for good condition and kept smooth and clean. It might be necessary to remove only the projecting beads. Pits in a flat smooth surface are not objectionable.

(b) When cleaning or dressing silver surfaced contacts, care should be taken to ensure that the silver is not removed.

(c) If the arcing contacts are badly burnt or pitted they should be renewed.

(d) Emery paper should not be used for grinding on contacts, as grains get embedded in the surface.

(e) File or sand contacts until a smooth good contact is made. Care should be taken to see that filings do not fall into the tank, by covering the tank with a tray or cloth unless the tank is removed out and contacts are dressed and washed with fresh oil.

(f) All oxide film must be removed by polishing with fine sand paper or crocus cloth. If a good contact cannot be made, replace the contacts. Poor contact is caused by too frequent operations of the breakr, improper adjustment of lift rods, bell cranks, interphase connections, toggles, or latches and by normal wear.

(g) Check contact travel and the compression movement after contacts on the closing stroke: For units above 600 amp. check alignment closely with a feeler gauge. Opening and closing a breaker five or six times will often remove scum and carbon on copper contacts.

(h) Do not file butt type contacts too much, because this removes the hard surface and leaves a soft contact which required excessive maintenance. If deion type moving contacts, made of copper, have mushroomed, remove them, place on a solid, flat plate, and hammer the material back into shape. This will make the surface harder and tougher. If this type of contact heats, check for oxide film.

(i) *Brush type contacts:*

Proper setting and maintenance of lift rod stops is particularly important for brush type contacts. Maladjustment may cause contact damage when the breaker is operated electrically. Since these contacts usually carry heavy currents, the contact compression and surface area is very important.

(j) To check contact pressure of brush type contacts, insert a sheet of paper and a sheet of carbon between them and close the contacts. The imprint on the paper should show about 75% of the surface area making good contact. Do not let the paper get between the laminations. Contact may also be checked by noting the flexing of contact laminations or by using a light and feeler gauge. Contact leaf springs that have been bent or sprung too much will not give satisfactory service.

(k) *Springs:*

Check springs for loss of temper, breaks or other deterioration. Replace where necessary.

(l) *Tightening:*

Tighten up all bolts and current carrying parts.

(m) *Shunts:*

Check flexible shunts at contact hinges for overheating and fraying. Replace the shunts if strands are broken.

(n) *Interrupters:*

Check arc chutes, de-ion grids,oil blast or other interrupters for burnt or warped insulating tubes. Remove carbonised oil and sediment. Be sure to check clearance between arcing tips of moving contacts and the inside of the explosion chambers.

Look for burns and shorts between the laminated sections of de-ion grids. If the insulating barrier is cracked replace it.

(o) *Contact cross head:*

Check contact cross head for misalignment, break, bends or looseness on lift rod.

(p) *Locking Pins:*

Check that all link pins are secure and that all cotter pins, locking places, nuts, set screws, etc. are in place and properly tightened.

(q) *Moving parts:*

Check for bent rods, twisted shafts, etc. Clean all moving parts of rust, dirt and accumulated grease and oil. Wash out bearings, pivots and gears with carbon tetrachloride and operate breaker several times to wash out dirt and old lubricants. Lubricate with new grease or oil. Wipe off excess oil.

(r) *Accelerating springs:*

Examine accelerating or balance springs and see that adjusting nuts are locked tight.

(s) *Dash-pots:*

Inspect oil filled dash pots to ensure that they are filled with oil. Clean out and replenish oil where necessary.

(t) *Stop clearance:*

Check stop clearance against the dimensions given by the Manufacturers' in their instruction books.

(u) *Lift Rods:*

Inspect lift rods and guides visually for burnt, cracked or broken parts. One method of finding a cracked lift rod is to wipe the oil off and then lay the rod in the sunshine. If more oil oozes out along a line, it may indicate a crack.

Occasionally an excess of old linseed oil may be found on lift rods. This may retard breaker tripping and should be removed by scrapping and cleaning. Then apply a coat of air drying varnish. Make certain the lift rod is not binding in the guide. Check for correct stroke length so that proper contact will be made. If there are wooden crossheads, look for burning or cracks.

See that the breaker mechanism operates smoothly and freely without binding.

(v) I.R. Value of lift rod:

If the insulation values of the lift rods are too low, replace them. If this cannot be done, remove them and clean thoroughly with solvent, then bake them at a temp. not exceeding 95°C. Drying time will depend on their size and the amount of moisture absorbed. When the resistance is satisfactory, apply two coats of a good insulating varnish.

NOTE: Cracked or damaged tension rods should be replaced immediately to prevent failure of the OCB in service, or during opening on fault.

(w) *Contact resistance:*

Before and after each overhaul the contact resistance shall be measured and recorded.

(x) *Stroke:*

Measure the length of the breaker stroke and check and adjust in accordance with manufacturer's instruction books.

(y) *Local/Remote operation:*

Operate breaker from local and remote controls and check that everything is in order.

4.04.05 Normal Schedule of Inspection and Maintenance of Oil Circuit Breaker

Sl. No.	Details of Inspection or maintenance	Monthly	Quarterly	Annual	Remarks
1.	Cleaning of bushing	✔	-	-	-
2.	Checking up of oil level in OCB and topping up if ncessary	✔	-	-	-
3.	Sampling and testing of oil in OCB tank	-	✔	-	or 6 fault trippings whichever is earlier
4.	Reconditioning or replacing of oil in OCBs and checking of Contact	-	-	✔	After I2 fault trippings or when quarterly test results are not satisfactory

Note:

1. 100 tripping in plain over load and/or hand trippings on load shall be taken as being equivalent to one fault tripping.
2. Eventhough test results are satisfactory, replacement of oil done once in a year.
3. Before commencement of inspection be sure that both incoming and outgoing lines are kept opened and earthed. A.C. and D.C. auxiliary supply fuses are removed.

		M.	Q.	A.	Remarks
4.	Detailed examination and maintenance contact, springs, dashpots tension rod assembly, Operating mechanism, breaker mechanism, closing solenoid trip coil, wiring etc. as detailed in the maintenance instructions.	-	-	✔	-
5.	Checking of foundation bolt and nuts.	-	-	✔	-

4.05 Maintenance schedule for Minimum oil circuit breaker

4.05.01 General

In O.C.B. the tank is at earth potential which warrants adequate clearance between tank and contacting element. But in MOCBs the tank is insulated and is at line potential. Hence it has to be supported on suitable insulators. Other features are almost similar as in the case of OCBs. Number of MOCBs ranging from II KV to 230 KV are in service in our grid.

4.05.02 Maintenance of BHEL - Make MOCBs

Inspection intervals.

Interval Measures connected with inspection.

1-2 years.	A. Lubrication of accessible bearings, sample test check of the circuit-breaker oil from one unit (not applicable to hermetically sealed units of HLR type) Check of the pressure in a pressurised unit of HLR type. Trial operation ON and OFF a few times. *Note:* During the first inspection the screw joints in the circuit-breaker and the operating device, all the line connections in the terminal blocks shall also be retightened. This retightening need not be repeated later other than at an inspection following extensive overhaul.
3-4 years	B. The work mentioned in "A" and in addition: Sample test check of the circuit-breaker oil from a unit of HLR type. Sample test check of the contact burn-off in one unit.
6-8 years	C. The work mentioned in "A" and "B" and in addition: Removal of inspection covers so that all mechanism parts become accessible for careful cleaning, anti-rust treatment and lubrication. Check of oil in the dashpot. Touch-up painting if necessary. Check of the functional value of the circuit-breaker.
12-16 years	D. The work mentioned in "A", "B" and "C" and in addition: Complete overhaul of the breaking units including dismantling, cleaning and a check of all the units as well as replacement of severely burnt contacts and arc-control device parts. Worn-out mechanism parts in the circuit-breaker and the operating device shall be replaced. Re-painting shall be carried out if necessary.

4.05.03 Cleaning

When cleaning insulating and mechanism parts it is important to use wiping cloths of non-fluffy material.

The use of cloths of non-fluffy material is specially important when cleaning inside the breaking unit and breaking unit parts, as fibres from fluffy textile or cellulose material have a strong insulation-reducing effect on the circuit-breaker oil.

Arc-control devices of cross-blast type are without movable parts and in certain cases cannot be dismantled without special tools. The most suitable method of cleaning them internally is rinsing with clean circuit-breaker oil.

The insulators of the circuit-breaker shall be cleaned from salt and dirt deposits at the same time as the other insulators in the switchgear are being cleaned.

BHEL's oil-minimum circuit-breakers are from and including the year 1975 "rinse-proof" all through. In other words, their insulators can be cleaned during service, by means of rinsing with water, without risk of water penetrating the breaking units.

4.05.04 Lubrication

The three types of lubricants mentioned in the table below are recommended for lubrication. In the information for BHEL's circuit-breakers they are designated as "Oil A", "Oil B" and "grease E".

Trade Name	Oil A	Oil B	Grease E
BHEL	117I 2011-102	117I 2013-301	1171 4015-501
BP	Energol 40/1	Energol RLP 65	Grease LS 1
Esso	Spinesso 34	Nuto E 44	Eascon P-290
Mobil	Mobilfluid 62	D.T.E. 24	Mobilgrease BRB zero.
Shell	Tellus oil 13	Tellus oil 27	Aero Shell Grease 4
SKF	—	—	SKF 63
Texaco	Low temp. oil	Rando oil ED A	All (low) temp. grease

The roller bearings (ball bearings and needle bearings) of the circuit-breakers and operating devices are lubricated with grease E when delivered and do not normally need to be lubricated other than during an extensive overhaul.

In cases where there are lubricating nipples at the bearings of the operating insulators, some grease E should be squeezed in at one - to two-year intervals.

Slide bearings for mechanism parts such as arms, links and link gears, are lubricated at delivery and erection, with grease E. They should be regularly (see "Inspection intervals") maintenance-lubricated with a few drops of oil B.

The cogs in the gears shall be lubricated with a thin layer of grease E.

The O-ring gaskets shall be properly greased with grease E when being mounted.

Oil A is only suitable for lubrication of fine mechanical parts where the force is low.

NOTE: When lubricating an operating device with a slip coupling, care shall be taken that oil or grease do not penetrate the coupling. In addition, the running surplus oil shall be wiped away after lubrication.

4.05.05 Filling dashpot with oil

In cases where the circuit-breaker and operating device are fitted with an oil dashpot with an oil filling plug, the oil level shall be checked at six to eight-year intervals. The oil shall come up to the filling hole when the piston is in its upper position.

For filling, circuit-breaker oil of the same quality as is used in the breaking units shall be used.

In dashpots without a filling plug no refilling with oil is necessary as long as no oil leakage is suspected.

4.05.06 Circuit-breaker oil

Fresh Transformer oil confirming to IS:335 must alone be filled up both for initial filling and during oil replacement.

4.05.07 Check of circuit-breaker oil

The dielectric stresses in modern oil-minimum circuit-breakers have been kept very low through the use of newer types of insulating material in the breaking units.

The condition of the circuit-breaker oil should, however be regularly checked.

For circuit-breakers of types HLC and HLD with "Open" expansion volume the oil should be checked at intervals of one to two years. For circuit-breakers of type HLR with hermetically sealed - pressurized expansion volume, the oil should be checked at intervals of three to four years.
For taking samples a clean bottle with a volume of at least 0.5 litre shall be used.

Firstly, approximately 1/4 of the oil which shall be tested shall be poured into the bottle. The bottle shall be rinsed with this oil and the oil used for rinsing shall be poured off. Then 0.5 l of the oil to be tested shall be put into the bottle. It shall be checked with regard to the following:

a. Purity: The oil becomes carbonized and black after a few breaking operations. It is not necessarily unusable because of this.

   It is only when the oil has become strongly polluted and there are sludge products in the oil sample that the oil should be filtered or changed.

b. Moisture content : Pure newly filtered oil contains 10-15 ppm. dissolved water. The oil can dissolve in addition approximately 30 ppm. water (=3 ml. water per 100 l oil). At approximately 45 ppm, the oil is saturated and cannot dissolve more water.

4.05.08. Insulating capability

New circuit-breaker oil shall have an insulating capability of at least 50 KV/2.5 mm. When it has been poured into the circuit-breaker, the insulating capability usually decreases somewhat owing to the fact that it is nearly impossible to clean the breaking units completely.

After filling with oil and on a newly delivered circuit-breaker, the insulating capability should not be lower than 30 KV/2.5 mm.

If the insulating capability of the oil sample is lower than 15 KV/2.5 mm, the oil should be filtered or changed.

4.05.09 Check of contacts

The moving plug contact and the contact fingers in the fixed contact of the circuit-breaker are tipped with heat-and arc-resistant copper - tungsten alloy. In front of the fixed contact there is also a so-called arcing ring of the same alloy. The arcing ring is an extra protection from arcing for the contact fingers.

A sample test check of the contact burning should be made at three to four year-intervals on one unit in each circuit-breaker.

Also of importance for checking the contacts is the number of high power breaking operations. The check should be made after:

4 breaking operations of 100% rated breaking current or

8 breaking operations of 60% rated breaking current or

16 breaking operations of 30% rated breaking current or

500 breaking operations of normal current.

As a rule, it can be assumed that circuit-breakers type HLR will withstand at least twice as many breaking operations as described above before a replacement of contacts becomes necessary.

Contacts and arcing rings should be replaced if they are heavily and obliquely burnt or if the burn-off approaches the values given in the instructions for overhaul for the respective circuit-breaker type. Minor burn damages and welding cinders can be smoothed away with a fine file.

4.05.10 Check of arc-control device

If the contact and the arcing ring are heavily burnt, the arc-control device should be examined.

A check shall be made that the slit discs of the arc-control device are not too severely burnt in the holes for the moving plug contact. The extent of burning which can be permitted is stated in the instructions for overhaul of the respective circuit-breaker type.

In addition, a check shall be made that the moving piston in an arc-control device of contraction type is easily movable and is returned to the end position by the return spring. If the arc-control device is strongly polluted by oil sludge and products of combustion, it should be cleaned. An internal cleaning or rinsing with circuit-breaker oil of the entire breaking unit may possibly be necessary.

4.05.11 Anti-rust treatment

In circuit-breakers and operating devices certain enclosed mechanical parts made of steel are finished by manganous phosphatizing and protected from rust by dipping in oil. This applies to, for instance, gear wheels, catches, link system and link gears.

The large closing and opening springs are protected from rust by being dipped in Tectyl.

In addition, a thin coat of rust-preventing grease E (containing an anti-rust additive) is sprayed over the mechanism of the operating device prior to delivery.

In spite of good anti-rust treatment, after some years rust can attack the above-mentioned parts - particularly if the circuit-breakers are in a strongly corrosive atmosphere.

The rust patches shall be smoothed away and a new anti-rust preparation painted or sprayed on. The anti-rust preparation recommended are grease E or Tectyl.

NOTE: Tectyl must not be sprayed into the bearings and locking mechanisms. When spraying, any slip couplings in the operating device shall be protected from the penetration of the anti-rust preparation.

4.05.12 Normal schedule of Inspection and maintenance of MOCBs

Sl. No.	Details of Inspection or maintenance	M	Q	Bi-A	A	Remarks
1.	Cleaning of insulating and mechanism parts	✔	-	-	-	-
2.	Lubrication	-	✔	-	-	-
3.	Application of Grease to bearings etc.	-	-	-	✔	-
4.	Filling dashpot with oil	-	-	-	✔	-
5.	Check of circuit breaker oil	-	-	✔	-	or 3 fault trippings whichever is earlier
6.	Replacing of oil in MOCBs and checking of contact	-	-	-	✔	or 6 fault tripping or earlier when oil test results are unsatisfactory
7.	Detailed examination and maintenance of contacts, dashpot, springs, tension rod assembly operating mechanism, control wiring etc.					—
8.	Anti Rust Treatment					—
9.	Checking of foundation bolt and nuts					—

Note : 1. Only new oil as per I.S. 335 must be used while replacing oil in MOCBs.

2. Eventhough test results are satisfactory, replacement of oil done once in a year

4.06 Guidelines for maintenance and repair of the pneumo-hydraulic operating mechanism of "delle" 110 KV OMCB

In view of the large number of "Delle" make minimum oil breakers in service in the Board and the special nature of servicing required for the pneumo-hydraulic operating mechanism of these breakers, the following instructions relating to these mechanisms are included in this code.

4.06.01 General

The main feature of this type of pneumo-hydraulic operating mechanisms is the closure and holding of the breaker provided by oil pressure. The tripping of the circuit breaker is provided by short travel compression springs provided in jack casing whose permanent energy is available at all times.

The energy required to close the circuit breaker is stored in two accumulators, one main and one back up. Each accumulator consists of a cylinder, a piston and pressurised Nitrogen. The energy for actuating the closing mechanism of the breaker is transmitted hydraulically to the rotating jack through the oil medium from the Nitrogen gas stored in the accumulators by partial expansion of the gas.

4.06.02 Procedure for checking up the condition of the Accumulator

The pre-charging pressure of the accumulators has to be checked once in 6 months/one year. Keep the breaker in tripped position and cut off the pump motor.

Fix the pressure testing device with its cocks K_2 and K_3 closed on the control block. Insert the drain tube into the Aeroshell oil filling hole on the top of the reservoir. In case of OP type accumulators, open the valve controlling the pressure gauge connection.

Open cock K_2. The pressure gauge will indicate some pressure reading in the neighbourhood of 300 Kg/cm^2.

Now open the cock K_3 to drain the oil from the accumulators into the reservoirs. The pressure gauge reading will come down to zero. This procedure is called "DEPRESSURISING THE HYDRAULIC CIRCUIT".

To determine the pre-inflated pressure of the accumulators the flow of oil from the accumulators into the reservoir is to be controlled. By adjusting the opening of the cock K_3 drain the oil from the accumulators into the reservoir. At a certain stage, the pressure will suddenly start falling off to zero. Note down this pressure, This will give "tripping pressure or pre-inflated pressure" of the accumulators.

Now close the drain cock and build up pressure of the unit by cutting in the pump motor. Simultaneously note down the time. In case of OP accumulators, hold the charging lever on the right side of the control block inwards tightly for a while until the pressure gauge reads about 230 Kg/cm^2 and thereafter the charging lever can be released.

Note down the pressure at which the pump motor starts automatically and also the time taken to build-up pressure from zero to the stopping of the motor.

Wait for 3 or 4 minutes and note the steady pressure indicated by the pressure gauge.

Now slowly open the drain cock (K3) of the pressure testing device and permit the oil into the reservoir. Note the pressure at which the pump starts automatically. Cut off the motor and continue the gradual draining of the oil from the accumulators. Note the pressure at which the low pressure lamp in the control cubicle comes on.

Close the drain cock and cut in the motor. Now the pressure starts building up. Note the pressure at which the low pressure lamp goes off.

When the motor stops automatically cut off the motor. Close the breaker. There will be a dip in the pressure reading. Wait for a few minutes till a steady value is reached. Note down this steady pressure.

Now cut in the motor and also simultaneously note down the time,.Note the time taken for building up the dip in pressure due to one closing operation.

Tabulate all the above readings as indicated below:

1.	Pre-inflated pressure/Tripping pressure	Kg/Cm^2
2.	Time taken by the pump motor to build up working pressure from zero pressure	Secs.
3.	Pump motor stopping pressure	Kg/Cm^2
4.	Steady working pressure	Kg/Cm^2
5.	Pressure at which the low pressure lamp goes off	Kg/Cm^2
6.	Pump motor starting pressure	Kg/Cm^2
7.	Pressure at which the low pressure lamp comes on	Kg/Cm^2
8.	Pressure observed after one closing	Kg/Cm^2
9.	Dip in pressure on closing the breaker	Kg/Cm^2
10.	Time taken by the pump motor to build up this dip in pressure	Secs.

After the completion of the above pressure test cut out motor and depressurize the circuit and release the pressure testing device from control Block. However in the case of OP accumulators first close the valve controlling the pressure gauge connection situated on the left side of the control block before arranging for removal of the pressure testing device with extension piece.

Significance of test results

If the time taken to build up pressure after the closure is within 60 seconds, the accumulators may be assumed to be in good condition. If it is between 60 and 75 secs. it indicates the presence of air pockets in the hydraulic circuit/deflation of any one of the accumulators. If it is above 75 seconds it indicates the presence of heavy air pockets in the hydraulic circuit/deflation of both the accumulators. Similarly if the time taken to build up pressure from zero to full pressure is within 180 secs., the accumulators may be taken to be in good condition and if it exceeds 180 secs., it indicates the presence of air pockets in the hydraulic circuit/deflation of the accumulators. In such cases, the condition of the accumulators has to be determined correctly by repeating the tests after completely removing the air pockets (explained later) present in the circuit. Minimum permissible pre-inflation pressure values for OP and OP2C type of accumulators are given below:

"OP" Type	—	180 Kg/Cm^2
OP2C Type	—	200 Kg/Cm^2

If the pre-inflated pressure readings measured are found to be less than the specified limits (20% drop from the full charging pressure of Nitrogen in the accumulator) seperate measurement of the pre-inflated pressure of both the main and auxiliary accumulators have to be determined as indicated below, so as to localise the faulty accumulator, either main or auxiliary.

Keep the breaker in "Tripped" position and "Switch off" the pump motor. Fix the pressure testing device (with its cocks closed) on the control unit.

Open cocks K2 and K3 and drain the oil into the reservoir. Separate the connection between the main and auxiliary accumulators. Place a stopper at the connection at the main accumulator. Remove the plug K5 of the pressure testing device. Connect the auxiliary accumulator to the connector K4 of the pressure testing device by the flexible copper tube. Close cocks K2 and K3. Now cut in motor and charge accumulators to maximum pressure.

Open cock K2 slowly in checking pressure gauge. As soon as pressure rises and reaches a steady value, reclose cock K2 rapidly. Wait for 3 or 4 minutes. Open cock K3 and drain oil from the auxiliary accumulator under test. Note the pre-inflated pressure as stated in the earlier paras.

(Depending on the pressure readings obtained, it can be judged which one of the accumulators main or auxiliary is defective and remedial action taken accordingly).

When the checking up of the condition of auxiliary accumulator is over, open cock K2 and drain the oil from the main accumulator into the reservoir. Disconnect the copper tube connecting the pressure testing device and the auxiliary accumulator and close plug K5 of pressure testing device. Reconnect the lines to the accumulators and the control unit.

Close cock K3 of the pressure testing device. Cut in pump motor and pressurise the circuit. Verify that no oil escapes from the connections of accumulators. Cut out motor. Depressurize the circuit and remove the pressure testing device.

Cut in the pump motor build up pressure in the accumulators.

NOTE: Separation of auxiliary accumulator for determination of its pre-inflated pressure as given in the aforesaid paras may be attempted only where the flexible copper tube to be used with the pressure testing device is available.

4.06.03 Procedure for the release of air pockets in the Hydraulic circuit

Fix the pressure testing device with cocks K2 and K3 closed on the control block. Cut out the motor. Open the valve controlling the pressure gauge connection in case of "OP" type mechanism. Open the cocks K2 and K3 of pressure testing device and drain the oil into the reservoir. When the pressure falls to zero, cut in the motor, keeping the drain Cock (K3) open and simultaneously press the yokes of the magnets of tripping and closing coils for a minute. Now all air locks will get released.

Precautions

While pressing the yokes of the magnets, contact with nearby live electric circuit should be avoided.

Release yokes of closing and tripping magnets and close drain cock K3. Check for pressure increase on the pressure gauge and also the smooth running of the pump.

Cut off the motor. Depressurize the circuit. Remove the pressure testing device after closing the valve for pressure gauge connection in case of 'OP' type accumulators. Cut in the motor and complete the charging of the accumulators. Cause several closing and tripping operations. Now all air locks present in the circuit will be eliminated.

4.06.04 Periodical checks and preventive maintenance

Perform the following checks/maintenance for increasing the reliability of the system.

Once in 6 months:

(1) When the accumulators are charged at maximum pressure and the circuit breaker is in the closed position, check up the oil level in the tank. It should not fall below the level mark made on the reservoir. Should the oil level be low top up to the mark; if the oil level is well above the mark, leave it, don't draw off any oil from the circuit.

(2) Check up the lubrication oil level in the pump sump. If it is low, top up the level with SAE 40 Grade Oil.

(3) Grease the motor bearings and also the hand pump swivel joints.

(4) Check up the condition of high and low pressure pipe lines.

(5) Check up the tightness of hydraulic circuit i.e. unions of low pressure and

high pressure pipes and the connections of suction pipes of the mechanism pump. Care should be taken to avoid over tightening/inadequate tightness of unions and connections and also no tightening should be done on high pressure.

(6) Conduct detailed pressure tests on the accumulators by using pressure testing device.

(7) Check up the condition of the coupling between the pump and the motor.

Every year

(1) Check up the tightness of electrical terminals and also the functioning of electrical heaters.

(2) Change the oil in the pump sump completely (use of SAE-40 Grade oil)

(3) Check up the pre-inflated pressure of the accumulators.

(4) Check up the condition of the fuses controlling supply to the pump motor.

Once in 5 years

Maintenance of inbuilt C.T. shall be carried out once in 5 years or whenever the breaker is shifted.

4.06.05 Important precautions to be followed while working on this pneumo-hydraulic mechanism

1. No works should be carried out on the operating mechanism without depressurizing the circuit with the prescribed pressure testing device.
2. The high pressure joints and unions should be tightened only, where the hydraulic circuit has been depressurised.
3. The accumulators should never be welded on or drilled at any rate. Also refrain from any disassembly.
4. Sufficient care should be taken while tightening/loosening the "Ermeto" connections. Forcible tightening of pipes results in appreciable additional stress on the pipes resulting in improper fitness and tightness of special joints, which should be avoided. Always avoid over-tightening and inadequate tightness of the ermeto unions and joints.
5. Works should be carried out in a clear (dust free) atmosphere. Contamination such as dirt, metal filings should never be permitted into the hydraulic circuit.
6. Filter the hydraulic oil carefully before it is used for refilling the circuit.

4.06.06. Trouble shooting guide for easy reference

Sl.No. (1)	Trouble (2)	Symptom (3)	Probable cause (4)	Remedy (5)
1.	Difficulty in building up the pressure in the hydraulic circuit with mechl. as well as manual pumps.	1. Low pressure alarm indication cannot be reset.	1. Presence of heavy air pockets in the hydraulic circuit.	1. By using the pressure testing device, release the air pockets present in the hydraulic circuit. A few closing and tripping operations of the breaker will also aid in eliminating the air pockets. In case of OP type mechanism before releasing the air pockets try to buildup pressure by holding the charging lever tightly inwards for a few minutes.
		2. Pump motor will be running continuously.	2. Dismounting of the needle of the charging lever in the case of "OP" mechanism.	2. Remove the charging lever and reshape the needle. Even with this if difficulties are experienced in building the pressure replace the lever with a spare one.

(1)	(2)	(3)	(4)	(5)
			3. Malfunctioning of the safety valve provided in the control block.	3. Replace the accumulator with a spare one.
2.	Leakage of hydraulic fluid (Aeroshell fluid) in the System. (External leaks)	(Leaks are visible and easily detected)	a. Inadequate tightness or over-tightness of unions and joints.	By using the pressure testing device, depressurize the circuit and the pipe lines/ermeto connections. Clean them properly and lightly oil them and make perfect connections by adopting proper tightness. Inadequate tightness/over-tightness should always be avoided. Allow the pipe lines to be pressurised again and verify that no oil leaks occur from the connections made.
	(a) Leakage of oil at various joints and unions of low and high pressure pipe lines.	Oil leakage cannot be arrested.	b. Presence of dust and other impurities in the threaded portion. c. Vibrational shocks due to opening/ closing of the breaker	
	(b) Leaks in the low/ high pressure pipes entry at the jack.	Leaks are visible and easily detected Oil leakage cannot be arreasted	-do-	Depressurize the circuit, loosen the connection at the end of the pipes and retighten them so that they seat properly.

(1)	(2)	(3)	(4)	(5)
	(c) Leaks from the connections of low pressure polythene tubes in "OP" mechanism.	-do-	Deterioration of polythene tubes due to ageing	Depressurize the circuit and change the low pressure polythene tubes with fresh ones.
	(d) Leakage from the joints of pressure switch.	-do-	Deterioration of the teflon gasket provided in the pressure switch	Depressurize the circuit and replace the pressure switch with a spare one.
	(e) Leakage from the joints of hydraulic relay	-do-	1. Deterioration or mis-mounting of joint between the body and drain block.	After releasing the pressure in the circuit, replace the hydraulic relay with a spare one.
		-do-	2. Deterioration of gaskets in the hydraulic relay.	Depressurize the circuit and remove the flattened gasket with a fresh one.
	(f) Leakage from the weeping holes of main accumulator/ aux. accumulator.		1. Deterioration of oil seals.	Depressurize the circuit and replace the defective main/aux. accumulator by a reconditioned one.

(1)	(2)	(3)	(4)	(5)
(g)	Leakage from the weeping hole (respiration hole) of rotating jack.	Oil leak cannot be arrested easily.	1. Deterioration of oil seal. 2. Presnece of impurities on the high speed return valve seat due to faulty bearing of the metal rim gasket.	1. Depressurise the circuit. Remove the high and low pressure pipe connections from the jack. Open the rapid return valve portion of the jack by using pipe wrenches and replace the wornout oil seal metal rim jack gasket with a new one. Reassemble the jack and reconnect the pressure pipe lines and pressurize the circuit again.
(h)	Leakage from the lubrication hole of the rotating jack.	Oil under high pressure fills the entire housing of rack and pinion arrangement of the jack and spurts out heavily through the hole provided for applying the grease for pinion gear during every closure of the breaker.	Damage caused to the entire piston linings and gasket.	Depressurise the circuit. Remove the low and high pressure pipe connections and lower the jack from the supporting structure after adopting necessary precautionary steps. Dis - assemble it. Replace the wornout linings with fresh ones. Assemble it and put it back into its position. Reconnect the pipe lines and pressurise the circuit again.

(1)	(2)	(3)	(4)	(5)
	(i) Leakage at the bottom of the oil receiver cover attached to the control unit.	Heavy oil leakage is observed.	Inadequate tightness of the fixing nuts.	After releasing the pressure in the circuit tighten the fixing nuts at the top. After reassembly, readjust the electrodes Be and Bd.
	(j) Leakage from the joints of manual pump (hand pump)	Oil leak cannot be arrested easily.	Deterioration of the 'O' rings provided between the pump body and control unit.	Depressurise the circuit and replace the failed, deformed 'O' ring by a fresh one.
	(k) Leakage by the small 2mm hole on the control block near the joint of the accumulator of the block.	Oil leak cannot be arrested easily.	The check valves in the control block are not tight.	After releasing the pressure change the main accumulator with a spare one.

(1)	(2)	(3)	(4)	(5)
3.	Mechanical pump fails to deliver oil (i.e. the motor runs continuously without the mechl. pump developing any pressure. Cut off the motor and see if pressure rises through manual pump. If the pressure is built up by manual pump then the fault lies in mechl. pumps and its circuit.	The motor will be continuously running but no oil is delivered from the pump. (Non-delivery of oil by the pump)	1. Pump valves are not tight. Pump not priming properly. 2. Air ingress into the connections/suction pipe.	1 & 2 Tighten the pump valves and connections. Prime the pump by releasing air from its connections by loosening the nut at the delivery pipe and also release the air pocket present in the circuit and suction pipe by adopting air release procedure.
			3. Low oil levels in the sump and the main accumulator.	3. Replenish the oil level in the main accumulator and sump.
			4. Presence of dirt and other impurities on the pump filter.	4. Remove the pump filter; clean and put back into its position.
			5. Presence of large quantities of Nitrogen gas in the oil due to the failure of piston gaskets and linings in the accumulators.	5. Check up the pre-inflated pressure of the accumulators. If it is below the specified limit the defective accumulator has to be changed.

(1)	(2)	(3)	(4)	(5)
			6. Wear of plunger oil ring; flattening of No.8 gasket etc. provided in the pump components.	6. Remove the pump and replace the wornout oil rings, gaskets etc. by good ones.
			7. Mechl. stuck up developed inside the pump (Ball valve of the pump may not be seated properly).	7. Replace the failed pump by a reconditioned/spare one. Till the mechl. pump is replaced by a spare one; cut off the pump motor and use emergency manual pump for building up pressure in the circuit.
			8. Internal leaks in the control block followed by the entry of air into the pump-suspected leak probably at the automatic discharge valve in the control unit.	8. Replace the control block (main accumulator) if the pump fails to develop pressure even after eliminating of air pockets in the circuit.

1)	(2)	(3)	(4)	(5)
			9. Dismounting of charging lever (in case of OP mechanism).	Dismantle the charging lever, reshape its needle and depress it and build up pressure. Even with this if the pr. is not built up, change the control block.
4.	Manual pump fails to develop pressure.	Difficulty in building up pressure in the circuit by using manual pump (hand pump).	1. Low oil levels in the main accumulator and oil reservoir.	Build up the oil level in the main accumulator and oil reservoir.
			2. Wear of plunger oil ring flattening of gaskets/'O' rings provided in the hand pump.	Replace the deteriorated oil ring gaskets by fresh ones.
			3. Mechl. stuck up developed in the pump.	Replace the failed manual pump by spare reconditioned pump.

(1)	(2)	(3)	(4)	(5)
5.	Pump motor fails to run.	Low pressure alarm/ indication will appear. Mechl. pump will not run.	1. Motor may be burnt due to	
			a. Single phasing caused by fuse blowouts and open out developments in the circuit.	Cut off supply to pump motor, build up pressure in the circuit by using hand pump and reset the low pressure alarm/ indication. Check up the condition of the motor and its starter contactor and also the voltage available at its terminals. If motor/starter has failed, replace the failed unit by a spare one.
			b. Inter turn shorts in stator windings.	
			c. Malfunction of the elecl. contactor of the motor.	Check up thoroughly the elecl. connections of the motor and set right the defects observed. Cut off the motor and try to improve the voltage available at its terminals.
			d. Very low voltage supplied to the motor.	

(1)	(2)	(3)	(4)	(5)
			2. Open circuit in the elecl. connections of the motor	
			3. Insufficient voltage available at the motor terminals.	Clean the contacts of micro switch and set right its funclctioning. If it is not possible, replace the pressure switch by a good one.
			4. Malfunction of pressure switch contacts.	
			5. The flexible coupling between the pump and the motor may be loose or damaged.	Check up the condition of the coupling and set right the defects observed
			6. Seizure of the shaft or the piston of the mechl. pump.	Remove the pump and set right the alignment of its shaft/piston. If it is not possible, replace the failed pump by a spare one.

(1)	(2)	(3)	(4)	(5)
6.	Loss of Nitrogen gas pressure in the main backup accumulator.	1. Spurting of oil through rubber gasket on the main accumulator in case of OP2C type and through the vent in case of 'OP' type mechanism at the time of tripping.	Deterioration of piston linings and gaskets in the piston ring packing of the accumulators caused due to ageing and due to the presence of dirt and other impurities in the hydraulic oil.	Locate the faulty accumulator by using pressure testing device and replace the same by a spare reconditioned one.
		2. Frequent running of pump motor and also abnormal rise in the time taken to build up the dip in pr. due to one closure, as well as the total time taken to build up full steady pressure from zero.	As a result of this, leakage of Nitrogen to the oil side and discharge of high pressure oil with air into the oil receiver (during testing) take place.	Locate the faulty accumulator by using pressure testing device and replace the same by a spare reconditioned one.

(1)	(2)	(3)	(4)	(5)
		3. Substantial emulsification of oil at the time of testing accompanied by hissing noise.		
		4. Failure to trip through automatic tripping device, when the pressure is very low.		
		5. Sudden spurting out and disappearance of entire oil in the sump accompanied with the continuous running of motor (In this case, the oil topped up can be taken as an indication of the failure of any one of the accumulators).		

(1)	(2)	(3)	(4)	(5)
7.	Rack of the signals jack, (which operates the OMCB auxiliary contacts) not returning to its original position on release of pressure.	1. OMCB-position indicator and the rack operating the OMCB aux. contacts fail to operate properly.	1. Foreign matter which finds a place in the jack during closure may obstruct the return of oil on release of pressure.	1. Dismantle the jack and clean or replace the jack by a spare one.
			2. Spacer between the rack and the piston slipped from its seating (This can happen only when attempts are made to operate the jack by hand, turning the pinion forcibly).	-do-
8.	Difficulty in closing the breaker after administering a tripping command.	Breaker cannot be closed (electrically) both from remote and local ends.	1. Oil pressure in the hydraulic circuit may be low.	1. Build up pressure in the hydraulic circuit by manual/mechl. pump.

(1)	(2)	(3)	(4)	(5)
			2. Presence of air pockets in the hydraulic circuit.	2. If there is any difficulty in building up the pr. in the circuit with manual/ mechl. pumps, there may be presence of air pockets in the circuit. Release the air pockets by using pressure controller.
			3. CE and AP relays may not be functioning properly.	3. Checkup the operation of CE & AP relays.
			4. Trouble in control circuit cables.	4. Checkup the control circuit cables.

(1)	(2)	(3)	(4)	(5)
9.	Frequent running of pump motor. (The pump can restart as much as twenty times a day. If the interval between 2 consecutive runs is not less than 20 minutes and the duration of the running of the motor does not exceed 3 minutes, the operation of the pump can be considered as normal)	Pump motor is running every half an hour and less.	1. Heavy External oil Leakage at the unions and joints of control block, Hydraulic relay, Rotating jack, pressure switch etc. Due to this there is less of oil in the reservoir.	Locate the cause for the external oil leakage and set it right. Build up the oil level in the reservoir.
			2. Imperfect tightness of the valves in the (a) control block (b) Hydraulic relay (c) Rotating jack due to the contamination present in the oil.	Try to remove the contaminates present in the hydraulic circuit by performing several tripping and closing operations. If even after this, the frequent running of pump cannot be stopped, locate the faulty component and replace it.
			3. Pressure switch and the pump shutdown micro switch may not function properly.	3. Determine whether the pressure switch or pump shut down micro switch is defective. Replace them with spare ones.

(1)	(2)	(3)	(4)	(5)
			4. Presence of heavy air pockets in the hydraulic circuit.	4. Release the air pockets present in the circuit by using pressure controller.
10.	Abnormal rise in the time taken by pump motor to buildup (a) the dip in pressure after one closure. (2) from zero to full working pressure. (Specified time limits or (i) to buildup the dip in pressure after one closure-60 seconds (ii) to buildup the working pressure from zero (180 seconds).	Time taken by the mechl. pump to develop (a) the dip in pressure after one closure and from zero pressure to full working pr. will be more than the specified limits.	1. Presence of air pockets in the hydraulic circuit.	1. Release the air pocket present in the circuit by using pressure controller.
			2. Depletion of main or aux. accumulators or both due to the deterioration of piston linings provided in them.	2. Check up pre-inflated pressure of main and aux. accumulators. If necessary, replace the defective one.
			3. Erratic operation of pressure switch or its pump shutdown micro switch.	3. Check up the working of pressure switch and its micro switch contacts. If necessary, replace the pressure switch/pump, shutdown micro switch.

(1)	(2)	(3)	(4)	(5)
11.	Motor pump set runs continuously	Pump delivers but fails to stop even when maximum working pressure is reached	When the Breaker is in open position	
			1. Heavy internal leaks in the control block with a discharge rate larger than that of the pump.	1. Replace the defective control unit with fresh/reconditioned one
			2. No pressure exists in the accumulators	2. Check up the precharged pressure of the accumulators and replace the faulty one
			3. Pressure switch does not shutdown the pump motor	3 Checkup the pressure switch and its micro switch contacts. If necessary, replace them
			4. Maladjustment of safety valve provided in the control block which opens before the pump shutdown micro switch J2 tilts	4. change the control block.

(1)	(2)	(3)	(4)	(5)
			5. Malfunction of magnetic contactor of the starter of the pump motor. When the breaker is in closed position	5. Checkup the magnetic contactor of the starter and if found defective, replace the starter.
			1. Causes are same as above except there is a possibility of external/ internal leaks in the components under pressure when the breaker is closed	1. Locate the cause for external/internal leak and replace the leak component with a spare one.
12	Pump delivers but the pressure does not rise (check up whether the pressure is built up by the manual pump or not)	Oil is delivered by the pump but the pressure in the circuit does not rise and as such the low pressure alarm/ lamp indicators cannot be reset.	1. Pump valves are not tight.	1. Tighten the pump valves. If the defect observed is not rectified, replace the pump.

(1)	(2)	(3)	(4)	(5)
			2. Leak in a component which in excess of pump output (even with the manual pump if pressure is not built up, it indicates the presence of heavy air pockets in the circuit)	2. Locate the faulty component and replace it. Release the air pockets present in the circuit by a pressure controller and by performing several opening and closing operations of the breaker
13	Breaker is not obeying both local and tripping commands(Mechanical as well as electrical)	Breaker cannot be tripped mechanically as well as electrically	Presence of heavy air pockets in the hydraulic circuit	Release the air pockets by using pressure controller
14.	Breaker closes and trips instantly upon a closing impulse supplied	Breaker trips immediately after the closure without a tripping impulse being supplied	1. Sharp fall in oil pressure due to internal troubles in the control block (i.e.) closing operation results in extremely high consumption of oil and the emergency automatic tripping valve in the control block remains in an intermediate position.	1. Replace the control block

(1)	(2)	(3)	(4)	(5)
			2. Misadjustment of the closing electro-valve or insufficient DC supply voltage, i.e. Too short impulses on the closing electro-valve. Also look for a poor contact in the electrical circuit of closing magnet.	2. Check up the closing electro-valve and its circuit
			3. Residual pressure after closing is lower than the static closing pressure consequent to a fall in the pre-inflation pressure of the accumulators	3. Locate the defective accumulator and replace it
			4. Fault in the hydraulic circuit supplying "drain valve return to auxiliary tank" (valve A H5) in the control unit ue to the blockade of output limiting device (AK) etc.	Replace the control block.

(1)	(2)	(3)	(4)	(5)
			5. Anti-pumping relay which interrupts too soon the supply to closing electro valve (AF) Actuation of Anti-pumping relay may be due to the (1) operation of electrical interlock (2) The closing push button being stuck up or the contacts CE2, CE3 in closed position (3) Protracted tripping impulse due to fault operation or vibration of tripping relay (If the consumption of oil for a closing operation is normal, the trouble is only in the electrical circuit)	Find out the cause for the operation of Anti-pumping relay and rectify it.

(1)	(2)	(3)	(4)	(5)
15.	Faulty opening/closing operation		A poor contact in the impulse circuit to the electro valves	Firmly tighten the connecting terminals of the closing/tripping electro valves.
16	When the breaker is in open position or in the position of being tripped		This mishap is very rare but occur when two conditions are fulfilled	
	The pressure falls to zero in the absence of an electrical impulse on the closing electro valve and the oil level rises in the tank of the control block and sprayed in the cubicle through the filling hole		1. Leakage of gas into the oilside of the piston in the accumulator.	Replace the main accumulator with a healthy one
			2. Substantial oil leakage through the discharge valve.	

4.07 Maintenance Schedule for Air Blast Circuit Breakers

4.07.01 General

A blast of dry air quenches the arc and regains its di-electric strength within a few microsec. This property is utilised in ABCBs, ABCBs are available in 110 KV and 230 KV level in our grid.

4.07.02 Maintenance of Air Blast Circuit Breakers

i) In ABCBs, after every interruption, the entire ionised air is exhausted and fresh, clean and dry air is filled in. Hence deterioration of quenching medium due to the effect of arc is nil, which leads to less maintenance. Anyhow check regularly, that the compressed air system is free from water.

ii) Contact erosion due to short circuit interruption is also minimised by the inherent design and based on experience of the utilities, it is felt that the contact needs replacement only after 10 years.

iii) Due to the ageing, the sealing material permanently deforms and subsequently fails to make the circuit breaker leak-proof. Hence spare gaskets, 'O' rings are absolutely necessary for maintenance purpose. Replace gasket rings or imperfect gaskets if they are damaged, deformed, or become brittle.

iv) 'Silicon' grease is generally used as lubricant in ABCBs. This has a long life under both high and low temperature conditions. Before applying silicon grease, the surfaces should be cleaned and regreased.

4.07.03 Schedule of maintenance for ABCBs

Sl. No.	Item of Inspection on maintenance	Daily	Monthly	Qty.	Bi Annual	Annual	Remarks
1.	Draining and blowing down of main air receivers, checking all air pressures and air conditioning flow meters.	✔	-	-	-	-	-
2.	Cleaning insulators with non-fluffy cloth (lightly clinging dust to be sprayed with water, firmly clinging dust to be removed mechanically)	-	-	-	-	-	As and when required
3.	Check/compare the compressor running times (increasing running times indicate leakage)	-	-	✔	-	-	-
4.	Check of compressed air system (ie) the system is free from water	-	✔	-	-	-	-
5.	Checking and adjusting oil levels in dampers	-	-	✔	-	-	-
6.	Examining contact faces, cleaning contact, applying contact grease, cleaning air filters and lubricating all with approved lubricants	-	-	-	-	✔	-
7.	Check that the capacitors are intact and do not show any sign of oil leakage	-	✔	-	-	-	-
8.	Complete overhaul of ABCB with replacement of gaskets wherever necesssary and regreasing all sliding gaskets and sealed sliding surfaces	-	-	-	-	-	Every 10 years or after 5000 operations
9.	Checking of opening and closing timings of Isolator and chamber contacts	-	-	-	-	✔	-

4.08 Do's and Don'ts for ABCB's

4.08.01 DO's

1. Heaters in switch cubicle and control box should be kept 'on' irrespective of whether the breaker is in service or not.
2. For insulators inside cleaning only chamois leather should be used. Cleaning of insulators need special care. Please follow suppliers instruction manual.
3. Use of specified lubricant shall only be made.
4. The valve connecting the breaker tank and air supply pipings should always be kept open when the breaker is energised.
5. Check at least every five years that the air filter is not damaged.
6. At the time of overhauling, all sub assemblies should be cleaned with mul-mul cloth and it should be ensured that no remains of cloth is left out after assembly.
7. Whenever aluminium surfaces come in contact with copper or brass, use shellac between the mating surfaces to avoid corrosion.
8. Compressed air pipes should be flushed clean of any dust or moisture before the breaker is taken into service.
9. Leaky oil condensors must be replaced immediately.

4.08.02 Don'ts

1. Do not leave the control uncovered at any time.
2. Do not disturb the safety valve settings
3. Pressure setting of pressure switches should not be disturbed. Periodic calibration is recommended.

4.09 SF_6 Circuit breakers

The last few years have seen notable progress being made in the field of circuit breakers. With extra high voltage breakers,sulphurhexaflouride (SF_6) breakers have more or less replaced the minimum oil and air blast technologies.

On the medium voltage front, with vast advances in vacuum technology being made in the last two decades wherein it has become possible to create and measure vacuum of the order of 10^{-7} torr produce high priority materials by zone refining etc., have all led to the development of the vacuum interruptor.

It is very interesting to note that very large molecules (SF_6) and no molecules (vacuum) should lead to progress in the same problem of switching a given current with the least severities being imposed on the system. Today both the technologies are available to the user in the medium voltage field and are a commercially viable proposition.

SF_6 gas qualities

(a) It has a high dielectric strength which is a function of its density (b) It has high heat transfer property (c) its pressure changes as a function of temperature are very moderate, thereby making it well suited for large temperature variations (d) its de-ionisation characteristic is particularly suited to withstand a high ratio of rise of dielectric voltage stress appearing across the breaker contacts, (e) its physical and chemical properties make it ideal for switchgear application. The gas is non-toxic, non-corrosive, colourless, odourless, non-inflammable and physilogically inert. It is easy to carry and transport. Leakage can be easily detected by means of halogen detecting instruments.

4.09.01 Interrupter designs

When an arc is drawn in SF_6 the temperature within the arc column will dissociate the gas into its various by-products and these will tend to recombine very rapidly in the cooler zones away from the immediate vicinity of the arc core. The heat involved in dissociation is thus extracted from the arc to be released subsequently in the cooler regions where the original properties of the gas are restored.

4.09.02 Operating mechanisms

While spring operating mechanisms are used in m.v. circuit breakers, pneumatic/electro hydraulic/spring operated mechanisms are used in HV/EHV breakers.

4.09.03 Maintenance

SF_6 circuit breakers require very little maintenance. Involved are those parts which are subject to wear and ageing. The paint finish and degree of contamination of insulators should also be checked.

Major Inspections involving examination of interruptor and electro hydraulic or pneumatic operated mechanisms require thorough knowledge of the maintenance instructions of the manufacturer and stocking of tools and spares. It is desirable that manufacturer is associated with such works.

4.09.04 Inspection and Maintenance of medium voltage SF_6 Circuit breakers during Operation

a. *General*

All the inspection and maintenance service must be performed with the circuit-breaker open, the closing springs unloaded and the main and auxiliary electrical circuits disconnected. Failure to observe these rules could cause serious accidents for the operator.

During normal operations the circuit-breakers require very little maintenance.

- The frequency of inspection and maintenance service is tied, on the other hand, to the severity of the operations, which in turn varies according to several elements, such as:
- Frequency of movements
- value of interrupted current
- power factor
- installation environment.

Conditions that may make more frequent maintenance necessary are :

1) Humidity at high ambient temperature
2) Corrosive atmosphere
3) Excessive dust and dirt
4) Frequent, heavy operation
5) Frequent interruptions for breakdowns
6) Plant long in continual operation without the benefit of even limited inspection or maintenance.
7) Information obtainable from the history of previous inspections.

These elements are so variable that it is not possible to give precise indications. In any case, the following rules are recommended.

- equip the circuit breakers with movement-counters
- circuit breakers that made only rare movements remain closed for long

periods must be actuated from time to time to prevent the tendency to grip causing slower opening and closing speeds;

- at least once during the first year of operation inspect the circuit-breaker and eliminate dust from the insulating parts, clean and lubricate the contact parts and the elements that transmit the pole shoe movement.
- Later, based on information obtained during the fifth year of operation, increase the interval of time between inspections, if warranted;
- If the installation position makes it possible, visual inspection of the circuit-breaker is advisable from outside during operation according to the program shown in Table 1 and a series of inspections according to the program shown in Table 2.

b. *Visual inspection program :*

To maintain the circuit-breaker in good repair, it is recommended to follow the following chart :

Table - 1 Inspection Program for SF_6 circuit breaker

Inspections	Troble Found	Remedy
Operating mechanism	Damage or loss of parts Accumulated dirt	Replace damaged or lost parts Clean off dirt
Movement–counter	Does not correctly indicate the operation of the device	Inspect, repair or replace movement–counter
Medium–voltage portion	Excessive accumulation of dust and dirt	Clean the insulating parts removing the dust with a dry rag

C. *Inspection Program :*

To assure the satisfactory operation of the circuit-breaker it is advisable to inspect it periodically according to the following program :

Table 2 - Inspection Program

Inspected Part	Prescribed Inspections and Troubles	Remedies
Insulating resistance on pole (with Megger)	Check Standard values; between main terminals and 2000 MΩ (2500V) mass between main terminals and mass with breaker open 2000 MΩ (2500V)	Insulation drops noticeable due to accumulated dust. Clean with a dry cloth until insulation is restored.
Gas pressure in each pole (check required in case of pressure switch intervention)	Check for standard value of 2.4 kg/sq.cm at 20°C or value recommended by manufacturer.	Restore to standard value with procedures outlined in manufacturer's instructions.
Operating mechanism	Anomalous performance of auxiliary contacts and mechanism releases	Eliminate the troubles discovered and replace damaged parts if necessary.
Main circuits	Lack of contact on parts of wiring	Restore contact using the procedures outlined in manufacturer's instructions.
Breaker circuits and arc contacts	Bad contact between the wiring and the terminals	Contact manufacturers
Controls	Dirt deposits, loose screws or nuts, damage or pieces missing Dry open/close test 5 times	Remove dirt. Tighten screws and nuts and replace damaged parts. Find nature of troubles, repair.

d. *Circuit-breaker life :*

The life of the circuit-breaker depends mainly on the degree of decomposition of the SF_6 gas, on the wear and tear on contacts due to operation and on the mechanical life of the operating mechanism.

e. *Gas decomposition :*

An indirect indication can be obtained by measuring the insulation resistance with Megger at 2500V between the terminals of the pole : acceptable value 2000 MΩ according Table 2.

f. *Wearing of contacts and breaker parts :*

The state of wear of the contacts can be detected in an indirect way by determining at what point the arcing contacts (fixed and moving) come in touch while the circuit-breaker is closing.

For this operation, the circuit-breaker must be closed very slowly, according to the following procedure.

Applicable for a particular make of circuit-breaker. (Refer to manufacturers instructions in respect of other makes).

— With the circuit-breaker open and off line, insert a tester between the terminals of the pole to be checked.

— Disconnect the rod linking the operating mechanism to the lever of the central pole ;

— Slowly rotate the external lever of the poles in a clockwise direction until contact is indicated by the tester, and note distance 'a' in this position.

On a pole with new contacts, dimension "a" is about 8.5mm for 12-24 KV breakers and about 13mm for 36 KV breakers (for a particular make of circuit-breaker).

With maximum acceptable pole contact wear, dimension "a" becomes about 22mm.

Pole reconditioning is therefore required for greater values.

In this event, it is advisable to have the other poles reconditioned as well. Since special precautions must be taken during reconditioning (absence of moisture inside the pole and a suitable level of cleanliness of the internal parts of the pole) manufacturers must be consulted.

To replace the pole, first disconnect the main lines connected to the pole terminals and the sheathed auxiliary cables of the pressure switches and, for the -50°C Circuit-breaker version, the thermostat probe, then remove the safety ring between the shaft and the external pole lever, remove the 4 screws holding the pole to the base and pull out the pole.

When mounting a new pole on the circuit-breaker trolley, the above operations must be performed in reverse order. The electrical life of the circuit-breaker depends on the devices used and is linked to wear on the arcing contacts, while the SF_6 gas is not significantly altered following power-outs.

The example of cumulative breaking currents shown below corresponds to what has been verified in direct laboratory breaker tests without reconditioning and to the requirements of the ENEL DY1501 specifications :

4	breaks at 12.5 KA +
12	breaks at 7.5 KA +
322	breaks at 3.7 KA +
252	breaks at 1.2 KA

The cycle described above corresponds approximately to 50 times the full break power, based on statistics for circuit-breaks in medium-voltage distribution plants in operation for at least 20 years.

At the end of this test cycle, the device still presents a considerable reserve of electrical life, based on the wear to live parts.

g. Mechanical life of the operating mechanism

See the indications in the instructions booklets. An inspection with lubrication every 5000 operations, or every 3 months, is recommended.

4.09.05 Recommendations for use of SF_6 gas in Medium-Voltage Equipment

a. *Protective measures and their purpose*

In areas where equipment using sulphur hexafluoride as a means of arc-quenching is installed, special written instructions should be displayed for personnel that could be exposed to sulphur hexafluoride (SF_6) and its by-products of decomposition when operating the equipment.

b. *Preliminary considerations*

Sulphur hexafluoride, in its pure state, is an odourless, colourless, non-toxic gas with a density about five times that of the air. For this reason, though it produces no specific physiological effects, it could cause effects typical of oxygen shortage.

Due to the effect of the electric arc, a small quantity of SF_6 contained in the pole casing (a few % max.) decomposes leaving both gaseous and powdery by-products with an acidic reaction and thus potentially aggressive. In a circuit-breaker these decomposition products, which as we said are quantitatively insignificant, normally remain closed inside the sealed equipment and absorbed by special filters :

The probability of contact with decomposed SF_6 is extremely low as pertains to these events.

c. *Gas leaks*

There is no risk for persons since the quantities of SF_6 are modest and decomposed even less.

d. *Opening the casing for maintenance*

Considering the long electrical life of the SF_6 equipment, the event is extremely improbable.

For MV circuit-breakers it is in any case advisable to replace the breaker elements, since the operation is simple and rather infrequent.

This maintenance service is really only probable for HV circuit-breakers.

e. *Breakage of the casing*

Considering the pressures used and the dimensioning of the casing, this should be regarded as a highly improbable accidental event.

4.09.06. Protective Measures and Procedures

In order to prevent the modest risks connected with the use of SF_6 in electrical equipment, it is advisable to comply with the following precautions and instructions:

a. Make sure there is sufficient natural air exchange in the areas in which the equipment is installed.

b. In the event the casings are accidentally broken, the presence of decomposed gas is perceptible even in extremely small quantities (1-3 ppm) because of its pungent, unpleasant odour, and the following procedure should be instituted.

   — thoroughly ventilate the area and, in the case of installation in a protective or armoured cabinet, make sure there is efficient air exchange; open the cabinet only after the characteristic odour of decomposed SF_6 is no longer perceptible;

   — wear protective rubber or plastic gloves and remove any powder that has escaped from the equipment, using throw away rags;

— personal hygiene is important after these operations. Thorough washing with soap and lukewarm water is a sufficient precaution to avoid irritation of the skin and eyes.

c. If the pole casings are opened for maintenance, it is advisable to follow the above instructions after recovering the gas.

4.09.07. Maintenance of EHV SF_6 Circuit-breakers

Circuit-breakers require very little maintenance. Involved are those parts which are subjected to wear and aging. The paint finish and degree of contamination of insulators should also be checked. The following are the factors which govern the maintenance of the breaker:

— number of short circuit interruptions

— switching frequency and service conditions

— number of years of service.

Maintenance and inspection should be carried out in accordance with the inspection schedule. The servicing intervals indicated below are only approximate and should be suitably altered to suit the operating service conditions.

The inspection and servicing jobs have been divided into three groups

— Routine check to be made every 5 years: These checks contain jobs only to be done at earth potential. Draining of SF_6 is not necessary.

— Minor inspection after 1500 operations or 10 years of service: in the case where in breaker operates more than 1000 times a year, inspection should be carried out after a maximum 3000 operations.

— Major inspection
After 3000 operations or 20 years of service. In the case of breaker operating more than 1000 times a year, inspection should be carried out after a maximum 6000 operations.

The life of the contacts normally matches the life expectancy of the breaker.

If the breaker performs the short circuit interruptions as indicated in Fig.4.1 before the inspection becomes due, it is necessary to check the contacts in accordance with the inspection schedule, and also after 3000 interruptions of normal rated current. Circuit-breakers that made only rare movements and remain closed for long periods must be actuated from time to time to prevent the tendency to grip causing slower opening and closing speeds.

4.09.08. Precautions to be taken

Before starting work on breaker carry out the following:

- isolate the breaker on both the sides.
- connect the breaker terminal to earth
- disconnect the auxiliary supply
- reduce the oil pressure of electro hydraulic mechanism to zero by opening the pressure relief valve. If spring operated unload the closing spring.
- transfer the SF_6 to the maintenance unit and vent the breaker. If no maintenance unit is available allow the SF_6 to escape.
- Comply with all local safety regulations.

4.09.09. General Instructions for maintenance

All the split pins, lock washers spring washers of bolted joints should be replaced with new ones when they are opened for maintenance.

All the gaskets, O-rings and rubber washers should also be replaced with new ones during reassembly.

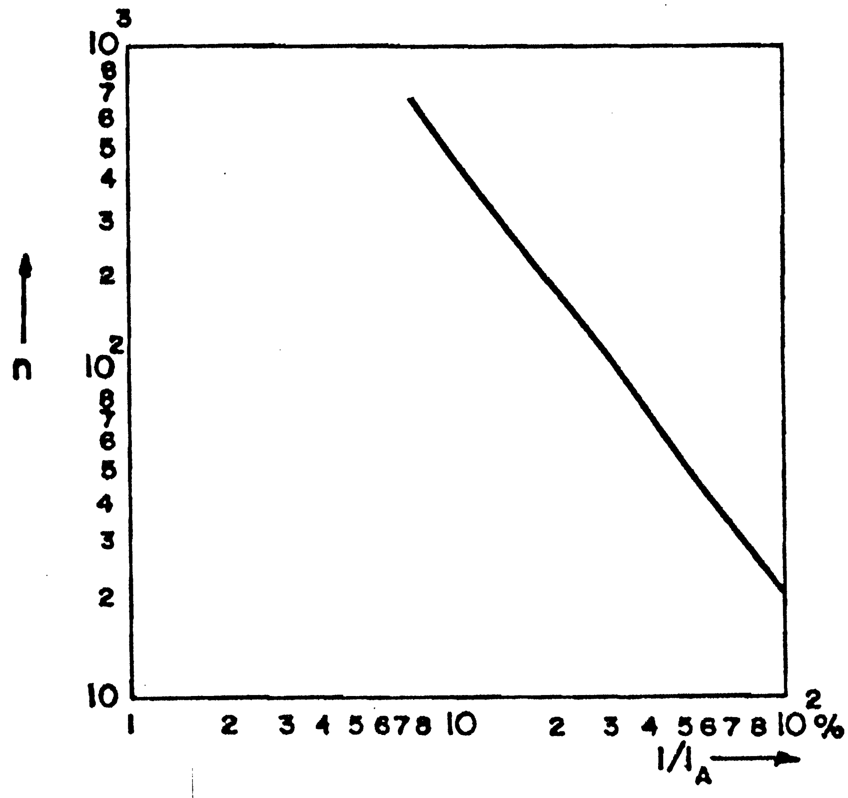
All the breaker parts dismantled for maintenance should be covered and protected against ingress of dirt and moisture while reassembly is in progress. Small quantities of metallic fluoride powder forms because of arc interruption of SF_6 gas. This metallic powder when in dry state is insulating and harmless. However the powder is hygroscopic and in the presence of water vapour the dust forms a paste which is conductive. As such this metallic fluoride powder should be cleaned with the help of a clean non-fluffy cloth or a vacuum cleaner, as soon as the interrupter is opened for inspection and servicing to prevent the formation of conductive paste which is very difficult to remove. The cloth once used should be thrown into dust bin. Separate cloth should be used for each interrupter. During cleaning of the metallic fluoride gloves should be worn.

Care is advised when working near the auxiliary switches and the piston rods of operating mechanism since any damage may cause leakage.

For cleaning and degreasing agents and special compounds to be applied during maintenance.

4.10 Vacuum Circuit Breaker (VCBs)

The main advantages of vacuum breakers are the virtual elimination of maintenance, flammable liquid and venting, reductions in unit sizes and weight and



n = Number of Interruptions
I = Interrupted current
I_A = Rated short circuit current

Fig 4.1.
Permissible stressing of the contact system as function of the interrupted short-circuit breaking current.

4.09.10 INSPECTION SCHEDULE

Routine Inspection	Minor Inspection	Major Inspection	No.	Item
■	■	■	1.1	General checks
■	■	■	1.2	Note the number of make-and-break operations and any particular occurrences
■	■	■	1.3	Check SF_6 filling
	■	■	2.	Draw out the SF_6
			3.	POLE COLUMNS
	■	■	3.1	Open all interrupter units and make a visual check of the contact system and the blast cylinder
		■	3.2	Check the sliding faces of the crosshead and the coupling pins and bearings for signs of wear.
		■	3.3	Examine and clean the operating rod.
	■	■	3.4	Replace filters
	■	■	4.0	AUXILIARY SWITCH : Sparingly oil the bearings, examine and grease the coupling linkage.
	■	■	5.	Fill in the SF_6
			6.0	ELECTROHYDRAULIC OPERATING MECHANISM
■			6.1	Carry out test operations
■	■	■	6.2	Make a visual leakage check of the hydraulic system
■			6.3	Check the oil level and its condition
	■	■	6.4	Drain the oil and clean both the oil tank and the intake filter

Routine Inspection	Minor Inspection	Major Inspection		
		■	6.5	Examine the accumulator, the main valve and the operating cylinders.
	■	■	6.6	Fill in new oil
■	■	■	6.7	Check the priming pressure of nitrogen.
	■	■	6.8	Raise the oil pressure in the accumulator to the nominal level. Measure the current input of the motor at this pressure.
	■	■	6.9	Carry out test operations
	■	■	6.10	Operate the breaker at reduced operating voltage
	■	■	6.11	Check the operating pressure of the safety valve
	■	■	6.12	Check the inner sealing of the hydraulic system
	■	■	7.0	Check the operating values of the SF_6 density monitor and oil pressure monitors
	■	■	8.0	Check the breaker pressure gauge for SF_6 and pressurised oil
■	■	■	9.0	Check the space heaters
	■	■	10.	Check the anti-pumping feature
	■	■	11.	Check all fully assembled breaker for SF_6 leaks
■	■	■	12.1.	Check that the external connecting leads are seated firmly
	■	■	12.2.	Tighten the internal terminals
■	■	■	13.0	Check the paint finish and touch up where necessary

interruption times fast enough to beat h.r.c. fuses. Only parts subject to normal wear and ageing need be serviced to ensure fully reliable operation. The intervals at which these maintenance should be carried out and amount of work involved depends upon the number of short circuit interruption switching frequency and actual service condition.

The service intervals indicated below are only approximate and should be adjusted to suit the particular operating conditions. Under normal conditions, the vacuum interrupters need not be serviced. The maximum permissible contact wear is 3 mm.

4.10.01 Inspection Schedule

Once a year, a general inspection should be carried out and if necessary the insulating parts should be cleaned with rag. More frequent checks may be necessary if the breakers are installed in a dust laden atmosphere.

4.10.02 Breaker operating mechanism

The operating mechanism should be oiled and lubricated every 10 years or after 10,000 operations whichever is earlier.

4.10.03 Vacuum interrupters

Replacing the interrupter is an exception. They may have to be replaced after 30,000 mechanical operations or when contacts have eroded by maximum amount and white 'dot' marked (or coloured mark on burn off indicator in some makes) on moving contact stem of the vacuum interrupter is not visible in breaker closed condition. Use of contact burn off calipers is recommended in certain makes. For guide the following number of operations are given for life of interrupters of certain makes. Manufacturer's instructions on particular makes may be used.

For a 36 KV, 1250A, 25 KA-VCB	For a 12 KV - 630A - 16KA-VCB
25 KA - 50	Normal load - 20,000
16 KA - 90	2.5 KA - 3,000
12.5 KA - 225	8.0 KA - 400
1250 A - 20000	16 KA - 100
Normal Current - 30000	

4.10.04 Important

Before starting any work on breaker, isolate, short circuit and earth, Disconnect the auxiliary supply. Open and close the breaker by hand until both closing and tripping springs are discharged.

Inspections and repairs should be carried out by qualified fitters who are familiar with switchgear of this type with due reference to operating instruction.

Only those lubricants, grease and corrosion protection agents recommended by the manufacturer shall be used.

4.10.05 Contact resistance

Check the contact resistance across the top and bottom pole supports after closing the vacuum interrupter through quick release of closing spring. The contact resistance should be around 15 to 20 micro ohms. This test is recommended as a bench mark while installing the new interrupter. Experience has shown that a degree of spread can be obtained in contact resistance measurements when the circuit breaker is closed, but these do not have the same degree of significance as in other types of circuit breakers. The results show that there is a tendency for the resistance to decrease as the switch is used. Any increase in the resistance figure does not indicate contact erosion as in most breakers and the fact that the contacts are in vacuum precludes the forms of deterioration which would take place in other media.

4.10.06 Check on Vacuum

In respect of preservation of the vacuum, the vacuum interrupters feature high reliability. Consequently, checking the vacuum is not included in the maintenance schedule. Checking is advised only in the following cases:-

i) When it is suspected that the interrupter was damaged externally during transport or installation and

ii) after the switchgear has been installed twenty years. Some manufacturers specify a routine maintenance check around once in 4 years, by one of the following methods:

(a) By mechanically pulling down the moving contact stem of the interrupter. If it moves freely it would indicate that the interrupter is full of air and hence lost vacuum.

(b) H.V. test The high voltage test may be undertaken according to manufacturer's instructions.

4.10.07. Warning

1) On conclusion of this H.V. test, bear in mind that the sections of the vacuum interrupter may have been capacitively charged. Established an earth before touching it.

2) Do not exceed the test voltage ratings because inadmissible high X-ray intensities could arise particularly at High d.c. voltages.

4.10.08 Inspection schedule of VCBs

Six months after commissioning and thereafter once a year	General inspection; check tightening of bolts. Clean insulating parts with non–fluffy cloth. Check the mechanism stroke settings. More frequent inspection may be necessary if the breakers are installed on a dust laden atmosphere.
Every 10 years or 10,000 operations	Lubricate operating mechanism with approved lubricants. Ensure the coil fixing screws are fully tight and locked by lock–tight fluid.
After 30,000 mechanical operations or when contacts have eroded a maximum amount.	Replace vacuum interrupter as per manufacturer's instructions.

NOTE: It may be necessary in certain cases to equip the VCBs with surge absorbers to take care of current chopping effects.

4.10.09 Check points for periodical inspection of VCBs

Sl. No.	Check point	Check Item	Check Method	Criteria	What to do	Remarks
1.	Entire Circuit Breaker	Tightness of bolts and nuts	By tightening them with screw driver and spanners	There should not be any fastener loosely tightened	Retighten the loose fastners properly	
		Dust and foreign matter	Visual check	The breaker should be clean and there should be no foreign matter.	Clean by compressed air flow. Also wipe the accessible components with a clean dry cloth.	
		Deformation, excessive wear and damage	Visual check	There should be no excessive wear or damage or deformation.	Remove cause and replace parts.	
		Lost or missing parts	Visual check	There should be no missing parts	Reinstate the missing parts to normal condition.	

Sl. No.	Check point	Check Item	Check Method	Criteria	What to do	Remarks
2.	Spring operated mechanism	Dust and foreign matter	Visual check	There should be no dust or foreign matter accumulated on mechanism.	Remove it by compressed air.	
		Smooth operation	Manual operation	Opeartion should be smooth	Apply proper grease to these points.	
		1. Lubrication of bearing pin 2. Lubrication of bearing blocks 3. Lubrication of breaker shaft ends 4. Lubrication of closing latch roller bearing.	Visual check and feel	All these points shall be well lubricated and rotating smoothly		

Sl.,No.	Check point	Check Item	Check Method	Criteria	What to do	Remarks
3.	Vacuum Interrupter	Contact wear	Visual check for measurement	Wipe length should be 3 ± 0.5 mm with the breaker closed.	If it is less than 1.0 mm, replace the vacuum interrupter.	
		Vacuum pressure			Replace the vacuum interrupter when vacuum pressure is not sufficient.	
4.	Auxiliary switches	Terminals	Tighten by screwdriver	There should be no loose connections	Retighten	
		Case and contacts	Visual check	There should be no damage and deformation	Replace if damaged	

SURGE ARRESTERS

5
Surge Arresters

CONTENTS

5. SURGE ARRESTERS

5.01 General

5.01.01 Electric Power systems are frequently subjected to over-voltage surges. The over-voltage surges that are dangerous to the power system are broadly classified as

— External over-voltages or atmospheric over-voltages caused by lightning. (Fast transients).

— Internal or system generated over-voltages

i) Switching over-voltages (slow front transients).

ii) Temporary over-voltages.

Major equipment failures, expensive repairs and unscheduled plant shut down, long down time are some of the consequences of inadequate protection from these voltage surges.

5.01.02 Surge arrester is an over-voltage protective device: more appropriately it is a voltage limiting device. Like a relief valve in a boiler, it safely discharges the dangerous over-voltage waves to ground and protects the equipments. The modern surge arresters are required to protect the apparatus both against atmospheric lightning over-voltages and system generated over-voltages.

5.02 Surge Arrester-operation

The basic operation of an arrester is simple. Its main function are to sense, limit and discharge the over-voltage surges-lightning or system generated-to earth. In its normal state, it acts as an insulator. When a high voltage surge impinges, it turns into conductor of negligible resistance in an infinitisimal time and returns to its original insulating state so as to get ready for meeting the next over-voltage wave. Thus, reliable surge arresters constitute the first rung in the protective ladder against over-voltages.

5.03 Types and Components of Arrester

5.03.01. Though there are several types of arresters, the conventional gapped arrester and the modern gapless or metal oxide arresters are widely employed. The active elements of a gapped arrester are the spark gap and the valve block (non-linear Silicon carbide resisters). These are housed in a porcelain shell for protection against atmospheric pollution and other degrading elements. The gap assembly serves as the switch, which turns on the arrester during over-voltage conditions. The non-linear silicon carbide resister block permits the flow of surge current but stops the flow of power frequency follow current. If acts like a valve; in addition, it consumes the surge energy that flows through it.

5.03.02 Metal oxide surge arrester has no protecitive gaps; by virtue non-linear characteristics, zinc oxide resistor elements are able to withstand the power frequency voltage during normal system operation. The metal oxide valve elements perform the functions of both the gaps and resistors in a conventional gapped arrester.

5.04 Surge Arrester Classification

5.04.01 The surge arresters are generally classified

— with respect to the kind of circuit to be protected such as power or communication circuit.

— with respect to location - whether it is used on distribution, sub-transmission or transmission sub-stations.

— with respect to weather protection - in-door or outdoor.

The discharge voltage for a given arrester rating at a given current is progressively higher for station, intermediate and distribution class arresters. Accordingly the protection afforded by the arrester decreases with the arrester class from station down to distribution. The main consideration in the choice of arrester class for an application is switching surge duty.

5.04.02 Distribution Class Arresters

These arresters are generally used in distribution net-works for surge protection to equipments. These are also used as line entrance arresters for 22 and 11 KV lines. The current rating of H.T. Distribution class arresters is 5 KA; arresters with the current rating of 0.5 or 1.0 KA are used in LT circuits. The voltage rating of HT arresters ranges from 3 KV to 18 KV.

5.04.03 Intermediate Class Arresters

These are light duty arresters and cost approximately two to three times as much as equivalent distribution class arresters. For this premium, these arresters have better protective level and higher surge withstand capability. These arresters also have a pressure relief system to safely vent internal pressure if the units fail. These arresters are generally used for the HV protection of power transformers in sub-transmission sub-stations. The current rating of these arresters is 10 KA. The voltage rating of these arresters range from 3 KV to 120 KV.

5.04.04 Station Class Surge Arresters

These are heavy duty arresters. These arresters have higher conductivity, lower residual voltages and greater withstand strength against switching surges but they cost about twice as much as equivalent intermediate units. Effective pressure relief system are provided in these arresters also. Station type arresters are generally employed at 400, 230, 110 and 66 KV circuits and sub-stations. The current rating of these arresters are 10 KA and 20 KA. Normally these arresters are used in the circuits rated 110 KV and above; but in a special circumstance these are employed in the circuits rated below 110 KV. Further these arresters are the only choice for the sub-stations that have transformers or other equipments with sub-normal insulation strength.

5.05 Surge Arrester Application

5.05.01 Following are the basic characteristics of the arresters that need to be considered for proper application.

i) Rated Power frequency voltage, this should not be less than the system voltage at any operating condition. (Gapped arrester)

ii) Maximum continuous operating voltage (MCOV). The system operating voltage should not cross this voltage under any conditions (Gapless arrester).

iii) Voltage limiting characteristics when passing surge currents of different magnitudes and wave shapes.

iv) Thermal limit (Switching surge duty).

The other important factors to be considered while selecting surge arresters are

— Maximum line-to ground voltage under system fault conditions.

— Over-voltages resulting from the sudden loss of load.

— Nature of system grounding and earthing factors.

— Ambient temperature, altitude and siesmic conditions.

— Pollution severity of the location.

— Arrester application on the delta tertiary windings of a transformer where one corner of the delta is earthed.

— Arrester application on the delta side of delta - Wye step down transformers.

5.05.02 The surge arresters should be located as close as possible to the protected equipment. An appreciable distance between the surge arrester and the protected equipment increases the voltage impressed upon the equipment at the time of surge discharge and leads to the failure. The arrester connecting leads should be kept as short as possible and the arrester ground terminals should be interconnected with that of the protected equipment metal housing. All these will help reduce the voltage impressed upon the protected equipment at the time of surge discharge.

5.06 Inspection and Maintenance

5.06.01 Though the type, acceptance and routine tests conducted on the arrester at the manufacturers' works ensure the satisfactory performance of the arrester at site, the components of the arrester gradually deteriorate while in service. For one thing surge arresters like other electric equipments are subjected to the effect of environmental factors like high temperatures, pollution, humidity, dust, etc., for another, there is the severity of the system imposed service conditions to be reckoned with. In other words gradual deterioration of the components of surge arresters from the day it moves out from the manufacturers works can be expected. The effects of supply outages owing to the failure of surge arresters in service will be equivalent in monetary terms to a significant percentage of the initial cost of the arresters. Hence appropriate remedial measures are to be taken to avert the inservice failure of surge arresters. The obvious method of achieving this, is the introduction of periodic non-destructive field measurements to detect significant changes in the state of the surge arresters. Though the periodical checks may not, by themselves, give out a definite forecast of further life, they increase substantially the probability of detecting an impending failure or development of serious defect before it has reached the terminal condition of failure. This enables timely remedial action being taken including in some cases replacement. The advantage of planned periodic field testing is thus the prospect of the utilization of the full potential life of the arrester.

5.07 Available Test Methods

5.07.01 Over the years a number of testing methods have been employed from the simple insulation resistance test with a megger to the Radio Influence Voltage (RIV) tests with sophisticated instrumentation at the other end of the spectrum. Following are the available test methods:

A. *Conventional Gapped Arresters*

i) Station and intermediate class.

— Insulation resistance test (Megger test).

— Leakage-grading current test (HVAC)

— On-line leakage current measurement by installing a surge monitor.

— Impulse spark-over test.

— Power frequency (50Hz) spark over test.

— Internal ionization and radio influence Voltage (RIV test)

— Potential gradient test by using Hipot bushing and insulation tester.

ii) Distribution class (H.T. and L.T.)

— Insulation resistance test (megger test).

— **Leakage - grading current test with 2.5 KV mains operated megger (HT arrester).**

— 400 V main-supply (LT arrester)

Among these tests, on-line leakage current measurement test and potential gradient test are exclusively site tests; Internal ionization and RIV test is possible only at a laboratory. The other tests can be conducted both at site and laboratory.

B *Gapless Arrester (station, Intermediate & Distribution class).*

— Insulation resistance measurement.

— Leakage current measurement.

— On line leakage current measurement by installing a surge monitor.

All these tests are "sitetests" only. The methodology and merits of these tests are briefly discussed below:

5.07.02 Insulation Resistance Test (Megger Test)

5.07.02.01 An arrester is acting as an insulator during most of its life span. To determine whether the arrester can be relied upon to be an insulator under normal operating conditions, this simple test is a very useful one. Mains operated 1000 V megger if available and if not, hand operated 1000V or 500 V. megger is employed. The principal value of a megger test is that it enables detection of a poor contact in the gapped arrester circuit which if it exists, will be an open gap. The presence of such a gap will not be detected when tested for 10 KV D.C. or more, since at these voltage levels the arrester will spark-over, whereas at 1000V or less, it will not. As a rough guide, if the meggered IR value is infinity or in the order of several thousand mega ohms, the unit is considered as open circuited. Similarly, if the IR value is 25 megaohms or less, it is considered a doubtful arrester so far as insulation is concerned. This holds good for gapless arrester also.

5.07.02.02 The voltage per arrester unit will be very low if the entire unit is checked with a 1000V or 500 V. megger and hence the test results are frequently uncertain. Further it is very difficult to ascertain the condition of a modern station class arrester with non-linear grading resistors with a megger. In view of this, this cannot be accepted as a significantly conclusive test, eventhough it can detect patently faulted units to a large extent. However because of its simplicity, it can be conducted as a course test for preliminary investigation. Prior to the application of HV tests on the arrester, a rough estimate on the status of an arrester insulation can be made out with this course test. If this test reveals something wrong with the arrester unit, a detailed investigation may be carried out before proceeding for further diagnostic tests.

5.07.03 Leakage Current Test

5.07.03.01 As stated earlier, a surge arrester is acting as an insulator over 99.9 percent of its life and this property of insulation is vulnerable to the ingress of moisture through its seal.

Information is therefore required to determine whether the arrester can be relied upon as an insulator under normal conditions. To gain information on the deterioration of the insulating qualities of an arrester, periodic leakage current measurements are to be conducted and the readings are compared with previous test results. Either HVDC or HVAC is applied. In a gapped arrester, the measurement of leakage current is an index pointing to both the conditions of the grading resistor, the non-linear valve blocks as well as the external surface conditions of the housing insulator. This test is useful to detect gross defects such as moisture ingress,shorted gaps and defective ageing grading resistors. This test is also useful to detect the defects in gapless arrester. To make these tests more effective, the first test should be conducted immediately after the arrester is put into service. This first test can be used as a bench mark for future periodic maintenance tests. If any significant variations are observed in the leakage current values during periodic measurements, the arrester unit under test may be considered as a unit with doubtful characteristics and further tests are to be conducted on it. Theoretically limiting values cannot be laid down for this test and the test results have to be interpreted on a comparative basis vis-a via the earlier recorded results. However, the permissible level for leakage current may be taken as 2mA at the rated voltage. For a gapless arrester, the leakage current value at rated voltage should not exceed the maximum level recommended by the supplier. Normally, the magnitude of this current will be around 3 milliamps. The test readings may 'therefore' be used as a guide to observe trends of degradation/deterioration of arrester components.

5.07.03.02 Another very useful application of this method is to test all arresters of the same voltage class, make and rating in a station at the same time. Then before an individual arrester unit is judged as 'suspect', its test value is correlated not only with its original test value but also from the average test values of the other arresters. Until experience suggests a different reference value, it is considered reasonable that an arrester insulation is not questioned until its test value is atleast twice or less than half the average value of other arresters. With careful attention to test details, particularly to the quality of external surface conditions, this test can be an effective way to detect a leaking arrester before it fails.

5.07.03.03 *HVDC Test:* Experience has shown that DC tests do not cause major stresses as an A.C. test of the same;peak voltage. It is simple and less time consuming because power requirement for HVDC testing kit is much lower than that required for a HVAC testing kit. Hence, periodical HVDC leakage measurements coupled with insulation resistance tests by a 1000 V megger are performed on arrester units at regular intervals and the test results are compared with previous values for any abnormal variation. The tests are usually conducted at reduced voltage. The tests i.e. 10 KV or 15 KV D.C., which however is a fairly large fraction of the rating of station class arresters, sufficient to reveal any abnormalities. Periodical HVDC tests on 12 KV rated surge arrester units may be done with 2.5 KV mains operated megger by introducing a suitable microammeter in the circuit for leakage current measurements. The practice in Board is to reckon proportionate value of leakage current corresponding to 2 m.A. at rated voltage as permissible level and to discard arrester units having leakage current exceeding this value. The voltages applied in this test are considerably below the voltage ratings of the arrester units and as such, the protective qualities of the arrester cannot be gauged correctly. Further performing 10 KV DC test on the modern arresters with magnetic blow out coils in their circuits may give erroneous information on their status. Owing to the inherently capacitive nature of the metal oxide resistors, this is not recommended for gapless arresters also.

5.07.03.04 *HVAC Test* : Internal disorders in an arrester assembly are bound to affect the capacitance orientation causing abnormal leakage current. Hence power frequency leakage current, measurements at a voltage very near to the rating of an arrester is prima facie a more appropriate practical field test to determine the condition of arresters in service. The test is performed by the gradual application of 50 Hz voltage output from a testing transformer direct to the surge arrester unit under test and measuring the magnitude of leakage current flowing through it. Similar to HVDV test, the test results are compared with previous test recordings for checking whether any significant changes have occurred. However, this test will not indicate the condition of spark gap in a gapped arrester, unless it is dead shorted or corroded. To assess the condition of spark gap, spark over test are to be conducted. Here again leakage current exceeding 2 mA is considered a pointer to the arrester being defective. This test is recommended for gapless arrester also. Leakage current exceeding the values given by the manufacturer is considered as an indication to the deterioration of the arrester.

5.07.04 On-line Leakage current test by using a Surge Monitor

It is a common test for both gapped and gapless arresters. Surge monitor is a device connected electrically in series between the surge arrester and the ground. It not only records the number of surge discharges that pass through the arrester but also monitors the leakage and grading current of the arrester poles. The counter of the surge monitor records the number of operations, performed by the arrester, while the ammeter shows the feel of the arrester at any time. The connection of surge monitor in series with the surge arrester does not affect the protective level of arrester and its active elements are properly matched with that of the arrester. A small current is always flowing through the grading resistors of an arrester in service and with the arrester at its operating voltage, this grading current should be within a range of 10 to 50 per cent of the full scale reading of the surge monitor ammeter. Deviation from this range of grading current signifies that the arrester is to be cleaned or suspected. If the deviation persists even after a thorough cleaning and washing off the surface of arresters, the arrester is to be suspected and further confirmative tests are to be conducted on it before a decision is taken for its continuance in service or replacement.

5.07.05 Impulse Sparkover Test

5.07.05.01 The condition of the spark gap assembly can be determined by impulse sparkover test. It is a fairly conclusive test. This test determines the protective characteristics of the arrester -i.e. its ability to protect the equipment from dangerous lightning and switching voltage surges and it can be safely conducted on an arrester unit without the danger of over-heating the non-linear grading resistors, provided the test is not repeated unreasonably within a short period. It is preferable to power frequency sparkover test, as danger of damage to non-linear gap shunting resistors is obviated. Non-standard, relatively slow rise waves, are used in this test. The testing kit adopted for this test contains a simple arrangement which would give test results in fair agreement with those obtained in the standard test using 1.2/50 micro sec waves.

5.07.05.02 The test is performed by gradual application of high voltage pulse output to the test specimen till it sparks over as portrayed by the breakdown indicator. The L.T. input voltage to the kit is noted and from a calibrated curve supplied by the kit manufacturer the sparkover voltage value is obtained. The higher limit of impulse sparkover for each arrester rating is prescribed in IS:3070 (Part I)/1974; no lower limit has been a specified in it. The minimum impulse sparkover may be approximately taken as arrester rating $x\sqrt{2} \times 1.45$. An arrester is considered to have passed this test, only when its sparkover voltage lies between the maximum and minimum limits. It is not necessary to determine the actual sparkover voltage as long as the arrester sparkover level falls between the tolerable higher and lower limits. Because of the statistical nature of the sparkover phenomenon, there may be large variations in the sparkover voltages of the arrester. It is, therefore, suggested that this test may be repeated several times to get a reasonable spark-over value.

5.07.05.03 **Arresters sparking-over, near or above the higher limit provide insufficient protective margin to the protected equipment and must be replaced.** Sparkover considerably below the lower limit set usually indicates some internal arrester damage and such units should also be discarded. Prior to this test, it is better to perform 50 Hz leakage current test on the arrester specimen. It is a good practice to conduct a megger test on the arrester unit before subjecting it to 50 Hz leakage current test or impulse sparkover test.

5.07.06 Power Frequency Sparkover Test

5.07.06.01 The condition of spark gap unit, the likely vulnerable part in gapped arrester can be easily determined by this test. It also helps to evaluate the ability of the arrester unit to withstand normal service voltages and to reseal after conducting power follow currents. Since any test using voltages in excess of arrester rating can seriously damage an arrester, this test should be done very carefully. When a 50 Hz spark-over test is applied with adequate caution and control, it is an effective test to check the protective characteristics of an arrester. There should be sufficient resistance in the circuit to limit the short circuit current and when the arrester sparks-over the circuit should be opened quickly with sufficient precaution, the transformer oil testing kit which is commonly available can be used for this test. It has been specified in IS:3070-Part I 1974 that 50 z spark-over voltage should not fall below 1.5 times the arrester rating.

5.07.07 Internal Ionization Voltage and Radio Influence Voltage Test (RIV test)

5.07.07.01 These are the latest diagnostic tests adopted on surge arresters. The radio influence and internal voltage tests are combined and they are performed at the rated voltage of the arrester. The RIV and the ionization voltages are measured at a frequency of 1.0 MHz or as near that frequency as practicable. The equipment and the test set ups should be in accordance with NEMA standards publication for measurement of radio influence voltage (RIV) of high voltage apparatus 107-1964. This equipment is available with major manufacturers of surge arresters in our country.

5.07.07.02 The radio influence and internal ionization voltage levels are measured in micro volts. The minimum permissible level is around 200 micro volts. A high level would indicate defects in the components of the arrester. The loose broken missing or extra parts inside an arrester will be revealed by these tests.

5.07.08 Potential Gradient Test by using Hipot Bushing and Insulation Tester

5.07.08.01 This imported kit available in the Board consists of hotstick having 3 sections, connecting leads and a meter. Each section of the Hot stick is provided with appropriate internal resistance. This kit is generally used to identify the defective disc in string of insulators. A potential gradient test conducted on arrester units from 11 KV to 220 KV rating with this kit has proven valuable in detecting internal faults. Common faults like short circuiting of gaps due to moisture, corrosion of gap electrodes etc., are detected by this test, the principle being that under such conditions, there will be reduced potential drop over the gap chamber and increased stress on the valve material in that particular arrester section.

5.07.08.02 In this test, the metal parts of each arrester unit in a phase commencing from line are touched one after the other by the hot stick; the corresponding meter readings give an indication of voltage drop in each of the arrester unit. By comparing the 3 sets of values obtained for the three phases, the defective arrester unit can be identified. The procedure followed in detecting a faulty or suspect arrester unit is illustrated in Annexure I with a set of readings obtained on a healthy and defective arrester assemblies. The main criterion followed in this testing method is that the voltage drop across an arrester unit in a phase should not be less than 50 per cent of the value obtained in the corresponding units in the other two phases. If the voltage drop is found to be less than 50 per cent of the value obtained in other two phases or is found to be zero then that unit can be discarded as a defective unit.

5.07.09 Of the several test methods available to evaluate the integrity of conventional gapped arresters (Station and intermediate classes) leakage current (HV AC) test and potential gradient test by Hipot live-line testing set are more significant. For a gapless arrester leakage current test is important. A gapped arrester shall not be discarded merely on the basis of leakage current test. Further confirmation tests such as impulse and 50 H_z spark-over test are to be performed before condemning a conventional arrester unit. When a suspect arrester is detected in an arrester pole, it is desirable to replace the entire arrester limb.

5.08 Inspection and Maintenance Schedules

5.08.01 Following are the schedules for periodical inspection and maintenance.

Maintenance Schedule 1

Conventional gapped arrester - Station & intermediate class

Sl. No.	Item of Inspection	Periodicity for Inspections/ Maintenance	Permissible value
1.	Cleaning of outer procelain housings; Examining for cracks or damaged glaze	Half yearly or When necessary or at every opportunity during pre-arranged shutdowns	
2.	Arrester provided with surge monitors. Recording of leakage current readings and surge counter registrations when the pointer of the leakage current indicator is found to be beyond the permissible limit, shutdown is availed at the earliest opportunity and the external porcelain surface of the arrester is thoroughly cleaned. After putting back into service, if the leakage current reading is still unsatisfactory, when the arrester under test may be defective. Further confirmative tests such as HVAC leakage current and potential gradient tests may be carried out.	Every shift	
3.	Arresters without surge monitors. Potential gradient test by hot-line crew with the aid of Hipot bushing and insulation tester. Leakage current (HVAC) test has to be conducted on the 'Suspect' arrester which does not pass the potential gradient test. The arrester units that fail to pass this leakage current tests are replaced. These released arresters may be subjected to impulse spark-over and power frequency sparkover tests.	Yearly	The voltage drop across an arrester unit in a phase should not be less than 50 per cent of the value obtained in the corresponding units in the other two phases. If the voltage drop is found to be less than 50 per cent of the value obtained in other two phases or is found to be zero then that unit can be considered as a suspect unit. Leakage current measured at power frequency sparkover tests should not exceed 2 mA at rated voltage. Impulse spark-over voltage should lie between the maximum voltage prescribed in IS 3070 (part 1) and the minimum value given by the formula (arrester voltage rating × ($\sqrt{2} \times 1.45$) *Power frequency Spark Over should not be less than 1.5 times the arrester rating.*

Schedule II
Conventional Gapped Arrester – (Distribution Class)

Sl. No.	Item of Inspection	Periodicity for Inspections/ Maintenance	Permissible value
1.	Cleaning of outer procelain shell examination of outer shell for any cracks or damaged glaze	Half yearly & as and when necessary or at every opportunity during pre-arranged shut down.	
2.	HT 11, 22 & 33 KV Arresters a. Insulation Resistance (Megger test) with 1 KV mains-operated megger. b. Leakage current test. This test may be conducted with 2.5 KV mains operated megger by introducing a suitable microammeter in the circuit.	Yearly Yearly	Insulation Resistance value should not be too high (infinity or several thousand mega ohms) or low (less than 25 Mega Ohms) Proportionate value of leakage current corresponding to 2 mA at rated voltage may be taken as the limiting value and the arrester units having leakage current exceeding this value should be discarded.
3.	L.T. Arresters a. Insulation Resistance (Measurement with a 500 V, hand-operated megger). b. Leakage current test. Rated voltage (AC) of the arrester may be applied and the corresponding leakage current may be recorded by introducing a suitable ammeter in the circuit.	Yearly Yearly	IR value should not be too high or too low. Leakage current should be in the order of a few micro amps.

Schedule III
Gapless Arresters – Station, Intermediate & Distribution Class

Sl. No.	Item of Inspection	Periodicity for Inspections/ Maintenance	Permissible value
1.	Cleaning of outer shell–examining for cracks or damaged glaze	Six months or as and when required or during Pre-arranged shutdowns	
2.	Insulation Resistance Test (Megger-Test with 1 KV megger)	Yearly	Insulation value should not be too high or too low.
3.	Arresters provided with surge monitors. Recording of leakage current and surge counter registrations when the pointer of the leakage current is found to be beyond the permissible limit, shut-down should be availed immediately and the external porcelain surface of the arrester thoroughly cleaned. After putting back into service if the leakage current reading is still unsatisfactory, the arrester unit is considered as suspect. For confirmation HVAC leakage current test may be conducted.	Every shift	Leakage current at rated voltage should not exceed the value given in the technical specification supplied by the manufacturer normally it is around 3 mA.
4.	Arresters without surge monitors. Leakage current test (HVAC)	Yearly	-do-
Note : Leakage current test with HVDC should not be conducted on this arrester.			

If the arresters are provided with surge counters, a record should be maintained for the surge counter registrations. If more operations of a particular arrester are indicated, the causes for such frequent operations should be analysed.

Manufacturers' instructions on receipt, storage, installation and commissioning of arresters should be strictly adhered to. The exhaust parts of the pressure relief system provided in the arrester should be directed away from the protected equipment and other arrester poles so as to prevent damage to them by the hot ionised gases emanating from these ports in the event of arrester failure.

5.09 Failure of arresters - Possible causes

The life of an arrester is dependent on various factors such as temperature, applied voltage (temporary and operating AC voltage), surge duty, (Lightning and switching surges) and external contamination. Excessive discharges of surges or power follow current may puncture the non-linear resistors and this will in turn cause damage to spark gap assemblies in gapped arresters. As regards the gapless arresters, it will result in arrester failure. Moisture ingress and partial breakdown of the internal insulation are some of the other adverse factors. Corrosion or contamination of the spark gap electrode surfaces are important contributing factors for the failure of conventional gapped arresters. Puncture of valve and grading resistors may be caused by severe service duty. Other factors that lead to degradation failure of a gapped and gapless arresters in service are

— Application of sustained power frequency voltage (50 H_z) in excess of arrester rating.

— Repeated discharges within a short duration.

— Improper handling during transport, installation and in-service.

— Contamination of external porcelain housings.

5.10 Surge monitors (Fig. 5.1)

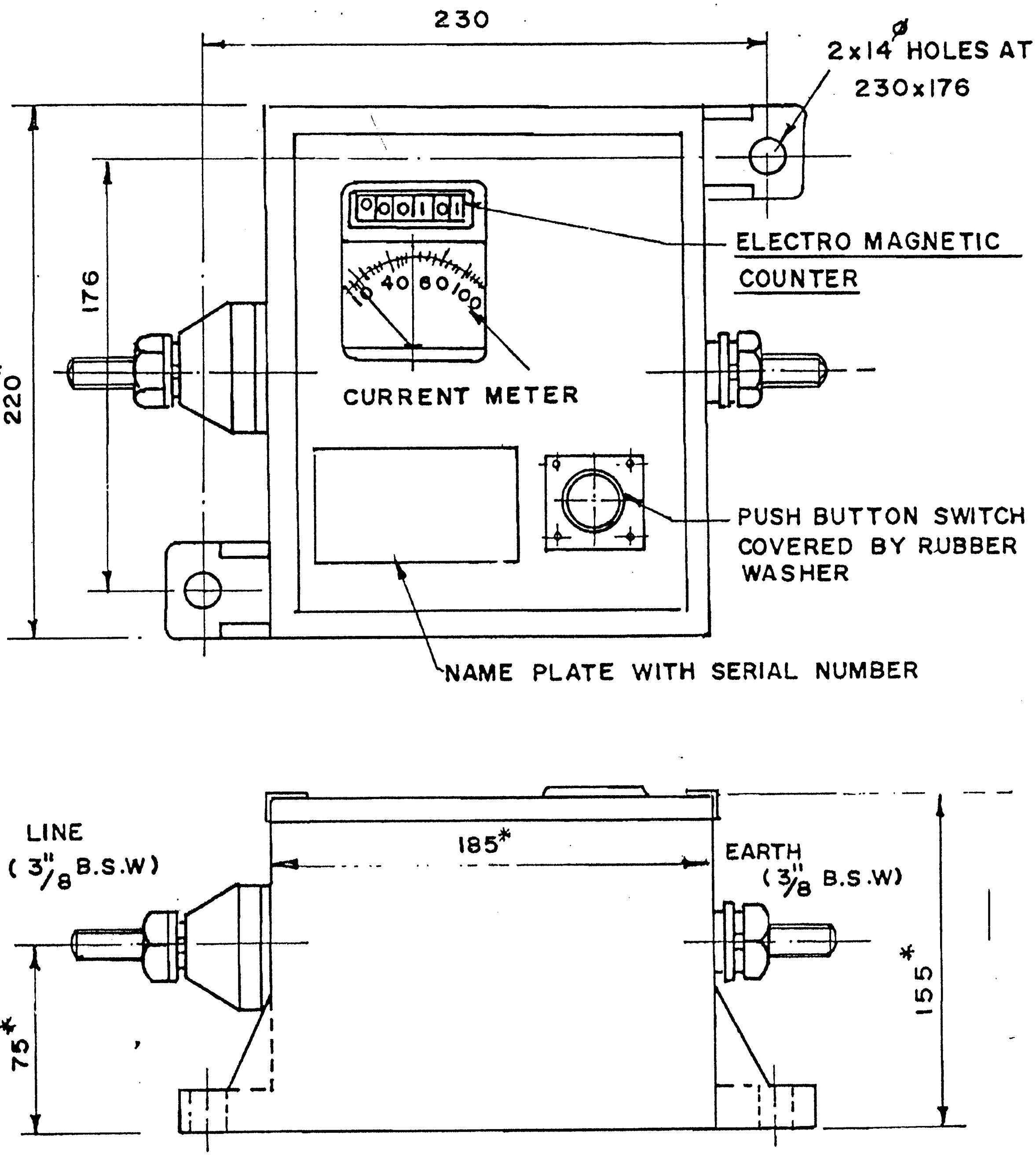
SURGE MONITOR is an exclusive device to determine the service performance of a lightning Arrester. This device monitors the on-line condition of the Lightning Arrester and in addition provides a ready count of the operations performed on it. The Surge Monitor is connected Electrically in series between the Lightning Arrester and the ground. (Fig.5.2.)

The cyclometric counter of the Surge Monitor records the number of the operations performed by the arrester (in other words its service duty) while the current meter shows the feel of the arrester at any time. The connection of the Surge Monitor in series does not add significantly to the protective level of the arrester.

5.10.01 Operation

When a surge - be it due to the natural lightning Phenomenon or the man made switching operations in the electrical system approaches a Lightning arrester, it offers an easy path for the transient through the surge Monitor to the ground. The surge monitor has active elements matched with those of the Arrester. The active elements provide the sensing signal for the cyclometer type counter. The current meter with its push button operator indicates the grading current of the lightning Arrester at any time.

The grading current for all the Arresters at its operating voltage should be within a range of 10% to 50% of the full scale reading. Deviation from this range of the grading current signifies that the arrester is to be cleaned or suspected. If the deviation persists even after washing off the surface of the arresters, the arrester is to be suspected or replaced.



NOTE:–

1. ALL DIMENSIONS ARE IN mm UNLESS OTHER WISE STATED
2. DIMENSIONS MARKED THUS * ARE APPROXIMATE.
3. CURRENT METER
   ———— GREEN BAND 0 To 50%
   – – – – RED BAND 50 To 100%

Fig. 5.1
Surge Counter with current meter

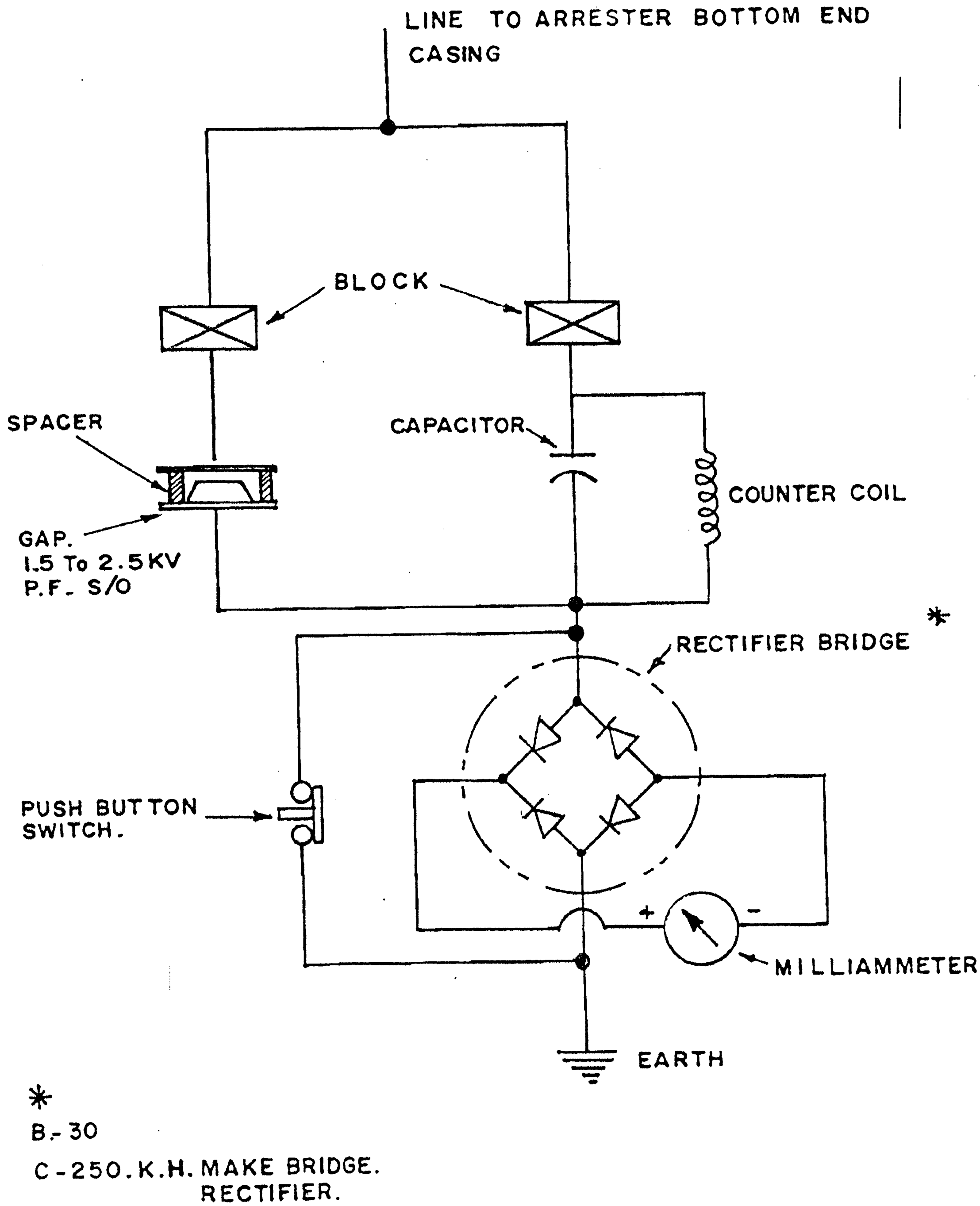


Fig. 5.2
Electrical Schematic Diagram of Surge Monitor

ANNEXURE I

CONVENTIONAL GAPPED ARRESTER

GUIDE VALUES

Case - 1 Healthy set of surge arresters

110 KV Surge arrester-Ratings-96 KV rms - 10 KA

Readings obtained during the test	Difference in the readings based on which the condition of the arrester is assessed.						Remarks
	R	Y	B	R	Y	B	
Top Unit	46	41	42	31	32	30	As the diffference in the test readings were comparable in all the 3 phases, the surge arrester units were declared to be healthy.
Middle Unit	15	9	12	12	6	10	
Bottom Unit	3	3	2	3	3	2	

Case – 2 Defective set of surge arresters

Readings obtained during the test	Difference in the readings based on which the condition of the arrester is assessed.						Remarks
	R	Y	B	R	Y	B	
Top Unit	45	43	40	29	31	4 *	* On comparison of similar units in all the 3 phases, the voltage drop across 'B' phase top unit was found to be much less and hence it was declared as defective.
Middle Unit	16	12	36	13	10	29	
Bottom Unit	3	2	7	3	2	7	

H.V.CAPACITORS, S.V.C. & SYNCHRONOUS CONDENSERS

6
H.V.Capacitors, S.V.C. & Synchronous Condensers

CONTENTS

6. INSTRUCTIONS FOR OPERATION AND MAINTENANCE OF HIGH VOLTAGE CAPACITORS

6.01 I. H.V. Capacitors

6.01.01 (a) General

Capacitors are the most economic, and durable devices to improve regulation and capacity of any electrical power system. But their life can be shorter due to over stressing, over heating, chemical changes, physical damage and repeated temperature changes beyond the design limits. Therefore the life expectancy of the capacitors depends upon the control of operating conditions involving voltage, temperature limits and physical care.

(b) Temperatures

The capacitors are manufactured for different categories of ambient temperature. Except where otherwise stated the maximum ambient air temperature is supposed to be equal to 40°C. It is therefore necessary to ensure, that proper ventilation for capacitor banks and the temperature is within the permissible ambient temperature limits given here under:

Temp. Category	Maximum permissible ambient temperature		
	Mean-over 1 hour	Mean over 24 hours	Mean over 1 year
Temperate	40°C	30°C	20°C
Tropical	45°C	35°C	30°C
Supertropical	50°C	45°C	35°C

6.01.02 Handling

H.T. Shunt power capacitors are designed and manufactured to have sufficient mechanical strength. Still, improper handling during transport and erection may cause damages. It is, therefore, necessary to follow certain precautions while handling the capacitors. Capacitors should not be rolled or dragged or roughly handled. Otherwise, the porcelain insulators and the capacitor cases will get damaged. Cracks in bushings will lead to leakage of impregnant.

6.01.03 Discharge Arrangement

While attending to any maintenance work on capacitors in service, first disconnect the capacitor bank from supply. When a capacitor is disconnected from a supply, it remains charged and may remain dangerous. To avoid this risk, the standard IS 2834 recommends the use of a discharge arrangement, discharging the voltage at the capacitor terminals to 50 Volts in less than 1 minute for apparatus whose voltage is less than or equal to 660 Volts. A capacitor therefore discharges to a safe level five minutes after its disconnection from supply. The capacitors should be discharged by insulated discharge rods and then earthed effectively during work. Before discharging and earthing, the capacitor should not be touched.

6.01.04 Stores

(a) The capacitors should be stored in a clean, dry place and protected from dust and moisture.

(b) They should be stored vertically and held above floor level to avoid rust formation.

(c) They should be stacked freely leaving sufficient space in between the units to avoid dents or scratches during handling.

6.01.05 Installation

i) Clean the capacitors thoroughly.

ii) Tighten up all screws and nuts.

iii) Avoid overtightening of the bushing terminals.

iv) Check for any leakages from bushing, soldered joints or seam welding.

v) Avoid stress on bushing by giving flexible bus connections.

vi) Ensure a minimum clearance of 3m for IIKV capacitors above ground level or enclose the capacitor bank suitably by fencing. Fine wire mesh fencing will help prevention of entry of birds, squirrels, mongoose etc.

vii) Measure the Insulation Resistance value by a 500-V megger between bonded terminals and earth. The value should be not less than 50 mega-ohm as per clause (I2) of IS 2834 of 1981. In case the value measured is less than 50 mega-ohms, such unit should not be put into service.

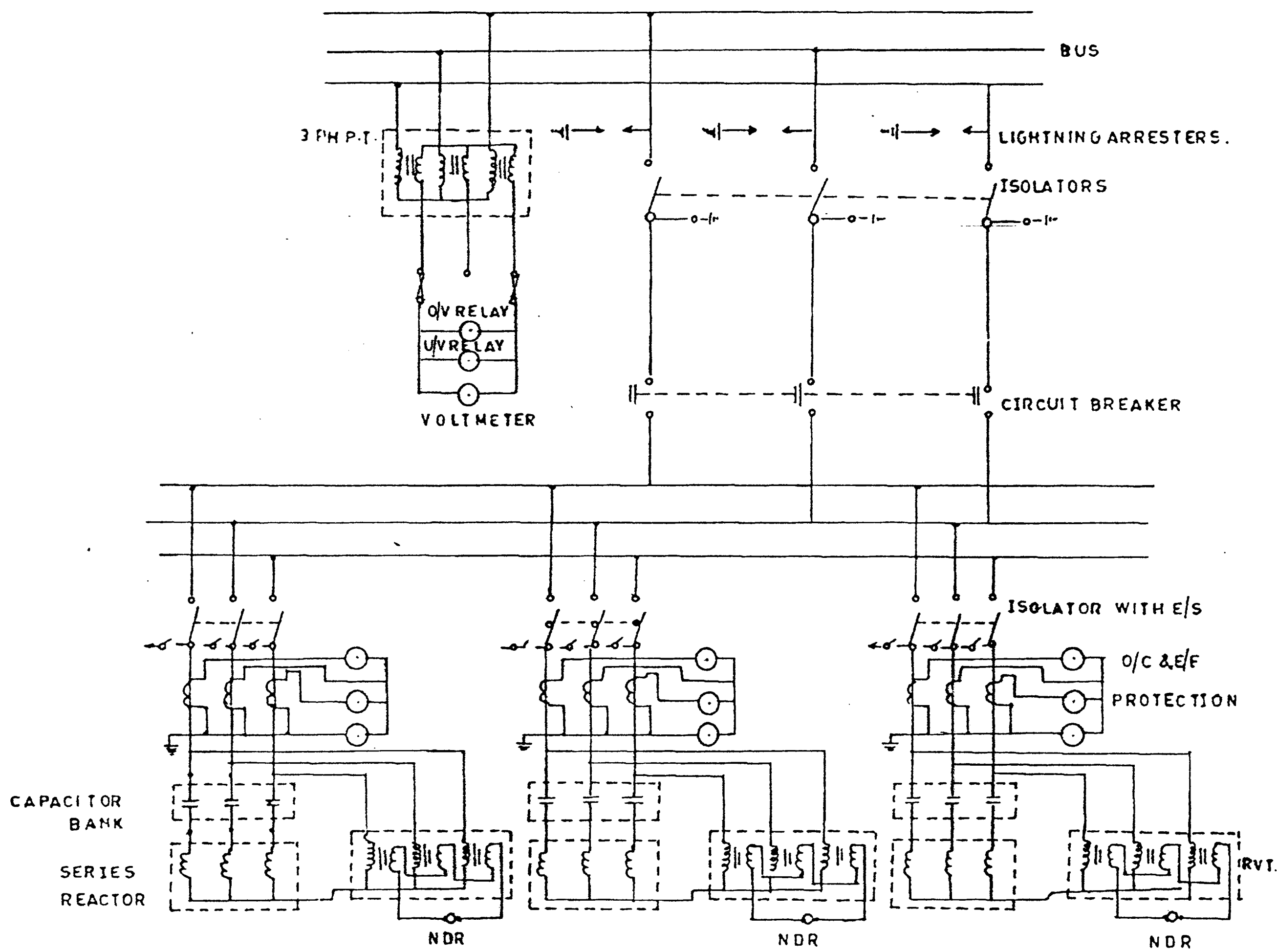


Fig. 6.1
Manually Operated Multistep Banks

viii) The capacitance value of each phase should be balanced.

ix) Ensure free circulation of the air around capacitor units. Capacitors should be clean, free from corrosive fumes, chemicals and dust.

x) Adequate earthing of capacitor units/banks should be ensured.

xi) Ensure that the circuit-breaker is of optimum switching duty.

xii) In ungrounded operation, ferroresonance is likely to occur. Further, the capacitors when switched off will discharge into the Residual Voltage Transformers (RVTS) also. Wherever RVTs are provided with an additional star-connected secondary winding (of phase-to-phase voltage of 110V), stabilising resistors may be provided between the three phases and the star-point, The value of the resistors may be such that the VA-capacity of the resistors is equal to the no-load VA-capacity of the RVT.

xiii) Neutral of star connected capacitor banks with RVT should not be earthed. (Fig. 6.1)

6.01.06 Preventive Maintenance

A periodic check of a few important parts of capacitor units/banks is very necessary, preferably once in a month by switching OFF the capacitor bank and fully discharged. Following check should essentially be done.

Item		Check for
Unit	:	Leakage of impregnant from terminals, lid and welded seam, and bulging and excessive temperature rise.
Busbars Fuses	:	Tight connections and deformation.
Post insulators	:	Cracking and cleanliness
Connecting strips	:	Tight connections and clearance.
Racks	:	Corrosion and dirt.

6.01.07 Operation

i) Before energising the capacitors check the following points:

a) Supply voltage, frequency and temperature of the area with the rating plate.

b) Ensure, no hardware or tools are left inside the rack assembly. This may cause short circuit and breakdown.

c) Ensure proper ventilation.

d) Ensure electrical and mechanical connections are done correctly and tightly.

e) Ensure correct size of fuse is used.

ii) After energising, Check, the following limits are not exceeded.

a) Voltage	:	Within 110% of the rated voltage especially during light load periods, if the capacitors are left in the circuit.
b) KVAR	:	The operation KVAR are within 130% of the rated KVAR at the highest system voltage.
c) Temperature rise	:	Container temperature should not exceed 75°C and 70°C. for paper type and magvar capacitors respectively. This should be measured by having a thermometer fixed with the wall of the container, keeping the bulbs at one quarter of height of capacitor box down from the top edge.
d) Noise	:	Observe for unusual noise.
e) Light load	:	Capacitors cause voltage rise in the system and at light load voltage across capacitor terminal can be beyond its permissible value. This could produce harmful effects on capacitors or on other electrical equipments. Therefore it is desirable to switch OFF capacitors at light loads. If this is not possible then it must be ensured that the voltage does not go beyond the rated voltage by more than 10% for which it is rated.

6.01.08 Repairs

Due to mishandling or mal operation, capacitors may develop some defects. The following repairs are suggested:

Symptoms	Cause	Remedy
1. Leakage of impregnant	Leak in welds Leak from terminal cap	After thorough cleaning and abrading by emery cloth apply Araldite or preferably solder the spot carefully.
2. Over heating of Units	a) Poor ventilation b) Excessive ambient temperature. c) Over voltage	Arrange for free circulation of air. Arrange for forced ventilation. Reduce voltage or switch off capacitors.
3. Current below normal value	a) Low voltage b) Unit fuse blown c) Loose connection	No repair Refer to manufacturers Tighten carefully.
4. Abnormal bulging	a) Impregnant almost leaked out	Disconnect the unit and refer to manufacturers.
	b) Gas formation due to internal arcing	Ensure phase currents are balanced with equal number of units and capacitance. Operation with unbalanced phases may cause further damages.
5. Cracking noise	Partial internal faults	Disconnect the units and refer to manufacturers.
6. Fuse blowing	a) Short circuit unit	Measure insulation resistance between terminal and case. Refer to manufacturers.
	b) Over current due to over voltage and harmonics	Reduce voltage and reduce/eliminate harmonics, wherever possible.
	c) Short external to the unit	Check and remove the short and ensure the unit is O.K. before recommissioning.

NOTE: Leakage of impregnant from lid assembly is not a serious problem but it should be immediately stopped. If application of above remedy does not help please refer the matter to manufacturers.

In all the above cases please ensure phases are balanced with equal number of units and phase capacitance. Operation with unbalanced phases may cause further damage.

6.01.09 Replacement of Faulty Unit

In case any unit in the bank is suspected to be defective then the Bank should be immediately de-energised and after discharging the visual inspection of the Bank should be done to find faulty unit. The easiest way to locate the defective unit is to check the fuses and if any of the fuse is found blown then that particular unit should be disconnected and checked for defects as detailed above.

For recommissioning of the bank the unit should be replaced by a healthy spare unit having capacitance value near as that of faulty unit. In case spare units are not available then for the banks operated with series reactors attempts should not be made to operate the Bank with less number of units than originally supplied for the reason that the capacitor with the series reactor may get tuned to fifth harmonics. However, for banks without series reactors the phase should be balanced by making equal number of units in each phase/group, and then the bank can be put into service. This is essential to avoid over voltage to the units in a phase/group where the number of units are lesser than the others.

6.01.10 Precautions in Handling Capacitors Filled with PCBs

Polychlorinated Biphenyl (PCB) is considered as environmental contaminant and injurious to certain aquatic, bird and animal life. Hence, the following precautions should be taken while using capacitors containing PCB.

(a) Avoid inhaling of vapours or process fumes of PCB.

(b) Avoid contact of PCB with eyes or prolonged contact with skin.

(c) Avoid contact of PCB with food, animal foodstuff or pharmaceuticals.

(d) Do not re-use contaminated clothing.

(e) Wash skin with soap and water and eyes by flushing with water.

(f) Extreme care should be taken to prevent any spills, leakages, vapourization or disposal.

  ii) Stop leakage of the capacitor (Even if it is a failed unit) with the help of araldite, solder or any mechanical means.

  iii) If leakage or spill occurs, PCB must be collected and disposed off.

(g) Do not sell old units to scrap dealers.

6.01.11 Disposal of Capacitors Containing PCBs

All waste PCB, failed capacitors, rags contaminated with PCB, etc. should be disposed off in an appropriate incineration plant (temperature 1000°C) or some land-fill sites away from the populated area. While selecting land-fill sites, care should be taken to see that the PCB is not carried into nature's water system by rainfall, drainage etc.

6.01.12. Periodicity of Maintenance of Capacitor Banks

For controlling the circuit-breakers, the bus and the relays, the schedules of preventive maintenance for circuit-breakers and protective relays already laid down in the Code of Technical Instructions 1981 are to be followed. For the series reactor, the schedule relating to transformers may be followed.

The following maintenance works are to be carried out on the capacitors as per the periodicity noted against each.

(a) *Capacitor units:*

i)	Check for cracks in the case of bulging	Weekly
ii)	Check for leakage of impregnant	Monthly
iii)	Examination of cracks or damage and removal of all dirty deposits from terminal bushings.	Monthly
iv)	Checking of IR Value	Half Yearly

(b) *Residual Voltage Transformers:*

a)	Check for healthiness of RVT fuses	Monthly
b)	Measuring the voltage across the open-delta of the RVT and comparing with the value obtained during commissioning.	Monthly

6.02 Static Var Compensators (SVC) (Fig 6.2)

Static Var Compensators are installed at 230/110KV Sub-stations at Singarapat, Trichy and Madurai. The equipments are supplied by M/s. BHEL partly with imported components at an approximate total cost of Rs.6.5 Crores. The conventional shunt/series capacitor banks improve the system voltage by compensating the inductive load and by improving the power factor. These are fixed capacitive units in banks of 500 KVAR & 1000 KVAR.

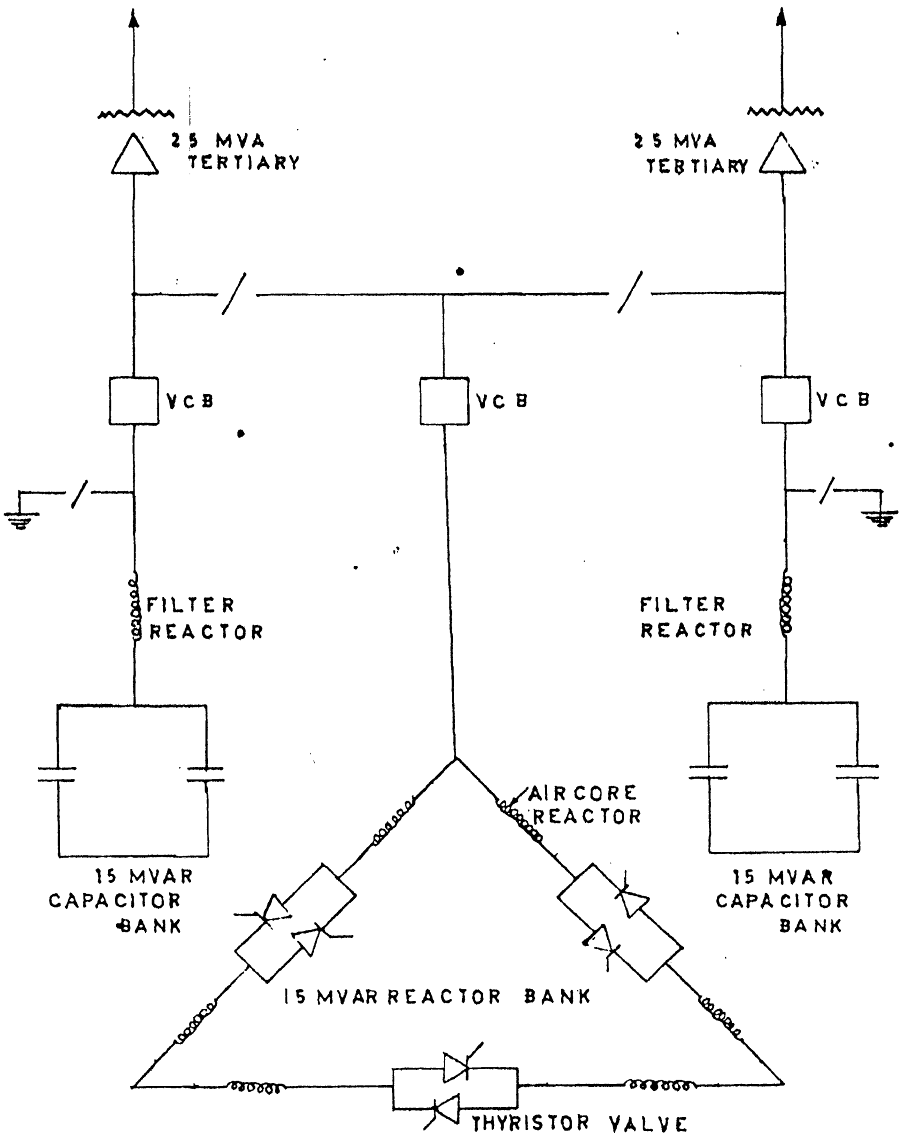


Fig. 6.2
General Layout of S.V.C.

The Static Var Compensators, besides improving the power factor and voltage are capable of stabilising the system during transient and dynamic conditions arising due to sudden load switching in or load rejections.

They suppress the system voltage fluctuations through micro processor controls and thyrister controlled reactors. They are capable of providing capacitive compensation during full loads to improve voltage and power factor, and inductive compensation during light loads to keep the voltage profile within limits.

This system consists of breaker switched capacitors and a thyristor controlled reactor connected to the tertiary of 230/110/11KV Auto-transformer.

The reactive power demands of – 15 MVAR to + 30 MVAR can be met by the SVC.

6.02.01 SVC features

Fast speed of response, low losses, low installation and maintenance costs, high reliability, favourable cost benefit factor, valuable tool for optimal VAR management and voltage control.

6.02.02 Equipments comprising Static Var Compensators

The SVC consists of Vacuum circuit breakers (VCB) capacitors, reactors, thyristor valve control system, voltage regulator and the cooling water system consisting of de-ionised water (DM water), heat exchanger, pumps and fans. The operation and maintenance of VCBs and capacitors are not different from those already in service; the reactors require little maintenance, except as stated elsewhere; the control system is of solid state and does not require any routine maintenance except periodical monitoring of parameters. The cooling water system requires some maintenance. These are described in the following paragraphs.

i) Capacitors
ii) Reactors
iii) Power Converter
iv) Valve Control System
v) Voltage regulator
vi) Recording unit
vii) Pumps
viii) Dimineraliser
ix) Heat exchanger
x) Lubrication
xi) Motors.

II. AIR CORE REACTORS

a) General

These instructions refer to air core reactors of single phase and three-phase designs, whereby the coils of each phase can be stacked on each other or mounted separately. The reactors can be designed for different duties, for example

- — current limiting purposes
- — in high power test laboratories
- — as part of a filter etc.

b) Installation and Connection

On arrival at site the reactors are to be cleaned, if necessary, and to be checked for eventual transport damage. Complaints are to be directed immediately to company representatives or to the corresponding sales department in CH-5401 Baden/Switzerland. The reactors can be supplied for indoor or outdoor erection.

The reactors should only be mounted with their axis in upright (vertical) position. In all directions there should be enough distance between coils and steel parts of bigger dimensions like steel reinforcings in concrete and steel constructions.

A distance of half the diameter of the coil is recommended.

The reactors are supplied with connection palms of aluminium alloy. The connection leads should therefore be aluminium too. For copper leads there will be required an inter-mediate material like Cupal-blades.

Further details can be obtained from the dimensioned drawing and special set-up drawing if such one has been specially made.

c) Maintenance

The indoor equipment require, besides occasional cleaning of the insulating surfaces (depending on the grade of pollution), no maintenance.

For outdoor equipment the supporting insulators should be cleaned regularly, depending on the normal intervals usual for the other outdoor equipment in the same installation. After an eventual cleaning, the connections and fixing bolts are to be checked for tightness and, if necessary, be retightened.

III. POWER CONVERTER

General Description

a) Purpose

Static compensators are necessary for full-electronic control and switching of elements of reactive power in plants for compensation of reactive power.

In the instruction for installation and operation the 3 phase static compensator and its maintenance and operation is described.

b) Constructional layout

Depending on the number of series connected thyristors one phase of a VERISTACK-Converter consists of one to three 'Thyristor modules'.

Three phases are mounted on a common frame to build the 3 phase converter VERISTACK.

Thyristor stack	:	The thyristor stack consists of thyristors each clamped between two cooling boxes for dissipating power losses. A package of Belleville washers determines the clamping force in the stack. 2 anti-parallel connected thyristor stacks are mounted in each phase.
RC-snubber circuits	:	An RC-snubber circuit is connected in parallel with each two anti-parallel connected thyristors. The RC-snubber circuit consists of a capacitor and a water-cooled resistor. The RC-snubber circuits are mounted one above the other on plates of insulating material.
Water tubing	:	The water tubing consists of two ascending tubes for inlet and outlet of cooling water and also of connections to the elements needing cooling. The ascending tubes are of polypropylene. Connections between ascending tubes and thyristors resp. resistors are by polyamide tubes.
Electronics for thyristors	:	Also mounted on plates of insulating material as the RC-snubber circuits, but on the opposite side of the thyristor stack, are the printed board assemblies of the electronics for the thyristors. These printed board assemblies serve for transformation of light pulses coming from the low voltage electronic equipment into electrical pulses for triggering thyristors. The light pulses are transferred by optical fiber cables run in a special optical fiber cable channel to the printed board assemblies.

c) Transport and storage

The VERISTACK is transported in a special transport crate.

After the VERISTACK has been unpacked the following checks are to be made:

- Has all packing material been removed?
- Is all material contained in the packing list available?
- Checking of polyamide tubes for damage.
- General check for damages.
- Clean if dirty. For cleaning plastic parts (especially the piping) no solvents must be used.
- Checking of cast resin post insulators for fracture or fissures, scratches, damage etc.

Deficiencies or damages which are established to be notified to the manufacturers and to the forwarder immediately.

Before installation the VERISTACK should be stored in a clean, dry room. To avoid damages it is advantageous to store the VERISTACK in its original transport crate.

d) Installation

The VERISTACK is to be installed in accordance with the plant layout.

The dimensions are to be taken from the dimension drawing.

According to the plant layout the following connections are to be made

- Main current connections
- Control leads
- Ground
- Water

The electrical diagram is to be observed.

e) Tests and Commissioning

For putting into service following work has to be executed on the VERISTACK:

— Check

  * all screw connections for tightness,
  * whether all electrical connections have been made and all light guides are properly connected,
  * Whether all water connections have been made.

— Fill clean-water circuits. The requirements for water quality given in the data sheet must be met. Start pump and allow it to run.

— Before connecting electrical energy the cooling circuit must be vented completely. For that, water must circulate for ≤ 8 hours in the circuit. During these 8 hours the water condition must be checked for air bubbles. This is accomplished by loosening the venting screw on top of the risers return circuits and have water drained off until air bubbles do not show any longer.

— After deaeration of the system the expansion cylinder must be filled to 50% (at room temperature) of its total content.

— Check tightness of clean-water circuit (visual inspection for leaking water).

— It is advantageous for the cooling circuit pump to run continuously, even if the power regulator is not working, otherwise it must be turned on at least 2 hours before voltage is applied. Continuous pump operation is also recommended to ensure that the required conductivity is maintained. (The water conditioning equipment only functions when the pump is running).

f) Causes of and remedial measures against faults

> **IMPORTANT**
>
> Before starting any work on the stack-modules, the plant must be disconnected from any voltage and be connected to earth.

Indication	Possible cause	Checks	Trouble shooting
TM shows a thyristor failure	Thyristor is defective, primary cause possibly at the RC-snubber circuit.	In case of a thyristor failure it is not evident, which of the two antiparallel connected thyristors is defective, because the defective thyristor makes a short-circuit across both thyristors. The defective thyristor may be found out by loosening the flexible cross connection and measuring the blocking voltage using an electronically controlled high voltage source (1000 V). Check of resistance.	Replace defective thyristor.
		Check of capacitance and insulation (by means of a high voltage source 1000V) of capacitor.	Replace defective element (R.C)
Thyristor* can not be fired or is fired by EOD.	Optical fibre cable failure.	Check that the optical fibre cable allows the light to pass, check snubber circuit for continuity.	Plug in spare optical fibre cable on both ends (to be found in the optical fibre cable channel).
Thyristor* cannot be fired or is fired by EOD.	Failure at the printed board assembly for trigger circuit power supply.	Measurement of pulse at the thyristor gate.	Replace printed board assembly.

Indication	Possible cause	Checks	Trouble shooting
TM. Thyristor monitoring electronics			
Response of water level monitor.	Leakage	Visual check for water leaks	Make watertight (replace the seal, tighten joints, replace defective part etc.)
Response of flow monitoring instrument.	Leakage	See above	See above
Response of flow monitoring instrument.	Obstruction	Rinsing through of cooling circuits with warm water, measuring the temperature at the components traversed by water. Low temperature indicates obstruction.	Rinse through, blow out or replace the obstructed part.

- See also description of valve base electronics and thyristor electronics.

g) Changing of parts

Dismounting and mounting of a thyristor

a) Unscrew the screw top of the stack in which thyristor to be replaced is mounted until spring package is totally loosened.

b) Pull off gate and auxiliary cathode connections at the appropriate thyristor. Dismount thyristor by lifting stack above thyristor to be replaced.

c) Mount new thyristor without delay in correct polarity. New thyristor to be treated as per manufacturing instruction prior to mounting.

d) Adjust new thyristor such that the position of its gate and auxiliary connections corresponds with the adjacent thyristors. The centering bolt has to be in the holes of thyristor and heat sink.

e) Align thyristor stack.

f) Screw the screw up and down until bolt it.

g) Plug in gate and auxiliary cathode connections at new thyristor.

h) Check that all tools and accessories have been removed from the stack-module.

> **Important**
>
> To assist in determining the cause of failure a record of all operating conditions at the time of fault, and any other relevant observations should be sent to makers together with the defective thyristor.

Changing polyamide tubes

For changing a polyamide tube the manufacturing instructions are to be observed.

i) *Dismounting and mounting of other components*
Dismounting of components such as resistors or capacitors or assemblies (printed board assemblies) requires no special tools and can be executed by skilled mounting staff. It is important, that when remounting *all* electrical connections are connected at the *same place as before*. Defective parts must be replaced only by parts with exactly the same electrical characteristics.

j) *Care and service*

When general overhauls of the plant are carried out the following work is to be performed on the VERISTACK:

— Check tightness (visual inspection for leaking water).

— Check that all screws are tight (plastic unions are only to be tightened in case of leakage)

— Clean if dirty. For cleaning plastic piping no solvents of any kind must be used.

— Check conductivity of cooling water. For measures to be taken in case of excessive conductivity see cooling system description.

— Check that all screws are tight.

— At the earliest after 5 years check of condition of all protection electrodes. Each electrode has to be replaced if the water conducting part is reduced to 20% of its original volume.

k) *Stocking of spare parts*
Spare parts according to a separate order accompany the delivery. It is recommended that depleted spare part stocks be replenished quickly.

l) Operation

m) General

n) Proper operation of the BBC power converter VERISTACK is ensured by adhering to the data specified by the maker on nameplate and in data sheet.

Prerequisites for operation
Prerequisite for trouble-free operation is correct functioning of the electronic controls and cooling, as well as of the water treatment.

o) *Measures to be taken in case of faults, fault records*
For the On and OFF switching manoeuvres, as well as for the various signals and the consequences thereof, we should refer to the general operating instructions of the plant. To assist in determining the cause of failure a record of all the operating conditions at the time of fault, and any other relevant observations should be sent to manufacturer together with the defective thyristor.

IV VALVE CONTROL SYSTEM

a. Introduction

The valve control system can be split up in the following three main components

(a) Valve base electronic

(b) Light signal transmission

(c) Thyristor-related electronic

The valve control system is the link between the control equipment, in particular the grid control set, and the thyristor at voltage potential. It fulfills the following tasks:

— simultaneous firing of all series-connected thyristors following emittance of a firing command from the regulating system.

— Bridging the voltage potential between each thyristor place and earth. The so-called thyristor place comprises two direct antiparallel-connected thyristors.

— It also carries out monitoring and protective functions with the aim of ensuring optimum performance of the entire compensator.

— Supervision of the blocking capacity of all thyristor places, supervision of light emitters and report signalling of emergency-fired thyristors. This enables continuous information to be obtained on the operating state of the thyristor valves and the redundant light system to control the thyristors.

— Monitoring the continuous information obtained on the operating state of the thyristor valves and protecting them by a shutdown when their blocking capability can no longer be assured.

— The valve control system therefore transmits commands from the regulating system or system control to the individual thyristors and, in reverse direction, report signals from the thyristor and its vicinity to the control. Both routes pass through the three main components: valve base electronic, light-signal transmission (light guides) and thyristor related electronic. The command-signal route from the regulating system or system control to a thyristor is termed a "firing channel', and the report-signal route in reverse direction a "report signal channel". Both channels are, of course, interconnected at certain points. The valve control process is shown in Fig.6.3

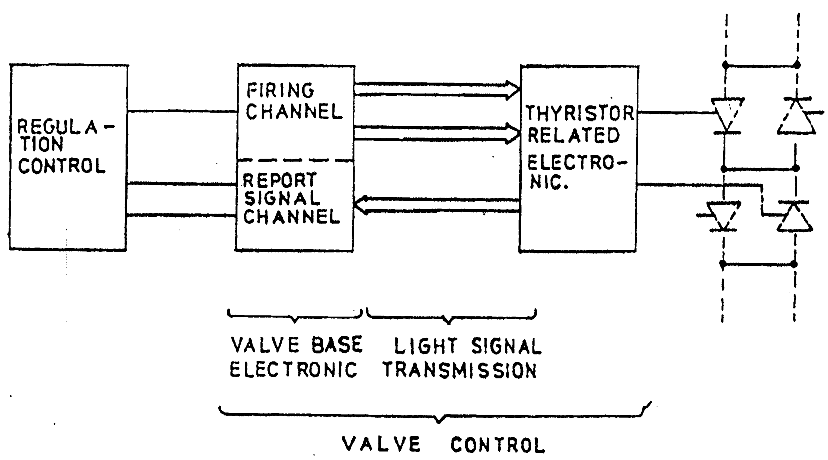


Fig. 6.3
Basic diagram of Valve Control System

b. Valve base electronic

The valve base electronic is the earth end section of the valve control.

Its main tasks consists in converting the electric firing pulses from the regulating system in a so-called light pulse telegram, which turns on the thyristor via light-signal transmission and the thyristor-related electronic, and in evaluating the report signals from every thyristor place. With the leading edge of the firing pulse a double pulse is transmitted to the thyristor-related electronic to enable the thyristors for firing. Simultaneously the thyristor fault monitoring is set to control eventual emergency-firing from the thyristors. With the trailing-edge of the firing pulse, first a single pulse, which terminates the firing readiness is transmitted and the thyristor fault monitoring is set to check the blocking capability of the thyristors. After a time delay, a second single pulse is transmitted with one of the two redundant light emitters disabled. The thyristor fault monitoring is then set to carry out an emitter test. Eventual faults are annunciated via LED's and relays.

c. Light signal transmission system

The light signal transmission transmits the light pulse telegram from the valve base electronic to the thyristor-related electronic and the report signals in reverse direction.

As each thyristor place has a different voltage potential than its adjacent one, or that to earth, the light-signal transmitter must also carry out the separation of potential. The light signal transmitter consists of bundles of light guides in which several single light guides are bundled together.

To give redundancy to the firing channel between the valve base electronic and the thyristor-related electronic, the light guide bundle is split up into two channels on the emitter side. Both channels are connected to each single light guide on the receiver side, i.e. the system works properly with only one emitter channel in function.

d. Thyristor-related electronic

The thyristor-related electronic converts the light pulse telegram into electrical signals which-connected to the thyristor voltage via a logic circuit – initiate a firing pulse to the thyristor. A certain amount of auxiliary energy is required for the emission of a firing pulse and this is obtained from the thyristor circuitry.

If the thyristor place is in good order the thyristor-related electronic is provided with power. Then every received single pulse is echoed back in form of a light pulse to the thyristor fault monitoring. This carries out the status and emitter test.

The thyristor-related electronic also contains a very important item, the emergency firing unit incorporating a break over diode (BOD). This turns the thyristor on when the blocking voltage rises to an inadmissible value (so-called protective turn-on), due for instance, to overvoltage in the power supply. In blocking direction the thyristors are protected by the anti-parallel connected ones.

When a thyristor is turned on by the emergency firing unit, a light pulse is transmitted simultaneously to the valve base electronic to signalize BOD-firing.

e. Maintenance

1. *Normal maintenance*

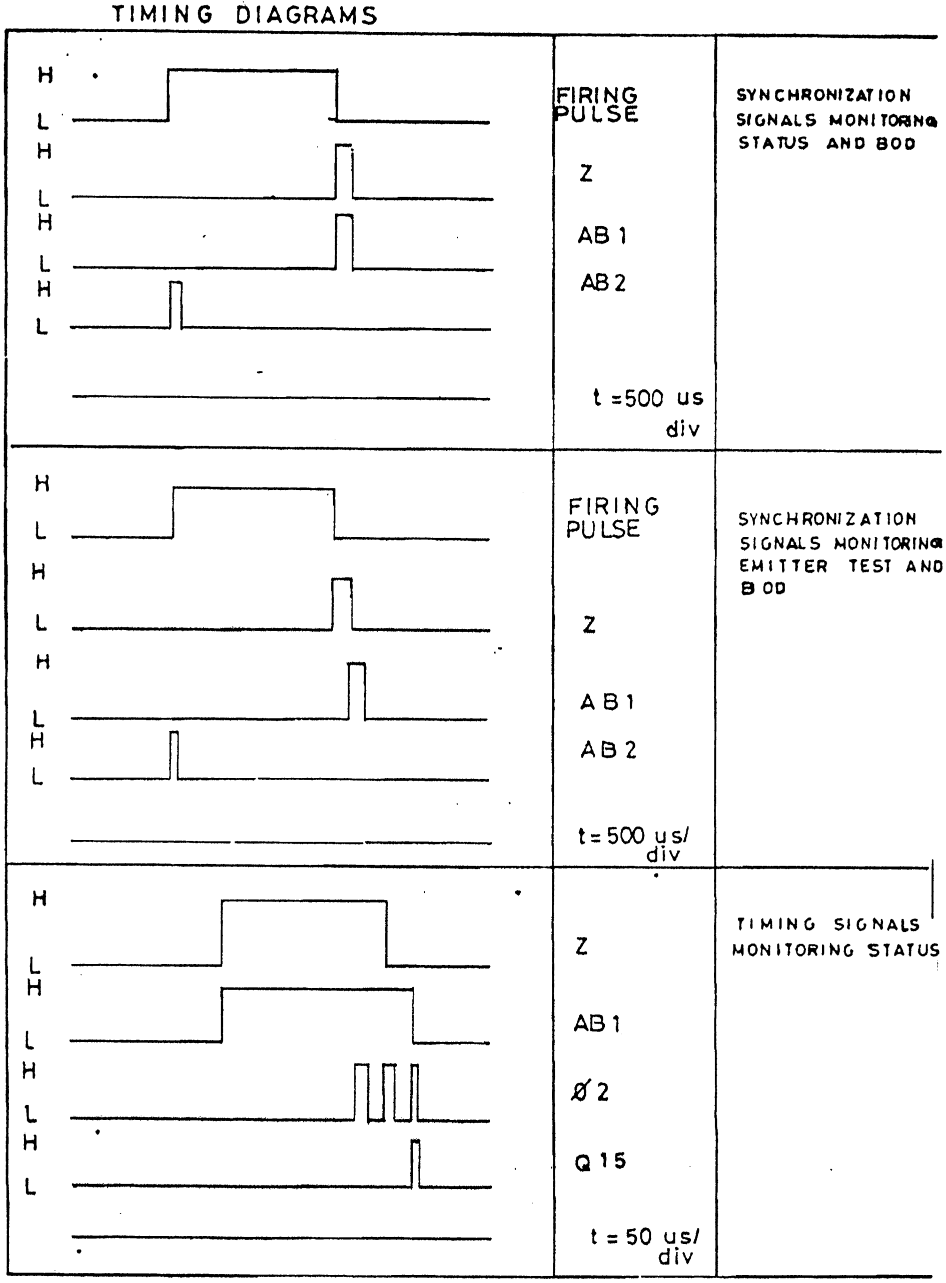
   Under normal circumstances no maintenance is needed. However it is advisable to check regularly the most important signals with a cathode ray oscilloscope. During the first six months of operation monthly, there after once a year. These signals can be picked up at the test sockets on the PCB's for type of signals and their location see Table I . For proper functioning the traces 1 through 7 (shown on the following pages) must be displayed on the oscilloscope. It should be triggered by one of the firing pulses A+ + C–. If adequate care is taken this maintenance work can be performed during operation.

TABLE I

TEST SOCKETS

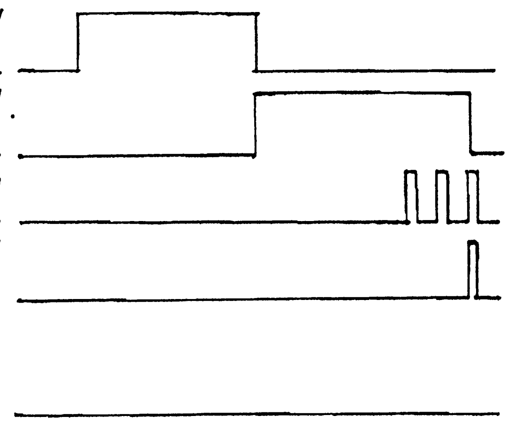
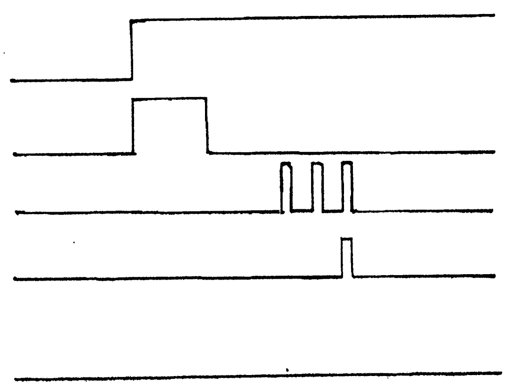
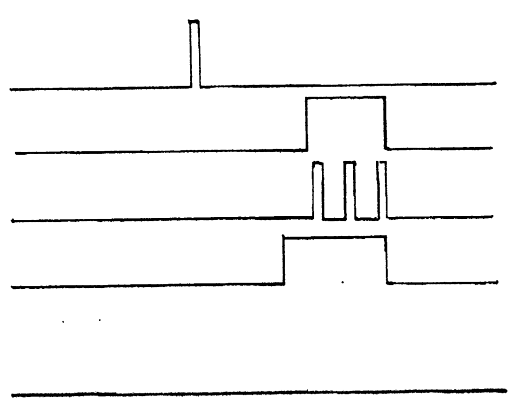
Signal name	Test socket no.	PCB place	PCB type
Z	X 4	HA 01	XV 8663a
AB1	X 2	HA 02	XV 8817a
AB2	X 1	HA 03	ST 8956a
02	X 2	HA 05	XV 8482a
Q 15	X 9	HA 05	XV 8482a
R 1	X 6	HA 05	XV 8482a
R 3 (inv.)	X 8	HA 05	XV 8482a
Enable phase A	X 6	HB 17	XB A 492 A
Enable print 1	X 1	HB 17	XB A 492 A
Enable print 2	X 2	HB 17	XB A 492 A
Enable print 3	X 3	HB 17	XB A 492 A
RL	X 9	HB 17	XB A 492 A
Firing pulse A+ F1	X 7	HB 18	XB A 492 A
" " C-F2	X 8	HB 18	XB A 492 A
" " B+F3	X 9	HB 18	XB A 492 A
" " A-F4	X 10	HB 18	XB A 492 A
" " C+F5	X 11	HB 18	XB A 492 A
" " B-F6	X 12	HB 18	XB A 492 A

TIMING DIAGRAMS



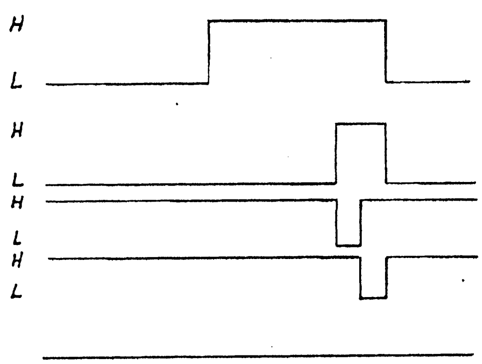
TRACES SHOWN ABOVE HAVE LEVELS "H" TYPICALLY +24 V AND LEVELS "L" TYPICALLY + 1 V. FOR MIN. AND MAX. VALUES CONSULT THE DATA SHEETS

TIMING DIAGRAMS.

	Z AB 1 Ø 2 Q 15 t = 50 µs/DIV.	TIMING SIGNALS MONITORING EMITTER TEST.
	FIRING PULSE AB2 Ø 2 Q 15 t = 50µs/DIV.	TIMING SIGNALS MONITORING BOD
	R 1 R 3 Ø 2 Q 15 t = 50 µs/DIV.	CONTROL SIGNALS ON CALCULATOR.

TRACES SHOWN ABOVE HAVE LEVELS "H" TYPICALLY +24V AND LEVELS "L" TYPICALLY +1V. FOR MIN. AND MAX. VALUES CONSULT THE DATA SHEETS.

TIMING DIAGRAMS.



ENABLE PHASE R	CONTROL SIGNALS FOR LIGHT RECEIVERS.
ENABLE PRINT 1	
ENABLE PRINT 2	
ENABLE PRINT 3	
t = 50µs/ DIV.	

TRACES SHOWN ABOVE HAVE LEVELS "H" TYPICALLY +24V AND LEVELS "L" TYPICALLY +1V. FOR MIN. AND MAX. VALUES CONSULT THE DATA SHEETS.

2. *Necessary testing equipment and accessories:*
   1. Cathode rays oscilloscope, 2 channels band width d.c. to 10 MHz min.
   2. *Test cable with 2 mm test plug.*
      The casing of the oscilloscope must be connected to cubicle ground.

> **Caution**
>
> Ensure total segregation from a.c. network.

3. *Initial commissioning procedure*

   Initial commissioning must only be carried out by a qualified specialist from the manufacturing company.

4. *Procedures before initial operation and after standstill periods.*

   As the valve control is automatically connected and disconnected no action is necessary either before or after an operating phase.

5. *Prohibited working methods*

   Tampering by unauthorized personnel during operation must be prevented at all costs. PCB's must not be removed during operation. It is, however, possible to perform measurements on the PCB's by using the test sockets provided. Care must be taken to ensure that no short-circuits are caused by a defect in the measuring equipment as this may cause important signals to be suppressed, thus endangering the compensator.

6. *Reference to the Technical qualifications of the maintenance personnel:*

   Tests and repairs should be performed by highly qualified personnel having thorough knowledge of general electronics and digital technology and are well acquainted in the inherent dangers of high voltage.

V. VOLTAGE REGULATOR

a) Short description

In this function group the supply voltage if 110 VDC from the battery is converted into + 24 VDC.
The voltage + 24 VDC is galvanically separated from the battery voltage.
For the electronic and the B448-bus a DC/DC converter converts the 24 VDC into ±15 VDC, 5VDC, 24 VDC-nv.

b. Detailed description

The DC voltage of 110 V from the battery is fed via manual circuit breaker – P01 to three DC/DC converters.

The three DC/DC converters generates the 24V supply voltages for:

(1) The sequence control cubicle (+W)

(2) Automatic voltage regulator (PHSC system)

(3) Firing pulse electronic

All input and output voltages from the converters are monitored.

If one DC/DC converter fails, a fault signal (SMEPSI, SMAPSI, SMEPS2, SMAPS2, SMEPS3, SMAPS3) is generated and an alarm or a trip will be activated.

(The NU-8979 converts the 24 V into all necessary voltages for the B448 bus and the gate control. The voltages ±15V and 5V are galvanically separated from the power supply voltage 24 V DC. In case of a fault the KX-8973 is switched off by the NU-8976)

c. Short description

This function group contains a fan which is required for cooling the control electronics.

d. Detailed description

The fan unit contains three blowers and one fault monitoring unit.
The current to each blower is monitored. If one blower fails it will be indicated with a corresponding LED on the front of the device and the output signal SMEFAN changes from a "1" – signal to a "O" – signal.

The fault signal SMEFAN will generate an alarm.

The monitoring circuit supervises the built-in fuse.

VI. RECOOLING UNIT FOR THYRISTOR VALVES

a General Description

The recooling unit serves for dissipating the heat-loss power generated in the thyristor-valves by means of deionized water.

Heat-dissipation is accomplished outdoors by means of a water/air-heat exchanger with forced ventilation.

The recooling equipment comprises two assemblies:
Pump aggregate resp. heat exchanger.

2. System-Description

The pump in operation M115/M116 receives the water from the expansion tank, which is under atmospheric pressure at the highest point of the closed circuit. A portion of the water flows back directly from the thyristor-valves through bypass E101.

Under pressure, the water is flowing through the heat exchanger.
From the heat exchanger the water is forced through the 3 thyristor-valves, thus cooling thyristors and resistors. After the thyristor-valve the water flows back into the expansion tank resp. via by-pass valve back to the pump.

The 2 pumps are in operation alternately, one being always standby. A defect on the pump in operation will be sensed by the diff. press. guage F242. Switch-over to standby-pump is accomplished immediately.
Periodic switch-over to ensure that each pump will be in operation regularly is made automatically.

3. Functional Principle of Monitoring Facilities in deionized water circuit

These essentially comprise

E106 Deionizer serves for continuous purification of water. The water-flow-through is set on valve E108 and monitored by flow-monitor F246.

F242 Press-gauge with indication monitors pump-pressure. In case of loss of pressure it will switch over to spare-pump..

F244 Flow-monitor supervises water-circulation in main-circuit and will switch OFF in case of flow failure.

F246 Flow-monitor supervises water-circulation in deionizer. Will activate an alarm in case of flow failure.

F247 Flow-monitor supervises water-circulation in expansion tank. Will activate an alarm in case of flow failure.

F252 Two stage duplex thermostat monitors water temperature after thyristor-valves.

Stage "A" initiates Alarm and stage "B" Tripping in case of over-temperature.

F255 Level-monitor in expansion tank signals lower water level (alarm)

F256/257 2 level-monitors deliver tripping-command for two low water-level (1 monitor is redundant).

B264 Conductivity-meter monitors water-quality in closed-circuit. By means of built-in temperature-compensation measured value indication will always be referred to reference temperature of 20°C. In case limit values are exceeded it will initiate alarm resp. tripping.

b. Installation and Maintenance

1. *Installation*

— The recooling unit comprises 2 assemblies, namely the pumps and the essential portion of monitoring facilities in free-standing frame. The expansion tank is mounted above these against the wall.

— the heat exchanger likewise free-standing, installed outdoors.

The interconnection piping between the assemblies and the thyristor-valves will be supplied along from manufacturers works ready for mounting.

2. *Work at Termination of Installation Filling of Deionized Water Circuit*

Following installation the cooling circuit is to be rinsed, before filling with pure water. For this the deionizers are to be shut off by closing the valves.

Fill-up water to be demineralized and filling-up to be accomplished via expansion tank or valve E102.

All valves in the closed circuit must be open. Utmost care regarding cleanliness in deionized water-circuit must be guaranteed.

Venting of water-circuit is automatic. For this purpose the water should pass through the expansion tank for at least 3 hours (i.e. the bypass-valve E101 is semi-closed).

Subsequently E101 is set for operation such that only a small water quantity will flow through the expansion tank. Thus venting of the closed circuit during operation is ensured.

3. *Measures and Checks for Commissioning*

— The "ISO" – Standard-Pump" has ball-bearings for oil-lubrication. Oil-level to be checked on inspection glass.

— Shaft-sealing is accomplished by sliding-ring gaskets which *must not* run dry.

— Important: Always fill in water first.

- Observe correct sense of rotation.
- Before switch-IN the setting-values to be checked
- Check tightness of entire cooling system.
- Check water-level in expansion-tank.
- Have water circulated until required conductivity – to be read on B264 – is obtained.

4. *Care and Service*

Cleaning of heat exchanger
Heat exchanger is to be cleaned on the air-side as required. As a rule brushing of air-intake-side will suffice. In case of heavy pollution a steam-jet cleaning may be required. Likewise clean and check fan.

Replacement of resin in deionizer.
Duty-cycle of a resin-filling will be approx. 2 years.

If resin-effect is exhausted, the water-conductivity will rise gradually. For replacement of resin see detailed instruction of equipment subsupplier.

The simplest way would be to replace the filled resin-container. Another possibility is to replace the resin proper.

Pumps
Check shaft-sealing: visible by water-leaking.

Check oil-level of bearing.

Fan
Besides cleaning the motor-fan does not require maintenance.

5. *Measures for shutdown*

No special measures to be taken for plant shutdown, upto several weeks. In case of plant shutdown for some considerable time (several months) it is recommended to drain off the water, in order to avoid standstill-corrosion.

When starting-up again checks have to be performed.

C. Operation

1. *Start-up*

The recooling system is automatically controlled and monitored by BHEL.

2. *Operation Monitoring*

- **General status (leakage etc.)**
- Temperature in deionized water circuit.
- Water circulation in deionized water circuit
- Water conductivity in deionized water circuit
- Abnormal noise (Pumps, Fans)
- Cleanliness of heat exchangers air-side
- Status of fan

VII CENTRIFUGAL PUMPS

a. General checks

1. *Pump shaft*

   The shaft should be easily turnable by hand.

2. *Direction of rotation*

   The direction of rotation of the driving member should correspond to the direction of rotation of the pump as indicated by an arrow mark on the pump. Decouple the pump and check the rotation of the drive by switching on for an instant.

   Wrong direction of rotation can be injurious to the pump and prejudices the pump performance.

3. *Stuffing box tightness*

   It is a good practice to check the stuffing box and see that the gland is not too tight. The pump shaft should be easily turnable by hand (applicable to mechanical seal also).

4. *Bearing lubrication*

   Pumps with grease-lubricated bearings are delivered with grease filling. No check is needed before starting up. Pumps with oil-lubricated bearings are delivered without oil. Before starting the bearing is to be filled with oil. Oil level should reach the middle of the oil level sight glass. In case of a constant level-oiler make sure that there is oil in the oil reservoir.

   Select the oil according to the lubricant chart.

5. *Priming the pump*

Before starting check that the suction pipe is leaktight and free of air. Air lock in the line and the pump has a negative influence on the performance of the pump.

During priming turn the shaft slowly by hand.

b. Operation under suction lift conditions

Before starting the suction pipe and the pump can be filled by evacuating the air with vacuum pump (with closed discharge valve) or pouring the liquid through the funnel fitted to the pump.

c. Operation under suction head conditions

In case of gravity feed the pump can be filled by opening the valve in the inlet pipe. Venting is effected by opening the discharge valve for a short while.

d. Starting

1. *Suction and discharge valves*

   The suction and vacuum compensation line valve should be opened and the discharge valve should be closed.

2. *Insufficient priming*

   If the head does not rise with increasing speed stop the pump and prime it again.

3. *Regulating the delivery*

   Once the operational speed is attained open the discharge valve until the required flow and head are obtained. The delivery can be increased as long as the motor is not overloaded.

4. *External sealing and flushing connections*

   Check that the necessary external sealing and flushing connections correspond to the existing shaft sealing arrangement.

5. *Operation with closed discharge valve*

   Long time running of the pump with closed discharge valve should be avoided because it can lead to the heating up of the pump and subsequent damage.

6. *Higher specific gravity of the pumped liquid*

   If the specific gravity of the liquid to be pumped is higher than designed ensure that the motor will not be overloaded.

7. *Higher capacity*

   If the capacity is greater than designed ensure that

   a) suction lift will not be too great,

   b) suction head is sufficient,

   otherwise cavitation might take place with subsequent damage.

e. *Operation*

1. *Watching the conditions of operation*

   During operation check the liquid level in the sump and the total head. Connections are provided for the corresponding instruments on the inlet and discharge branches of the pump (on delivery of the pump from the factory the connections are sealed with screw plugs).

2. *Permissible bearing temperatures*

   The bearing temperature can rise 50°C above the normal room temperature, however it should not be higher than 80°C.

f. Stopping the pump

1. *Sequence of closing the control valves.*\

   In the absence of a check valve close the discharge valve.

   If the pump is delivering from a vessel under vacuum close the valve in the vacuum compensating line. If the shaft sealing is with a stuffing box and external sealing, don't disturb this.

2. *Suction and control instrument*

   If the suction end control instrument is not provided with a pressure relief valve, close the isolating valve.

3. *Motor*

   Switch off the motor.

g. Restarting

Before restarting check that the shaft is stationary and not rotating in the opposite direction. The pump might turn in the reverse direction due to the return flow if the discharge valve is leaking.

h. Switching on during reverse rotation

Switching on during reverse rotation can damage the shaft.

i. Measures to be taken during long shut-down

During long shut-downs the delivery medium might change in concentration, crystallise or solidify. Therefore the pump is to be drained and flushed with a suitable liquid.

j. Running maintenance

1.. *General*

The pump shaft should run without vibration.

The suction lift and head conditions should not be disturbed due to change in the level of the liquid of the supply vessel.

Don't overload the motor above the power given on the name plate.

2. *Shaft sealing*

Stuffing box with packing rings
Leaking stuffing box

Excess leakage at the stuffing box during the early period of operation stops itself after the run-in time. If necessary tighten the gland nuts. Avoid excess tightening. There should be a slight leak at the stuffing box to carry away the frictional heat generated at the packing.

3. *Leakage too great*

If the leakage is too great and tightening does not help, the packings should be renewed because they might have lost their elasticity.

4. *Replacing the packing*

Proceed as follows:

— Slide back the deflector (if fitted) away from the stuffing box towards the bearing cover.

— Remove the nuts and push back the gland towards the bearing cover.

— Remove the packings and the lantern ring from the stuffing box and clean the latter thoroughly.

— If the surface of the shaft sleeve indicates severe scoring it is to be replaced.

— If ready-formed packing rings are not available, cut sufficient lengths from new packing roll. Form them into rings over a pin of the same diameter as the shaft. The ends of the rings should be cut at an angle to the axis of the shaft.

— If soft packing rings are available cut them at an angle, deform them, slide them over the shaft and form them into rings carefully.

— It is preferred to have a gap of 1 mm between the ends of the rings. Stagger the joints of the rings.

— Tighten the gland nuts unifromly until resistance to turning of the shaft is felt. Once again loosen the gland and retighten.

5. *Cooled stuffing box*

   Pumps for handling volatile liquids should have cooled stuffing boxes so that the packings do not run dry due to vaporization of the liquid.

6. *Mechanical seal Life*

   The life of mechanical seals depends upon many factors including the purity and lubricating quality of the pumped liquid. In view of the various conditions of operations and the various makes it is not possible to specify the life of mechanical seals.

7. *Dry running*

   Dry running of the mechanical seal even for a few seconds should be avoided.

8. *Replacing*

   If it is necessary, replace the mechanical seal.

9. *Flushing*

   Vaporization of the liquid between the sliding faces of the mechanical seal and the resulting dry running should be avoided. Especially when handling liquids at temperature near the boiling point flushing is necessary.

   If there is the risk of abrasive particles getting into the space between the sliding faces, flushing is necessary. Very fine particles can easily get between the sliding faces, destroy the surfaces and thereby cause the unserviceability of the mechanical seal.

   Due to these reasons the various modifications of mechanical seals are provided with flushing, internal or external.

10. *Trouble shooting. (Fig.6.4)*

    The following chart indicates the reasons for troubles during the operation. If troubles other than mentioned here crop up ask the company or the concerned representative.

Reasons ▼ / Troubles ▶	Capacity too low	Head too low	Poor or no suction	Intermittent delivery	Noisy operation	Pump leaking	Power consumption too high.	Bearing temperature too high.	Pump comes to a stop jams
Speed too low	A	A							
Casing or shaft-sealing leaky	B	B	B	B		B			
Foot valve or suction pipe leaky	B	B	B	B					
Suction lift too high or suction too low	C	C	C	C	C				C
Viscosity of the delivery liquid too high	D	D					D		
Specific gravity of the delivery liquid too high							D		
Improper installation or strain on the pump					E	E	E	E	E
Loose or jamming in the pump			F		F		F		F
Wear rings clearance too big due to wear	G	G							
Wrong direction of rotation	H	H							
Discharge line friction loss too high	K								
Improper fabrication							L	L	
Pipes and/or fittings clogged or crusty	M		M		M				

Fig. 6.4
Trouble Shooting Chart

Clearing the troubles

A	Check frequency and voltage.
B	Ensure if the trouble is caused by the casing, shaft sealing, suction pipe, foot valve or suction strainer. Accordingly either: Renew the gaskets on the casing Tighten the shaftsealing or renew. Ensure the leak tightness of the suction pipe. Check the leak tightness of the foot valve. Clean the suction strainer.
C	Clean the suction pipe, footvalve and suction strainer: if needed replace the flange gaskets jutting out into the pipe. Check the suction pipe. If the temperature of the delivery liquid is higher than assumed, reduce the suction lift or increase the inlet head.
D	Pump and motor are determined according to the data specified in the purchase order. Troubles arising due to different data can be cleared only by consulting the pump supplier.
E	Readjust the alignment of pump and motor. Check that no strain is transmitted to the pump by pipings and flange connections.
F	Disassemble the pump and replace the defective parts.
G	Replace the wear rings.
H	Interchange the phase connections of the meter.
K	If the piping cannot be changed in order to reduce the pressure loss, a pump with a higher head should be installed. Consult the pump supplier.
L	Heating of the anti-friction bearings often is caused by too much instead of too little grease. If needed dis-assemble the bearing, clean, reassemble and refill with grease. In case of oil-lubrication without constant level oiler: fill up to the middle of the oil level sight glass. In case of oil-lubrication with constant-level-oiler: fill up the reservoir of the constant-level-oiler.
M	Clean or replace the piping and/or fittings.

VIII MIXED-BED DEMINERALIZER

Operating Instructions

The mixed-bed demineralizers, type MRE are very easy to operate. Be sure to follow the instructions very closely:

The unit is ready for operation when it is connected with the water tap and attached to the electric supply. No warm water:

a. Indication of operation

After connection to the electric supply, the pointer of the conductivity indicator oscillates to the right just to the end of the green section of the scale. This means that the unit is ready for operation. The pointer stays in the green section until the resin is almost exhausted. Then the pointer slowly moves into the red section.

b. Water supply "ON"

The connection joint is equipped with an orifice reducing the flow rate of the incoming water. Please do not enlarge the opening of the orifice without consulting the company before.

c. Water supply hose

If you want to remove the water supply hose, please take care that the mouth piece of the hose is always higher than the filter to avoid penetration of air into the resin, as oxidation of the filling would reduce the capacity.

d. Gaskets

The gasket surfaces between the filter unit and the conductivity indicator and in the joints must be entirely free of resin beads and other impurities.

e. Regeneration

When conductivity indicator enters into the red section of the scale or reaches value in µs/cm wanted, resin in cartridge is exhausted. Conductivity meter and water supply hose have to be unscrewed, the holes to be closed and cartridge to be sent for regeneration.

f. Transport and storage of ion exchange resins

If temperatures below zero are expected, add to exhausted cartridge a hand full of sodium chloride salt (not de-icing or road salt). Temperature should not exceed 10 – 30°C. If, during transport, the temperatures have been lower, warming up is not to be effected by artificial heating elements.
Resins must always be kept humid. To this effect, the cartridges must be kept tightly closed.

IX HEAT EXCHANGER CLEANING

The cleaning of the heat exchanger (HE) is very important for a long and trouble-free operation. Smoke, vapours, salt or dust charged air, foliage, insects, etc. may be drawn in and clogg to the fins, which may affect the HE performance. The frequency and scope of the cleaning is governed by the operating and atmospheric conditions and have to be determined by the competent people of each individual plant.

a. Cleaning the exterior (air side)

Normally it is possible to clean the HE fins during operation. The cleaning method depends on the degree of soiling. The exterior part of the HE may be cleaned mechanically, by hydraulic method or using chemical agents.

1. *Mechanical cleaning*

   If the dirt deposit is of slight, dry or dusty nature, the HE fins can be cleaned by means of a jet of compressed air.

   If the soiling and accumulated fibrous material is mainly around the fins inlet area, it is to be eliminated with a soft brush (e.g. nylon).

2. *Hydraulic cleaning*

   If the soiling of the fins is of more resistant nature, a cleaning appliance with a high pressure water jet shall be used. If it is matter of oily or sooty deposit, a cleaning agent should be added to the water. Be careful not to deform the blades when applying the water jet.

3. *Chemical cleaning*

   If a chemical agent is used for the cleaning, find out previously and make sure that it does not attack the material of the HE. After the chemical cleaning of the HE neutralise it and rinse well.

b. Inside cleaning (side of the medium)

If a rather heavy soiling is to be expected, the HE should be designed with removable collectors.

The elimination of dirt deposits or product remnants from the tubes or collectors is an easy task. According to the degree of soiling, the tubes can be cleaned in different ways:

1. *Mechanical cleaning*

   The accumulated dirt deposits can be removed with a special brush. As to the material and hardness, these brushes are matched to the used HE tubes. Rinse the tubes thoroughly at the end of the of cleaning.

2. *Hydraulic cleaning*

For the inside cleaning, just as for the exterior, a cleaning appliance with a high pressure water jet can as well be used (required pressure: up to 500 at). Through a nozzle head at the end of a tube plain water is being pulverized under very high pressure against the soiled inner side of the HE tube. The cleaning effect results from the very sharp water jets which breaks up the incrusted layer without damaging the tube.

3. *Chemical cleaning*

Boiler scale, lacquer-like layers, oily remnants, etc. are removed by cleaning the tubes with a solvent of

— 10% formic acid solution for boiler scale and

— Trichloroethylene for organic layers.

The chemical cleaning is applied in cases, where the rate of soiling is not very high or on heat exchanger with totally closed collectors or chambers.

The pump's delivery rate is to be chosen so as to attain in the tubes a speed matched to the cleaning effect.

After the chemical cleaning of the HE neutralize it and rinse well.

X LUBRICATION CHART

Below mentioned recommendations about lubrication and maintenance of grease lubricated ball and roller bearings.

The roller bearings are to be lubricated in accordance with the following tables. If there are really rough conditions to be overcome, apply the lubrication instructions.

a. Motor Bearings

The periods and grease volumes of a relubrication depend on the number of revolutions and my be gathered from the following table.

Motor type IEC	Grease Volume in grams	service hours at r.p.m.			
		1'500	1'000	750	500
80	4	11000	16000	22000	33000
90	4	9000	14000	20000	29000
100	7	7000	11000	15000	22000
112	7	7000	11000	15000	22000
132	10	6000	9000	12000	19000
160	15	5400	8200	11000	17000
180	20	5000	8000	10500	16000
200	20	4800	7500	10000	15500
225	25		6500	9000	14000
250	25		6500	9000	14000

All motors from the size 225 on are provided with a relubrication device.

b. Fan Bearings

For the use under normal conditions (i.e. operating temperature up to 70°C) apply the values in the following table.

Shafts mm	Grease volume in grams	Service hours at r.p.m.		
		750	500	250
50	25	2500	2600	2700
65	35	2000	2200	2500
80	50	1800	2000	2200
100	80	1500	1700	2000

c. Lubricants

As lubricants shall be used only very high grade roller bearing greases on lithium basis, with a dripping point at 180°C (NLCI class 2 or 3, application range III or IV), e.g. Shell alvania R 2, R 3, Esso Beacon 2,3, EP 2 or similar.

d. Cleaning of the roller bearing

Bearings without relubrication service have to be cleaned and refilled with grease every 16,000 to 20,000 service hours, depending on the operating conditions. On bearings with the said device, this is to be done after five relubrications. To this end the bearings have to be removed and thoroughly washed with clear gasoline or benzene. As soon as this cleaner has evaporated fill the bearing totally with the appropriate grease and the bearing housing cavities upto around 30%

e. Balancing

The rotor is dynamically balanced with a full leatherkey fitted in the shaft extension. Therefore, the transmission element be balanced without a key in its keyway.

f. Connections to power supply

Standard design motors are provided with a terminal board with 6 terminal studs and are to be connected up as shown on the connection diagram in the terminal box. The cross-sectional area of the power cables should be so selected that excessive voltage drop is avoided for direct-on-line starting. The motors are suitable for connection to one of two different voltage levels in the ratio I: √3 (e.g. 220/380 V).

In the case of the higher of the two voltage levels given on the rating plate the connections are to be arranged in star.

W_2 U_2 V_2
o——o——o——
U_1 V_1 W_1

In the case of the lower voltage level the connections are to be arranged in delta

W_2 U_2 V_2
| | |
U_1 V_1 W_1

In principle. star connection is always applicable for the higher voltage.

When a star delta starter is to be used, no links are required on the terminal board and all 6 terminals are connected to the corresponding terminals of the starter. Connecting the power cables LI, L2, L3 to the motor terminals UI, VI, WI respectively will produce clockwise rotation when viewed from the drive end. If anti-clockwise rotation is required, interchange any two power cables.

g. Earthing

Motor earthing and the associated switching elements must be in conformity with the latest national standards. An earthing screw, identified with earthing symbol, is provided in the terminal box.

h. Maintenance and lubrication

Care should be taken that the ventilation openings are clear and that motor is cleaned at regular intervals. B.B.C. motors are delivered with greased bearings ready for operation.

i. Roller bearing grease

The commercially available, roller bearings are greased with a lithium saponified roller bearing grease Type K 3k according to DIN 51825, consistency No.3.

The above information applies to insulation classes E and B and at normal ambient temperatures (upto 40°C).

For insulation classes F and H, as well as for some higher ambient temperatures, special greases have to be used.

j. Abnormal phenomena, operational faults

1. *Bearing trouble*

   sluggish running and hot bearings are indications of roller bearing defect. The cause could be inaccurate coupling alignment, too high pulley belt tension or dirty bearings.

   The same indications could also result from the employment of unsuitable lubricants, or from over or under-lubrications.

2. *Remedy*

   Heat new bearings in an oil bath up to approx.

   80°C and pull into position on shaft (do not hammer on)

3. *Motor fails to start*

   When the power supply is not interrupted and the motor terminals are under voltage, the cause could be in too low terminal voltage, solidly seized bearings or an earth fault. In the case of wound rotor motors the cause may be that the brushes are not making contact.

4. *Jerky starting*

   This phenomenon can arise in wound rotor induction motors as a result of a faulty or wrongly connected or nonsuitable motor starter.

   An inter turn short circuit in the rotor winding could also be the cause of non-smooth starting.

5. *Sluggish starting unacceptable loss of speed at load*

   In addition to the possibility of damage in the starter such as interturn or core short circuits, the supply voltage could be too low or the voltage drop in the power cables too high. A further possibility is incorrect connecting of the stator terminals (e.g. star instead of delta connection)

   Motor develops irregular hum, and current fluctuation.

These faults are caused by rotor winding damage, e.g. broken bars in cage rotors.

6. *Motor heats up quickly, hums and has high no-load current*

   In addition to the possibility of wrong connection of the stator terminals (e.g. delta instead of star connection) stator damage could be the cause, i.e. interturn, phase or core short circuits.

7. *Bearing types*

   With regard to optimum adoption to the application in question, BBC motor can be supplied with various kinds of bearings:

   * Lifetime bearing, both sides sealed, maintenance-free
   * Bearing with grease prelubrication, one or both sides fitted with dust cover.
   * Bearing with relubrication nipple, grease quantity regulator and grease chamber.

8. *Relubrication interval*

   The initial filling for grease prelubricated bearings running under normal operating conditions lasts for at least 10000 operating hours for 2 pole motors and for at least 20000 operating hours for motors with 4 or more poles.

9. *Grease quantity*

   Excessive lubrication of the bearings can lead to unacceptable increase in temperature.

   Therefore, the grease quantities as determined by the formula below, should not be exceeded:

   Initial lubrication $m = d$

   Relubrication $m = \frac{D \times B}{200}$

where

m	=	grease quantity in g
d	=	bore diameter of bearing in mm
D	=	outside diameter of bearing in mm
B	=	width of bearing in mm

It should be noted that relubrication of sealed lifetime bearings (2 RS) is not possible. These bearings must be replaced when the motor is serviced. The makers also recommend replacement of bearings with dust covers. Motors equipped with bearings requiring relubrication are fitted with a data plate showing the lubrication interval and grease quantity. This plate should be consulted for details.

10. *Severe operating conditions*

In severe operating conditions such as, high degree of humidity, increased or fluctuating bearing load, relative high pollution or ambient temperature above 40°C, the relubrication interval is to be shortened.

11. *Carbon brushes*

When changing the brushes on wound rotor induction motors ensure that the replacement brushes are of the same quality and dimensions as the originals. Each brush must be seated on its whole contact surface. the contact pressure should be approx. 1.8 to 2.2 N/mm^2. Under certain circumstances, operation at partial load can cause increased brush wear. In such cases please contact the manufacturers.

6.03 Synchronous Condensers

6.03.01 25 MVA Synchronous condensers of Westinghouse and BHEL makes are at present in service, apart from the two old BTH make 5 MVA condensers commissioned during 1953 at Korattur S.S These synchronous condensers are air cooled with two pedestal bearings, damper windings on the rotor, a direct connected exciter ventilating fans, etc. Accessories may include starting auto transformers or motors AVR air coolers, fire protection equipments, relays & instruments, oil lift pumps, bearing oil handing system etc. Installation, commissioning and recommissioning after overhaul shall be done as per manufacturer's instructions.

The windings, field coils and armature coils are cooled by air circulating through and around these coils. Air from the inlet duct goes through the oil coolers (in some designs) and is pulled into the condenser by front and rear fans. The air flows along the air gap through the spaces between the field poles and then through air vents in the stator iron to the outlet duct. Louvre dampers may be provided in the pit baffle separating the inlet and outlet ducts and doors are installed in the inlet and outlet ducts.. If there is fire in the condenser, the ventilating air is shut off by closing the inlet and outlet ducts. CO_2 is fed into the condenser and the electrically operated pit louvres are opened to allow CO_2 to circulate through the machine. The exciter is cooled by the blower action of the rotating armature. Lube oil coolers are located in the air ventilating system or separately equipped with oil/water heat exchanger.

The pedestal bearings are provided with insulated liners to prevent the flow of shaft circulating current which will pit the babbit. The oil circulating piping and the oil lift piping (where applicable) are also insulated. Conduit to the bearing thermostat and thermometer must also be insulated.

6.03.02 Operation

a. Starting Synchronous Condensers

General :

Synchronous condensers can be started by one or more of several generally recognized methods. These methods are as follows:

(i) A.C. self-starting by means of auto transformers or from taps on main power supply transformers which impress a reduced voltage (usually 20 to 35% of line voltage) across the terminals of the synchronous condenser.

(ii) Starting by means of a direct-connected starting motor (usually a wound-rotor induction motor).

(iii) A.C. self-starting by use of reactors to reduce the impressed starting voltage to the desired value.

(iv) A.C. self-starting by a special series-parallel connection of the stator winding. The stator winding is designed for starting on the series connection and running on the parallel connection. This is equivalent to starting on a 50% voltage tap. The starting inrush current is greater for this method and can only be used on large systems where the starting demand is not a factor.

The most common method is to use auto transformers. The starting voltage can be selected to start the synchronous condenser satisfactorily with the minimum starting inrush and hence minimum system disturbance for this method of starting.

However, the very minimum of starting disturbance results when a wound-rotor motor is used. This method (ii) would cause intolerable system disturbances. The more general use of this method is limited by the fact that it requires auxiliary starting resistors, drum controller, more complicated switching and also occupies additional space in the station.

Only method (i) will be described as it is the most generally used.

b. Self-Starting-Method

After all sequence devices and auxiliary apparatus involved have been checked and found to be satisfactory, the condenser can be started in line with the following typical sequence.

(i) The field winding should be short circuited either through a starting resistor, the exciter armature or "dead shorted" as the case may be, before the starting cycle is begun.

Caution
Never start with field circuit open

(ii) close the starter for the oil circulating pump motors, if such pumps are provided.

(iii) close the starter for the oil lift pump motors, if such pumps are provided. Some synchronous condensers, rated 7500KVA and above, are equipped with oil pressure starting equipment to reduce the starting friction and hence the starting voltage and starting inrush. The lift pumps (if provided) are to be operated before the circuit to the starting transformer is energized. Observe the pressure developed by the pumps to be sure it is adequate to lift the rotor, as determined by previous preliminary test.

(iv) After the rotor is lifted, the starting breaker should be closed thus impressing reduced voltage across the condenser terminals.

(v) When the machine has begun to turn freely, the oil pressure pump can be shut down. It should not be allowed to run longer than necessary.

(vi) When the condenser has reached approximately full speed, as it usually will on the starting tap, the field winding should be excited and the transfer made to line voltage.

If the field is connected directly to the terminals of the direct connected exciter, the excitation is applied automatically.

The alternative method of first switching to full voltage and then applying the exciting current, is sometimes used. Should the switching arrangement be such that the circuit must be opened for an appreciable interval during the transfer from starting to running, there may be less line disturbance if this method is employed.

The determination of the most optimum excitation can be obtained as outlined in the following titled "Optimum Transfer Current".

C. Optimum Field Current before Transfer to Line Voltage

Fig.6.5 shows characteristic curves for an air-cooled synchronous condenser.

Curve "A" is the "V" curve for a synchronous condenser having no load and full load saturation curves as shown.

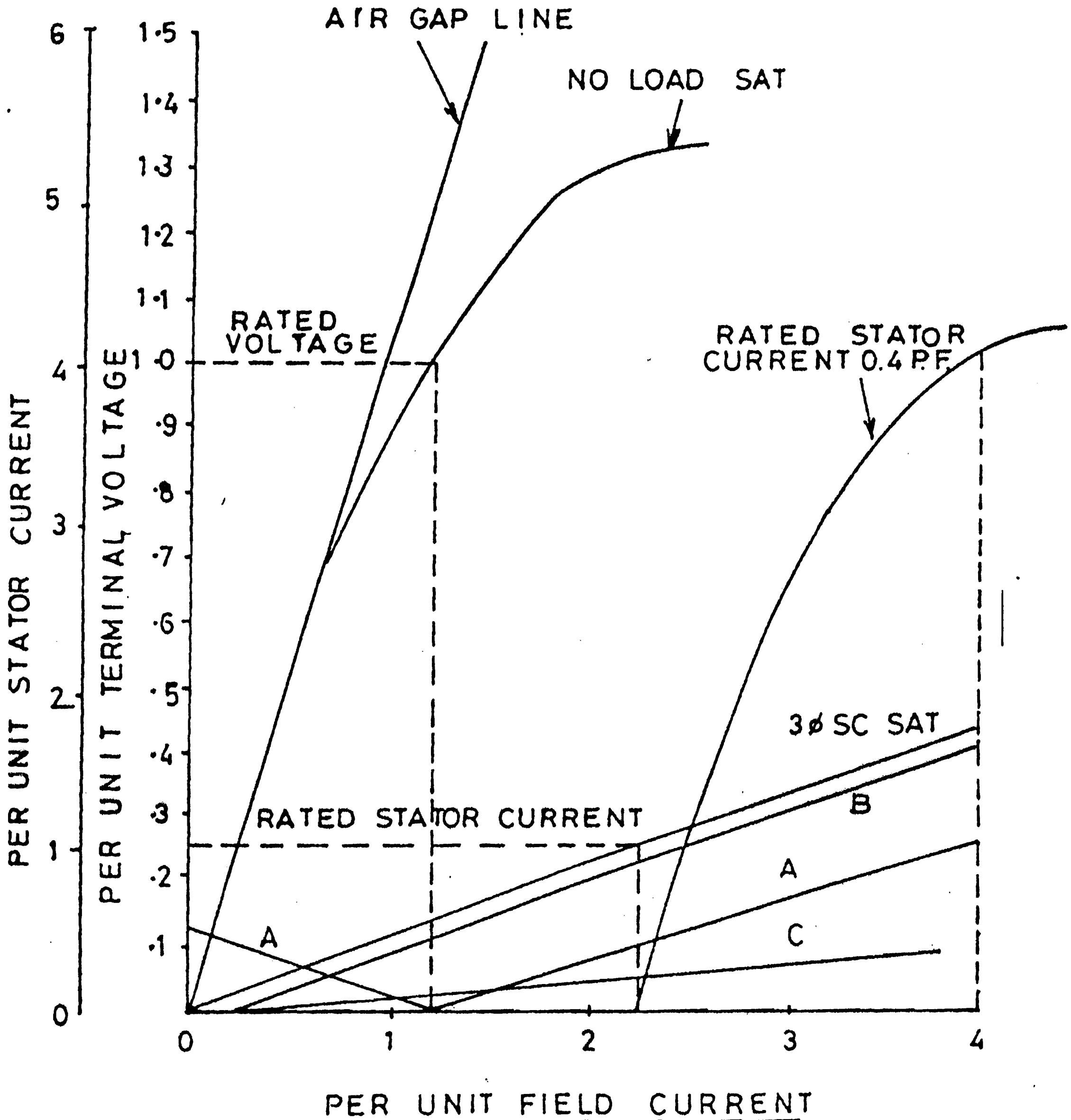


Fig. 6.5
Charasteristic Curves for Air Cooled Synchronous Condenser

The standard air-cooled synchronous condenser is designed for 50% lagging or under excited capacity at rated voltage, with slightly more than zero field current. Sometimes it is designed for 100% lagging capacity also.

Since the "V" curve is a plot of the variation in armature current with field current for a given voltage, the curve is fixed by the following points: (1) field current for rated stator current and rated voltage 0% .P.F. leading (overexcited):

(2) Field current for no load rated voltage and zero stator current.

(3) Field current for one half (50%) rated stator current and zero field current. These points determine the "V" curve, "A". Since we are only interested in the leading or over-excited part of the curve, we will ignore the lagging portion or that portion having field current values below no load.

Another no load "V" curve based on the starting tap (in this case 20%) can be plotted, such as curve "B". If the ordinates of this curve are referred to line voltage by multiplying by the percent starting voltage (in this case 20%), the curve "C" will be obtained.

The intersection of curves "A" and "C" will give the optimum field current I_F to be used before transfer to line voltage.

d. Synchronizing

Before the condenser can be synchronized on the line, its field must be excited to generate rated A.C. voltage at the stator terminals.

Any commonly used method can be used to synchronize the condenser. The most general method is to use a synchronoscope. If a synchronoscope is not available, electric lights can be used and so connected that they will be dark when the voltages are equal and in phase.

When the conditions for synchronizing exist, that is, when the condenser voltage, phase rotation and phase angle is correct, the line breaker can be closed, thereby connecting it to the line.

e. Condenser Operation

A synchronous condenser differs in its function from other synchronous machinery in that it does not do any mechanical work or deliver any power. It actually takes some power from the system to overcome its losses. By control of the field current the corrective KVA can be varied from rated capacity leading (over-excited) to rated capacity lagging (under-excited). It is this characteristic which permits automatic control of system power factor or line voltage eventhough the load and power factor is a variable. The variation in A.C. amperes with field excitation is shown by the "V" curve "A", Fig.6.5.

The standard synchronous condenser is designed to operate safely and continuously over a voltage range of plus or minus five per cent (5%) of its nameplate voltage when delivering its nameplate KVA at zero per cent power factor (over-excited).

It should be noted that operation above the KVA and voltage range for which the machine is designed may result in excessive heating and hence shortens the life of the machine.

Since a synchronous condenser does not deliver any mechanical load, the shaft and bearing dimensions are determined by bearing load and not torque.

Condenser Shut Down

When the condenser is to be shut down, the following sequence should be applied.

(i) Unload the condenser by reducing the excitation to the no load value (note saturation curve Fig.6.5)

(ii) Trip the main circuit breaker.

(iii) Trip the field circuit breaker.

(iv) After the condenser rotor has come to rest, shut down the oil circulating pump motors. Each of these operations is performed manually.

6.03.03 Maintenance

(i) Caution

Keep the machine clean: If the ventilating ducts become "clogged" with dirt and foreign material the machine will operate at increased and possibly dangerous temperatures and its life will be materially reduced. The presence of conducting material such as oil and carbon dust, in sufficient quantity, can provide paths for surface discharges which may seriously reduce the life of the coil insulation and the structural material such as spacers and blocking.

Do not permit the machine to operate for extended periods of time without a thorough inspection. Periodic inspections will frequently reveal minor troubles such as movement of stator coils due to loose coil and bracing, presence of dirt or oil on windings, looseness of stator iron, etc., any of which if neglected may result in machine outage and costly repair bills.

(ii) Cleaning

Several methods are commonly used to clean the windings of electrical apparatus. The most effective method will depend upon the type and degree of "dirtiness" of the apparatus to be cleaned.

COMPRESSED AIR is the most convenient method of removing an accumulation of dirt which is not too firmly fixed to be blown out. The only precautions to be observed are that the air line be free from moisture, and that the dirt be blown and not compacted or embedded into some inner recess within the machine where it will be difficult to remove and where it may close some of the ventilating ducts. The air pressure should be about 3kg/sq. cm.

WARM WATER can be used effectively when the dirt is soluble in water. The washing should be rapid and the parts which are washed should be wiped immediately with a dry cloth and then dried. A jet of hot air, if available, may be used or the apparatus can be covered with a tarpaulin and some source of heat used to dry out the apparatus.

SOLVENTS should be used where the accumulation of dirt contains grease or oil. There are several solvents which can be used to remove grease and oil from machine parts but the one which is generally recommended and generally used is carbon tetrachloride.

Carbon tetrachloride is an active solvent and some-what corrosive in its action. It should be applied sparingly with sponges or rags. Thorough drying afterwards is essential to avoid damage to the insulation.

(iii) Caution

Carbon tetrachloride is a non-inflammable compound - but it is toxic and must be used intelligently. The chief danger in its use is that the vapour is heavier than air and will accumulate in pits or confined spaces. It should only be used in locations which are adequately ventilated, as prolonged or concentrated exposure to the fumes is dangerous to life and respiratory membranes.

A special nose mask is recommended as a protection against over exposure to such fumes.

As an additional safety measure it is suggested that any cleaning work be done by more than one workman. With more than one workman it is not likely that all would be affected simultaneously and if one is overcome the others can help him to fresh air.

After the windings have been cleaned, it is recommended that a coat of insulating varnish be applied to protect the insulation.

(iv) Collector Rings and Brushes

A) Sparking

If sparking between the brushes and the collector rings develop, the following usual causes should be investigated and the suggested remedy applied.

	Usual Causes	Suggested Remedy
1.	Insufficient brush pressure	Adjust to 140 g/cm^2 for grooved ring and 200 g/cm^2 for smooth rings
2.	Brush holder vibration	Remove source of vibration
3.	Brush Chatter	Change to less abrasive brush. Grade L-1 brush should be used with the standard condenser
4.	Oil vapour	Clean ring and brush surfaces and remove source of oil vapour.
5.	Collector ring	True up by grinding or turning surface of rings - preferably at full speed
6.	Spotted rings	change to a more abrasive brush

(v) Selective Action between Brushes

This condition is generally aggravated by any of the causes of brush sparking and if the same remedies are applied, it will usually be improved.

This action is attributed to the formation of an air film under some of the brushes and has been generally eliminated by the wiping action of helical grooves in the ring surface. It is good practice to periodically (say once a week) blow dust from the brush boxes and adjacent parts. Take hold of each brush shunt and move brush shunt and move brushes up and down in their boxes to shake out dust and check free movement. If the brush is not free, check the clearance by inserting a piece of fish paper between the brush and the holder all the way down to the collector ring.Check brush wear. Replace when top of the brush is flush with the top of the holder box. Brushes can be replaced a few at a time when the condenser and exciter are running.

During a scheduled shut down, the brush and ring assembly should be inspected and serviced.

(vi) Collector Rings

The Collector rings of standard-air cooled synchronous condensers are made of steel. The surface of the rings is grooved to eliminate selective action of the brushes.

In general, collector ring troubles can be attributed to four causes: 1) uneven wear, 2) unclean surface, 3) development of spots and 4) formation of brush imprints.

1) Occasionally uneven wear will result if the ring material is not of uniform hardness. The only ultimate cure for this trouble is to replace the rings.

2) It is important that the collector rings be kept clean at all times. If dirt and dust are permitted to accumulate, sparking and cutting of the ring surface will usually result. Many collector ring troubles are due to lack of proper care and maintenance.

3) Spotting of the ring surface develops in some cases for reasons which are not well understood. These spots are not serious in themselves, but will lead to pitting of the rings unless removed. If the condition is corrected as soon as it is found, by lightly rubbing with fine sandpaper, no harm will be done to the rings.

4) Sometimes an imprint of the brushes will be found on the surface of the collector rings. This usually occurs on a machine which is exposed to moisture or acid fumes. When the machine is not operating, the fumes act on the surface of the ring which is not in contact with the brushes.

   The difference in surface condition caused by this action may cause a slight burning as the ring rotates. Brush imprints due to moisture of fumes will occur at any point where the machine happens to stop, as compared to imprints due to ring inaccuracy, which will always occur at the same place on the ring.

   Brush imprints on the rings may also be caused by a slight inaccuracy which may cause a jerk or movement in the brush once every revolution. The brush jumps slightly with a small arc, which in time, burns an imprint of the brush on the ring. Elliptical or eggshaped rings may also cause this condition.

   The remedy for these troubles, of course, is to remove the cause. When "truing-up" a ring be sure to grind or turn the surface at full speed. Hand grinding or turning is not advised because the eccentricity may actually be increased by this method.

6.03.04. Bearings

(i) The design of bearings has a background of many years of operating experience and with reasonable maintenance and attention they should give long and trouble-free service. Periodic inspections should be made to be sure the oil level in the bearing pedestal is upto the normal mark on the gauge. The oil should be sampled at intervals to check its viscosity and purity and to be sure it is acid-free. Openings are provided in the bearing cap over the oil rings for the purpose of adding fresh oil and inspection of the oil rings.

The bearings of synchronous condensers may be provided with temperature detectors or indicating thermometers embedded in the bearing shell close to the bearing surface. These are specified as necessary apparatus.

The temperature of the bearing should be observed regularly by the operator so that a sudden change or an unusual rise in temperature can be detected. A normal continuous operating temperature as determined by the embedded detectors is 80 to 85 deg. C. If bearing thermostats are supplied with the condenser, they are usually set to sound an alarm or trip off the machine at a temperature of 96 deg.C.

If external oil coolers are provided to cool the bearing oil, such coolers should be inspected regularly to be sure they are clean and operating efficiently.

(ii) The cause of overheating of a bearing may be any one of or a combination of the following:

1. Insufficient oil in the reservoir.
2. Dirty oil or oil of poor quality.
3. Failure of oil rings to revolve.
4. Excess end thrust resulting from an installation with the bedplate badly out of level or from the axial magnetic pull resulting from the magnetic contents of rotor and stator being out of line.
5. Pitting due to bearing currents.
6. Rough bearing surface due to corrosion.
7. Blocking of oil coolers and filters.

6.03.05. Lubricating Oil

Keep the oil in the bearings clean. The frequency of oil changing depends to such an extent on local conditions, such as severity and continuity of the service, the room temperature, the state of cleanliness, etc. that no definite instructions can be given. The oil may be considered deteriorated when the flash point is below 150 deg.C (kept in open cup) impurities exceed 0.1% (sample taken from lowest part of the tank) Viscosity changes above 15-20% maximum total acidity is higher than 0.4 mg KoH/gm. A conservative recommendation would be to clean and refill the bearing and pedestal every six months.

Use any good grade of lubricating oil, free from acid and having a viscosity of 200 to 250 sec. Saybolt at 100 deg.F. The circuit is to be emptied when the oil is still hot in order to avoid separation of impurities and deposits in ducts.

6.03.06. Rotor Windings

Maintenance of the rotor should begin by measurement of the insulation resistance prior to placing the unit in service. Following this, a thorough check up of all parts of the rotor should be made at the end of a year's operation and annual inspections thereafter should include the following steps:-

1. Check damper winding for loose bars in the iron, connections of each bar in the ring segment, and joints in ring segments between poles.
2. Check clearance between blowers and coils.
3. Check for movement or shifting of field coils.
4. Check the dirt on winding and take cleaning steps necessary.
5. Inspect strap field coils for conditions of turn-to-turn insulation.
6. Check condition of ground insulation and washers or collars.
7. Check connections between coils and to the collector.
8. Measure insulation resistance to ground of field winding including the collector using a device which applies not more than 500 volts D.C. from the winding to ground.
9. Refinish with suitable recommended varnish as required.
10. Check balancing weights for proper seating
11. Compare the impedance of the winding with the original value.

Replacing pole coils, if it arises, shall be done as per manufacturers instructions.

6.03.07. Stator Windings

Maintenance should begin with operation of the unit and therefore, before the unit is started, measurements should be made of the stator insulation resistance. It is desirable to take this reading immediately after the dryout run at the elevated temperature as this would provide a more nearly correct "bench mark" for future reference.

Annual inspections are recommended unless unusual service conditions require frequent inspections. The first annual inspection should include a thorough check up of all parts of the stator windings as listed below, as well as a general clean up of the winding, by blowing with dry air or by wiping with dry rags. If the winding is dirty, take cleaning steps necessary with solvents as described in section titled "CLEANING".

After the first annual inspection, subsequent inspections should include the following steps along with proper cleaning as necessitated by service conditions:

(1) Check for loose wedges.

(2) Check for broken, damaged or missing wedges.

(3) Check end wedges for movement at the end of the core and all other wedges for position.

(4) Check coil ends for distortion.

(5) Check security of all lashing and spacers.

(6) Check tightness of coil support brackets, if any.

(7) Check for loose coils in the slots.

(8) Check coil ends for cracks in the insulation or other mechanical damage.

(9) Check all connections between coils and connections around frame.

(10) Measure insulation resistance of winding to ground, from the machine terminals.

(11) Clean thoroughly where required.

(12) Protect the finish by revarnishing as needed. Use only varnish or compound recommended by manufacturer. Never varnish or paint a dirty or greasy winding.

(13) Check the core for evidence of hot spots or damaged punchings.

(14) Measure resistances of all phases and compare with the original values.

(15) Clean air coolers (where provided)

Insulation Resistance

Insulation resistance is useful in determining the presence of moisture or dirt upon the winding surface and a complete record kept of insulation resistance is useful in determining when cleaning or drying of the windings are necessary. It is suggested that insulation resistance readings be taken every six months preferably summer and winter, and over a period of years. Any sudden trend of the insulation resistance values will indicate that maintenance steps need be taken. The method of taking insulation resistance should be definite, controlled, and the following routine is suggested:

(1) Adopt a definite time of application for taking readings, preferably after 1 minute of voltage application.

(2) Always use the same voltage instrument.

(3) Keep a complete record of date, temperature of winding and ambient temperature, relative humidity and condition of winding. Insulation resistance factor varies from 1 at 75°C. to about 14 at 25°C.

(4) Take readings at machine terminals, being sure other cables, switches, etc. are isolated.

(5) Whenever motor driven or electronic instruments are used to take readings over a period of time longer than 1 minute, as in the case of dielectric absorption curves, it is essential that, *before a repeat reading* of the same part is taken, that the winding be discharged to ground for a time at least equal to the total time of voltage application when readings were first taken.

Rotor

Pole Dovetail keys:

The rotors of all air-cooled synchronous condensers are given a "Shake-down" run at the factory. This consists of running the rotor at *25% above the rated speed* for a period of time; bringing it to rest and then driving the dovetail keys. It has been found that the keys which were driven in initially, before the rotor was run at the overspeed, can usually be driven in further after the "shake-down" run. This procedure assures that the keys will be tight and remain tight under normal operation, after the unit is placed in service.

During the operation of the condenser it is periodically started and stopped and in so doing may be subjected to "bumps". Also it may be operating *single phase* during fault conditions and be subjected to vibration. In addition there is some further *seasoning* which takes place as a result of *temperature changes* and *centrifugal* *forces.* As a result of such operating conditions, the dovetail keys may loosen and *require periodic tightening.* If sufficient key material is projecting beyond the spider, the keys can be driven tight by use of a sledge. In some extreme cases it may be necessary to drive out the old keys and replace them with new keys. This is quite improbable, if the unit is regularly inspected and properly maintained.

Field Coil Braces:

After the condenser has been in service for some time, the insulting spacers may shrink to some extent and may compress slightly due to the forces acting upon them. This action may result in the braces becoming loose. *Therefore, the braces should be checked periodically and tightened, if necessary.* Failure to keep *the coil braces tight will result in unbalance and may lead to more serious trouble.*

Re-insulation of Field Coils

After some period of operation, the condenser rotor may develop short-circuited turns or grounds. Such developments do not mean that the material or workmanship was inferior at the time of manufacture. Abnormal operation failure to keep machine parts clean; failure to keep field coil braces and dovetail keys tight; can all be instrumental in causing such troubles.

When such troubles develop, the repair work should be undertaken in consultation with the manufacturer. The ground insulation between the field coil and the pole consists of mica and asbestos which is built up on the entire inside surface of the coil. The operation requires tools and processes which may not be available at site. Also the turn insulation is a specific material which is subjected to a variable but predetermined pressure under large hydraulic pressure.

Considerable difficulty may be experienced in some cases in removing the poles and coils from the rotor. This is generally due to the fact that the dovetail keys become rusted and frozen to the spider. In such cases it may be necessary to use special tools, materials and methods which may not be available at site. Many purchasers, therefore return the entire rotor and bearings to the manufacturer, as it is then possible to run the rotor in its own bearings; shake down the rotor; drive the dovetail keys and balance the reassembled rotor.

Manufacturers should be consulted when major field coil repairs are necessary.
Drying out of stator and rotor:

The following formula is recommended as a guide to maintenance personnel regarding safe IR values.

$$\text{Min.IR value} = \frac{\text{Rated voltage}}{1000} \text{ Meg ohms}$$

Drying out operation is considered complete when IR of the winding under hot condition reaches a sufficient higher value with a good polarisation index which is equal to

$$\frac{\text{IR at end of 10 Min.,}}{\text{IR at the end of 1 Min.}}$$

When measured by a motorised megger, this value shall normally be not less than 2.0.

Various methods of drying out can be used depending upon available facilities at site. Space heaters can be located within the enclosure and below the windings to dry them out. Frequently D.C. welding sets are available and field winding can be dried by connecting the welding set to copper clamps attached to the collector rings. The copper clamps will prevent burning of collector rings. A small fan can be used to provide some circulation of air and thereby accelerate the drying out process. In general the drying should proceed slowly at first, when the heating being gradually increased as the insulation dries. The temperature of the insulation as measured by the thermometer should not be allowed to exceed 65°C. If embedded temperature detectors are used to read temperatures, the permitted temperature is 80°C.

Insulation resistance measurements should be taken periodically throughout the drying out process. It will usually be noted that the resistance will decrease at the start of the dryout, but will finally increase until the values are reasonably constant. When the resistance is constant and above the maximum value, the condenser can be placed in service.

Schedule of maintenance of synchronous condensers.

Weekly:

1. Blow dust from the brush boxes and adjacent parts.

2. Take hold of each brush shunt and move brushes up and down in their boxes to shake out dust and check freedom. Check the clearance by inserting a piece of fish paper between the brush and brush holder all the way down to the collector ring.

3. Check brush wear: Replace when top of brush is flush with top of brushholder box.

Once in 3 months:

1. Analyse Lube oil for physical and chemical properties.

Once in 6 months:

1. Clean carbon dust filters
2. Clean magnetic filters in Lube oil circuit
3. Measure I.R.Values of all windings and polarisation index.
4. Inspect the collector and brush rigging for evidence of oil and dust. They should be washed with suitable solvent.
5. Scored collector rings must be ground and polished to restore a smooth condition.
6. Defective brush holders should be replaced.
7. New brushes should be installed where necessary.
8. Check bearing insulation.

Once a year:

1. Overhaul all pumps, motors and fans.
2. Clean heat exchangers.
3. Check damper operation and CO_2 operation (without discharging CO_2)
4. Dismantle part of the end shields to inspect and clean end windings and fans.
5. Dismantle bearing covers to check up journals, oil rings, etc.
6. Check all protection relays.
7. Tighten all accessible bolts and nuts.
8. Check lub oil circuit for any leakage.

Once in 4 years:

Major overhaul with the rotor dismantled.

(Before dismantling, record Bearing clearance and gap in each pole.)

Other works to be arranged to

1. Thorough check up of stator parts as described earlier
2. Thorough check up of rotor parts
3. Thorough check, up of bearings, journals, oil rings and oil handling system.
4. Measure resistance of windings.
5. Check all protective relays and instruments.

PROTECTIVE RELAYS

7
Protective Relays

CONTENTS

7. PROTECTIVE RELAYS

7.01 General Inspection

All protective relays should be checked and tested atleast once a year according to the manufacturers' instructions. The following are however, some of the main items of the inspection tests and maintenance to be carried out and may, if necessary, be modified as per Departmental instructions:

The equipments and their wiring should be inspected for any fault.

The relay settings should be checked to see, if they conform to the approved schedule.

7.02 Tests

i) *Insulation and continuity tests on Wiring*

All wiring and cables associated with the protective relays should be tested for insulation to earth and between cores, with a 500 V megger. The test results should be recorded together with a note about the weather at the time of test especially when wiring on outdoor gear is included in the test.

If any wiring is replaced as a result of the tests, it should be ensured by further tests on the associated gear that the new wiring is correctly connected.

ii) *Secondary Injection tests*

Tests should be carried out on all relays by injection of current and/or voltage into the relay coils. The following are some of main tests to be carried out on various types of relays.

a) Attracted armature type relays

Tests should be carried out for drop off and pick up values. Operating times of current relays should be noted for 1,2 and 4 times the setting or rated value.

Check should be made for contact bouncing and adhesion between armature and pole face.

b) Induction type over current relays

The relay should first be tested for minimum operating current and time of operation for minimum operating current. Times of higher operating currents should be determined and checked to see if they conform to the characteristic curves of the relays.

The resetting time of the disc (at the time setting in use) should be noted and recorded to check the strength of the permanent magnets.

If the relay timings do not conform to their characteristic curves, the relays should be adjusted so as to get the timings as close to the curve as possible.

c) Directional Relays

Normal voltage should be applied to the voltage coil and the minimum current required for the operation of the relay determined. The results obtained should be compared with those obtained during the commissioning tests or the previous routine tests.

Times of operation of relay for minimum currents and for higher currents should be noted and checked with characteristic curves.

The minimum voltage for operation of the relay should be noted with normal current (corresponding to setting value) passing through the current coil. The time of operation should also be noted in this case and the values obtained compared with those got during the previous tests or during the commissioning tests.

The contacts should be checked for rebouncing.

d) Impedance relays (distance type):

Tests should be carried out to determine time distance curves for 2 or 3 values of current.

Note: The insulation resistance of all relays coils, internal connections, terminals, etc., should be measured with a 500V megger and results recorded.

e) Other auxiliary relays

Relays not coming under any of the above categories may be got tested annually in combination with the main relays for checking up for satisfactory operation and also individually as per manufacturers' instructions.

iii) *Primary Injection tests*

Primary injection tests need not be carried out normally as a routine measure. Such tests should be carried out whenever necessary to investigate into causes for wrong operation or non-operation of protective gear.

iv) *Circuit breaker timing tests*

A check of the performance of the tripping mechanism of the circuit breaker should be made by measuring the time interval between the time the trip coil of the breaker is energised and the time the main contacts of the breaker separate. A note should be made of the D.C. voltage at the time of test.

v) *Testing of series trip relays*

Series trip relays may be tested in the same manner as indicated in (ii) (b) above.

vi) *Testing of Trip circuits*

The trip circuits should be checked during the annual tests of relays and before putting back the O.C.B. in service after taking out on any occasion. This check can be made by idly charging the O.C.B. and manually tripping through the relay.

vii) *Checking up of flag indicators*

Mechanical flag indicators may be checked by slowly rotating the relay disc and seeing whether the flag falls first before the trip contacts are closed. Electrical flag indication may be checked by idly charging and tripping the O.C.B. through the relay.

NOTE: The tests enumerated in sub-paragraphs (ii) to (vii) should be done by M.R.T. branch.

viii) *Checking up of insulation of current transformers and potential transformers*

Current transformers and potential transformers should be tested for insulation by megger periodically.

Current transformers need not generally, be tested for ratio error annually, However, ratio test may be conducted whenever any maloperation of relays is experienced.

During commissioning, open circuit characteristics of C.Ts. should be checked and recorded for future reference. The current transformer should be suitably demagnetised after every open circuit characteristic test.

7.03 Maintenance of relays

a) A thorough examination should be made of all parts of the relay, special attention being given to the following:

i) Cleaning of contacts.

ii) Aligning of contacts.

iii) Separation of contacts.

(Separation of contacts should not generally be less than 6.25 mm. If a smaller separation is adopted it should be checked that vibration do not cause accidental closing of contacts)

iv) Proper operation of the moving elements.

v) Removing any dust or resin drops from heated windings on disc and between the gaps of the brake magnet.

vi) Elimination of any friction between the discs and magnets and friction due to dirty bearings of rough or cracked jewels.

a) Cleaning of relay contacts may be done with fine sand paper and finished off, with chamois leather. Convenient tools may be made by gluing sand paper and chamois leather to thin strips of wood. After cleaning, any particles of abrasive or chamois adhering to the contact should be carefully removed by blowing off by means of a rubber tube with a fine nozzle cleaned with petrol or spirit. An electric torch and a mirror may be used if necessary for examining the contact surface.

b) An annual programme of tests on relays should be prepared by the M.R.T. branch of each system to cover all the relays in the system so that tests on all the relays may be carried out within the due dates. The programme should be approved by the Superintending Engineer and strictly adhered to by the M.R.T. sub-division.

The following registers should be maintained in the M.R.T. sub-division of each system to facilitate watching of relay operation, revision of relay settings, etc:

i) Register of relay settings.

ii) Register of relay operations.

iii) Register of peak loads on current transformers.

c) The register of relay settings should contain the following information regarding all the relays in the system.

i) Make and type of relay.

ii) Available range of settings (current, voltage, time, D.M.T. etc.)

iii) Location of the relay giving name of station and feeder or equipments.

iv) Approved settings of relays (with reference to the concerned memos approving the settings). Entries should be made whenever any revision in the relay settings is made.

v) Current transformers and P.Ts operating the relays (available and adopted ratios, overcurrent factor etc.)

vi) Particulars of networks, resistances, chokes, etc., if any in relay circuits.

vii) In the case of special types of relays with complicated connections, a diagram of connections of the protective gear.

The register of relay operations should be maintained from the monthly interruption reports received from the field. Operations of protective gear should be reviewed every month and any remedial measures needed recommended to the Superintending Engineer/Protection & Communication, Madras for study. and approval.

The register of peak load on all current transformers should be maintained from the quarterly returns submitted by the field and reviewed by the Assistant Executive Engineer/M.R.T. to see that no current transformer, relay or instrument is over loaded. If such overloading is noticed, suitable remedial measures should be recommended to the system Superintending Engineer for approval and adoption by the field.

7.04 Efficiency of protection

At the end of each year, an analysis of the operation of all protective gear in the system should be made in the M.R.T. sub-division and the results tabulated as shown below:

Analysis of relay operations in the year ending

		110 KV system	66 KV system	33 KV system	22 KV system	11 KV system
1.	Total number of operations					
2.	Correct operations numbers					
3.	Incorrect operations numbers					
4.	Correct operations percent					
5.	Number of incorrect operations, due to					
	(i) Faulty relay					
	(ii) Incorrect relay setting					
	(iii) Human element					
	(iv) Other causes.					

The protective efficiency of the system should then be got from the results. The protective efficiency of the system may be defined by the expression.

$$\frac{\text{Number of correct protection operation}}{\text{Total Number of protection operation}} \times 100$$

NOTE:

(i) The table above should be based on individual relay operation rather than on the number of faults.

(ii) An operation should be recorded as correct if the various relays operate in accordance with the designed plan, even if the circuits are tripped unnecessarily as for instance in the case of over lapping of the zones of protection.

(iii) An operation should be taken as incorrect, if the fault is not cleared by the appropriate relays breakers even if cleared correctly by the back up protection.

(iv) Failure of relays to operate should be classified under incorrect operations.

(v) Failure to trip due to faults in circuit breakers, instrument transformers, wiring etc. should also be included under incorrect operations.

(vi) Trippings of circuits by mistake or carelessness of the staff engaged on switchgear and protective gear maintenance or testing may be ignored while arriving at the protective efficiency.

Details of all incorrect operations should be recorded, classified and reviewed periodically with a view to improve the protective efficiency of the system and an annual report submitted to the Chief Engineer/Distribution and Chief Engineer/Operation with a copy to the Superintending Engineer/Protection & Communication Madras.

7.05 Inspection and Maintenance of Switch Boards

7.05.01 Panels

Weekly: Check for general cleanliness and condition of finish. Clean off dust, dirt and grease. Use a solution of mild soap and water to remove dirt and grease from panels. Many cleaning compounds are harmful to the finish and should not be used. Wax may be used where the gloss is not objectionable. Oil base polish has a tendency to collect dust and retain finger prints. Linseed oil may be used on slate panels, if used sparingly and wiped dry.

7.05.02 Panel Wirings

Weekly: Clean panel wiring with a feather brush.

Annual:

(i) **Where compressed air equipment or supply is available, blowout wiring and equipment on back of panels with clean dry compressed air.**

(ii) **Check insulation resistance of wiring with all devices connected.**

7.05.03 Control Switches and Push Buttons

Monthly:

wherever possible try out operation of all control switches or push buttons to see if operation is correct.

Annual:

(i) Examine contacts and refinish with fine files if burnt or corroded.

(ii) Check contact operating cams, levers or drums.

(iii) Check contact spring pressure.

(iv) Tighten connections.

(v) Examine insulations.

7.05.04 Indicating Lamps

Monthly:

(i) Inspect lamps, series resistors and colour caps.

(ii) Check to see that each lamp gives the correct intended indication.

(iii) Check fuses on lamp circuits.

Annual: Tighten all connections.

7.05.05 Position Indicators

Monthly:

(i) Check for correct positioning between transmitter and receiver.

(ii) Check if pointer is moving freely.

Annual: Check for friction and vibration of moving element and excessive heating.

7.05.06 Terminal Blocks

Monthly:

(i) Clean with dry brush.

Annual:

(i) Inspect for cracks, breakage, dirt and loose connections and mounting screws.

(ii) Examine connections for mechanical defects and dirt. Inspect connections for open circuits, short circuits at terminals and damaged insulation.

(iii) Remark conductor tags or designations before they become obscure. Replace lost conductor tags.

(iv) Tighten connections at terminal points.

7.05.07 Test Blocks

Monthly: Clean with a dry brush.

Annual:

(i) Examine to see that there are no loose connections and no cracked bases or covers. Check if contacts are in good condition.

(ii) Check wiring connections to see if any changes have been made in circuits or associated equipment.

(iii) See that covers are tight as to exclude dirt, dust, moisture and insects.

7.05.08 Meters and Instruments

Monthly:

Examine for sticking of moving element of indicating and recording instruments, watt-hour meters, unsatisfactory inking of recorder charts. Have faults, if any, corrected at earliest opportunity.

Annual:

(i) Check calibration of important instrument and recorders or others suspected of being incorrect. Check watt-hour meters against rotating standard and adjust as necessary.

(ii) Check to see that movement is free and unobstructed.

(iii) Examine pivots and bearings and repair or replace as necessary.

(iv) See that cover gaskets are tight so as to exclude dust, dirt moisture and insects. Clean cover glasses.

(v) Check external resistors and potential fuses.

(vi) Tighten connections.

(vii) Check wiring connections to see, if any changes have been made in associated circuits or equipments.

7.05.09 Protective Relays

Monthly:

(i) Examine visually for anything unusual about contacts, coils of moving elements.

(ii) Check settings to see if they conform to approved schedule.

(iii) Check operation by shorting the trip contacts of the relays provided at the back.

(iv) Check that covers are tight as to exclude dirt, dust, moisture and insects.

Annual: Have the relays tested by the Meter and Relay testing branch.

NOTE: Testing of relays on group control OCBs in a sub-station should be done once in six months instead of annually.

7.06 Inspection and Maintenance of Control Equipment

7.06.01 Auxiliary and Control Relays

Monthly:

(i) Check condition of contacts.

(ii) Note whether coil temperature is excessive.

(iii) Check noise and vibration of contactor, magnet frame and armature.

Annual:

(i) Examine contacts and finish with fine file. Pits in the contact surface are not objectionable but projections must be removed. Replace contacts if repair is impracticable.

(ii) Check flexible shunts.

(iii) Check contact spring pressure and contact wiping action.

(iv) Check that arc chutes, blow out coils and barriers are in good condition. See that turns of blow out coils are not short-circuited and that coils are properly assembled to blow arc outward.

(v) Check insulation between circuits of phases.

(vi) Note whether operating coil temperature is excessive and if so check resistance for possible short circuited turns.

(vii) Check alignment and vibration of magnet frame and armature and examine shading ring. A noisy solenoid generally indicates poor alignment or broken shading ring, either of which will cause heating of the solenoid.

(viii) Tighten connections.

7.06.02 Knife Switches

Annual:

(i) Check hinges and clips for good contact.

(ii) Tighten connections.

(iii) Clean insulating base, if dirty

(iv) Open and close several times after smearing contact surface with a light coat of lubricant, if necessary. Do not use grease which may harden upon exposure to air.

7.06.03 Fuses

Monthly:

(i) Check that fuses of the proper rating are used.

(ii) Note that fuses are not running too hot.

(iii) See that fuses are right in the clips and contact surfaces are clean.

(iv) Check that spare fuses are on hand.

7.06.04 Latches and Trip Devices

Annual:

(i) Check latches or latched in contactors or manually operated starters for wear and secure holding.

(ii) Check solenoid of trip devices for insulation and operating current.

(iii) Check time delay dash pots for binding, low, dirty or incorrect oil and leaking valves.

7.06.05 Auxiliary Switches

Annual:

(i) Clean and dress contacts if corroded or pitted.

(ii) Check spring pressure.

(iii) Check operating levers and linkage.

(iv) Check opening and closing adjustment with respect to main contacts.

(v) Tighten connections.

7.06.06 Miscellaneous Control Devices

Annual:

Check and clean contacts of control devices such as push buttons, time switches, pressure, vacuum or float switches, etc. and see that they are in proper operating condition.

7.06.07 Power supplies and Wiring

Annual:

(i) Check and tighten wiring connections at terminal points.

(ii) Inspect wiring for open circuits, short circuits and damaged insulation.

(iii) Check insulation resistance of wiring with all devices connected.

Schedule-II

Protective Relays and Controls and Metering Equipment

Serial number and name of apparatus	Details	Period between inspections
1. Control Switches	Cleaning and lubricating contacts	Yearly
2. (a) Cable boxes	(i) Examination and topping up.	Six months after first servicing
	(ii) Meggering	Quarterly
(b) O.C.B. control cables	Meggering	Quarterly as and when O.C.B. is taken up for maintenance
3. Kiosks	Cleaning, checking up all bolts and nuts, vermin, proofing arrangement checking of all porcelain inside and outside of kiosks against cracks or damage. Greasing of links and contacts.	Quarterly as and when O.C.B. is taken up for maintenance.
4. Relays	Relays testing	Should be tested by the M.R.T. once in a year
5. Telephone panel	Checking of connections, greasing, etc.	Monthly
6. Fire extinguishers	(a) Checking liquid level	Monthly
	(b) Testing and refilling	Yearly
	(c) Testing containers for pressure	Once in three years

MAINTENANCE DUE : RELAYS

Month	Whether Monthly Maintenance Done on Relay								Reason for Slippage	Whether Quarterly Maintenance Done on Relay								Reason for Slippage
	1	2	3	4	5	6	7	8		1	2	3	4	5	6	7	8	
April																		
May																		
June																		
July																		
August																		
September																		
October																		
November																		
December																		
January																		
February																		
March																		

* Note : Mark ✓ if maintenance is done, otherwise x may be used.

POWER LINE CARRIER COMMUNICATION EQUIPMENTS

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8
Power Line Carrier Communication Equipments

CONTENTS

8. MAINTENANCE OF POWER LINE CARRIER COMMUNICATION EQUIPMENTS

The Power Line carrier equipments (PLCC) may be broadly classified into two:

a) Out door equipments

b) Indoor equipments

8.01 Outdoor Equipment

This consists of (1) Wave Trap; (2) Coupling capacitor (cc.) (3) Coupling capacitor with potential devices (CCPT) (4) Line matching unit (LMU) and (5) Co-axial cable.

8.01.01 Wave Trap

This consists of a wound coil either made of Aluminium or copper, tuning pack and a lightning arrester. The lightning arrester and tuning pack are mounted inside the wound coil. The top and bottom of the coil are covered with bird barriers. The wave trap is connected in series in the line and is designed to carry the line current and instantaneous fault current also.

Once in a year the bird barrier in the wave trap should be removed and checked for any foreign materials such as twigs, wire materials, etc. If such extraneous materials are found inside the wave trap, they should be removed. The condition of the lightning arrester should be checked, and if found damaged it should be replaced. The condition of the tuning pack should also be examined for any damages; if replacement is required, the Power Line Carrier communication staff should be contacted. The wire connection between the coil, lightning arrester and the tuning pack part should be examined and tightened if found necessary. The clamps connecting the wave trap and the lines and switches should be thoroughly examined and tightened if found necessary. Invariably glow will occur during nights if the clamps are loose and hence it is very necessary that all the current carrying parts are properly tightened as and when required.

8.01.02 Coupling Capacitor

As it is a sealed unit no maintenance is normally required. During Line Clear the porcelain portion should be cleaned thoroughly, and check should be made for any oil leak in the coupling capacitor either due to chipping/cracks of insulators or from the bottom point from where tapping is connected to Line Matching Unit.

8.01.03 Coupling Capacitor with Potential Devices

It is similar to a coupling capacitor except that there will be one Potential Transformer inside metal tank at the bottom of the coupling capacitor. The coupling capacitor portion is a sealed unit, and hence no maintenance is required. The potential Transformer should be checked for any oil leak. The oil level in the gauge glass shall be checked for normal level. If there is an oil leak, action should immediately be taken to arrest it. As in the case of wave trap the current carrying clamps should be securely tightened, the connection between the bottom of the coupling capacitor (hot point in the coupling capacitor with Potential Transformer) and the Line Matching Unit should be checked for any loose connections and tightened.

8.01.04 Line Matching Unit

This consists of one coupling device, drainage coil and earth switch. The drainage coil forms a very low impedance path for the 50 Hz supply and offers high impedance to high frequency carrier signals. Hence it is absolutely necessary that the connection between the drainage coil should be securely connected and tightened. If by accident the earth connection to the drainage coil is cut off, then full line to neutral voltage of the line will appear at the top end of the drainage coil and may cause fatal accident to the personnel who are close by. Hence the earthing connection of all the equipments of Power Line Carrier Communication should be thoroughly checked once in a year.

The door of the coupling devices shall be opened and cleaned off any cobwebs.

8.01.05 Coaxial Cable

This normally connects the Line Matching Unit to the carrier equipments inside the carrier room (or control room) and it should be examined that the cable is not cut or damaged anywhere.

8.02 PLCC Indoor Equipment

This consists of

1. Carrier Panel
2. Protection coupler
3. Four Wire Group Selector

4. Private Automatic Exchange (PAX)

5. 48V battery and 48V charger.

Once in a week the swing door of the carrier panel shall be opened and interior of the panel shall be cleaned free of dust and of cobwebs. If fans are provided, they shall be examined for any noise; the fans shall be lubricated periodically.

The above works are to be attended by the station maintenance staff. They may contact the Power Line Carrier communication staff wherever assistance is required. The maintenance of the Power Line Carrier Communication equipments such as carrier sets, PAX, etc., are governed by manufacturing standards and instructions issued from time to time by the Board.

GROUNDING PRACTICE

9
Grounding Practice

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9. GROUNDING PRACTICE

9.01 General

Provision of adequate earthing in a sub-station is extremely important for the safety of the operating personnel and equipments as well as proper system operation.

9.01.01 The resistance to earth of an electrode of given dimensions is dependent on the electrical resistivity of the soil in which it is installed. Earth conductivity is essentially electrolytic in nature and is affected therefore by moisture content of the soil and its chemical composition and concentration of salts dissolved in the contained water. Grain size and distribution and closeness of packing are also contributory factors since they control the manner in which the moisture is held in soil. The soil temperature also has some effect on soil resistivity but is important only near and below freezing point, necessitating the installation of earth electrode at depths to which frost will not penetrate. The site should be naturally not well drained. Electrodes should preferably be situated in a soil which has a fine texture and which is packed by watering and ramming as tightly as possible.

9.01.02 Effect of Moisture Content on Earth Resistivity

Moisture content is one of the controlling factors on earth resistivity. The moisture content is expressed in percent by weight of the dry soil. Dry earth weighs about 1440 kg/m^3 and thus 10% moisture content is equivalent to 144 Kg i.e. 144 litres of water per cubic metre of the dry soil. A difference of a few percent moisture will make a very marked difference in the effectiveness of earth connection if the moisture content falls below 20%. Above 20% moisture the resistivity is affected very little and almost constant. The normal moisture content of soil is about 10% in summer and 35% in wet season with an average of 16%.

Moisture alone is not the predominant factor in the low resistivity of soils. If the water is relatively pure it will be of high resistivity and unless the soil contains sufficient natural elements to form a conducting electrolyte the abundance of water will not provide the soil with adequate conductivity.

9.01.03 Effect of Temperature on Earth Resistance

Below 0°C the water in the soil begins to freeze and the frozen soil presents a decided increase in soil resistivity. In severe winter seasons the frost may penetrate upto 2 metres below the ground surface. This has the effect of shortening the active length of electrodes in contact with soil of normal resistivity.

9.01.04 Artificial Treatment of Soil

To reduce the soil resistivity immediately surrounding the earth electrode, it is necessary to dissolve in the moisture, normally contained in the soil, some substance like common salt which is highly conductive in its water solution. Approximately 90% of the resistance between a driven rod and earth lies within a radius of about 2 metres from the rod. The simplest application is by excavating a shallow basin around the top of the rod 1 metre in diameter and 30 cm deep and applying common salt in this basin. The basin should be filled several times with water, which should be allowed each time to soak into the ground. Thus common salt in electrolyte form diffuses throughout the effective cylinder of earth surrounding the driven rod. The salt content is expressed in percent by weight of the contained moisture. Salt content of 5% gives the maximum reduction in soil resistivity and further increase has no effect. Annual measurement of earth resistivity should be made and additional treatment given if necessary.

9.01.05 Potential Gradient

The step potential that appears across the feet and touch potential that appears across hand and feet should be as low as possible say of the order of 25 to 30 volts. This voltage drop is not however, always readily calculable, but the size of connection required for thermal consideration will in general be sufficient to keep these voltage-drops within safe limits. The resistivity of the various soil is given in the table below:

Sl. No.	Type of Soil	Resistivity in Ohm-metre
1.	Clay	20 to 60
2.	Sandy clay	80 to 200
3.	Sand	250 to 500
4.	Rock	10,000 and More.

The step and Touch Potential are given by

i) Step Potential E (Step) = $\frac{165 + Ps \text{ volts}}{\sqrt{T}}$ and ii) Touch Potential E (Touch) = $\frac{165 + 0.25\, Ps \text{ volts}}{\sqrt{T}}$ where

Ps = Soil resistivity in Ohm-metre just beneath the feet of a person.

T = Time in seconds to clear earth fault by the concerned breaker.

The Step and Touch Potentials may be lowered by reducing the mesh interval of the grid. Special attention should be paid to points near the operating handles of apparatus and potential equaliser grillages of closer mesh securely bonded to the structure and the operating handle, should be buried below the surface where the operator may stand when operating the switch.

9.02. Earth Electrodes

9.02.01 The main criteria for the electrode is that it should resist corrosion for a long time. It should also form close contact with the earth. The recommended materials are copper, copper clad iron, cast Iron and Galvanized iron. The various types of earth electrodes are (i) rod and pipe electrodes (ii) Strip or conductor electrodes and (iii) plate electrodes.

9.02.02 Rod and Pipe Electrodes

GI pipes or cast Iron pipes can be used for this purpose. These electrodes should have a clean surface not covered by paint, enamel or poorly conducting material. Rod electrodes of steel or galvanized iron, shall be at least 16 mm in diameter and those of copper shall be at least 12.5 mm in diameter. Pipe electrodes shall not be smaller than 38 mm internal diameter if made of galvanized iron or steel and 100 mm internal diameter if made of cast iron. Electrodes shall, as far as practicable, be embedded below permanent moisture level. The length of rod and pipe electrodes shall not be less than 2.5 metre. Except where rock is encountered, pipes and rods shall be driven to a depth of atleast 2.5 metre. Where rock is encountered at a depth of less than 2.5 metre the electrodes may be buried inclined to the vertical. In this case too the length of the electrodes shall be atleast 2.5 metre and inclination not more than 30^{o} from the vertical. Deeply driven pipes and rods are however, effective where the soil resistivity decreases with depth or where substratum of low resistivity occurs at depth greater than those to which rods and pipes are normally driven. Pipes or rods as far as possible, shall be of one piece. For deeply driven rods, joints between sections shall be made by means of a screwed coupling which should not be of greater diameter than that of the rods which it connects together.

To reduce the depth of burial of an electrode without increasing the resistance, a number of rods or pipes shall be connected together in parallel. The resistance in this case is practically proportional to the reciprocal of the number of electrodes used so long as each is situated outside the resistance area of the other. The distance between two electrodes in such a case shall preferably be not less than twice the length of the electrode. Small holes are driven in the pipe at 15 cm. intervals. Around the pipe, alternate layers of charcoal and salt are filled. This is to absorb and retain the moisture.

9.02.03 Strip or conductor Electrodes

Strip electrodes shall not be smaller than 25 mm by 1.60 mm if of copper and 25 mm by 4 mm if of galvanized iron or steel. If round conductors are used as earth electrodes, their cross-sectional area shall not be smaller than 3.0 mm^2 if of copper and 6.0 mm^2 if of galvanized iron or steel. The length of buried conductor shall be sufficient to give a required earth resistance. It shall however be not less than 15 metres. These shall be buried in trenches not less than 0.5 metre deep.

9.02.04 Plate Electrodes

Plate electrodes when made of galvanized iron or steel shall be not less than 6.30 mm in thickness. Plate electrodes of copper shall be not less than 3.15 mm in thickness. The size of plate shall be atleast 60 cm. Plate electrodes should be buried such that its top edge is at a depth not less than 1.5 metre from the surface of the ground- Wherein the resistance of one plate electrode is higher than the required value, two or more plates shall be used in parallel- In such a case two plates shall be separated from each other by not less than 8 m. Plate shall preferably be set vertically. Use of plate electrodes are recommended only where the current carrying capacity is the prime consideration, for example in generating stations and sub-stations. A pipe. rod or strip will have much lower resistance than the plate of equal surface area. The resistance is not inversely proportional to the surface area of the electrode. The diameter of an electrode has a minimum effect on the resistance of the electrode to earth connection because the same relative cylinder of earth is created for both a 1/2 inch and a 1 inch rod. The cross section specifications are concerned with maintaining fault current density, mechanical integrity and providing sufficient material in anticipation of corrosion and loss of metal. To increase the relative cylinder of earth the rod should go deeper into the soil. The resistance of rod or pipe electrode is given by

$$R = \frac{100\rho}{2\Pi l} \log_e \frac{(4 l)}{d} \text{ Ohms}$$

where

ρ = resistivity of soil in ohm-metre.
l = length of rod or pipe in cm.
d = diameter of rod or pipe in cm.

This formula also indicates that theoretical resistance to earth of a driven rod electrode depends to a large degree upon its buried length and to a lesser extent upon its diameter. When driven in a soil of uniform resistivity the resistance of a rod electrode decreases with depth but there is little to be gained by driving the rod to more than 3 to 3.5 metre.

9.02.05

The resistance of strip electrode can be calculated from the formula

$$R = \frac{100\rho}{2\pi l} \log_e \frac{(2 l^2)}{wt} \text{ Ohms}$$

where

ρ = resistivity of soil in ohm-metre,

l = length of the strip in cm,

w = depth of burial of the electrode in cm, and

t = width (in the case of strip) or twice the diameter (in the case of round conductor) in cm.

Consideration of the above formula will show that variation in the width of strip or depth of burial have little effect on the resistance value. It is recommended that the electrode should be buried at a depth of not less than 0.5 metre.

9.02.06 The resistance of plate electrode can be calculated from the formula

$$R = \frac{\rho}{4} \sqrt{\frac{\pi}{A}} \text{ ohms}$$

where

ρ = resistivity of soil in ohm-metre

A = area of both sides of plates in m^2.

In practice little gain is obtained by increasing the plate area of one side by more than 1.75 square metre.

9.02.07 The earth electrodes shall have low resistance depending on the system voltage and fault current envisaged under all climatic conditions. The rise in potential between the earth system and general body of the earth shall be kept as low as possible. The earth electrodes should be capable of carrying such currents as may arise in normal operation and during fault and surge conditions without undue increase in resistance. The electrodes shall be so placed that all lightning protective earth may be brought to the earth electrode by as short and straight a path as possible to minimise surge impedance. If the prospective fault current is high (more than 6 KA) plate electrodes may be used in which case it shall not be less than 1.2 x 1.2 metre size and of 12.5 mm thick if made of iron or steel or 6 mm thick if made of copper. As an alternative to plate in the above conditions, cast iron pipes not less than 100 mm in diameter, 3 metres long and not less than 12 mm thick may be used or mild steel pipes not less than 35 mm in diameter may also be used.

9.03 Earthing Grid

9.03.01 Each earthing conductor installed between structures or equipments and the grid shall be of copper or steel and have a cross sectional area not less than the value given below:

Fault current in Kilo amps.	Size of copper earthing conductor Cross section (in^2)
Not exceeding 22	1 1/2 x 3/16 (38.1 mm x 4.76 mm)
do - 30	1 1/2 x 3/16 (38.1 mm x 4.76 mm)
do - 44	2 x 1/4 (50.8 mm x 6.35 mm)

9.03.02 The minimum dimensions of the copper strip are based on the use of 1/2 inch (12.7 mm) bolt for connections. If bolts larger than 1/2 inch (12.7 mm) diameter are employed, the strip width shall not be less than 50.8 mm (2"). The use of steel ground rods and copper grounding conductors ensures a grounding system which is durable under normal condition of surrounding soil atmosphere and adjacent ground plates. Special measures may be required where corrossive soils are encountered. These may take the form of soil treatment, drainage or the use of special metals in the grounding system. The earth connection should carry a fault current for at least 1/2 a second and the area of the cross section in in^2 should be the fault current, divided by 15,000.

9.03.03 Joints

Joints should be kept down to a minimum number. All joints and connections to the earth grid shall be braced. Where bolted joints are used it is perferred that two 1/2" (12.7 mm) diameter galvanised steel bolts at 1 1/2" (38.1 mm) centres are used.

9.03.04 Arrangement of grounding conductors

A continuous grounding conductor should surround the station perimeter to enclose as much ground as possible. Additional grounding conductors should be laid in parallel lines at reasonably uniform spacing along rows of structures or equipment. Cross connection resulting in meshes should be provided for multiple paths especially from such points as transformer neutral connections. Typical size of meshes adopted is 4 metres by 5 metres.

9.04 Earthing of structures and Equipments: (within sub-station grid)

Atleast two legs preferably diagonally opposite on each metal structure shall be provided with an earthing conductor.

9.04.01 Isolators and switches

The handles of switches shall be connected to earth grid. A flexible earth conductor shall be provided between the handle and earthing conductor attached to the mounting bracket. The size of the flexible shall be 7/8" x 1/8" (22.23 mm x 3.18 mm) tinned copper, of nominal area 0-048 in^2 (30.97 sq.mm).

9.04.02 Lightning arresters

The bases of the lightning arresters shall be directly connected to the earth grid by conductors as short and straight as practicable to ensure minimum impedance. In addition, there shall be as direct a connection as practicable from the earth side of the lightning arresters to the frame of the equipment being protected.

Individual ground electrodes should be provided for each lightning arrester for the reason that large grounding system in itself may be relatively of little use for lightning protection. These ground electrodes should be connected to the main earth system.

In the case of lightning arresters mounted near transformers, earthing conductor shall be located clear off the tank and coolers in order to avoid possible oil leakage caused by arcing.

9.04.03 Circuit Breakers

The supporting structure of each circuit breaker unit shall be connected to the earth grid, P.T. tanks, C.T. chambers, busbar chambers and cable glands shall also be connected to the earth grid.

9.04.04 Transformer

Power Transformers

The tank of each transformer shall be directly connected to the main grid. In addition there shall be as direct a connection as practicable from the tank to the earth side of protecting lightning arresters.

The Transformer track rails shall be earthed either separately or by bonding at each end of the track and at intervals not exceeding 60.96 metres (200 feet)

9.04.05

The earthing of neutral bushing shall be by two separate strips to the earth grid and shall likewise be run clear to tank cell and coolers.

9.04.06 Current Transformers and Potential Transformers

In addition to earthing of bases, all bolted cover plates to which the bushings are attached shall be connected to the earth grid.

9.04.07 Ground wires

All ground wires over a station shall be connected to the station earth grid. In order that the station earth potentials during fault conditions are not applied to transmission line ground wires and towers, all ground wires coming to the station shall be broken at and insulated on the station side of the first tower or pole external to the station by means of 10" disc insulator.

9.04.08 Cables and Supports

Metal sheathed cables within the station earth grid area shall be connected to that grid. Multicore cables shall be connected to the grid atleast at one point. Single core cables normally shall be connected to the grid at one point only.

Where cables which are connected to the station earth grid pass under a metallic station perimeter fence, they shall be laid at a depth of not less than 762 mm (2'-6") below the fence, or shall be enclosed in an insulating pipe for a distance of not less than 1524 mm (5') on each side of the fence.

9.04.09 Panels and cubicles:

Each panel or cubicle should be provided near the base with a frame earth bar of 38.1 x 4.76 mm copper (1 1/2" x 3/16" copper) to which shall be connected the metal bases and covers of switches and contactor unit. The frame earth bar shall in turn be connected to the earth grid by an earthing conductor.

9.05 Grounding of sub-station fence:

9.05.01 The station fence should generally be far outside the sub-station equipment and grounded separately from the station ground. The station ground and the fence ground should not be inter-linked. To avoid any risk to the person walking near the fence inside the station, no metal part connected to the station ground, should be nearer to the fence than 1524 mm (5') and it is desirable to cover a strip about 5048 mm (10') wide inside the fence by a layer of crushed stone which keeps its high resistivity even under wet conditions. If the distance between the fence and the station structures cannot be increased to atleast 1524 mm (5') and if the fence is too near the sub-station equipment structures etc., the station fence should be connected to the station ground, as otherwise a person touching the fence and the station ground simultaneously would be subjected to a very high potential under fault conditions, when the fence is connected to the station ground the danger zone will be outside the fence.

In a fence very near to the station area, high shock voltages can be avoided by ensuring good contact between the fence sections and by grounding the fence at frequent intervals.

The station fence should not be connected to the station ground in general but should be grounded separately. If however, the fence is close to other metal parts of the station, it should be connected to the station ground.

Wherever fences are provided it should be ensured that they are atleast 1524 mm (5') away from the sub-station equipment and grounded separately. Care should also be taken to see that no metal part connected to the station ground is nearby this distance.

9.06 Maintenance

9.06.01 Records should be kept of the initial resistance of each earth electrode and of subsequent tests carried out. The station earths including the transformer and lightning arrester earths should always be maintained in very good condition as to present low resistance. Both the combined earth resistance and individual earth resistance or sub-station earths should be measured monthly at all stations by operation and maintenance staff and half yearly by MRT staff.

9.06.02 The earth connections at joints etc., should be checked monthly at all stations. The resistance of earth system shall not exceed the limits specified below:

Major sub-stations	1 Ohm
Other sub-stations	2 Ohms
Distribution Transformer Stations	5 Ohms

9.06.03 The sub-station yard should be covered with a layer of crushed stone of size 3 to 5 cm to a layer thickness of 8 cm to 10 cm. By this way the possible maximum value of shock voltage can be reduced by 50% to 90%. The stone layer helps to conserve moisture in the soil beneath and thus keeps down the soil resistivity. The stone layer also inhibits the growth of plants which might decrease the resistance beneath the feet and serves more or less as an insulated platform for the operating personnel who handle the switches. Further it prevents the spread of oil splashes. Sub-station operating staff must have good protective foot-wears and use gloves for manual operation of equipments in the sub-station yard. Growth of vegetations in sub-station yards should be removed then and there.

9.07 Transmission line tower grounding

9.07.01 Structure ground resistance of less than 15 Ohms provide line service with very few lightning outages. If footing resistance of more than 15 ohms are encountered grounding improvement is undertaken. The preferred maximum after improvement is 15 ohms but where this can not be obtained within reasonable cost, 25 ohms is tolerated before resorting to continuous counterpoise. Although generally accepted grounding methods are used in the department, special methods and techniques are necessary where poor grounding conditions are encountered. The various methods of grounding of transmission line towers are discussed below:

(a) Grounding rods are driven at the base of the tower to obtain a measured resistance of less than 15 ohms.

(b) If this is not feasible, an electrode location is sought within 60.96 metres (200') of the tower. If a resistance of less than 25 ohms can be obtained within 60.96 metres (200') the ground rods are provided at that point and tied to the tower base by a single buried wire.

(c) If a resistance of less than 25 ohms cannot be obtained within 60.96 metres (200') of the structure, crow-foot counterpoise with 4 wires is installed. The counterpoise conductors may be 6 SWG galvanised steel wire or wire ropes released from power stations. The four-wires are taken away from the tower mutually at right angles and are kept atleast 15.24 metres (50') apart. Each of the wires is terminated on a rod at the nearest point where a resistance of less than 150 ohms can be obtained.

9.07.02 If any of the counterpoise wires cannot be terminated within half a span from the tower, the wire is carried through a continuous counterpoise to the next tower, where the procedure is repeated starting with the first step.

9.07.03 When the crow foot counterpoise grounding wire is terminated on a resistance greater than 150 ohms, a positive voltage reflection returns from the termination to add to that portion of the surge voltage still present and results in a flash-over of insulation. For this reason no grounding conductor, including those of a crow-foot counterpoise is terminated except on an electrode with a resistance of less than 150 ohms.

9.08 Measurement of resistance of earth electrodes and soil resistivity

The detailed procedure for these measurement is furnished below:

9.08.01 Measurement of earth electrode resistance

a) Fall of Potential Method

In this method two auxiliary earth electrodes, besides the test electrode, are placed at suitable distances from the test electrode (see Fig 9.1) A measured current is passed between the electrode 'A' to be tested and an auxiliary current electrode 'C' and the potential difference between the electrode 'A' and the auxiliary potential electrode 'B' is measured. The resistance of the test electrode 'A' is then given by:

$$R = \frac{V}{I}$$

where

R = resistance of the test electrode in ohms,
V = reading of the voltmeter in volts, and
I = reading of the ammeter in amperes.

If the test is made at power frequency, that is, 50 c/s, the resistance of the voltmeter should be high compared to that of the auxiliary potential electrode 'B' and in no case should be less than 20,000 ohms.

Note In most cases there will be stray currents flowing in the soil and unless some steps are taken to eliminate their effect, they may produce serious errors in the measured value. If the testing current is of the same frequency as the stray current, this elimination becomes very difficult and it is better to use an earth tester incorporating a hand-driven generator. These earth testers usually generate direct current and have rotary current-reverser and synchronous rectifier mounted on the generator shaft so that alternating current is supplied to the test circuit and the resulting potentials are rectified for measurement by a direct-reading moving-coil ohm-meter. The presence of stray currents in the soil is indicated by a wandering of the instrument pointer, but an increase or decrease of generator handle speed will cause this to disappear.

The source of current shall be isolated from the supply by a double wound transformer.

At the time of test, where possible, the test electrode shall be separated from the earthing system. The auxiliary electrodes usually consist of 12.5 mm diameter mild steel rod driven up to 1 m into the ground.

All the test electrodes and the current electrodes shall be so placed that they are independent of the resistance area of each other. If the test electrode is in the form of rod, pipe or plate, the auxiliary current electrode 'C' shall be placed at least 30 m away from it and the auxiliary potential electrode 'B' shall be placed midway between them.

Unless three consecutive readings of test electrode resistance with different spacings of electrodes agree the test shall be repeated by increasing the distance between electrodes 'A' and 'C' up to 50m and each time placing the electrode 'B' midway between them.

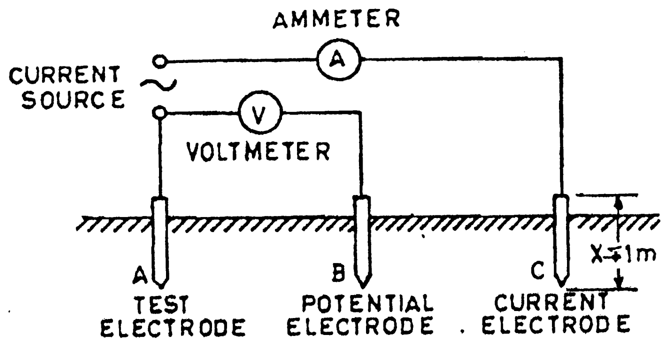

Fig 9.1
Method of measurement of Earth electrode resistance

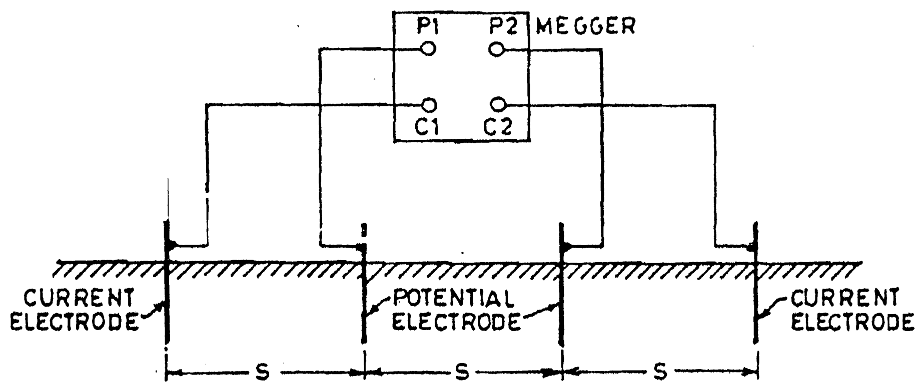

Fig. 9.2
Connections for a four terminal megger

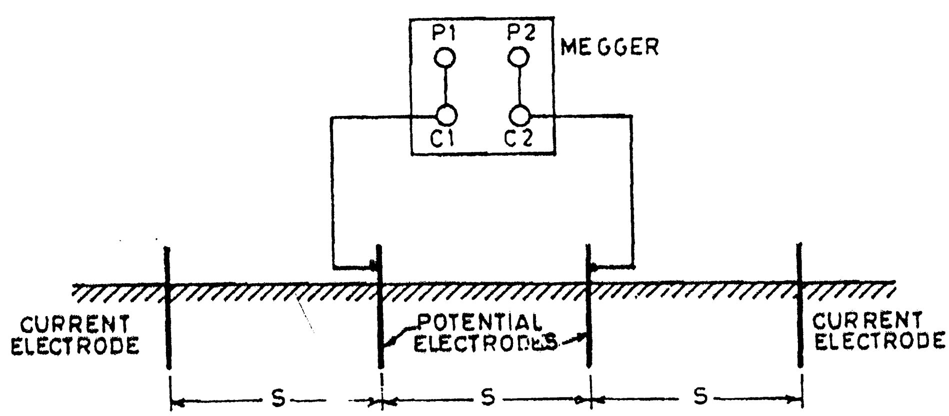

Fig. 9.3
Test connection to measure the sum of the Potential Electrode Resistances

(b) **Alternative Method**

The method described in (a) may not give satisfactory results if the test electrode is of very low impedance (one ohm or less). This applies particularly, while measuring the combined resistance of large installations. In these cases, the following method may be adopted.

Two suitable directions, at least 90 degrees apart, are first selected. The potential lead is laid in one direction and an electrode is placed 250 to 300 metres from the fence. The current lead is taken in the other direction and the current electrode located at the same distance as the potential electrode. A reading is taken under this condition. The current electrode is then moved out in 30-m steps until the same reading is obtained for three consecutive locations. The current electrode is then left in the last foregoing position and the potential electrode is moved out in 30-m steps until three consecutive readings are obtained without a change in value. The last readings then correspond to the true value of earth resistance.

9.08.02 Measurement of earth resistivity

(a) **Test Locations**

In the evaluation of earth resistivity for substations and generating stations, four or five test locations shall be chosen to cover the whole site. This number shall be increased for very large station sites or if the test results obtained at various locations show a significant difference, indicating variations in soil formation.

In case of transmission lines, the measurements shall be taken along the direction of the line throughout the length approximately once in every 4 km.

(b) **Weather conditions**

The resistivity of earth varies over a wide range depending on its moisture content. It is, therefore, advisable to conduct earth resistivity tests during the dry season in order to get conservative results.

(c) **Principle of tests**

Wenner's four electrode method is recommended for these types of field investigations. In this method, four electrodes are driven into the earth along a straight line at equal intervals.

A current I is passed through the two outer electrodes and the earth, as shown in Fig 9.2 and the voltage difference V observed between the two inner electrodes. The current I flowing into the earth produces an electric field proportional to its density and to the resistivity of the soil. The voltage V measured between the inner electrodes, is therefore, proportional to this field. Consequently the resistivity will be proportional to the ratio of the voltage to current.

The following equation holds for:

$$\rho = \frac{4s\pi \frac{V}{I}}{1 + \frac{2s}{\sqrt{(s^2 + 4l^2)}} - \frac{2s}{\sqrt{(4s^2 + 4l^2)}}} \qquad (1)$$

where

ρ	=	resistivity of soil in ohm - metre
s	=	distance between two successive electrodes in metres,
V	=	voltage difference between the two inner electrodes in volts,
I	=	current flowing through the two outer electrodes in amperes, and
l	=	depth of burial of electrodes in metres.

If the depth of burial of the electrodes in the ground 'l' is negligible compared to the spacing 's' between the electrodes then

$$\rho = \frac{2\pi sV}{I} \qquad (2)$$

Earth testers normally used for these tests comprise the current source and meters in a single instrument and directly read the resistance. The most frequently used earth tester is the four-terminal megger shown in Fig. 9.2.

When using such a megger, the resistivity may be evaluated from the modified form of equation (2) as given below:

$$\rho = 2\pi sR \qquad (3)$$

where

ρ	=	resistivity of soil in ohm–metres,
s	=	distance between successive electrodes in metres, and
R	=	megger reading in ohms.

(d) Test Procedure

At the selected test site, four electrodes are driven into the earth along a straight line in the chosen direction, at equal intervals 's'. The depth of the electrodes in the ground shall be of the order of 10 to 15 cm. The megger is placed on a steady and approximately level base, the link between terminals as p1 and c1 opened and the four electrodes connected to the instrument terminals as shown in Fig 9.2. An appropriate range on the instrument is then selected to obtain clear readings avoiding the two ends of scale as far as possible. The readings are taken while turning the crank at about 135 rev/min.

Resistivity is calculated by substituting the value of R thus obtained in equation (3). In case where depth of burial is more than 1/20 of spacing, equation (1) should be used instead of (3).

Correction for Potential Electrode Resistance:

In cases where the resistance of the potential electrodes (the two inner electrodes) is comparatively high, a correction of the test results would be necessary depending on its value. For this purpose the instrument is connected to the electrodes as shown in Fig.9.3. The readings are taken as before. The correction is then effected as follows:

Let the readings of the megger be R_p with the connections as shown in Fig.9.3 and the electrode spacings s metres. If the uncorrected value of soil resistivity is ρ' and the resistance of the voltage circuit of the instrument used to obtain R (as indicated inside the scale cover of the meter) is R_v the corrected value of earth resistivity would be

$$\rho = \frac{\rho' \,(R_p + R_v)}{R_v}$$

Testing Soil Uniformity

During the course of above tests, it would also be desirable to get information about the horizontal or vertical variations in earth resistivity over the site under consideration. The vertical variation may be detected by repeating the tests at a given location with a number of different electrode spacings, increasing from 1 metre to 50 metres or more, preferably in the following steps 1, 5, 10, 25, and 50 metres. If the resistivity variations are within 20 to 30 percent, the soil in the vicinity of the test location may be considered uniform. Otherwise a curve of resistivity versus electrode spacing shall be plotted and this curve further analyzed to deduce stratification of soil into two or more layers of appropriate thickness. For single rod and multiple rod installations, the resistivity value corresponding to an electrode spacing equal to the length of the rod may be used in the empirical formulae, with reasonable accuracy, for precalculation of resistance.

The horizontal variation may be found out by comparing corresponding resistivity values obtained along the line route.

9.09 General Earthing arrangements at substations

A typical earthing arrangement for an outdoor substation is shown in Fig.9.4

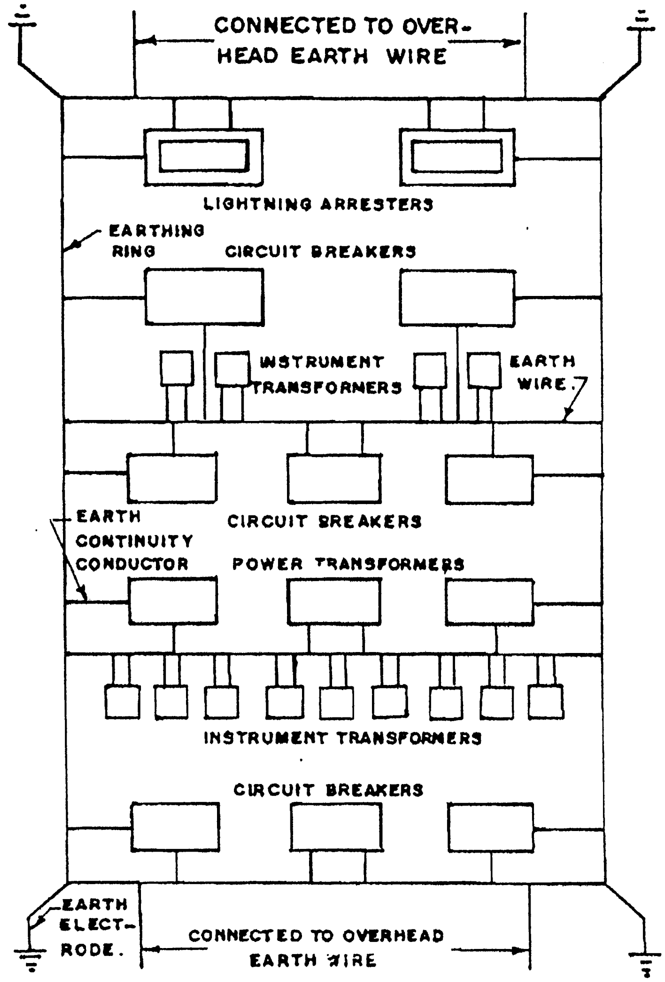

Fig. 9.4
A typical earthing arrangement for an outdoor sub-station

9.09.01 Substations Giving No External Low-Voltage Supply

Common earth electrodes should be used for both system earths and equipment earths. The items which need to be earthed separately from the main station earth electrode are the perimeter fence which are 2 m away from the earth bus and any coupling capacitors associated with carrier current equipment.

9.09.02 Substation Giving an External Low-Voltage Supply-(Excluding Pole Mounted Transformers) - The low-Voltage system neutral should be connected to the station earth system. The electrode resistance shall be sufficiently low to avoid, as far as possible the risk that an earth fault on the high-voltage system may cause a voltage rise of the neutral of low-voltage system and consequent damage on that system.

Low-voltage cables from a substation fed by high-voltage overhead lines shall be insulated within the resistance area of the substation earth electrode unless it has been assured that there is no risk of dangerous rise of potential.

9.09.03 Pole-Mounted Transformers – In the case of pole-mounted transformers on overhead line systems difficulties may arise in areas of high soil resistivity. Here, if the pole also carries isolating switchgear with low-level operating handle, up to three separately earthed electrode systems may be required:

a) For the neutral of the low-voltage system. It is usually provided at a pole one span away on the low-voltage line;
b) For the high-voltage metal work (transformer tank, switch framework, support metal work). It consists of one earth electrode at or near the pole; and
c) In addition, an earth mat shall be provided, near the ground surface, in the position taken up by a person operating the switch handle; this mat shall be connected to the switch handle. The mat shall be electrically separated from the main electrode; this is achieved by spacing the nearest element of that electrode at least one metre from the periphery of the mat and by placing the two earth wires on opposite side of the pole.

9.09.04 Substation Giving an External High-Voltage Supply

Here also it is recommended to have common earth bus for both high-voltage and low-voltage systems. Where there are manual operating levers for high-voltage switchgear it is recommended to connect the operating handle to the system earth electrode.

To remove any voltage gradient that may exist between the operating lever and the ground on which the operator stands, a metal grid should be placed just below ground level and shall be connected to the system earth electrode.

9.09.05 Earthing of Carrier-current equipment – A separate earth electrode generally a driven rod or pipe, should be provided immediately adjacent to the structure supporting the coupling capacitors. The earth connection thereto should be as short and free from changes of direction as possible. This earth shall be used only for the high frequency equipment. The structure supporting the coupling capacitors shall be earthed in normal way.

9.09.06 Earthing of Cables – Metal pipes or conduits in which the cables have been installed should be efficiently bonded and earthed. At specified points on the route where the presence of stray currents in suspected, the joints, the metal sheath and armour, if any, of the cables shall be bonded to the earthing system and connected to one or more earth electrodes. The cross-sectional area of every bond shall be not less than 65 mm^2 and in any case shall be such that the resistance of each bond connection shall not exceed the combined resistance of an equal length of metal sheath and armour, if any, of the cable.

9.09.07 Bonding single-core cables in trefoil formation

The method of bonding the metal sheaths of single-core cables in close trefoil formation shall preferably consist of sheet lead 3 mm in thickness and approximately 10 cm wide, wrapped round the trefoil cable assembly in such a manner as to make close contact therewith. The edges of the lead strip shall be bell mouthed so as to improve the wiped connection which shall be made at each side. Free ends of lead small be left so that connection can be made thereto by means of tinned copper strip between the lead ends and two outer copper backing strips. Three 8 or 10 mm galvanized steel or phosphor bronze bolts shall be used for the connection of the copper strip to the lead bond.

When buried direct in the ground the complete bond shall be enclosed in a creosoted wood box which shall be filled in solid with bituminous compound.

FIRE EXTINGUISHERS

10
Fire Extinguishers

CONTENTS

10. FIRE PROTECTION IN SUB-STATIONS

10.01 General

Fire can break out in any equipment in a Sub-Station. Power Transformers which contain large amount of oil are especially vulnerable. Fire in a transformer could be prevented by

i) Erecting & commissioning it as per manufacturer instructions.

ii) Preventing heavy short-circuit currents by proper maintenance of relays, batteries and control wiring.

iii) By keeping up the schedule of maintenance of tap changers and

iv) Avoiding maloperations like charging a transformer with the earth switch 'on'.

v) Adhering to the maintenance schedule and overhaul of transformers (where re-entrant type bushings are used, special care is to be taken during erection with the help of manufacturers).

The effect of fire in a transformer could be blunted by making provision for draining the transformer oil quickly into a sump at a safe distance. Otherwise the transformer could burn for several hours posing a hazard to other equipments. The explosion vent in the transformer should be directed away from other equipments cable duct etc.

Fire in one transformer should be prevented from spreading to others by erecting partition walls and plugging all cable ducts thereby preventing flow of oil or fire to nearby Transformers / equipments.

Power and control cables shall be segregated so that fire in one does not cause damage to the other. Naked flames shall be avoided in the vicinity of cable ducts. Welding, if any, near the cable ducts shall be done under the supervision of the Asst. Executive engineer.

After taking all precautions and keeping portable fire extinguishers ready, effective fire barriers shall be provided where the cables from switchyard enter the control room. It is good practice to pave the switchyard with broken stones which prevents burning oil flow and which reduces the step potential in case of earth faults.

Close liaison with the local Fire Departments of Govt. and other industrial organisations is to be maintained so that their assistance could be drawn to fight a fire. For this purpose the address and telephone number of the Fire Department should be exhibited in the S.S.

In respect of control rooms with central air conditioning, there must be provision for quick closing of dampers in the air duct during fire. Sprinkler type of fire protection system shall be kept in good repair by periodical test operations.

Halon 1301 systems find ready application in computer rooms, electrical and electronic control rooms, telephone exchanges etc. The life-safety property of the agent and its lack of residue or effects on operating computer equipment are primary reasons for this.

The most frequent cause of the fire protection system performing unsatisfactorily is mechanical malfunction of one or more system components - a valve in a bank of cylinder fails to open, a fire detector failing to act, a sprinkler getting choked up, a pump failing to start and inadequate water in sprinkler systems.

Portable fire extinguishers are generally reliable and shall be provided in adequate numbers in all sub-stations. Guide lines on portable extinguishers are furnished in detail in the following paragraphs.

Portable fire extinguishers are installed in all sub-stations and offices. These equipments are essentially 'first-aid' devices and as such they are not expected to deal with large fires. They are all very valuable in the early stages of fire when used promptly and effectively. Provision of unsuitable types. incorrect operation, improper maintenance of the extinguishers will lead to failure in tendering the fire effectively in the incipient stages, thus involving greater loss of life and property.

10.02 Installation

10.02.01 The extinguishers should be placed in conspicuous positions and shall be readily accessible for immediate use.

10.02.02 All extinguishers installed in a place should preferably have the same methods of operation. For example an "upright" extinguisher should not be installed near a "turn over" extinguisher. This will avoid confusion during the break out of a fire.

10.02.03 The passage leading to the fire fighting equipments should always be kept unobstructed. The fire buckets containing sand and water should be so located that travel distance is 15 metres from any point to reach them. It is desirable that a sketch indicating the location of fire fighting equipments and other useful information are displayed at suitable places.

10.02.04

(a) **In Open**

Fire extinguishers should be placed on masonary platforms or in wooden or metal cabinets in such a way that their bottom is 750 mm above the ground level. Suitable covers or shades should be constructed to protect the extinguishers in the open from excessive heat and cold unless they are housed in wooden or metal cabinets.

(b) **Inside a Building**

Fire extinguishers whether hung on brackets or kept on shelves should have their bottom 750 mm above the floor level.

10.02.05 Extinguishers fitted with hose may be used for tendering the fires in places which cannot be easily reached. A spray rather than a jet is more suited to cover a fairly large area. Surface fires in ordinary combustibles can be dealt with more effectively by a spray.

10.03 Types of Fire Extingishers

10.03.01 The types of fire extinguishers and their suitability for various classes of fires are lited below:

S.N.	Type of Extinguishers		Suitability
1.	Soda Acid	:	Suitable for fires involving combustible materials of organic nature such as wood, paper, rubber etc. only. *These extinguishers should not be used on fires involving FLAMMABLE liquids and energised electrical* equipments; also unsuitable for fires involving flammable gases and combustible metals.
2.	Chemical FOAM	:	Best suited to put out fires involving combustible materials of organic nature and flamable liquids like transformer oil. *They are not suitable for fires involving flammable gases* under pressure and combustible metals which are reactive to water and water containing agents. Foams are electrically conductive and therefore are *not recommended for use on electrical fires.*
3.	Dry Powder	:	This type of extinguisher is suitable for fire involving flammable liquids and flammable gases under pressure and also best suited for fires in electrical equipments. They are *unsuitable for fires involving combustible materials of organic nature like paper, rubber etc.* and also for fires involving combustible metals.

S.No.	Type of Extinguishers		Suitability
4.	Carbon-dioxide	:	-do- -do- it is ideally suited for electrical fires indoor equipments and not so effective in open air usuage.
5.	Fire Buckets Water (in a round bottom bucket of 10 litre capacity)	:	This method of fire extinguishing can be used when the cooling effect of water is essential for extinction of fires. (e.g.) fires involving paper, plastics etc. It is unsuitable for tackling liquid and gas fires and the fires in electrical equipments.
6.	Sand (in round bottom bucket of 10 litre capacity)	:	Sand can be used to extinguish fires where a blanketing effect is essential (e.g.) fires involving combustible materials of organic nature like wood, paper etc. and flammable liquids.

Note:

(1) When an energised electrical equipment is involved in a fire, the non-conductivity of the extinguishing media is of utmost importance and only dry powder or carbon-dioxide type fire extinguishers (without metal-horn) alone should be used. Upon de-energisation of the equipment, other types of extinguishers can be used, Water expelling type extinguishers like soda acid and foam type extinguishers should not be used on fires involving live electrical equipments under any circumstances.

(2) Use of Chemical foam is not desirable for fires involving alcohols and other water miscible flammable liquids. Dry powder type extinguishers should be used for dealing with such fires.

(3) Where cleanliness and contamination of sensitive electrical equipment are of importance, only carbon-dioxide type should be used

10.03.02 Departmental Norms for the Provision of Fire Fighting Equipments.

Furnished vide ANNEXURE. I.

10.04 Construction, Method of Operation and Principle of Working of various types of Fire Extinguishers

10.04.01 Soda Acid Type

i) **Construction**

It is the most commonly used water expelling type fire extinguisher. The various parts and contents of a soda acid extinguisher are indicated in Fig.10.2.

ii) **Method of Operation**

To operate the extinguisher, remove the guard cup and strike the plunger against a hard surface like the floor. Direct the jet emerging from the nozzle on the base of fire. Before proceeding to use this type of extinguishers, care should be taken to note that the extinguishers provided at a place are upright type or turn over type depending on their method of working.

iii) **Principle of Working**

When the plunger is struck, it breaks the acid phial (bottle) placed inside the extinguisher. As a result the sulphuric acid and sodium bicarbonate solution react together and release carbon dioxide and a solution of sodium sulphate mixed with water. The carbon dioxide generated creates the required pressure inside the cylinder and it forces the water as a jet out of the extinguisher.

Note:
The CO_2 acts only as a propellant and the sodium sulphate solution that comes out of the extinguisher extinguishes the fire by cooling effect.

10.04.02 Chemical Foam Type

i) **Construction**

It is made in a variety of sizes. The important parts and contents of a chemical foam type fire extinguisher (9 litre capacity) are given below. The extinguisher consists of two containers, the inner and the outer. The outer container holds a solution of sodium bicarbonate to which a foam stabilizer is added. The inner container (a long metal tube) has a solution of Aluminium Sulphate.

ii) **Method of Operation**

Remove the extinguisher from the socket. Pull the knob and turn the extinguisher over to ensure the mixing of two liquids. Then direct the jet of foam at the fire. Do not direct the jet directly into the liquid under fire since this will drive the foam beneath the surface and render it ineffective. Always direct the jet with a gentle sweeping movement so that the foam is allowed to drop down and lie on the surface of the liquid. Normally the jet from a foam extinguisher will have a length of atleast 6 metres.

Note:
Foam solutions are electrically conductive and therefore, are not recommended for use on electrical fires:

iii) **Principle of Working**

Extinguishing the fire is by blanketing or smoothening with a heavy layer of foamy substance consisting of largely tiny bubbles of carbon dioxide. When in operation, the sodium bicarbonate and the Aluminium Sulphate solutions inside the outer and inner containers intermixes producing foam and it is expelled from the extinguisher by the carbon dioxide gas produced in the reaction. The foam thus expelled forms a blanket over the surface of the burning liquid and cuts out its contact with the air and extinguishes the fire.

10.04.03 Dry Powder Type (Gas Cartridge Type) 10 kg & 22.5 kg

i) Construction

The construction of this type of extinguisher is shown in Fig.10.1. The chemical powder is stored in the main shell of the extinguisher and carbon dioxide gas is held under high pressure in a sealed cartridge.

ii) Method of Operation

Carry the extinguisher to the place of fire and keep it upright. Remove the safety clip and strike the knob located in the cap to actuate the piercing mechanism which in turn breaks the sealing disc of the cartridge. Direct the stream of escaping powder at the base of the flame. For effective result stand about 5 to 6 feet away and direct the stream near the seat of the fire. Progress forward, moving the nozzle rapidly with a side to side sweeping motion. On out door fires, always operate the extinguisher from the wind ward side of the fire to extend the effective range of the spray.

iii) Principle of Working

Sodium based chemical powders are generally employed and when applied to a fire, they undergo chemical reaction. The free radicals which are responsible for sustaining any fire, are put out of action by the dry chemical powders and as a result, the fire dies out very fast. When this extinguisher is operated, the cartridge containing the CO_2 gas is broken, allowing the gas to escape to the main shell and push out the dry chemical powder stored in the outer container in the form of fog. It is quite useful for quenching fires in out door equipments.

10.04.04 Carbon Dioxide Type

i) Construction

The principle parts of this extinguisher are shown in Fig.10.3 Carbon dioxide is retained in the cylinder as liquid under pressure. The cylinder is filled with the charge to about two thirds by weight of its total water capacity. Liquid carbon dioxide when released by trigger or valve sends out a shower of gas or snow which both cools and smoothens the fire.

ii) Method of Operation

Carry the extinguisher to the place of fire. Remove the safety pin and operate

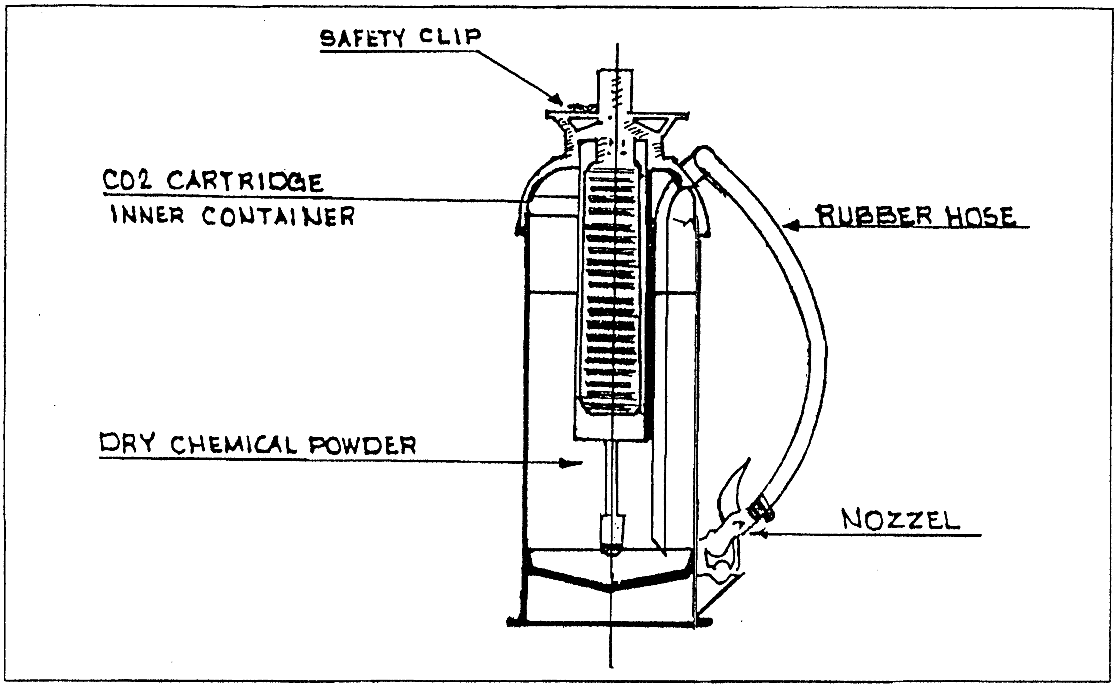

Fig. 10.1 Dry Powder Type Extinguisher

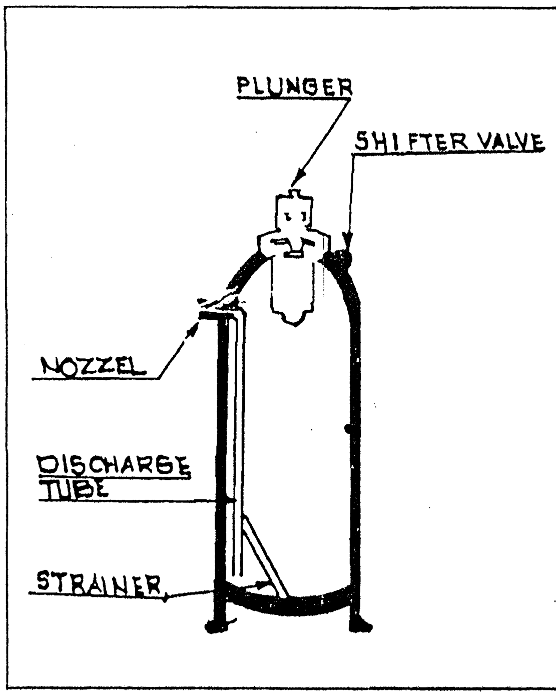

Fig. 10.2 Soda Acid Type Fire Extinguisher

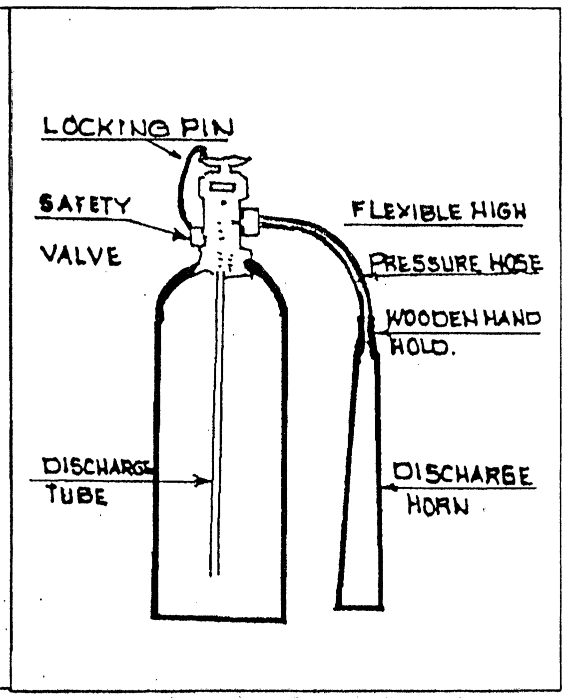

Fig. 10.3 Carbondioxide Type Fire Extinguisher

the discharge device or unscrew the valve depending on the designer. The CO_2 gas coming out of the cylinder is delivered by means of a discharge horn through a pressure flexible hose. Direct the jet at the base of the fire, starting at one edge and sweeping across the surface of the burning material. When used in open air, the operator should stand up-wind of the fire and apply the gas in downward direction as close as possible to the fire. On fires in electrical equipment first cut off the supply and then direct jet or horn straight at fire. The gas at the time of discharge makes considerable noise. The user should therefore be more careful to avoid the jet from being misdirected during the first a few vital seconds.

iii) **Principle of Working**

When the extinguisher is actuated the liquid carbon dioxide from the cylinder comes out with a considerable velocity into the atmosphere and vapourises, forming a layer of gas which is about 1 1/2 times heavier than air. The vapour blanket puts out fire by displacing the air and cutting off the oxygen supply needed to continue combustion. CO_2 is a non - combustible gas and it can penetrate and spread to all parts of the fire area.

Note: Carbon-dioxide extinguishers are not to be used in

i) Fires involving chemicals that contain their own oxygen supply.

ii) Fires involving reactive metals such as sodium, potassium and magnesium.

10.05 Maintenance, Inspection and Testing

10.05.01 General

Routine maintenance, inspection and testing of all fire extinguishers in respect of mechanical parts, extinguishing media and expelling means should be carried out at the prescribed time intervals. All the sand and water buckets should be filled with clean sand and water respectively at frequent intervals. The hose and nozzle connections should be checked to ensure tightness of joints. The procedure outlined below may be followed for maintenance, inspection and testing of all extinguishers so that it can be made sure that they have not been accidently discharged or lost pressure or suffered damage.

10.06 Work at Site

Work at site mainly consists of charging the extinguishers where necessary and placing them at appropriate locations. Each extinguisher should be allotted a special number by which it shall be referred to in the records. The following details should be painted with white paint on the body of each fire extinguisher.

a) Serial number.

b) Date of last refilling (Performance test)

c) Date of last inspection.

d) Date last leakage/pressure test:

The above details should be repainted every time the extinguisher is tested or inspected.

10.07 Records

The records of maintenance, inspection and testing of all first-aid fire extinguishers should be maintained in the register as appended below. One page may be allotted to each extinguisher:

a) Serial Number of the extinguisher

b) Type of extinguisher

c) Location

d) Date of installation and purchase order number if available.

S.No.	Date	Details of test, inspection and repairs	Remarks

Annexure-I
Departmental Norms

Sl.No.	Location	Type of Fire Fighting Equipment	Norms for Provision.
1.	400 KV. Sub-stations	a) Mulsifyre System of Protection or	1 No. for each 400 KV Transformer.
		i) Foam type fire extinguishers (Trolley mounted) 45 litres capacity.	2 Nos. for each 400 KV Transformer.
		ii. Dry chemical powder fire extinguishers (Trolley mounted) 22.5 Kg.	3 Nos. for each 400 KV Transformer.
		b) Foam type fire extinguishers (Trolley mounted) 45 litres capacity.	2 Nos. for the Switchyard.
		c) Dry chemical powder fire extinguishers (Trolley mounted) 22.5 Kg.	4 Nos. for the Switchyard.
		d) Dry chemical powder fire extinguishers (Trolley mounted) 10 Kg.	1 No. for each Circuit Breaker limited to a maximum of 3 Nos. irrespective of voltage, class, category, type etc.
		e) Dry chemical powder fire extinguisher (Trolley mounted) 10 Kg.	1 No. for a set of 2 CT/CVT/PT limited to a maximum of 5.
		f) Dry chemical powder fire extinguishers (Trolley mounted) 22.5 Kg.	2 Nos. for the control room.
		g) Dry chemical powder fire extinguishers (Trolley mounted) 22.5 Kg.	1 No. for Carrier Room located separately from Control Room.
		h) Dry chemical powder fire extinguishers (Trolley mounted) 10 Kg.	1 No. for D.C. Control Panel room.
		i) Dry chemical powder fire extinguishers – 5 Kg.	2 Nos. for D.C. Control Panel room.

Sl.No.	Location	Type of Fire Fighting Equipment	Norms for Provision.
		j) Dry chemical powder fire extinguishers (Trolley mounted) 22.5 Kg.	4 Nos. for Cable room.
		k) Fire Buckets – 10 litres – Sand.	8 Nos. for Cable room.
		l) Dry chemical powder fire extinguishers (Trolley mounted) 10 Kg.	1 No. for Battery room.
		m) Dry chemical powder fire extinguishers 5 Kg.	2 Nos. for battery room.
		n) Dry chemical powder fire extinguishers (Trolley mounted) 10 Kg.	1 No. for A.C. Plant room.
		o) Dry chemical powder fire extinguishers 5 Kg.	2 Nos. for A.C. Plant room
		p) Dry chemical powder fire extinguishers (Trolly mounted) 10 kg.	2 Nos. for Store-room.
		q) Fire Buckets – 10 litres – Sand.	10 Nos. for yard.
		r) Fire Buckets – 10 litres – Water.	10 Nos. for Battery room.
		s) Half drums filled with sand.	6 Nos. for yard.
2.	230 KV and 110 KV sub-station	a) Foam type fire extinguishers (Trolley mounted) 45 litres capacity	1 No. for a bank of 3 transformers.
		b) Dry chemical powder fire extinguishers (Trolley mounted) 22.5 kg.	2 Nos. for a bank of 3 transformers.
		c) Dry chemical powder fire extinguishers (Trolley mounted) 10 Kg.	1 No. for each Circuit Breaker limited to a maximum of 3 nos. irrespective of voltage, class, category, type, etc.
		d) Dry chemical powder fire extinguishers 5 Kg.	2 Nos. for the Control room.

Sl.No.	Location	Type of Fire Fighting Equipment	Norms for Provision.
		e) Dry chemical powder fire extinguishers 5 Kg.	2 Nos. for Carrier room located separately from control room.
		f) Foam type fire extinguishers – 9 litres capacity.	6 Nos. for the switchyard.
		g) Fire Buckets – 10 litres – Sand	2 x 4 Nos. for the switch yard.
		h) Fire Buckets – 10 litres – Water	4 Nos. for battery rooms with 110/220 V batteries.
		i) Half drums filled with sand	2 Nos. for yard.
3.	66 KV. and 33 KV Sub-stations.	a) DCP fire extinguishers (Trolley mounted) 22.5 Kg.	2 Nos. for a bank of 3 power transformers
		b) DCP fire extinguishers (Trolley mounted) 10 Kg.	1 No. for each Circuit Breaker limited to a maximum of 3 Nos. irrespective of voltage, class, category, type, etc.
		c) DCP fire extinguishers 5 Kg.	1 No. for the Control room.
		d) DCP fire extinguishers 5 Kg.	2 Nos. for the yard.
		e) Foam type fire extinguishers 9 litres capacity.	4 Nos. for the yard.
		f) Five Buckets – 10 litres – Sand.	4 Nos. for the yard.
		g) Fire Buckets – 10 litres – Water.	4 Nos. for the battery rooms separately located.
		h) Half drums filled with sand.	2 Nos. for yard.
4.	Capacitor Bank	a) DCP fire extinguisher (Trolley mounted) 10 Kg.	1 No. for each Bank of 1 MVAR or less.
5.	Indoor Sub-stations (33/11 KV)	Same as given for outdoor 33 KV Sub-stations.	

Sl.No.	Location	Type of Fire Fighting Equipment	Norms for Provision.
6.	Indoor Sub-stations (11KV/433V)	a) DCP Fire extinguishers 5 Kg.	3 Nos. for the Control room and Transformers.
		b. Fire Buckets – 10 litres – Sand.	4 Nos.
7.	Offices	a) Soda acid type fire extinguishers – 9 litres.	1 No. for every 1000 sq.ft. area with a minimum of 2 Nos.
8.	MRT Laboratory		
	i) Main testing centre	a) CO_2 fire extinguishers 4.5 Kg	3 Nos.
	ii) Regional testing centre	b) CO_2 fire extinguisher 4.5 Kg	1 No.
9.	Special Maintenance	a) Foam type fire extinguishers – 9 litres capacity.	3 Nos.
10.	Central Stores		
	i) Indoor sections	a) DCP Fire extinguishers 5 Kg.	2 Nos.
		b) CO_2 fire extinguisher 4.5 Kg.	1 No.
	ii) Outdoor Sections	a) Soda acid type fire extinguisher 9 litres	3 Nos.
	(where combustible materials like wooden	b) Fire Buckets – 10 litres – Sand.	4 Nos.
		(c) Half drums filled with sand	4 Nos.
	scrap, used tyres etc. are stocked)		

Sl.No.	Location	Type of Fire Fighting Equipment	Norms for Provision.
	iii) Trans-formers in stock	a) Foam type fire extinguishers 9 litres	3 Nos.
11.	Sub Stores		
	i) Indoor	a) DCP fire extinguishers 5 Kg.	2 Nos.
		b) CO_2 type fire extinguisher 4.5 Kg	1 No.
	ii) Outdoor	a) Fire Buckets – 10 litres Sand.	3 Nos.
		b) Hal drums filled with sand	2 Nos.

NOTE: (i) The yard stick proposed for the transformers need not be followed if mulsifire equipments are available.

(ii) Partition walls have to be built between tranformers.

Annexure II
Maintenance Schedule

S.No.	Type of Extinguisher	Monthly maintenance	Annual inspection (other than performance test)	Performance test	Pressure testing leakage testing	Remarks
I	II	III	IV	V	VI	VII
1.	Soda acid	a) Clean the exterior of the extinguisher, polish the painted portion with a little colourless wax polish, the brass/silver polish. b) Check the nozzle outlet and vent holes and the threaded portions of the cap for clogging. Check that plunger is in fully extended position and that it is clean and free. c) Check the cap washer grease the threads of cap plunger rod and wipe clean. d) Check all mechanical parts thoroughly. e) Make sure that the extinguisher is in proper condition and it is not accidently discharged.	a) Open the extinguisher withdraw the cage and remove the acid bottle and examine it for crack Check the main liquid level and empty the main liquid charge into a clean container. Remove acid bottle if cracked. Renew the main liquid Charge if level is appreciably reduced. Examine the extinguisher body internally and externally. Corroded and damaged parts should be replaced. Examine nozzles trainer Vent holes etc. and clean them properly. Check the operating mechanism for free movements and sealing washers for correctness and replace them if necessary. Clean the extinguisher internally and externally and return the original charge to the extinguishers and make up the level with water slightly less	a) Once in two years, Operate 50% of the extinguishers available in a place and observe their performance (There must be a jet of atleast 8 metres for a minimum 60 seconds) Recharge the extinguisher after the test. In case in this test more than 5% of the extinguishers selected for test fail, remaining extinguishers shall also be tested. The extinguishers shall be so selected that all are tested by rotation.	a) Once in two years this test should be conducted on all extinguishers. Before conducting the test, the extinguishers body should be examined for any sign of rust and corrosion and replace if it is rusted or corroded. Tests are to be conducted in accordance with the procedure prescribed in the relevant ISS. The extinguisher should withstand a test pressure of 17.5 Kg/Cm^2 (1.75pa) for 2.5 minutes without any leakage or visible distortion. The extinguishers which fail in this test should be replaced. Timing for annual test could be chosen with advantage.	

I	II	III	IV	V	VI	VII
2.	Foam (Chemical)	-do- In addition to the above monthly maintenance, once in a quarter dismantle the components; check for any damage, clean and grease them as required, stir the solution in the inner and outer containers with separate clean and dry sticks. Do not use the same stick for stirring both solutions and do not pour the solutions into any receptacle for stirring. By using two separate clean spoons pour one spoonful of liquid from inner and outer containers in open palm and check whether there is the formation of copious foam. If there is no foam at all, recharge the extinguisher immediately. Do not use the same spoon for both the solutions. Top up with clean and fresh water as necessary.	-do- a) Open the extinguishers check the liquid level. Pour liquid of inner and outer container in separate receptacle gently to see if there is any sediment at the bottom of two containers. Reject the charge if there is any sediment at the bottom of two containers. Reject the charge if there is sufficient sludge formation on two charges b) Examine the extinguishers externally and internally for any corrosion or damages. c) Examine nozzle, vent holes, cap washer, plunger disc and plunger rod for free movement and clean thoroughly. d) Return the original charges if it is in proper condition otherwise use new charges.	-do-	-do- (In this case of the extinguisher should project a distance of not less than 8 M for a minimum period of 30 seconds)	

I	II	III	IV	V	VI	VII
3.	Dry Chemical Powder	..do..	a) The dry chemical extinguishers should be opened in a dry room and for a minimum possible time to avoid the effect of atmospheric moisture on powder. b) If discharge control is fitted on the nozzle, it should be operated before opening the extinguisher so as to ensure that there is no pressure in the extinguisher. c) Weigh the extinguisher and compare its weight with that marked on its body as well as with the weight recorded in the register, when it was first put into service. d) Open the extinguisher and compare its weight with that stamped on its body, if a loss of 10% or more is noted, replace it with a new cartridge.	a. Once in 'three years', operate 50% of the extinguishers available in a place and observe their performance. In case more than 5% of extinguishers selected for the test fail, remaining extinguishers shall also be tested. The extinguishers shall be so selected that all are tested by rotation. b. Recharge the extinguishers after this test.	..do.. except that the test interval in this case is 'three years'	

I	II	III	IV	V	VI	VII
			e) Check the operating mechanism and discharge control for free movement and clogging. Examine nozzle hose, vent holes, piercing mechanism cap of cartridge holder, grease and wipe clean. f) Remove the inner shell and clean pert holes. Also check the pert holes, in the cartridge holder and clean them if necessary. g) Empty the dry powder in a dry container and examine for caking lumps and foreign matter if caking granulation is observed replace it with fresh dry powder charge. h) Examine the extinguisher body internally and externally for any damage or corrosion and replace corroded or damaged extinguisher. Clean the extinguisher using dry air. Return the original charge to the extinguisher and fit the cartridge and other fittings.			

I	II	III	IV	V	VI	VII
4.	Carbon dioxide	-do- The pressure gauge if any is to be checked for correct pressure.	a) Examine the extinguisher body externally damaged or corroded extinguisher should be replaced. Weigh the extinguisher. Compare its weight with that marked on its body for fully charged condition. It should be sent for refilling if a weight difference of 10% or more is observed. Clean and polish the external body of the extinguisher. Examine hose, horn and valve assembly and clean.	-do- Except the test interval which is 5 years	-do- except the test interval and test pressure to be followed for this test. For this type of extinguishers, the pressure leakage tests are conducted whenever the cylinders are sent for recharging. The test pressure adopted in this case is 21 pa (210Kg/Cm^2) for 2.5 minutes.	

SUB-STATION (GENERAL)

11
Sub-station (General)

CONTENTS

11. SUB-STATION (GENERAL)

11.01 General

A Sub-Station constitutes a nodal point in the transmission and distribution network of an electric power system. Basically it provides a point for controlling the flow of electric power along different routes by means of various equipments like transformers, circuit breakers etc.

1. The following layouts/charts shall be displayed conspicuously in the sub-station control room:

   i) Schematic electrical layout of the station with all equipment details.

   ii) A layout of the station earthing arrangement.

   iii) Layout of HT feeders with the details of all sectionalizing switches, spurline tappings, length and conductor sizes of main feeders, percentage regulation at Tail end etc.

   iv) Details of incoming 110/66/33 KV spurline in the case of sub-transmission sub-stations (Tapping point location, length, conductor size, impedence, distance between the tapping point and the main feeding stations).

   v) Peak loads on transformers and feeders. (Peak so far reached and the present peak), and Maximum and minimum bus voltage so far reached.

   vi) Fault levels at 110/66/22/11 KV buses during maximum and minimum generation periods.

11.02 Maintenance of Various Items in the Control Room

11.02.01 Details of Boards to be kept in the Control Rooms

(i) LC Key Board and normal key board with lock arrangements.

(ii) List of authorised persons to perform O&M works on the substation equipments.

(iii) Artificial respiration chart.

(iv) Duty Operator Board.

(v) Safety slogans.

11.02.02 The following approved instructions shall be available at the operator's desk in the control room:

(i) Operating instructions for issue of line clears on Equipments and Feeders.

(ii) Break down operating instructions.

(iii) Instructions for Emergency Operations (non-tripping of feeder breaker, group control breaker, DC supply failure etc)

(iv) Buchholz and differential relay operating instructions.

11.02.03 Accessories

Discharge rods, and earth rods conforming to the specifications in the Board Safety Manual, gloves, gauntlets, rubber mats, torch lights, petromax lights, emergency lamps, first aid box, fire fighting equipments, belt ropes, ladder, RED and GREEN Demarcation flags etc.

11.02.04 Books and Registers

i) Log Books,

ii) Maintenance Register on Equipments and battery.

iii) Failure and breakdown of Equipments.

iv) Relay operation and tripping.

v) Feeder tripping register.

vi) Relay setting register.

vii) Daily and monthly observations and

viii) Special observations (abnormal occurances) register.

11.03 Maintenance of Disconnecting Switches

All disconnecting switches should be inspected annually and maintenance works carried out as detailed below:

11.03.01 Insulators

(a) Switch insulators should be cleaned and examined thoroughly for any damage such as cracks, flashover marks, chipped portions, broken away cement, etc., chipped spots shall be repaired by painting with Glyptol lacquer.

NOTE:

i) If the insulators are subjected to excessive dirt or smoke, they may be cleaned with water or carbon-tetrachloride.

ii) Broken insulators should be replaced. Only insulators with slightly chipped portions should be repaired with Glyptol.

(b) Check base and cap bolts for tightness. Check for loose bolts or inadequate supporting structure.

11.03.02 Contacts

(i) Clean the contacts and examine them for wear.

(ii) Check pressure of springs in contact and hinge and replace if not adequate.

(iii) Examine flexible shunts and replace if frayed.

(iv) See that the blades are properly aligned to engage contacts.

(v) Check condition of contacts and refinish with fine file if burnt or corroded. Lubricate contacts with graphite grease or petroleum jelly. Operate switch several times and check that full contact is maintained.

11.03.03 Arcing Horns

(i) Check arcing horns on air break switches to see that they are not bent out of shape and are properly adjusted.

(ii) Clean horns if burnt.

11.03.04. Operating mechanism, latches, interlocks, connexions, etc.

(i) Examine operating mechanisms for ease of operation and proper travel. Examine also for lost motion, mechanical connexions and excessive deflection of controls or mounting.

(ii) See that rods, levers and cranks are in serviceable condition and repair as necessary. Lubricate pivots, bearings interlock cams and gears. Flush out oil or lubricate with grease as necessary. Operate switch a few times after lubrication to ensure smooth operation.

(iii) Check break distance, clearances between live parts and travel.

(iv) Check latches for proper engaging and holding of blade against opening force.

(v) See that stops are in place and tight. This is specially necessary in the case of tilting type air break switches as the stops are intended to absorb the shock of operation. If the stops are not adjusted properly, the post type unit of the switch might fail.

(vi) Check and tighten all bolts, screws and lock nuts.

(vii) Examine bimetallic junctions, if any, between the switches and busbars etc., irrespective of the fact whether the junction is aluminium-copper, aluminium galvanised iron or copper galvanised iron.

(viii) Check and tighten line terminals and operating handle ground connexions. Check that ground cable is not broken.

(ix) Check mechanical interlocks such as between main disconnecting switch and ground switch for fool proof operation.

(x) See all switch locks for security, positiveness and ease of operation.

11.03.05 Periodical Testing

Where an insulator tester is available, test all switch insulators once in five years and record results. Any defective insulator revealed by the tests should be replaced.

11.04 Schedule of Inspection and Maintenance of Station, Bus, Instrument Transformers and other Auxiliaries

Name of apparatus	Details	Periodicity for inspections.
1. Yard, bus-bars, support insulators, air break switches, fuses, contacts etc.	(a) Examining post and switch insulators, Busbar expansion joints etc. Cleaning contacts and lubricating bearings-swivel pins of AB switches.	Half yearly or during pre-arranged shutdowns.

Note:

Check if all parts are mechanically tight on AB switches etc. In case tilting post type switches, the adjustment stops should be checked since they are intended to absorb the shock of operations. If the stops are not adjusted properly the AB switch post type unit may fail. All AB switch locks should be tried occasionally and kept in a ready and useful condition. Interlocks should be checked periodically.

Name of apparatus	Details	Periodicity for inspections
	(b) Examination of bimetalic junctions if any between AB switches or busbars to line (irrespective of its being Aluminium-copper, Aluminium-galvanised iron, copper-galvanised iron).	Yearly
2. Potential transformers	(i) Cleaning of bushings	Weekly or at every opportunity during prearranged shutdown.
(a) 110 KV and 66KV Potential Transformers	(ii) Checking oil level in tank.	-do-
	(iii) Checking oil level in bushings.	-do-
	(iv) Breathers inspection, Cleaning removal, or reactivating of drying medium	As for power transformers.
	(v) Filtering of oil.	-do-
	(vi) Testing of oil samples	Half Yearly.
	(vii) Checking of gap settings.	-do-
(b) 11, 22 and 33 KV potential transformers	(i) Cleaning of bushing	Weekly or at every opportunity during prearranged shutdowns.
	(ii) Checking oil level	Quarterly or during shutdowns.
	(iii) Reconditioning or replacing oil.	Once in five years or when oil test results are bad. In the case of outstations without testing facilities or when the quantity of oil is small, the oil may be renewed (completely).
	(iv) Testing oil Samples.	Half Yearly.

Name of apparatus	Details	Periodicity for inspections
3. Current Transformers:		
(a) Oil filled CT's	(i) Checking oil level.	Quarterly or when shutdowns are arranged.
	(ii) Replacing of oil	
	(a) 11,22 and 33 KV CTS	Yearly
	(b) 230,110 and 66 KV CTS	Oil samples may be tested every six months and oil may be replaced if test results are not satisfactory.
(b) Air cooled CTS and compound filled CTS	L.T. secondary wiring megger testing and inspection of wiring.	Yearly.
4. Insulation resistance.	Conducting megger tests for transformers P.Ts, C.Ts. boosters, generators, motors etc.	Monthly or when shutdowns are arranged for other works. In recording the reading it should be noted whether the apparatus is hot or cold, the temperature being given wherever possible. At 60°C, the I.R. value should be 2 Megohms/K.V. at lower temperature the I.R. Value should be correspondingly more. The insulation resistance of power Transformer, should be taken with a 1000 volts megger immediately after the transformer is switched off after a load run and the temperature at which these insulation resistances are meggered should also be noted.

TRANSMISSION LINES

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12
Transmission Lines

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12. TRANSMISSION LINES

Special attention on the maintenance of Transmission System of the Board is necessary in view of the fact that many of the transmission lines have completed more than 40 years of service and their continued satisfactory performance has to be kept up.

Maintenance works of Transmission lines are categorised below:

12.01 Maintenance of Right-of-way, Jungle Growths etc

12.01.01 Inspection must be done in detail before the onset of monsoons. During the rainy seasons the inspection must be done once in a month positively.

Jungle growth should be immediately cleared to maintain required right-of-way and to keep the growth away from the fall-off distances of the Towers.

12.01.02 The Assistant Engineer should cover all the EHT lines at least twice in a year, the Assistant Executive Engineer at least once in a year, the Executive Engineer at lest 50% in a year and the Superintending Engineer whenever possible.

12.01.03 A register (called Jungle clearance Register) should be maintained for this work wherein all the details of the inspection, important points noted and remedial measures carried out should be entered. The format furnished as Appendix III may be followed in the register.

The register must be periodically reviewed and it should be ensured that the periodicity is maintained meticulously. Any back-log should be cleared and the register made upto date periodically.

12.02 Tower Footing Examination

12.02.01 It should be ensured that the tower-foots (Stubs) are provided with adequate coping so that stagnating rainwater or slush do not come into contact with the Tower legs. As there will be a tendency for the ground level in the cross country to rise due to addition of manure, made up earth etc. the tower footing must be constantly checked. Contamination with slush and rain water will cause rusting and corrosion of Tower members to the detriment of the very safety of the Towers.

12.02.02 Tower leg inspection must be done to a quarterly schedule so that all the Tower legs are inspected in a calender year-such Inspection must be faithfully recorded. The inspection must be intensive during the rainy season and the irrigation season when the fields are expected to be water-logged.

12.02.03 Whenever contamination is observed, it should be cleared and the Tower leg coping redone. The coping height has to be increased suitably to ensure that the metallic parts are definitely above the water level or slush level.

12.02.04 Tower Foundation

a. Inspection of Tower Foundation may be made at random once in 3 months to assess the condition and to initiate remedial action wherever necessary.
b. Whenever there is heavy rain or storm, foundation shall be checked at vulnerable locations.

12.03 Tower Inspection

12.03.01 The towers should be inspected at regular intervals to ensure that all the Tower members are intact wherever they are found missing, immediate action should be taken to replace the missing parts.

12.03.02 Wherever thefts of tower parts are found to be very frequent, action may be taken to convert the bolted joints into welded joints.

12.03.03 Special patrols must be arranged to check the theft of tower members with the help of the local police so that an awareness can be inculcated in the minds of the public about the vigil being kept as this will instill a sense of involvement in them and they will also help towards prevention of such thefts.

a. Wherever tower members are not galvanised, action should be taken to examine the members periodically and repaint them when deterioration of painting or consequent rusting is observed.
b. A time-bound schedule should be prepared for such repainting-repainting of all such towers should be completed once in 5 years as a routine maintenance besides touching up rusted parts now and then.
c. In highly polluted areas and Saline areas, it is preferable that rubberised painting of towers is adopted instead of galvanising.
   Rubberised painting is expected to last for 50 years whereas galvanising may stand for 15 years.

12.04 Insulators (both at suspension and at tension parts)

12.04.01 All the insulators should be inspected with binoculars and chipped insulators should be replaced promptly; wherever feasible hot-line techniques should be adopted for this work.

12.04.02 Wherever insulators are liable for contamination and coating caused due to environmental conditions (like saline or chemical exhaust from factories), a time-bound programme should be drawn to replace these insulators. The released dirty insulators should be arranged to be cleaned and got ready for replacing elsewhere. The dirty released insulators should be moved to the lines section yard where this programme of cleaning must be carried out as a continuous process.

12.05 Line Conductors

12.05.01 During every inspection (premonsoon, regular or Breakdowns) the conductors of the line should be inspected with a binocular and the following points should be examined.

i. Hot spots
ii. Condition at Joints
iii. Distortion of Strands

Immediate remedial measures must be taken after availing line clears wherever necessary. Till such time lineclear become available, by-pass arrangements should be arranged for at these points utilising hot line accessories.

12.06 Parallel Groove Clamps

12.06.01 Use of P.G. Clamps has been dispensed with. However in old lines, where P.G. Clamps are still in service, the following points should be checked whenever line shut downs are availed:-

i. Check that P.G. clamp is connected on the slack side of the conductor. On no account should the P.G. clamp be left connected to the tension side of the conductor.
ii. Open out and inspect the P.G. clamp. Before reassembly, the contact surfaces should be prepared properly and set to ensure permanent and efficient connection.
iii. The contact surfaces of the clamp and conductor where the clamp is applied, should be liberally coated with suitable grease (shell Corbula F.H. 14, Graphite grease or Lanoline grease), and then abraded through the coating with a wire scratch brush.
iv. The clamp should then be assembled on the conductor without removal of the grease, in order to seal up the interstices inside the clamp against the entrance of oxidising or corrosive agents.
v. The groove at the sides and ends of the clamp should be filled with the grease for further protection.
vi. After filling up the clamp with grease as detailed above, tighten the clamp to the conductor adequately.
vii. A record of such inspection and action taken should be maintained. A

consolidated report on this should be sent to the H.Qrs. Office annually along with other reports on inspection of Transmission lines.

viii. The line staff should be instructed and educated to observe specially the P.G. clamps during patrol and note down suspected locations. The suspected locations should be attended to at the earliest opportunity.

12.07 Compression Joints

The compression joints at the jumpers and the conductor joints must be inspected at regular intervals and during breakdown inspection. Any tendency for the conductor to come out of the compression joints should be noted carefully, recorded and remedial measures taken immediately.

12.08 Granding Rings

The grading rings provided on the insulator strings should also be inspected and their satisfactory condition recorded. Any abnormality should be recorded and immediate arrangement made to replace the grading rings.

12.09 Stock Bridge Dampers

The position of the stock bridge dampers in the three phases may be checked and confirmed that they are uniformly placed. In case they are found disturbed they must be restored to their correct positions after availing line clear. This is very important because any shifting from their original position will affect their damping effect and will defeat the purpose for which they are provided. Any abnormal observations noted and the remedial measures taken thereto may be recorded.

12.10 Earthing

12.10.01 All the points mentioned for the phase conductors shall be checked in the case of the earth conductor also.

12.10.02 In case the earth resistance values around the towers are not satisfactory and any remedial measures have been taken, it shall be checked that these remedial measures are in-tact. In case they are disturbed or distorted immediate action should be taken to restore the original condition.

12.10.03 Particular care should be taken wherever counter poise earthing arrangement is provided. All observations made should be recorded so that future comparative studies are made feasible.

12.10.04 In general, Earthing arrangements in towers should be checked at least once in six months.

A comprehensive check list for inspection of EHT lines viz. various aspects as outlined above is furnished in Appendix I.

Appendix I
Check List for Inspection of E.H.T. Lines

Name of the Feeder :

No. of Circuits :

Voltage KV Locations Inspected: From: To:

No. of Locations : Conductor: Copper/ACSR.

Date of Commissioning: Size :

1. Provision of phase sequence plate/Number plate. If it is a road side tower, whether plate with legend of the feeder is provided. :
2. Accessibility of the tower :
3. Bottom space of the tower (Is it clear of bushes and other weed?) :
4. Tower Foundations:
   a. Signs of external damage :
   b. Settled/washed out soil :
   c. Tilted stubs :
   d. Slippage of stubs from encasing chimney concrete :
   e. Uneven settlement of footings :
   f. Disappearance of gravel blanket projection. :
   g. Damage to embankment, retaining walls, abetments :
   h. Disappearance of external earth backing :
5. Defects in Structures (Indicate whether it is G.I.M.S.)
   a. Leaning structures :
   b. Deformed members :
   c. Buckled structures :
   d. Missing fasteners and members :

e. Accessories removed :

f. Peeling off paints :

g. Corrosion of tower members :

h. Missing/Damaged/Broken earth strip :

i. Other defects like rusting loose step bolts, corrosion of step bolts etc. :

6. Tree Clearance

a. All tall trees within 12m on either side of the lines and all trees which on falling would foul the line are to be cut.

All bush growth 6m on either side to be completely cleared :

Grafted fruit trees which will not grow tall may be left out :

b. Fallen branches/trees to be cleared :

7. Bird nests/creepers/bits of wires and kites to be removed :

8. Flashed over insulator/disc. to be replaced. :

9. Chipped/broken insulators to be replaced. :

10. Deposits of contaminants on the insulators (which require immediate clearing) :

11. Missing locking devices like nuts, washers to be replaced :

12. Burnt out fittings :

13. Deflected strings :

14. Missing/Displacement of arcing horns, Missing/Displacement of armour rod condition of wire armour rod at suspension point and also the condition of ferrule pieces :

15. Loose jumpers and jumpers out of shape :

16. Flash-over marks in X arms :

17. CONDUCTORS:

   a. Nicking or abrasion at the compression joints/compressed surfaces :

   b. Strands cut and opened up in phase wire and suspension/tension points :

   c. Bulging/reduction in the sectional area of the conductor. :

   d. Strands cut and opened up earth wire. :

   e. Blackening or pitting of the conductor. :

   f. Condition of horn gaps at terminal. :

   g. Black patches on the line near the suspension clamp mouth. :

18. Reduction of electrical clearance due to construction works :

19. Details of buildings, huts, embankments/fencing constructed below the lines. :

20. Unusual sag in any phase conductor. :

21. PRONE TO POLLUTION:

   a. Fog whether insulators are used or not. :

   b. Protective Grease is applied or not. :

   c. Damage to protective coating if any is noticed. :

   d. Insulators require replacement. :

22. a. Whether bird guards are provided, if prone to bird faults :

   b. Whether the tower locations are prone to lightning :

   c. Whether lightning arresters are necessary for the line entrance points at the terminal stations. :

23. Reduction of size/corrosion is noticed in the stem of the insulator. :

24. Breakage of strands of the conductor at the clamping point of damper is checked / condition of dampers at tension points. Slipping Displacement of damper. :

25. Ground clearance of the line Adequate/Inadequate. :

26. Vertical & Horizontal clearance of the line from the nearby rock if the line passes through a hilly region/nearby building structure if it passes through urban areas, earth dumps. :

27. Unusual/loose sag :

28. Condition of spacers if it is a bunched line :

29. Condition of P.G. clamps (tightness) if they are provided :

30. Condition of earth wire whether it is provided with 'D' shackle or Hook. :

31. Location of HT/LT line (beneath/side ways) whether adequate vertical/horizontal clearance is available between the conductors of EHT line and that of HT/LT line. :

32. While patrolling, look for deepening of nearby wells by blasting :

33. Any other defects. :

Appendix – II
Maintenance Schedule for EHV Transmission Lines

Sl. No.	Work to be carried out.	Periodicity	Action required if inspection shows unsatisfactory condition.
1.	Maintenance of right-of way, jungle growths etc.	Once a month during rainy season.	Jungle growths should be immediately cleared to maintain the requisite right-of way.
2.	Checking of hot spots along lines at locations of conductor joints and clamp joints.	Once in 3 months.	Immediate repair of very hot joints. Other hot joints should be repaired at the earliest opportunity.
3.	Checking for damaged insulators, vibration dampers etc.	Once in 3 months.	Damaged insulators should be replaced by hot-line techniques immediately. Polluted insulators should be washed. Similarly damaged vibration dampers must also be replaced.
4.	Checking members on towers, conditions of foundations.	Once in 3 months	Missing members on tower structures should be replaced immediately. For foundations, if water logging/erosion and such other defects are noticed, dewatering/making of necessary embankments and repair work must be carried out immediately. Inspection of foundations should also be carried out soon after heavy rains/storm.
5.	Earthing	Once in 6 months	Take suitable action if the earthing resistance is high.

Sl. No.	Work to be carried out.	Periodicity	Action required if inspection shows unsatisfactory condition.
6.	Pre-monsoon Inspection (Inspection of P.G. clamps, Compression joint. Insulators, Dampers, arcing horns, Tower Earth wire, Hardwares etc. - Inspection of spacers, bunched conductors, check up of gap setting at terminal towers and hair-line cracks broken/chipped to be checked.	Once in a year	Take appropriate action to rectify the defects noticed in insulators, clamps etc.
7.	Inspection for insulator polluted regions	Once in a quarter preferably from January.	Polluted insulators should be hand wiped. If the situation warrants, apply protection greases/replace the contaminated insulators,

Appendix – III
Format for Jungle Clearance (j.c.) Register

Date of Inspection	Officer Inspecting	Section Inspected	Observations Made	Rectifications Carried Out	Remarks	Signature of Inspecting Officer

Appendix – IV
Format for Recording Results of Periodical Inspection of Conductors and Dampers of Transmission Lines

Month	Date	Total Number	Circuits		Phases			Clamps		Black patches or lines about the suspension clamp mouth
			1	2	Red	Yellow	Blue	Tension	Suspen-sion	
1	2	3	4	5	6	7	8	9	10	11

Conductors

Nicking or abrasion at the compressed surfaces.		Number of strands broken				Corrosion	
		Suspension Points		Tension Points			
Outer layer	Inner layer	Outer layer	Inner layer	Outer layer	Inner layer	Bulges, brittleness or reduction in sectional area of conductor	Blackening or pitting of conductor.
12	13	14	15	16	17	18	19

Dampers					
At suspension points		At Tension Points			Remarks
Type	Number per Span	Type	Number pr span	Perfor-mance	
20	21	22	23	24	25

DISTRIBUTION SYSTEMS

13
Distribution Systems

CONTENTS

13. DISTRIBUTION SYSTEMS

13.01 Choice of conductor

Distribution system should be operated such that there is proper voltage regulation at all tail ends of the lines under maximum load conditions. The choice of conductor for a HT and LT distribution is primarily decided by this consideration. The distribution network configuration, No. of feeders, sizes of conductor on various lines shall be reviewed from time to time and reinforced to keep pace with the load growth. Even so, it may be necessary to keep the voltage of the distributors at the 33 KV, 66 KV or 110 KV substations at higher levels, making optimum use of the tapchangers available on the power transformers. As palliative measures, boosters may be operated along the HV distribution lines.

13.02 Insulators

Reliability is another important criterion and it should be ensured that insulators and other accessories, of proven quality are used in construction of lines. The dry and wet flash over values of insulation used in distribution lines should not be less than the values given below:

Description		Flash over voltage KV	
		Dry	Wet
i.	33 KV strain and suspension insulators	170	120
ii.	33 KV Pin insulators.	140	100
iii.	22 KV Pin, strain and suspension insulator.	120	85
iv.	11 KV pin insulators, strain and suspension insulators	85	50
v.	L.T. Pin and shackle insulators for use on 400/230 volts in units.	25	12

13.03 Clearances

From the view points of safety and fault-free operation, the statutorily laid-down clearances should be scrupulously followed:

13.03.01 Line to ground clearance

The height from the ground of the bottom most conductor of distribution lines and service lines should not be less than the following under most severe conditions of temperature and wind.

	Vertical clearance to ground in feet			
	400 V / 230	11KV	22 KV	33KV
a) Places inaccessible to vehicle traffic and elsewhere than along or across any street.	13 (4.0m)	15 (4.58m)	17 (5.20m)	17 (5.20m)
b) Along streets	18 (5.5m)	19 (5.8m)	19 (5.8m)	19 (5.8m)
c) Across streets	19 (5.8m)	20 (6.1m)	20 (6.1m)	20 (6.1m)

13.03.02 Clearance to Buildings

A. Medium and low voltage lines and service lines:

Power lines should not be taken over buildings as far as possible and every effort should be made to divert the line away for all buildings. Where, however, buildings cannot be avoided, the minimum clearances specified in Rule 79 of I.E.Rules 1956 extracted below shall be maintained.

"1. For any flat roof, open balcony, verandah, roof and lean to roof.

i) When the line passes above the building a vertical clearance of *8 feet* (2.5m) for the nearest point.

ii) When the line passes adjacent to the building a horizontal clearance of 4 *feet* (1.25m)."

"2. Any conductor so situated as to have a clearance less than that specified above, shall be adequately insulated and shall be attached by means of metal clips at suitable intervals to have earthed bearer wire having a breaking strength of not less than 317.5 Kg (700 lbs)

"3. The horizontal clearance shall be measured when the line is at a maximum deflection for the vertical due to wind pressure."

B. **Clearances for Building of H.V. lines.**

1. Where a H.V. overhead line upto and including 33KV passes above or adjacent to any building or part of a building it shall have a maximum safe vertical clearance of not less than 12 feet (3.75m) above the highest part of the building immediately under such line.
2. The horizontal clearance between the nearest conductor and any part of such building shall on the basis of maximum deflection due to wind pressure be not less than

a)	for HV lines upto and including 11 KV	=	4 feet (1.25m)
b)	for HV lines above 11KV and upto and including 33KV	=	6 feet (1.85m)

C. **Clearance between lines of different or same voltage on independent supports.**

If lines of different voltages or same voltages carried on independent supports. the supports should be so located that the clearance between the lines is not less than the height of the taller support.

D. **Clearance between LT & HT line carried on the same supports**

Where HT & LT lines are run on the same supports the minimum distance between the lines shall be

a)	LT line & 11KV line	=3 feet (0.92m)
b)	LT line & 22KV or 33KV line	=5 feet (1.5m)

If 2 or more lines are carried on the same pole the higher voltage line shall be erected above the lower voltage line.

E. **Clearance between HT lines of the same voltage carried on same supports**

Clearance between circuits (Vertical formation)		Phase to phase of each circuit	
11 KV	.. 3'-6" (1.07m)	3'-0"	(0.91m)
22 KV	.. 4'-6" (1.37m)	3'-6"	(1.07m)
33 KV	.. 4'-6" (1.37m)	4'-6"	(1.37m)

F. **Minimum clearance to be adopted at crossings of lines may be as follows:**

i) Crossing between Power and Departmental communication lines:

Minimum clearance between bottom-most Power conductor and top-most conductor of communication lines.			Minimum clearance between communication lines and the ground wire where used.	
LT lines	—	4'-6" (1.37m)	3'-6"	(1.07m)
11 kV	—	5'-0" (1.5m)	4'-0"	(1.25m)
22 kV	—	5'-0" (1.5m)	4'-0"	(1.25m)
33 kV	—	5'-0" (1.5m)	4'-0"	(1.25m)

ii) Crossing between Power lines:

Minimum clearance between lines

11 or 22KV line Crossing LT line	4 feet (1.25m)
33KV line crossing LT line	5 feet (1.5m)
11, 22 or 33 KV line Crossing 11, 22 or 33KV line	5 feet (1.5.m)

G. Clearance between lines when crossing at mid span and at pole.

An overhead line crossing below another overhead line at a point between 2 poles carrying the upper line, shall not under any conditions, have less than following clearances between the conductors of such lower line and the nearer of the 2 poles of the upper line according to the voltage of the lower line.

a)	Low voltage lines	..	4 feet. (1.25m)
b)	H.V. lines	..	6 feet. (1.85m)

Where the conductors of the lower line are attached to insulators fixed to the poles carrying the upper line, the above clearance shall not apply.

H. Clearance between lines and guard wires:

a)	for L.V. lines	..	1 feet (0.3m)
b)	for H.V. lines		
	i) 11KV	..	1 1/2 feet (0.46m)
	ii) 22KV	..	2 feet (0.61m)
	iii) 33KV	..	3 feet (0.91m)

Note: Provisions of Rule 88 of I.E Rules shall be satisfied for the guarding wires.

I. Clearance between Power and Telephone line on the same supports.

Rated voltage of line.		Vertical clearance
11KV	..	5 feet (1.5m)
22KV	..	6 feet (1.85m)
33KV	..	7 feet (2.14m)

J. Distance of separation between communication lines belonging to P & T Department and Power lines.

33Kv	..	400 feet (121.92m)
22KV	..	300 feet (91.44m)
11Kv	..	200 feet (60.96m)

K. Permissible limit for induced voltage on Telecom lines paralleling Power lines (HT & LT)

The Electromagnetic induced voltage on the Telephone/Telegraph/Railway signalling lines of the P&T Department, in the event of an earth fault on the paralleling power line is limited to 430 volts, for P&T lines not involving signalling circuits, the induced voltage due to parallelism may be limited to 650 volts.

L. Crossing of Departmental HT and LT lines with the Communication lines of P&T Department.

Wherever Departmental HT & LT lines cross communication lines of P&T Department, the regulation given in the code of PTCC should be followed.

M. Tree Clearances:

Minimum Tree clearances required for distribution lines of various voltages are furnished below:

No.	Lines	Tree clearance required.	Relaxation
1.	L.T.lines 230-400 volts.	Left to the discretion of the field staff.	Nil
2.	11KV Rural lines	All growth within 15 feet (4.5m) on either side from centre line of support and all trees which, on falling, are likely to foul the lines.	In the case of betel leaf garden, all the growth within 10 feet (3.0m) on either side of the line only need be cleared.
3.	22KV Rural	All growth within 18feet (5.55m) on either side from centre line of support and all trees which, on falling, are likely to foul the lines.	-do-
4.	11KV&22KV lines and 33KV Rural lines.	All growth within 20 feet (6.1m) on either side from centre line of supports and all trees which on falling are likely to foul the lines.	-do-
5.	33KV Trunk lines.	All growth within 25 feet (7.6m) from the centre line of support and all trees which on falling are likely to foul the line.	In the case of betel garden, all the growth, within 15 feet (4.5m) on either side of the line only need be cleared. Eucalyptus tree growth must be closely watched and cleared when found necessary.

13.04 Data for Mechanical design

13.04.01 Wind Pressure

i) On Conductors:

a) Interior regions	:	15 lb/sq.ft. (75kg/m^2) on 2/3rds projected area of the conductor.
b) Coastal areas	:	20 lbs/Sq.ft. (100Kg/m^2 on 2/3rds of the projected area of the conductor.

ii) On supports

a) Interior Region	:	25 lb/sq.ft (125Kg/m^2) in 1 1/2 line projected area of one face of lattice steel structures and towers. 25lbs/sq.ft. (125kg/m^2) in 2/3rd projected area for tubular supports, RCC poles etc.
b) Coastal area	:	Instead of 25 lbs (11.36Kg) adopt 30 lbs (13.6KG) on the above.

13.04.02 Sag and Tension

a. The maximum permissible sag of the conductor depends upon the span, size of the conductor and the range of temperature. A temperature range of 50° to 150°F may be assumed for sag calculations.

b. In calculating sags and tensions, allowance should be made for elasticity and co-efficient of expansion of the conductor.

c. *Span*: The maximum permissible span for the various sizes of conductors and the various types of supports should be decided based on the strength of the supports, wind pressure, ground clearance etc. In the case of L.T. (Single phase or 3 phase) overhead lines erected in, over along or across streets, the I.E. rules prescribe that the intervals between supports should not exceed 220 feet (66.73m). In Town or village distribution schemes, where street lighting is also involved, the span should normally be 150 feet (45.49m). In cases where H.T. and L.T. lines are taken on the same supports, the span should not normally exceed 220 feet (66.73m) but relaxation upto 300 feet (90.98m) may be allowed for rural lines.

The maximum working load on the insulators shall not exceed.

Shackles	..	1800 lbs (818KG)
Pins	..	600 lbs (272.7Kg)

13.05 Guys

Guys are provided at any point where there is an unbalanced strain in the line such as at angles and dead ends. Guys are fixed at an angle of either 30° or 45° to the vertical. The horizontal component of the tension in the guy wire is equal to the sum of the tension of the conductor. Guy wires should be designed for a factor of safety of 2.5 on ultimate strength. Stay wires of galvansied steel (7/2.50) of 4500 Kg minimum breaking load quality is adopted. In cases, where larger working strength is required suitable sizes and quality may be proposed. Guy insulators should be provided in all guys in urban and village areas accessible to people irrespective of the system voltage. The guy insulator should be so located that, if the guy breaks, the insulator shall hang below the lowest conductor. The minimum height of the guy insulator above the ground shall not be less than 10 feet (3.0m).

13.06 Earthed screen between HT and LT lines

An earthed screen should be provided between HT and LT lines carried on the same poles within Municipal and Town limits and such other inhabited places. In cases of rural lines such earthed screen are not necessary.

13.06.01 Road crossings

Where HT Distribution lines cross National Highway, a tension point may be provided on one side of the line as far as possible with a comparatively short span. The use of bridlug cross arms (with double insulators) is not considered necessary for rural lines.

13.06.02 Special devices for effectively earthing snapped conductors and rendering the line dead shall be provided on L.T.lines.

i) At road crossings in Cities, Towns and other thickly populated areas and Main Trunk road crossings: The L.T. line may be brought to a triangular formation with two phase wires and the neutral split into 2 carried on a 3 phase cross arm. Cross lacings may be suspended from the two neutral wires at intervals of 3 feet (0.91m). With this arrangement any broken wire will fall in the cradle formed by the neutral wires and the cross lacings and blow out the fuses on the lines.

ii) *At crossings of roads and cart crossings in rural areas:* An angle piece of size 1" X 1"X1/4" (2.54cm X 2.54cmX0.63cm) and about 2' - 9" (0.834m) long carrying a 3/8" (0.95cm) MS or GI rod fixed at its end and extending for about 2' (0.61m) on either side of the pole may be fixed on each pole of the crossing span about 1'6" (0.45m) below the conductors. The 1" X 1" X 1/4" (2.54cm X 2.54cm X 0.63 cm) angle iron cross arm should be connected to the neutral conductor by means of a short conductor so as to ensure proper connection to neutral when the conductor snaps and falls on the GI rod and positive blowing out of the HG fuses on the line.

iii) At crossings of foot paths, bridge paths etc. fork guarding may be provided. The guard may be with No. 8 GI wire held lightly under the shoulder of collar of the pin insulator, against the cross arms.

13.07 Earthing of Distribution lines

13.07.01 H.T. Line.

i) *Lines carried on Metal poles.*

Every fifth pole and all supports provided with mass or block concrete foundation shall be earthed.

ii) *Lines carried on RCC & PSC Poles.*

The metal cross arm and the insulator pins should be bound together and earthed at every pole.

13.07.02 L.T. Lines with Multiple Earthed Neutral

i) *Lines carried on Metal Poles.*

Every fifth pole and all supports provided with mass or block concrete foundation shall be earthed.

ii) *Lines carried on RCC and PSC Poles.*

The metal cross arm and the insulator pins shall be bound together and earthed at every fifth support.

Note: When the cross arm is of RCC, the insulator pins should be bound together and earthed.

13.07.03 All special structures carrying switches, transformers, fuses etc. shall be earthed.

The lightning arrester earth shall have an earth connection to the body of the transformer tank.

13.07.04 The supports on either side of the road, railway, a river crossing span shall be earthed.

13.07.05 All supports (Metal, Wood or RCC) of both LT and HT line running through inhabited location and along such other places where earthing of all poles is considered desirable by the field staff on safety considerations shall be earthed.

13.07.06 It is imperative that the earthing provided shall be good and maintained with as low a resistance as possible as otherwise the earthing is of no value.

13.07.07 Whenever transmission or distribution lines pass close to a well or a permanently moist place, an earth shall be provided in the well or the marshy place and connected to the transmission or distribution line support.

13.07.08 Earth resistance

The ohmic resistance of the earth should be as low as possible and should not in any case exceed 25 ohms.

13.08 Painting of Distribution line supports and cross arms

13.08.01 R.S. Joists and tubular poles in all locations and rail poles in cities, Towns and major Panchayats-Bottom portion upto 1 1/2 foot (0.45m) above G.L. shall be given 2 coats of anticorrosive black paint. The portion above GL shall then be given a coat of red lead or such other approved type of primer. After erection at site, the portion above GL shall be painted with one coat of I.S.I. quality aluminium paint.

13.08.02 Rail poles in Minor panchayats, villages and rural areas-no painting is necessary for the upper portion.

13.08.03 Cross Arms

All metal cross arms shall be painted with a primary coat of red lead or such other approved type of primer at the works. This may be followed by a coat of grey or black paint after erection at site.

13.09 Isolation and Protection of Distribution lines

HT lines are normally protected by circuit breakers at the substation. Sectionalising switches may be provided on primary circuits at intervals; these switches may be located with consideration to accessibility, proximity to roads etc. Branch or spur lines less than 2 kms in length need not be protected with fuse. Wherever these fuses are provided, they must be of proper rating and have adequate co-ordination with upstream fuses or relays on the feeder in the substation. Fuses should not be provided on industrial feeders.

13.09.01 LT lines are protected with fuses at the distribution transformer station or other locations. As far as possible, the size of the fuse wire shall be just adequate to take the load on the line and at the same time blow out immediately for snapped conductor or other faults on the line.

13.09.02 All HT distribution lines shall be provided with distribution or line type L.A's at the S.S. end for protection of the station equipment. Each L.T. feeder from a distribution transformer need not be provided with a set of LA.

It would be adequate if one set of LA is used for each distribution transformer at the bushing terminal, if the capacity of Transformer is 50KVA or above.

13.09.03 Distribution type LA's should be provided at

i) all H.T. metering points.

ii) on the HT side of all distribution transformers of capacity 50KVA and above.

iii) At junction of overhead HT lines and long cables, when the cable length exceeds 150 feet.

13.10 Route of Distribution lines

i) Route of the lines should be chosen along and in the close vicinity of main highways, consistent with site conditions and limitations.

ii) Straight line alignment should be secured as far as possible and long spans adopted; winding sectors of the roads may be bypassed for this purpose.

iii) Distribution lines run along the highways should be run on the same side of the road, to avoid crossing and to allow the use of the other side for communication or other lines.

iv) The maximum distances for the reerection of poles and for laying of cables on road margins:

a) 22 feet (6.67m) from the centre of the road for National Highways and Provincial highways and

b) 11 feet (3.33m) from the centre of the road for major district roads and other district roads

v) Lines run on secondary roads should be located a short distance from the right-of-way to permit widening of the road and the use of guys.

vi) The route of the lines should be, as far as possible such that the shortest distance between the supply points and loads are secured and back feeds towards source are eliminated on branch lines.

vii) Close parallelism with communication lines should be avoided.

viii) Regulations regarding erection of power lines in the vicinity of airports and temporary landing grounds should be followed both for LT and HT lines.

ix) Railway lines should be crossed outside station limits. Crossing span should be short so as to obtain required clearance over the rails.

x) Telegraph and Telephone lines should be crossed preferably at 90° and wherever it is not feasible, the Telephone or Telegraphic lines may be deviated.

xi) Route of the distribution lines must be marked on scale map of the locality showing complete details of roads, streets etc.

xii) Routes of distribution lines rated at 33KV should be got approved by chief engineer.

xiii) Routes of 33KV distribution lines running parallel to Telegraph and Telephone lines of the P&T Department should be got approved by P.T.C.C.

13.11. Distribution Transformer Station

13.11.01 Normal ratings of distribution transformers are 25, 50, 63, 75, 100, 150, 200, 250 & 500KVA.

13.11.02 Temperature rise

Temperature rise shall be

i) by oil Thermometer — 40°C over ambient temp.

ii) by winding thermometer — 50°C over ambient temp.

13.11.03 Fluctuation in voltage and frequency

Transformer may be subjected to variation of voltage upto ±12 1/2% on HT side and of frequency upto ±3CPS.

13.11.04 Lightning protection for Distribution transformer

Lightning Arrester should be provided for distribution transformer of capacity 50KVA and above. Adequate lightning protection depends upon.

i) the selection of distribution transformer and other equipment that have adequate insulation strength.

ii) the selection of arrester which are so efficient that they will limit the lightning stresses well below the standard impulse level of transformer.

13.11.05 Earthing at Distribution transformer station

Distribution transformers should be provided with 3 separate pipe earths. Transformer tank, AB switch down-rod, transformer secondary Neutral and structure should be connected by means of 2 separate earth leads - LA'S should be connected separately to the third earth pit which should be interconnected to the other two earths. The LA earth lead should be connected to the transformer body earth also.

13.12 Services

13.12.01 In the case of LT single phase service, the consumer NEED NOT provide a separate earth in the form of an earth pipe or earth electrode driven into the ground, but he shall connect up his equipment to the departmental neutral terminal made available at his premises.

13.12.02 In the case of LT 3 phase service, the consumer's equipment shall be earthed by two separate and distinct connections with earth, of which one may be the multiple neutral terminal made available by the department, at the consumer's premises and other a separate pipe earth. The consumer shall also interconnect his earthing system with departmental earth terminal.

13.13 Maintenance of Distribution systems

13.13.01 Schedule of periodical inspection of lines

Designation of staff	Trunk lines (33 KV)	Branch and rural lines (22 KV & 11 KV)
LM, WM or LI	Once in a month.	Once in a month
AE or JE	Once in a month	Once in 3 months.
AEE	Once in six months.	Branch lines yearly-Rural lines whenever possible.
E.E.	Yearly	Whenever possible.

Note: Common to all lines.

1. After every tripping-inspection by lines staff.
2. Every line B.D. to be checked afterwards at site by AE.
3. Premonsoon inspection by AE or JE.
4. Additional inspection depending upon locality and circumstances.

13.13.02 Maintenance Schedule for Distribution Transformers

Sl.No.	Work to be carried out	Person responsible for the work	Person responsible for the completion of the work.
1.	2.	3.	4.
I Monthly			
1.	(a) Maintaining the transformer yard and the earth-pits neat and tidy and watering the earth-pits. (b) Cleaning the entire transformer including the bushings (c) Checking the oil level and reporting if the level is below the mark (d) Checking for oil leaks and reporting if any noticed. (e) Checking the earth connections (f) Reconditioning the breather (by reactivating silicagel or replacing it if necessary) (g) Checking the LT fuses and renewing them if necessary	Area Wireman	Line Inspector/ Foreman
2.	Topping up oil where necessary	Lineman	Line Inspector/ Foreman
II Quarterly			
1.	Renewing the H.G. Fuses	Lineman	Line Inspector/ Foreman
2.	Measuring the insulation resistance	Line Inspector Foreman	Section Officer
3.	(a) measuring the load current (b) Measuring the voltage at the transformer and at the tail-ends of the feeders	Section Officer	Assistant Executive Engineer

1.	2.	3.	4.
III Annual			
1.	(a) Lubricating the AB switches and checking their operation (b) Checking the line and earth connections of AB switches (c) Checking the line and earth connections of the LT lightning arresters. (d) Checking the HV and LV bushing connections	Lineman	Line Inspector/ Foreman
2.	Getting the oil samples tested for dielectric strength	Line Inspector/ Foreman	Section Officer.
3.	Measuring the earth resistance	Section Officer	Assistant Executive Engineer.

NB:

1. The Assistant Executive Engineer should inspect every distribution transformer in the Sub-division once every year and ensure that maintenance works are carried out as per this schedule.

2. The Section Officer should inspect every distribution transformer in the section once every quarter and ensure that maintenance works are carried out as per this schedule.

3. The Line Inspector/Foreman should inspect every distribution transformer in his jurisdiction once every month and ensure that maintenance works are carried out as per this schedule.

UNDERGROUND CABLES

14
Underground Cables

CONTENTS

14. UNDERGROUND CABLES

14.01 Different Types of Cables

14.01.01 The following are the types of cables generally used in Tamil Nadu Electricity Board

A. Solid Type – A cable insulated with solid insulant without any device to maintain internal pressure.

i. Using paper as insulant.

a.	Draining type	Belted type (upto 11 KV) 'H' type (11 KV - 33 KV)
b.	Mass Impregnated Non-Draining type (MIND)	S.L. type (33 KV).

ii. Using P.V.C. as insulant (For L.T. Cables only)

iii. Using XLPE as insulant (11 KV - 110 KV).
Korattur - East Anna Nagar U.G. Feeder is 110 KV - XLPE.

iv. Using Low Density Poly Ethylene as insulant (230 KV).

B. **Pressure Type Cables – Any paper insulated cable maintained under a positive** pressure (Oil/gas). Oil filled cable of 110 KV grade is used in Madras city (R.A.Puram - Chinthadripet - Vyasarpadi).

14.02 Handling, Transport and Storage of Cable Drums

14.02.01 Handling

A movable crane of suitable capacity is best suited for handling the cable drums. The drum is to be slung evenly while lifting. The angle of the sling at the hook shall not be greater than 60°. Greater angle may cause a break down of the sling and/or crushing of the cable drum at the top. For unloading the cable drum, from a truck, crane/ramp is to be used. Dropping the drum from the truck should be strictly avoided as it causes damages to the cable.

14.02.02 Transport

While transporting the drums, they are to be tightly fastened with rope. Providing wedges to the cable drums is necessary to avoid rolling about of the drums during transit. Moving the drum for short distances of about 10 mts. can be resorted to by rolling the drum in the direction of the arrow indicated on the flange. In such cases, the surface on which the drum is rolled should be hard, levelled well without any protraction, undulation etc.

14.02.03 Storage

The site chosen for storage of cable drums should be well drained and should preferably have a concrete/firm surface. All the drums should be stored in such a manner as to leave sufficient space between them for air circulation. It is desirable for the drums to stand on battens placed directly under the flanges. During storage the drums should be rolled to an angle of 90^{o} once every three months. In no case, the drums should be stored on the flat sides; when storing is for along period, the drums should be protected from sunlight. While rewinding cable to another drum, the barrel of new drum should not be less than the original drum. The ends of the cable should be sealed with end caps.

14.02.04 Laying

1. The desired minimum horizontal clearances as given below may be maintained:

a. Power Cable to Power Cable	Clearance not necessary; however, larger the clearance, better would be current carrying capacity.
b. Power cable to control cables.	0.2 m.
c. Power cable to Communication cable	0.3 m.
d. Power cable to gas/water main	0.4 m.

2. The minimum depth of laying from ground surface to the top of the cable shall be as follows:

a. Low voltage and control cables	0.75 m.
b. 11 KV cable	1.2 m.
c. 33 KV cable	1.2 m.
d. 110 KV cable	1.5 m.

3. The bends of the cable trenches should not have a radius less than the minimum bending radius of the cable laid in that trench.

14.02.05 Jointing

1. Before and after the jointing work, insulation resistance is to be measured and the HV DC test shall be conducted.
2. The jointing in all circumstances should be carried out under a tent in a clean atmosphere. Cleanliness while handling the insulation is very important. Any contamination of the insulation by dust, moisture (sweat) is detrimental to the joint.
3. Correct quality and size of jointing materials and accessories like ferrule, solder, insulating compound, heat shrinkable kit shall be used.

14.02.06 Protection

1. Adequate lightning protection shall be arranged for all cables of 11 KV class and above.
2. A secure ground system shall be provided for all cable routes.
3. Overloading of cables should always be avoided as it reduces its service life.
4. All the three single core cables should be run in the same duct.
5. In the case of single core cables, transposing should be done at one-thirds and two thirds of the total length.
6. The armours of the single core cables should be bended together and earthed.

14.02.07 Ordering

In the control room of power houses and load despatch centres, fire-resistant - low-smoke (FRLS) cables of adequate capacity shall be used.

14.03 Maintenance

1. Insulation resistance and HVDC tests shall be conducted periodically on 11 KV & 33 KV feeders and a record of these results shall be maintained to have an idea of the remaining useful life of the in-service cable.
2. In the case of 110 KV oil filled cables the following maintenance works shall be carried out:

i. Daily

a. Checking the execution of civil works near the cable route.

b. Recording the oil pressure of cable, load on the cable and ground temperature.

c. Check the power supply to alarm indicating panel and healthiness of the indication circuit.

ii. Monthly

a. Observing the termination ends of the cable for:

1. Damages or Pollution of Sealing ends.
2. Soundness of connection of earth leads.
3. Deformation of the exposed cable due to external damage.

iii. Yearly

a. Visual inspection of Link box whether water ingress is found or not.

b. Check the soundness of connecting leads.

c. If something unusual about the oil pressure is reported check the following:

1. Sealing ends
2. Oil feeding pipes
3. Valves
4. Connectors
5. Oil pits
6. Oil feeding tanks
7. Oil detection pipes.

In the case of 110 KV XLPE cable, the maintenance works indicated in (i) (a), (ii) (a), (iii) (a) and (b) are to be followed:

14.04 Testing of Cables

The following tests are to be done on the cables in service.

i. **110 KV XLPE and Oil Filled Type:**
   Yearly (a) Power Cable Sheath.
   i. Measuring of insulation resistance of anti corrosion sheath using 500V Megger.
   ii. D.C. Test: 5 KV DC is to be applied between sheath/screen and earth for a period of 1 min.
   b. Surge divertor: Measuring insulation value by using 1000 V Megger.

ii. 33 KV & 11 KV: The Cable shall be tested whenever new joints are introduced due to deviation/fault rectification by applying the HVDC voltage as per IS 1255 between conductor and sheath for 5 mts. For old cables this voltage should be limited to 1.5 times rated voltage or less depending upon the age of this cable.

iii. Voltage Rating of IR Tester: The voltage rating of insulation resistance tester for use on cables of different grades are given below:

Voltage Grade of Cable	–	Voltage rating of IR tester.
L.T.	–	500 V
11 KV	–	1000 V.
33 KV	–	2.5 KV.

14.05 Check Lists

Check Lists for guide lines, matters of Transport, Storage, Handling, Laying, Jointing are furnished in Annexures I, II and III.

Annexure – I
Transport & Storage

1.	For unloading from wagons/trucks, is a ramp or a crane available?	Yes/No (If Yes, indicate ramp/crane).
2.	Have you noted the 'roll this way' sign painted on the drum?	Yes/No
3.	Are you rolling the drum in the direction of the arrow?	Yes/No
4.	Are you storing the drums with their flat side on the ground?	Yes/No
5.	Does the storing surface have loose, marshy, or water logging soil?	Yes/No
6.	Are the drums exposed to direct sunlight?	Yes/No
7.	Is there enough space between the drums for air circulation?	Yes/No
8.	Do the drums stand on battens placed below the flanges?	Yes/No
9.	Are end caps provided for cable?	Yes/No
10.	Are the stored drums rolled once in three months by an angle of 90°?	Yes/No

Note: It should be 'No' for items '4' 5 & '6' and 'Yes' for the rest.

Annexure – II
Handling and Laying

1.	Has the preliminary survey to select the route complete? Is there road cutting, road / bridge / railway track crossing involved and if so, necessary permission obtained?	Yes/No
2.	Has the length been measured and the location of joints and terminations fixed?	Yes/No
3.	Are the cable trenches dug upto the specified depth taking into account of the permissible horizontal clearances from power / control / communication cable and gas/water mains	Yes/No
4.	Whether the permissible bending radius has been taken care of in the bends of cable trenches?	Yes/No
5.	Whether sharp stones, iron pieces etc lying in the cable trench have been removed?	Yes/No
6.	Has the trench been provided with sand bed?	Yes/No
7.	Whether sufficient number of rollers are placed in the cable trench for smooth pulling of cable?	Yes/No
8.	Has the length of the cable in the drums selected been checked to be sufficient upto the next joint location?	Yes/No
9.	After removing the planks of the drum, has the condition of the cable been checked for left-over nails if any?	Yes/No
10.	Has the cable in the drum been meggered?	Yes/No
11.	Are cable jack pairs or iron wheel being used for mounting the cable drums?	Yes/No
12.	Is the cable pulled from the cable drum in a direction opposite to "roll this way arrow"?	Yes/No
13.	Are grippers or pulling eye being used for pulling the cable?	Yes/No
14.	Have the rollers been checked to ensure that they roll freely so that the cable is pulled gently over the rollers?	Yes/No

15.	Is the cable being pulled following the sequence viz., lifting it up - dragging it on the ground - dropping it on the ground, and again lifting it up, dragging and so on?	Yes/No
16.	Does the cable form kinks while pulling	Yes/No
17.	Whether the ends of the two cables meeting at a joint-pit have an overlap of more than half the length of joint box.	Yes/No
18.	When cables cross roads or railway tracks, have reinforced spun concrete or cast iron or steel pipes been used to protect the cable? Have spare ducts been also provided for future expansion?	Yes/No
19.	Has the cable been covered with RCC - troughs before refilling?	Yes/No
20.	Is there any broken trough used for covering the cable?	Yes/No
21.	Has the bare end of the cable been covered with end caps?	Yes/No
22.	Has the cable trench been filled up as per specification?	Yes/No
23.	After laying the cable has it been checked to ensure that all cable ends are undamaged and sealed?	Yes/No
24.	Before the trench is filled up, have all joints and cable positions been plotted?	Yes/No
25.	Have the trenches been watered & rammed in successive layers of about 0.3 metre to improve consolidation?	Yes/No
26.	Has a crown of earth of about 50mm is left in the centre and tapering towards the sides of the trench to allow for settlement?	Yes/No
27.	Has the temporary reinstatement of roadways been inspected especially during rainy seasons and further filling of the trenches been arranged, till such time the soil thoroughly settles down?	Yes/No

28.	After the subsidence has ceased has it been arranged or followed up with Municipal Authorities for reinstatement (Black topping) of the road cut portion?	Yes/No The following are applicable to single core cables only:
29.	Whether all the three single core cables are run in the same duct?	Yes/No
30.	Whether the spacing between the single core cables is not less than the diameter?	Yes/No
31.	Has the transposing been done at one-third and two-thirds of the total length?	Yes/No
32.	Have you bonded together the armours of the three single core cables and earthed them?	Yes/No

Note: It should be 'No' for items 15, 16 & 20 and 'Yes' for the rest.

Annexure III
Joints & Terminations

1.	Is the joint pit near any pipe or at the bend of the cable trench?	Yes/No
2.	Is the joint-pit wide enough to accomodate the jointers?	Yes/No
3.	Is the depth of the joint pit atleast 0.3 metre below the cables to be jointed?	Yes/No
4.	Have the sides of the pit been draped with tarpaulin sheets to prevent loose earth from falling on the joint during splicing?	Yes/No
5.	When jointing in water logged ground has a sump hole been excavated at one end of the pit to bale out water?	Yes/No
6.	Has the floor of the pit been well consolidated before commencing the splicing work?	Yes/No
7.	Has a tent been provided over the joint pit?	Yes/No
8.	Whether the type and size of the selected joint/termination kit is in conformity with the type and size of the cable?	Yes/No
9.	Has the manufacturer's instruction manual been checked to satisfy that all the accessories required for jointing/termination have been taken to the site?	Yes/No
10.	Has the cable been meggered before jointing?	Yes/No
11.	Have the cable-ends been prepared as per the jointing kit manufacturer's instructions?	Yes/No
12.	Has the sequential operation suggested by the jointing/terminating kit manufacturer been followed?	Yes/No

NOTE: It should be 'No' for item 1 and 'Yes' for the rest.

STORAGE OF EQUIPMENTS

15
Storage of Equipments

CONTENTS

STORAGE

15. HANDLING AND STORAGE OF CIRCUIT BREAKERS AND SPARES WHICH ARE IN OIL DURING SERVICE

The following general instructions should be followed regarding the safe handling and storage of O.C.Bs and spares which are in oil during service:

Each breaker is usually despatched in two units, viz:

1. Breaker complete with tank, front, plate and operating mechanism.
2. Supporting framework

15.01 Handling

The total weight of the breaker given in the name plate should be noted for using the proper kind of slings for handling. While using slings, do not allow the sling to strike or jam the bushings. The centre of gravity of the breakers generally fall at a higher level and therefore when moving the breaker care should be taken to prevent their toppling over.

15.02 Storage

When an oil circuit breaker can be set up immediately in its permanent location, it is advisable to do so even though it will not be placed in service for sometime. The protective coverings should not be taken from the insulator until after the breaker has reached its permanent location, all overhead work completed and all tanks filled with oil.

If the breaker cannot be installed in the final location immediately, and it is necessary to store the equipments it should be protected from possible mechanical injury, and internal insulating parts protected against moisture. To avoid moisture and dust, first keep the breaker under cover. Clean all the insulation and parts within the breaker tank including the inside of the tank and fill up with tested oil up to the required level. The oil has to be periodically tested and filtered if necessary.

Circuit breakers should not, on any account be kept in the outdoor yard without oil as this would result in the deterioration of the tension rods, guide plates, etc. which are of seasoned wood.

Special care should be taken to protect the machined parts of the operating mechanism, etc., against rusting by coating with grease or a good rust inhibiting material. If the breaker is stored for any length of time it should be inspected periodically to see. if rusting has started and to guard against such rusting.

There are several dehydrating materials which may be used with advantage in protecting the breaker during temporary storage. Among these are silicagel and activated Alumina. Three or more small bags of any one of these materials may be hung within the operating mechanism housing. It must be understood that these materials are not 100 percent moisture absorbent nor are they continuously effective over long periods. They are suggested only as an added protection in conjunction with other reasonable precautions.

15.03 Storage of Other Parts

Regarding storage of other insulators and spare parts, they should be stored in a warm and dry place. As far as possible, they should be kept in the special protection covering as supplied by the manufacturer. It is desirable to keep the stores where these parts are stacked at a temperature 5°C above the ambient. In buildings free from vermin and insects, it is usually sufficient to store spare parts unpacked and standing separately so that it is easy to make visual inspection of the surface of insulation and/or protective wrappings. If the materials are stored in cases they should be raised clear of the floor so that air can circulate freely beneath them. When special water-proof and dust-proof housing are not available, and where damage may be caused by insects, rats and other vermin, it may be desirable to store the parts in oil. In that case paraffin wax wrappings must be removed before immersion. It will still be necessary to take precautions to prevent condensation of moisture in the oil.

15.04 Storage of Bushings

(1) Outdoor condenser bushing when installed in circuit breakers or transformers are not sensitive to weather or atmospheric conditions, because the lower end is kept immersed in oil which prevents it from coming in contact with excessive moisture and the upper end is sealed. In storage other means must be employed to protect the lower end. The ideal storage is mounting vertically with a small tightly oil sealed tank or tube enclosing the lower end. If the tank is oil filled, air space should be left at top equal to 1/6 to 1/5 the volume of oil.

Bushings shipped separately from the apparatus used to have the lower end wrapped for shipment with overlapping tape and then dipped in asphalt. This serves as a protection against moisture and dirt and against damage due to rough handling. This protection should not be removed until the bushing is placed in the apparatus, or the lower end is placed under oil for storage. Ripcords are provided for removing the treated cloth and gum. All gum should be removed from the condenser and the flange as it will discolour the oil in the tank or in the circuit breaker arc shield.

The storage place, if the lower end is not enclosed in tank or tube, should be clean, very dry and ventilated. Bushing should not be stored in cellar outside shed or similar places.

The condition of stored bushings can be determined best by the power factor test. Periodic tests showing a high or increasing power factor indicate improper storage conditions. Such bushings should be removed to better storage.

Bushings not already filled with oil and not required for immediate use should be stored in their cases, provided the latter show no indication of damage in a warm, dry and well ventilated place.

When storage cannot be effected under these conditions, the bushings should be unpacked, filled with oil and stored vertically.

Bushings containing oil should always be stored vertically

15.05 Storage of Spare Coils and Spare Limbs

The coils should be stored in racks in a room which is kept above the outside temperature. The air in the room should be clean and fairly dry. The coils are stacked on racks so as to have free circulation of air and are wrapped with a protective covering which is removed only when the coils are required. Spare limbs for transformers, gaskets, tension rods of O.C.Bs, etc., should be stored in a tank filled with insulating oil. The tank shell may be fitted with a breather of approved type to prevent ingress of moisture.

15.06 Storage and Handling of Insulated Power Cables in Drums

(i) **Protecting Cables from Weather**

Reels should be kept off the ground so that moisture will not harm the cable reel flanges and laggings. All site chosen for storage of cable drums should be well drained, hard packed soil or preferably having a hard surface which will not cause the drums to sink and so lead to flange rot and difficulty in moving the drums.

(ii) **Stacking Drums**

All drums should be stored in such a manner as to have sufficient space-between them for air circulation. It is desirable to place the drums on battens placed directly under the flanges. "Safety scotch" must be placed on either side to prevent any movement of the drum. Tier stacking is normally not recommended. In no case must drums be stored in flat condition i.e. with flanges horizontal. If the cable is not of the non-draining type the drum should be rolled through an angle of 90° atleast once in three months to prevent the possibility of impregnating compound draining from the upper portion of the coils and settling on the lower portion.

(iii) Unloading of Reels

When drums are unloaded from lorry or wagon, lifting and lowering gear must always be used. If this is not available then the drum should be carefully rolled down suitably arranged ramp or rails. When lifting drums, the lagging is to be left in place to prevent the flanges crushing on to the cables. The drums should never be dropped as the resultant shock may cause serious damage to the inner layers of cable.

(iv) Rolling the drum in the direction of the Arrow

Drums of cables must always be rolled in the direction of the arrow painted on the drum. Care should be taken to avoid big stones or sharp edges when rolling drum on rough ground.

For rolling the drum in proper direction, it may be necessary to turn the drum. Two steel plates with grease in between should be used for this purpose. The use of a steel bar placed under the bolt heads to jump the drum round is dangerous to operatives and likely to damage the drum.