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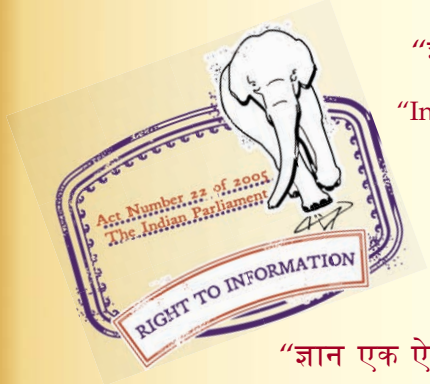

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Indian Standard

CODE OF PRACTICE FOR SELECTION, INSTALLATION AND MAINTENANCE OF SWITCHGEAR AND CONTROLGEAR

PART IV MAINTENANCE

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CODE OF PRACTICE FOR SELECTION, INSTALLATION AND MAINTENANCE OF SWITCHGEAR AND CONTROLGEAR

PART IV MAINTENANCE

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(*Continued on page* 54)

Indian Standard

CODE OF PRACTICE FOR SELECTION, INSTALLATION AND MAINTENANCE OF SWITCHGEAR AND CONTROLGEAR

PART IV MAINTENANCE

0. FOREWORD

0.1 This Indian Standard (Part IV) was adopted by the Indian Standards Institution on 19 January 1982 after the draft finalized by the Code of Practice for Power Installation and Maintenance Sectional Committee, had been approved by the Electrotechnical Division Council.

0.2 The object of this standard (Part IV) is to provide guidelines for the maintenance of switchgear and controlgear equipment and the associated auxiliaries.

0.3 It has been generally felt that the requirements of switchgear of different voltage ratings can be conveniently covered in a single section. Keeping this in view, the Indian Standard IS : 3072-1975* was brought out to cover equipment for indoor and outdoor use. Equipment so covered included circuit-breakers, isolators and other switches operating on ac or dc. Separate Indian Standards have also been formulated as follows, for detailed code of practices for fuses, ac induction motor starters, high voltage ac circuit-breakers, isolators and other switches :

IS : 3106-1966 Code of practice for selection, installation and maintenance of fuses (voltage not exceeding 650 volts).

IS : 3914-1967 Code of practice for selection of ac inductor motor starters (voltage not exceeding 1 000 volts).

IS : 5124-1969 Code of practice for installation and maintenance of ac induction motor starters (voltage not exceeding 1 000 volts).

IS : 5987-1970 Code of practice for selection of switches (voltage not exceeding 1 000 volts).

IS : 7987-1976 Guide for selection of high voltage ac circuit-breakers.

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

0.4 This standard is being brought out with a view to update the contents of these standards and to present in a cogent fashion, the codes of practices for the various types of switchgear and controlgear used in electric power system, filling up the gaps, utilizing the latest in concepts introduced in the product specifications.

0.5 This standard presents the subject product-wise, bringing out the relevant good-practices recommended for LT and HT applications. This standard is being brought out in four parts:

Part I General

Part II Selection

Part III Installation

Part IV Maintenance

All these parts shall be read in conjunction with each other.

0.6 In the preparation of this standard, considerable assistance has been derived from the information contained in the Indian Standards listed in **0.3**. On publication of this standard (Parts I to IV), the Indian Standards in **0.3** would be withdrawn.

0.7 During the drafting of the various parts of this standard, the expert Panel responsible for the same, had kept in view the fact that the standard could at best give guidance on the bulk of the equipment used in the country and should be understood in the manner that aspects relating to selection, installation or maintenance of the EHV equipment as well those intended for very special use would have to be supplemented with additional data, not attempted by the present series.

0.8 In the preparation of this standard (Part IV) assistance has also been derived from the following standards issued by the British Standards Institution.

5405-1976 Code of practice for the maintenance of electrical switchgear for voltages up to and including 145 kV.

Doc : BS 79/28033 DC Code of practice for the maintenance of electrical controlgear.

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

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

1. SCOPE

1.1 This standard (Part IV) covers guidelines for maintenance of all types of switchgear and controlgear for indoor and outdoor application.

1.2 The requirement provided here shall be read in conjunction with those provided in Part I of this standard.

SECTION 1 GUIDANCE ON SAFETY DURING MAINTENANCE

2. SAFETY CONSIDERATIONS FOR MAINTENANCE OF SWITCHGEAR AND CONTROLGEAR

2.1 Safety of Personnel

2.1.0 It is assumed that prior to engaging in any maintenance work in equipment, steps shall be taken by a responsible engineer to adequately safeguard the personnel carrying out such maintenance. It is essential to have a simple code of 'Safety Rules'. In the case of high-voltage equipment they should be based on a system of 'Permit-to-work' (*see* IS : 5216-1969*).

2.1.1 It is important that maintenance personnel shall be fully familiar with the operation of the various devices that they are called upon to handle.

2.1.2 *Voltage Indicators* — All voltage indicators should always be tested on a known 'live' source immediately before and after use.

2.1.3 *Ladders and Tools* — It is essential that personnel working in outdoor sub-stations where isolation is by separation in air between bare conductors, due care and attention is taken with regard to disposition of tools and handling of physical aid to maintenance, such as ladders and slings.

2.1.4 *Isolation Before Maintenance Work* — Before any work is carried out on or near parts which are normally live, or where danger would arise to men working if the motor were to be inadvertently started, it is essential that the apparatus be isolated and proved dead. In the case of equipment operating above 650 volts the conductors should be efficiently earthed.

Where provision is made for so doing, the isolator may be locked in the OFF position and caution notices may also be exhibited at the points of isolation. Where fuse carriers and their fuse-links are removed to assist maintenance of controlgear, reliance should not be placed on retention of

*Guide for safety procedures and practices in electrical works.

these to prevent the circuits from being made live again, since there is a danger that duplicates might be inserted. It is preferable to provide beforehand special unfused dummy carriers, clearly identified as such, and to insert them in the place of those which have been removed.

The operation of an external handle of an isolator should not be assumed to have opened all or any of the blades, as cases of mechanical failure have been known to occur. In particular this may happen when a handle is operated against a mechanical interlock. Tests should therefore be carried out to ensure that the equipment is dead, that all the blades of the isolator are open and all the correct fuse carriers removed. These should include tests between each phase and earth to cover the possibility of wrong connection. It is in addition a wise precaution before starting work to attempt to restart the motor as a final check that the correct circuit has been isolated.

Controlgear enclosures frequently contain circuits having sources of supply different from those of the motor. Examples of these are alarm and live sequence interlock circuits. All such circuits should be isolated by the main isolating handle when it is moved to the OFF position. This, however, may leave live contacts in the enclosure occupied by the isolator, even when the fuses controlling the feed to the motor are withdrawn. Sequence interlock circuits will generally have means provided for defeating the interlock so that drives may be run independently. In all such situations a warning plate should be fixed to the cover of the isolator enclosure warning the maintenance men that there are sequence interlock and alarm terminals in the enclosures which are not isolated by withdrawing the appropriate motor fuses.

The function of interlocks is to ensure that operations are carried out in the correct sequence. It is essential, therefore, that no steps are taken to defeat the interlocks as fitted, otherwise dangerous occurrences are likely to happen.

NOTE — Master keys are often provided with mechanical key type interlocks. These keys are for use in emergency only. It is recommended that the master key be placed in a box with a glass front in the sub-station, such that the key can be obtained only by breaking the glass.

2.1.5 *Observation of Live Equipment* — It is sometimes necessary for live equipment to be observed with the covers removed while operating. Only authorized persons should be permitted to do this and no one should do such work alone. The companion to the authorized person should know beforehand exactly what work has to be done and what he should do if an accident occurs. Accidental contact with any live conductor can generally be prevented by the use of insulating barriers which may be inserted before the work is commenced.

2.1.6 *Precautions against Auxiliary Circuits* — Precautions should be taken to ensure that control circuits to automatic equipment are disconnected from the supply before work is commenced on such equipment. It should not be assumed that the isolation of the main supply to the equipment isolates auxiliary circuits. For example, a voltage transformer may be made 'live' back from another source.

In isolating auxiliary circuits to automatic equipment, care should be taken that the tripping supplies to other units are not affected.

2.1.7 *Precautions against Naked Flames* — Smoking or the exposure of naked flames, such as blow-lamps, in the vicinity of switchgear which has operated on fault, or when emptying or filling switchgear tanks, is highly dangerous as it may lead to an explosion or fire. Where oil fumes are likely to be present, the vicinity of the circuit-breakers should be thoroughly ventilated before work is commenced.

2.1.8 *Precautions for Oil-Immersed Equipment* — Where oil circuit-breakers, oil-immersed contactors, oil-immersed rheostats, or any other oil-immersed equipment is used, no smoking or naked flames should be permitted in the neighbourhood of the circuit-breakers or contactors, especially after operation on a fault, or of the rheostat, or other equipment if overheating has taken place, because an explosion and/or fire may result. Where the presence of oil fumes is suspected the space should be ventilated and kept ventilated whilst work is in progress (*see* also IS : 1866-1978*).

2.1.9 *Bulk Oil Circuit-Breakers* — Do not enter the tank of a bulk oil circuit-breaker until at least 10 minutes after removing the covers so as to allow the oil vapour to disperse. It is advisable to have a fan blowing air into the circuit-breaker tank whilst personnel are inside to maintain fresh air circulation and at the same time ensure that perspiration is not deposited on any insulation inside the circuit-breaker.

2.1.10 *Earthing* — Before touching any equipment which has been energized and after taking precautions regarding switching off supplies, the equipment shall be earthed. It is wise to assume that the circuit is alive at full voltage until it is proved that it is dead.

Many makes of switchgear have special arrangements supplied for earthing. This may take the form of special attachments fitted to the switchgear, so that bus-bars or feeders may be earthed through the circuit-breaker. This is the safest method and should always be used if the equipment is available.

If this equipment is not available, earthing should be carried out using a covered flexible earthing lead, which has been first clamped to the

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

earth bar and is then touched on the parts to be earthed by a suitably insulated rod. The earthing lead shall have a cross-sectional area commensurate with the short-circuit rating of the switchgear. Recommended sizes of earthing lead are given in **17.3.2** of IS : 3043-1966*.

2.1.11 *Maintenance of Earthing Connections* — All equipment, other than those of all-insulated construction, should be adequately earthed. It is very important to ensure that earthing connections are mechanically sound and that all contact screws are tight and good contact obtained. After maintenance all bolts and screws should be replaced, together with any locking devices.

Where pendant or wandering control devices such as foot switches working at mains voltage rely for their earthing connection on a flexible conductor, regular and frequent examination and testing for earth continuity is extremely important and the use of continuous earth monitoring may be worthwhile. Undue flexure of the flexible connection should be prevented because this might cause failure between routine examinations.

NOTE — For further information regarding earthing (*see* IS : 3043-1966*).

2.1.12 *Fire Extinguishing Equipment* — All personnel should be instructed as to the dangers arising from the use of water on electrical equipment in case of fire, and instructed in the correct method of use and limitations of the fire extinguishing equipment provided. All personnel should be thoroughly familiar with the methods of raising an alarm in case of fire.

Care should be exercised in the choice of extinguishing medium as materials employed in certain fire extinguishers are harmful to personnel and electrical equipment.

Automatic fire extinguishing equipment is not generally required for controlgear, but in situations where it is installed it should be rendered inoperative during maintenance of the controlgear. Alternatively it may be changed over to manual operation where possible; in either case suitable warning notices should be displayed. After maintenance personnel have been withdrawn automatic operation should be restored.

2.1.13 *First-Aid* — A placard of inspection for the treatment of persons suffering from electric shock should be affixed in a prominent position (*see* also Appendix F of IS : 5216-1969†).

It is desirable that all maintenance personnel be trained in the application of artificial respiration.

First-aid equipment should be made available for the treatment of burns, cuts and abrasions. The address and the telephone number of the

*Code of practice for earthing.

†Guide for safety procedures and practices in electrical works.

nearest doctor, first-aid centre or hospital should be prominently displayed on the premises (preferably on the First-Aid Chart itself).

2.1.14 *Summary of General Safety Precautions* — Except where it is necessary to work on 'live' low-voltage or medium-voltage switchgear, no person should carry out work of any description (including maintenance, repairs, cleaning and testing) on any parts of apparatus which are normally 'live', unless such parts of the apparatus are:

a) Dead;

b) Isolated and all practicable steps taken to look off from 'live' conductors;

c) Checked (where practicable) with voltage indicator;

d) In the case of high-voltage apparatus, efficiently connected to earth at all points of disconnection of supply to such apparatus, or between such points and the point(s) of work,

e) Adjacent equipment screened where necessary to prevent danger and 'Caution' and 'Danger' notices fixed ; and

f) Released for work by the issue of a 'Permit-to-work' where appropriate.

It should be the duty of the person issuing the 'Permit-to-work' to ensure that the foregoing provisions are complied with and that the person carrying out the work is fully conversant with the nature and extent of the work to be done and with the location of equipment which will remain alive during the work.

Making 'live' or 'dead' by signal or by a pre-arranged understanding after an agreed interval should be forbidden.

Before returning switchgear to service, a final check should be made of the complete apparatus to ensure that everything is in working order. Tools or appliances that have been employed during the inspection should be checked to ensure that none has accidentally been left inside the apparatus and that all temporary earth conductors and devices have been removed. Omission of this precaution has been known to cause serious accidents.

It would be advisable to have a check list made of all tools and tackles employed and also any temporary shortings, earthings and other connections for enabling maintenance works. Care shall be taken to check out these operations before switching on the equipment.

2.2 Safety of Equipment

2.2.0 *General* — Many of the features which make for safety of electrical equipment generally are inherent in the original design (as appropriately covered in the respective ISS), layout and installation of the gear involved

(*see* Part III of this standard) and also of the buidings housing them. A clear appreciation of the various risks that apply may enable the maintenance engineer to initiate steps which might prove of great value in limiting the damage that a fault might cause. If by this means a potential 'shut down' can be limited to a 'minor disturbance', the time and trouble taken in planning and carrying out appropriate safety measures will have been very well spent.

2.2.1 *Ingress of Moisture* — The presence of moisture always constitutes potential danger to electrical apparatus. If a switchroom is damp, or if normal temperature variations result in condensation on insulators or switchgear enclosures, steps should be taken to correct this condition. The action to be taken may include improving the ventilation and/or the provision of heating. If heating is necessary the greatest efficiency will result from having the heating units as close as possible to the apparatus, compatible with safety.

2.2.2 *Minimizing System Disturbances* — Supply can generally be restored more quickly after shutdown with switchgear installations which are segregated into electrical sections than with those in which no sub-division of the switchgear is possible. Physical separation of sections and the introduction of fire-resisting barriers can greatly assist.

Holes in floor, through which cable pass, should be sealed to minimize the spread of flame, smoke, oil or water and also to prevent the passage of vermin. Gravel or pebbles shall be provided in catchments for smothering burning of oil when it occurs, as well to prevent spread. These shall be periodically inspected and renewed when necessary.

2.2.3 *Fire Extinguishing Equipment* — The provision of fire extinguishing equipment of an appropriate character, suitably placed and adequately maintained, may limit damage in event of fire following an electrical breakdown.

While maintenance personnel are working on switchgear, the automatic feature of any fire extinguishing equipment should be rendered inoperative in accordance with the manufacturer's instructions and, where possible, the equipment should be restricted to manual operation. After maintenance personnel have been withdrawn, automatic operation should be restored.

Adequate and suitable fire extinguishing equipment should be made available for use by maintenance personnel.

After a fire or the operation of fire extinguishing equipment, adequate precautions should be taken to ensure that the area is safe to enter. Fire extinguishing equipment should be replaced or recharged as soon as possible.

SECTION 2 MAINTENANCE OF SWITCHGEAR AND CONTROLGEAR

3. MAINTENANCE OF COMPOSITE UNITS OF AIR-BREAK SWITCHES AND FUSES FOR VOLTAGES BELOW 1 000 V

3.0 General — The following recommendations assume that the necessary precuations to render the apparatus safe to work upon, have been taken.

3.1 Complete Overhaul — The equipment should be maintained regularly in accordance with the instructions of the manufacturer. These units are used in such a wide variety of circumstances that no general recommendation can be given about the period between complete overhauls. In the case of continuously operating plant it may be necessary to co-ordinate maintenance with demands of the production programme. Periodical inspection should be made for corrosion, evidence of overheating, and any obstruction which would impede operation. However, the following factors shall be borne in mind in deciding the interval between two complete overhauls:

a) Recommendations of the manufacturer,
b) The rating of the switchgear and normal load interrupted,
c) Environmental conditions,
d) Frequency of switching operation,
e) Rated rupturing capacity and the actual short-circuit level,
f) Type of switchgear, and
g) Relative importance of the location of the switchgear.

The interval shall preferably not exceed, in any case 5 years. In the intervening period routine maintenance as given in 3.2 shall be adhered to.

3.2 Routine Maintenance — The following programme should be followed:

3.2.1 *Cleaning* — All loose external dirt should first be removed.

Cloths used for cleaning purposes should be free of loose fibres, metallic threads or similar particles. Brushes and blower nozzles should contain no metallic material.

Care should be taken to prevent loose parts, tools, metal filings or dirt falling into the apparatus.

3.2.2 *Insulation and Bushings* — Clean and inspect. Renew where necessary. Porcelain insulation should be examined for cracks or other defects. Bonded and laminated fibrous insulation should be examined for signs of tracking, blistering or delamination. Insulation resistance tests are recommended (*see* also **10**).

All insulations should be cleaned with material which is non-fluffy. For insulations which are not immersed in oil, a soft dry cloth is suitable. The only liquids allowed are benzene, trichlorethylene or the like.

For insulation immersed in oil, it is even more important that non-fibrous material be used for cleaning and chamois leather is recommended for this purpose. Insulations in general should be examined visually for cracks or signs of tracking and then cleaned. Porcelain insulators or bushings should be examined for cracks or damage and cleaned. In case of paper insulators or bushings, surface should be examined for damage, and if necessary, sealed with a good air-drying varnish. Dust and dirt should be removed with a soft dry cloth.

3.2.3 *Contacts and Contact Shrouds* — Examine for burning, overheating* or other damage and recondition or renew as required.

Fixed and moving copper contacts may be dressed by using a fine file or fine glass paper. (Emery of carborundum paper should not be used.)

Silver or silver-plated contacts seldom require cleaning despite a black appearance. If it is required to clean them, plate polish may be used.

Alignment and wiped should be checked when contacts are replaced. Where practicable a check should be made to ensure that the contact pressure is adequate.

3.2.4 *Mechanism* — Clean, examine and renew worn parts. Re-lubricate and check for correct operation.

3.2.5 *Indicating Devices and Interlocks* — Examine 'ON' and 'OFF' indicators if fitted and also interlocks and padlocking devices. Adjust where necessary.

3.2.6 *Fuses* — Check fuse-links for continuity, tightness of connections and correct rating. In the case of semi-enclosed fuses the fusible element should be renewed.

3.2.7 *Compound Level* — Any compound-filled cable terminations associated with the switchgear should be examined for compound leakage.

3.2.8 *Final Checking* — Check tightness of circuit and earth connections. Test insulation resistance.

Operation should be checked before returning the apparatus to service.

3.3 Maintenance After Operation Under Fault Conditions — After operation on a fault, the opportunity should be taken of a visual inspection and to carry out as many of the checks enumerated under routine maintenance as may be practicable **3.2**.

*Overheating may be caused by overloading, loose connections, insufficient contact pressure, ineffective fuse-link contacts or lack of alignment of switch contacts.

3.4 Maintenance of Ancillary Equipment — Recommendations applicable to ancillaries which may form part of the equipment are given in 7.

4. MAINTENANCE OF AIR-BREAK SWITCHGEAR

4.0 General

4.0.1 The following recommendations assume that the necessary precautions to render the apparatus safe to work upon, have been taken. For power-closed apparatus it is important to ensure that the apparatus together with any associated remote controlling equipment is rendered inoperative.

This can usually be achieved as follows :

a) For solenoid-closed gear the main solenoid supply fuses should be withdrawn,

b) For spring-closed gear the spring should be discharged and in the case of motor-wound spring-closing mechanisms the motor-supply fuses should also be withdrawn, and

c) Fuses or links in the tripping circuit should be withdrawn.

Particular care is necessary when working on the isolating contacts of draw-out type metalclad switchgear to ensure that these are 'dead' and the use, wherever possible, of voltage indicators as a final check before commencing work is strongly advocated. Any shutters covering isolating contacts which remain 'live' should be locked if the locking facility is provided.

4.0.2 A suggested preventive maintenance inspection schedule for power circuit-breakers and a trouble-shooting chart are given in Appendices A and B respectively.

4.1 Frequency of Overhaul — The interval which can be allowed between consecutive overhauls of switchgear will depend upon the operating conditions of the circuits controlled. In the case of continuously operating plant it may be necessary to co-ordinate maintenance with the demands of the production programme.

These recommendations are therefore based on conditions appropriate to the majority of air-break switchgear in service, assuming that the gear is installed in situations which are dry, well ventilated and where the atmospheric conditions are not unduly corrosive.

4.2 Routine Operation of Circuit-Breakers — Circuit-breakers not periodically operated may fail to trip on fault due to stiffness developing in the mechanism or to defects in the trip circuit. It is therefore recommended that every automatic circuit-breaker should be tripped and reclosed at least once every six months.

In the case of switchgear controlling circuits without alternative supplies, this interval may have to be extended. Every endeavour should be made to avoid such extensions, as switchgear mechanisms are more reliable when operated regularly.

Circuit-breakers with trip coils should be tripped by operation of the relay and those with series trip coils should be tripped by manual operation of the plungers, where this is possible. Circuit-breakers with built-in release should be tested mechanically for tripping through each of the tripping elements separately.

4.3 Routine Inspection and Maintenance — A general inspection of the sub-station or switch-room should be made at regular intervals, attention being given to general cleanliness, heating and ventilation, evidence of overheating, and audible discharge. Regular checks should be made to ensure that ancillary equipment such as special tools, isolating equipment, earthing equipment, etc, are available and in good condition.

All switchgear, whatever its class of duty, should be given close examination at intervals not exceeding one year in order to determine the extent of maintenance required. In power stations and important switching stations the intervals may be shorter, for example six months.

In special cases a shorter interval may be desirable such as when switchgear controls highly inductive circuits, transformers not on load, or capacitative circuits such as power-factor correction capacitors. Particular attention may also be required where switchgear is subject to frequent operation or installed in adverse conditions or by reason of its age.

For routine maintenance, the following programme should be followed. The recommendations are supplementary to and should be read in conjunction with the manufacturers' operation and maintenance instructions.

Replacement parts should be obtained from the manufacturers to ensure interchangeability. In this connection the manufacturers' spare parts list is useful.

Suitable caution notice boards of adequate number shall also be available for display.

4.3.1 *Cleaning* — All loose external dirt should first be removed. When cleaning switchgear it is most important not to use what is generally woven from loose fibres, metallic threads or similar particles. Brushes and blower nozzles should contain no metallic material.

Care should be taken to prevent loose parts, tools, metal filings or dirt falling into apparatus.

4.3.2 *Insulation* — Clean and inspect. Renew where necessary. Porcelain insulation should be examined for cracks or other defects. Bonded

and laminated fibrous insulation should be examined for signs of tracking, blistering or delamination. Insulation resistance tests are strongly recommended (*see* also **10**).

4.3.3 *Contacts* — Examine for burning or other damage and recondition or replace as required. Check that any backing springs are exerting proper pressure and that contacts are in correct alignment.

Slight discoloration or burning of copper or copper-alloy contacts is not necessarily harmful but may be removed by using a fine file or fine glasspaper (emery or carborundum papers should not be used). When cleaning contacts it is essential to ensure that the minimum amount of material is removed, as excessive filing of contacts may result in more rapid wear.

The amount of material removed from contacts should be kept to a minimum and it is imperative that the spring pressure between the contact surfaces should not be materially reduced.

Modern high-pressure point or line contacts will normally carry their rated current satisfactorily, even if there is some pitting of the surface. Large beads, or ridges on the contacting members that would seriously impede closing should be removed.

In the special case of circuit-breakers using high-pressure contacts (for example high-speed circuit-breakers) it is usually undesirable to attempt to clean or to dress the contacts and the manufacturers' recommendations should be followed.

Silver contacts seldom require cleaning despite a black appearance. If it is required to clean them, plate polish may be used.

In the case of laminated brush contacts the manufacturers' recommendations should be followed.

When contacts are replaced or renewed, contact pressures, alignment and wipe should be checked.

Any flexible braids should be examined, especially for fraying at the terminations, and renewed if necessary. In situations subject to corrosive atmosphere the braids may be provided with a protective compound.

4.3.4 *Arc-Control Devices and Phase Barriers in the Vicinity of the Arc* — These should be examined and cleaned or, if badly burnt, renewed.

Arc-control devices made from compressed fibrous material may be cleaned by draw filing with a fine file and smoothing the surface with glasspaper. Porcelain may be cleaned by wiping or washing.

Other materials should be treated in accordance with the manufacturers' instructions.

Any air-puffer device should be checked for correct operation.

4.3.5 *Mechanism* — During inspection or maintenance of the mechanism care should be taken to avoid the fingers being trapped in any part of the mechanism and to avoid the possibility of anyone being struck by moving parts of the mechanism or the moving contacts.

Clean, examine and renew worn parts. It is particularly important to ensure that rolling or sliding surfaces in the trip mechanism are free from dried-up lubricant. The mechanical details of the closing mechanism should be checked. Re-lubricate and adjust as required and check for correct operation.

Extreme care should be taken to verify that the adjustments conform with the manufacturers' instructions.

4.3.6 *Auxiliary Switches, Indicating Devices and Interlocks* — Auxiliary switches should be kept in clean and in sound condition because on them depends the correct functioning of other items of equipment, including protective gear.

Examine the contacts and clean or renew if necessary. Check for good contact pressure, freedom of the operating links and for correct timing of the contacts in relation to the circuit-breaker contacts. Indicating devices, such as mechanical 'ON' and 'OFF' indicators, semaphores, etc, should be examined to ensure that they are in good order.

Interlocks and locking devices should receive particular attention, especially those associated with earthing and testing facilities. A strained or worn locking device may result in a dangerous reduction of clearances.

Particular attention should be paid to the timing of the auxiliary contacts controlling the trip circuits to see that these make before the main contacts.

4.3.7 *Isolating Contacts* — Clean, examine for signs of overheating, recondition or renew as necessary.

4.3.8 *Overload Devices and Protective Relays* — Recommendations for routine maintenance are given separately in **9**.

4.3.9 *Instrument and Protective Transformers* — Recommendations for routine maintenance are given separately in **7**.

4.3.10 *Control Relay or Contactor* — Check mechanical parts for free movement with control and main solenoid or motor fuses withdrawn. Clean arc chutes. Examine contacts and renew if necessary.

4.3.11 *Main Connections* — Ensure that all fastenings are tigh, and good contact is maintained.

4.3.12 *Secondary Wiring* — Ensure that connections are tight, that good contact is maintained and that terminal boxes are free from dirt and

moisture. Check insulation resistances and continuity of wiring to the time-limit fuses, instrument transformers, relays, instruments, motors and other associated items.

Auxiliary plug and socket contacts should be cleaned and re-lubricated where necessary. Fuses should be tested for continuity. Fixed contacts carrying the fuses should be cleaned and tested for satisfactory contact.

4.3.13 *Final Checking* — An insulation resistance test should be made and before the circuit-breaker and its ancillary apparatus is returned to service it should be checked for correct operation.

Where practicable, the closing and tripping of the circuit-breaker, after it has been restored to the service position, should be checked.

The correct operation of safety shutters should be checked as the breaker is restored to the service position.

4.4 Maintenance After Operation Under Fault Conditions — After fault operation it is desirable that a complete inspection and overhaul be made as soon as possible in order to restore the making-capacity, breaking-capacity, normal-current carrying capacity and insulation level to their switchgear. In this respect inspection and overhaul after operation on fault will broadly follow as given in **4.3**, but special attention should be given to the following points.

4.4.1 *Cleaning* — Insulation and other parts liable to the deposition of metallic vapour should be cleaned and inspected for signs of cracking, burning or other damage. An examination for signs of tracking should also be made.

4.4.2 *Contacts and Arc-Control Devices* — Contacts should be examined for burning or other damage and reconditioned or renewed if necessary. Check contact pressure and alignment and wipe.

To remove traces of metallic deposits, it will generally be found necessary to remove the arc-control devices, recondition them as recommended in **4.3.4** and replace them.

4.4.3 *Mechanism* — The mechanism should be checked for correct operation and particular attention should be paid to settings and clearances after contacts or arc-control devices are replaced.

4.4.4 *Insulation Resistance* — A test should be made of the insulation resistance before putting back into service (*see* also **10**).

4.5 Maintenance of Ancillary Equipment — Recommendations applicable to ancillaries which may form part of the equipment are given in **7**.

5. MAINTENANCE OF OIL SWITCHGEAR

5.0 General — The following recommendations assume that the necessary precautions to render the apparatus safe to work upon, have been taken.

For power-closed apparatus it is important to ensure that the apparatus together with any associated remote controlling equipment is rendered inoperative.

This can usually be achieved as follows :

a) For solenoid-closed gear the main solenoid supply fuses should be withdrawn,

b) For spring-closed gear the spring should be discharged and in the case of motor-wound spring closing mechanisms the motor supply fuses should also be withdrawn,

c) For pneumatically-closed gear the air system of the circuit-breaker concerned should be exhausted and locked off, the local air receiver drain valves being left open during the whole of the time while work is being carried out on the gear. To ensure that the air pressure has been completely released a check should be made on the pressure gauge reading to conform that this is indicating zero pressure, before commencing work.

d) Fuses or links in the tripping circuit should be withdrawn.

When emptying or filling switchgear tanks or where oil is directly exposed to the atmosphere no naked flame or smoking should be permitted in the vicinity.

Particular care is necessary when working on the spouts of metalclad switchgear to ensure that the isolating contacts are 'dead', and attention is drawn to the safety precautions of **2.1.10.** The use of voltage indicators, is strongly advocated. Any shutters covering spouts which remain 'live' should be locked closed.

5.1 Frequency of Overhaul of Circuit-Breakers — The interval which can be allowed between consecutive overhauls of switchgear will depend upon the operating conditions of the circuits controlled. In the case of continuously operating plant it may be necessary to co-ordinate maintenance with the demands of the production programme.

These recommendations are therefore based on conditions appropriate to the majority of oil switchgear in service, assuming that the gear is installed in situations which are dry, well ventilated and where the atmospheric conditions are not unduly corrosive. For outdoor switchgear, it is assumed that the atmospheric conditions of the site are reasonably clean and that the switchgear is not subject to excessive pollution such as occurs in some industrial or coastal areas.

5.2 Routine Operation of Circuit-Breakers — Circuit-breakers not periodically operated may fail to trip on fault due to stiffness developing in the mechanism or to defects in the trip circuit. To guard against such eventualities, it is recommended that every automatic circuit-breaker should be tripped and reclosed at least once every six months.

In the case of switchgear controlling circuits without alternative supplies, this interval may have to be extended. Every endeavour should be made to avoid such extensions, as switchgear mechanisms are more reliable when operated regularly.

Circuit-breakers with battery-operated trip coils should be tripped by operation of the relay and those with series trip coils should be tripped by manual operation of the plungers where this is possible.

5.3 Routine Inspection and Maintenance — A general inspection of the sub-station or switch-room should be made at regular intervals, attention being given to general cleanliness, heating and ventilation, evidence of overheating, and audible discharge. Leakage of oil or compound, any unusual smell which may denote overheated or acid oil, an electrical discharge or noise indicating surface leakage or looseness of a component, should be investigated.

Regular checks should be made to ensure that ancillary equipment such as special tools, isolating equipment, earthing equipment, etc, are available and in good condition.

All switchgear, whatever its class of duty, should be given close examination at intervals not exceeding one year in order to determine the extent of maintenance required. In power stations and important switching stations the intervals may be shorter, for example six months.

In special cases a shorter interval may be desirable such as when switchgear controls highly inductive circuits, transformers not on load, or capacitative circuits such as power-factor correction capacitors. Particular attention may also be required where switchgear is subject to frequent operation or is installed in adverse conditions or by reason of its age.

For routine maintenance the following programme should be followed. The recommendations are supplementary to and should be read in conjunction with the manufacturers' operation and maintenance instructions.

Replacement parts should be obtained from the manufacturers to ensure interchangeability. In this connection the manufacturers' spare parts list is useful.

5.3.1 *Cleaning* — All loose external dirt should first be removed. When clearing switchgear it is most important not to use what is generally known as 'cotton waste'. Cloths used for this purpose should be clean and free from loose fibres, metallic threads or similar particles. Brushes and blower nozzles should contain no metallic material.

Care should be taken to prevent loose parts, tools, metal fillings or dirt falling into the apparatus.

5.3.2 *Insulation* — Clean and inspect. Renew where necessary. Porcelain insulation should be examined for cracks or other defects. Bonded and laminated fibrous insulation should be examined for signs of tracking, blistering or delamination. Insulation resistance tests are strongly recommended (*see* also **10**).

Oil-filled bushings should be examined for leaks and the oil level should be checked.

5.3.3 *Contacts* — Examine for burning and other damage and re-condition or replace as required. Check that any backing springs are exerting proper pressure and that the contacts are in correct alignment.

Slight burning or tarnishing of copper or copper-alloy contact faces may be removed by using a fine file or fine glasspaper. (Emery or carborundum papers should not be used.) Silver contacts seldom require cleaning despite a black appearance. If it is desired to clean them, plate polish may be used.

The amount of material removed from contacts should be kept to a minimum and it is imperative that the spring pressure between the contact surfaces should not be materially reduced.

Modern high-pressure point or line contacts will normally carry their rated current satisfactorily, even if there is some pitting of the surface. Large beads, or ridges on the contacting members that would seriously impede closing should be removed.

In the case of laminated brush contacts the manufacturers' recommendations should be followed.

When contacts are replaced or renewed, contact pressures, alignment and wipe should be checked.

Any flexible braids should be examined, especially for fraying at the terminations, and renewed if necessary.

5.3.4 *Arc-Control Devices* — These should be examined and cleaned, or if badly burned, renewed. Care should be taken that vent holes and orifices are cleaned and the devices should be flushed out with clean oil before being replaced.

Resistors, if fitted, should be checked for continuity or resistance value.

5.3.5 *Isolating Contacts* — Clean, examine for signs of overheating, recondition or renew as necessary.

Removable plug contacts for busbar selection should be withdrawn and treated in the same manner.

5.3.6 *Venting* — Examine the venting system to ensure that a free passage for oil and gases exists. Where there is a joint between fixed and movable portions of the gear ensure that it is in sound condition.

5.3.7 *Mechanism* — During inspection or maintenance of the mechanism care should be taken to avoid the fingers being trapped in any part of the mechanism and to avoid the possibility of anyone being struck by moving parts of the mechanism or the moving contact.

Clean, examine and renew worn parts. It is particularly important to ensure that rolling or sliding surfaces in the trip mechanism are free from dried-up lubricant. The mechanical details of the closing mechanism should be checked. Lubricate in accordance with the manufacturers' instructions.

Extreme care should be taken to verify that the adjustments conform to the manufacturers' instructions. Check for overall correct operation.

NOTE — Operation with the tank removed or empty of oil is undesirable, unless the manufacturers' instructions specifically indicate otherwise.

5.3.8 *Auxiliary Switches, Indicating Devices and Interlocks* — Auxiliary switches should be kept clean and in sound condition because upon them depends the correct functioning of other items of equipment, including protective gear.

Examine the contacts and clean or renew if necessary. Check for good contact pressure, freedom of the operating links and for correct timing of the contacts in relation to the main contacts. Indicating devices such as mechanical 'ON' and 'OFF' indicators, semaphores, etc, should be examined to ensure that they are in good order.

Interlocks and locking devices should receive particular attention, especially those associated with earthing and testing facilities. A strained or worn locking device may result in a dangerous reduction of clearances.

Particular attention should be paid to the timing of the auxiliary contacts controlling the trip circuits to see that these 'make' before the main contacts.

5.3.9 *Overload Devices and Protective Relays* — Recommendations for routine maintenance are given separately in **9**.

5.3.10 *Instrument and Protective Transformers* — Recommendations for routine maintenance are given in **7**.

5.3.11 *Control Relay or Contactor* — Check mechanical parts for free movement with control and main solenoid or motor fuses withdrawn. Clean arc chutes. Examine contacts and renew if necessary.

5.3.12 *Insulating Oil* — Take a representative sample of oil from the circuit-breaker tank as described in **5.7**. The handling and testing procedure should be observed as described therein and oil, samples of which do not conform to the tests specified, shoud be reconditioned or changed as necessary. Refill to correct oil level.

If, due to lack of testing facilities, it is not possible to carry out all the tests described in 5.7 and the oil is found to be discoloured or has an acrid smell, or if there is evidence of free water, it should be changed.

In addition to the above routine maintenance, a regular check should be made on oil levels, where practicable.

5.3.13 *Tank and Tank Linings* — Tank linings should be examined for evidence of burning or other damage, paying special attention to the edges for signs of separation of the laminae, which often indicates the presence of moisture. If moisture is suspected, a sample of the lining should be immersed in oil heated to approximately 125°C. The presence of moisture will be indicated by frothing. Damp or damaged linings should be reconditioned or renewed as necessary. They should not be refitted until the tank has thoroughly cleaned and dried. Gaskets should be examined and renewed where necessary. Ensure that all tank bolts are properly tightened in the correct sequence when replacing the tank.

5.3.14 *Tank-Lifting Mechanism* — Where the tank-lifting mechanism is integral with the circuit-breaker, the rope (where fitted) and operating mechanism should be inspected for wear and freedom of moving parts. Where the device is separable from the circuit-breaker, inspection in accordance with the prescribed rules may be necessary.

5.3.15 *Main Connections* — Ensure that all fastenings are tight and good contact is maintained.

5.3.16 *Secondary Wiring* — Ensure that connections are tight, that good contact is maintained and that terminal boxes are free from dirt and moisture. Check insulation resistances and continuity of wiring to the time-limit fuses, instrument transformers, relays, instruments, meters and other associated items.

Auxiliary plug and socket contacts should be cleaned and re-lubricated where necessary. Fuses should be tested for continuity. Fixed contacts carrying the fuses should be cleaned and tested for satisfactory contact.

5.3.17 *Final Checking* — An insulation resistance test on the primary connections should be made and before the circuit-breaker and its ancillary apparatus is returned to service it should be checked for correct operation.

Correct operation of safety shutters should be checked as the switchgear is restored to the service position.

Where practicable, the closing and tripping of the circuit-breaker, after it has been restored to the service position, should be checked.

5.4 Maintenance After Operation Under Fault Conditions — After fault operation it is desirable that a complete inspection and overhaul be made as soon as possible in order to restore the making-capacity, breaking-

capacity, normal current-carrying capacity and insulation level to their original rated values. This is particularly important in the case of older switchgear.

Isolation of withdrawable metalclad circuit-breakers should be delayed for not less than 10 minutes after operation on fault to allow for the dispersal of any ignitable gases in the live spouts.

The maintenance required after operation under fault conditions should generally follow the recommendations of **5.3**, but special attention should be given to the following items.

5.4.1 *Current-Carrying Parts* — All contacts, including isolating contacts, should be examined. The arcing-contacts and arc-control devices should be reconditoned or renewed as required.

Lack of attention to arcing-contacts may result in burning of the main current-carrying surfaces at some future operation.

5.4.2 *Insulation* — The insulation should be examined to see whether it has suffered damage and should be reconditioned or renewed as necessary.

5.4.3 *Tank Linings* — Tank linings should be cleaned and examined for burns and renewed if necessary.

5.4.4 *Insulating Oil* — If the oil is badly discoloured or shows evidence of carbon particles in suspension, it should be reconditioned or changed in accordance with the procedure detailed in **5.7.**

5.4.5 *Joints and Seals* — All joints and seals should be examined for tightness and particular attention should be paid to tank gaskets where these are fitted.

5.4.6 *General Mechanical Inspection* — A general inspection for mechanical damage or distortion of the general structure and mechanism, both internal and external to the tank, should be made. The switchgear should be closed and tripped by each of the methods provided.

5.5 Maintenance of Oil Switches and Oil Isolators — Maintenance should broadly follow the recommendations for oil circuit-breakers. Interlocks and locking devices should receive particular attention, especially those associated with earthing and testing facilities. A strained or worn locking device may result in a dangerous reduction of clearances.

5.6 Maintenance of Air-Break Isolating Devices Associated with Oil Switchgear — The devices usually require attention similar to, and at the same intervals as the associated switchgear.

Linkages should be carefully cleaned and greased using a suitable lubricant, and their adjustment should be checked.

Contacts should be examined, cleaned and treated with a suitable contact oil.

Any flexible braids should be examined, especially for fraying at the terminations, and renewed if necessary. In situations subject to corrosive atmospheres the braids should be of tinned copper or, if bare copper, should be treated with hot lanoline or a similar protective compound.

Insulation should be carefully cleaned and examined for damage such as cracks. Any defective units should be renewed.

5.7 Maintenance of Switchgear Oil — The maintenance of oil for switchgear and transformers is dealt with in detail in IS : 1866-1978*.

5.8 Maintenance of Ancillary Equipment — Recommendations applicable to ancillaries which may form part of the equipment are given in 7.

6. MAINTENANCE OF AIR-BLAST SWITCHGEAR

6.0 In view of different designs and constructions of air-blast switchgear and its ancillary equipment, comprehensive guidelines for maintenance are not being made. In all cases, instructions for maintenance given by the manufacturer should be closely followed to be supplemented by operating experience on particular installations.

6.1 Maintenance of Ancillary Equipment — Recommendations applicable to ancillaries which may form part of the equipment are given in 7.

7. MAINTENANCE OF ANCILLARY ITEMS

7.0 The following enumerate guidelines for the maintenance of ancillary items common for the types of switchgear covered in 3 to 6.

7.1 Tripping and Closing Current Supply — It is important that the equipment for the supply of current for tripping and closing gear be kept in good condition.

7.2 Secondary Batteries — Secondary batteries may be used for closing and tripping circuits and frequently, in the case of larger batteries, they also supply indicator lamps and provide emergency lighting when necessary. They should be kept in a satisfactory state of charge and the condition and level of electrolyte should be regularly examined. Where batteries are used for tripping, they should be provided with an instrument having a loading resistor and test switch so that a simple switching operation can reveal the state of the battery. It is advantageous if the dial includes a danger mark to indicate the critical condition. Most modern installations include a

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

continuously operating trickle-charging equipment and the operation of this apparatus may be readily observed and checked. Where periodical charge and discharge take place, more attention will be needed to guard against unusual drainage of the battery or overload of the trickle charger.

Experience has shown that under trickle charging conditions stratification of the electrolyte can occur and it is recommended, particularly where batteries are used for closing, that at intervals of approximately two years the battery should be given a charge and discharge cycle, alternatively a boost charge.

In all cases the recommendations of the battery manufacturer for the particular type of battery installed should be closely followed.

7.3 Primary Batteries — Where primary batteries are used in place of secondary batteries for tripping circuits, they should similarly be provided with a test instrument which readily indicates their condition.

7.4 Other Sources of Supply — For rectifier and compressed-air or similar apparatus, the maker's instructions should be followed.

7.5 Current Transformers — Steps should be taken to ensure that a current transformer is 'dead' and isolated before it is examined. When installed in cells or other locations which will allow them to be made accessible, maintenance attention to current transformers should consist of general inspection and the checking of main and secondary connections to see that all connections are tight. The oil in high voltage oil-filled current transformers should be checked for correct level and the electrical condition tested. Insulating bushings should be cleaned and examined thoroughly for any damage such as cracks, track marks, etc. Oil in bushings should be checked as above and an examination made for leakages. Current transformers enclosed in metalclad gear, or otherwise inaccessible, are usually safe against mechanical damage and they can only be checked electrically. Where testing windings are provided, this operation can be carried out without difficulty. Where such provision is not made, however, special means may have to be devised : an insulation resistance and a continuity test of the secondary winding should be regarded as an essential minimum.

7.6 Voltage Transformers — Steps should be taken to ensure that a voltage transformer is 'dead' and isolated before it is examined. Particular care should always be taken to ensure that a voltage transformer is not liable to be inadvertently made 'live' due to a feed-back via the secondary side.

Attention as described above for current transformers is appropriate to voltage transformers. In addition the isolating contacts of withdrawable voltage transformers should be cleaned, examined for damage, reconditioned if necessary and re-lubricated.

Protective fuses and current-limiting resistances, if provided, will need checking for continuity of circuit and for general soundness.

7.7 Lifting Devices — The maintenance of lifting devices should not be overlooked.

NOTE — Portable and transportable devices as distinct from integral devices are subject to inspection, tests and certification under the Factory Act.

7.8 Spares — In order that the full benefit of maintenance can be obtained it is recommended that adequate spares, properly stored, be kept available, for example fuses, arc-control devices, contacts and insulation.

8. MAINTENANCE OF ELECTRIC MOTOR CONTROLGEAR

8.0 General — This Code of Practice covers such a wide range of equipment that it is impracticable to set out detailed instructions for every variety of design in every class of equipment. The following paragraphs outline a procedure which if followed cover most maintenance needs.

8.1 Maintenance Instructions

8.1.1 *Inspection*

8.1.1.1 *Inspection card* — It is advisable to keep the record of all inspections of each starter. The card should contain all nameplate details of the equipment and any other relevent data, including a reference to the machine driven by the motor controlled by the starter.

After each inspection, the maintenance personnel should record the condition of each important component of equipment, such as contacts and overload devices, and the action taken.

8.1.1.2 *Frequency af inspection and maintenance* — It is difficult with starters to recommend precise maintenance intervals. From experience the person responsible for planning the scheme should decide how long it would take for any item of equipment which is in good condition to deteriorate to a condition which may give rise to trouble under normal conditions of usage It should then be ensured that the item is inspected at intervals which are shorter than this period of time.

The frequency of maintenance will depend on a number of factors, the most important being the conditions under which the equipment operates and the severity of duty. For continually operating plant it may be necessary to co-ordinate routine maintenance with the demands of the production programme, but where there are regular periods during which the plant is shut down, maintenance schedules may be arranged to coincide with those periods.

In general it is recommended that the motor starter should be checked simultaneously when the motor controlled by it is being checked. The most important thing to check in a motor starter is its contacts which should be examined for burns, pitting, tightness of electrical connections and freedom of movement of contacts. In oil dash-pot type of starter, the oil requires frequent replacement. The level of oil in the dash-pot should be frequently checked and, if necessary, oil of proper grade should be filled in.

8.1.2 *Use of Control Rooms* — Rooms and cubicles containing switchgear are generally kept unlocked and use is often made of them as stores for articles unrelated to the equipment installed there. Such practice shall be condemned. Nevertheless a small number of spare parts, tools and instruments suitable for the equipment installed in the control room may be housed in proper receptacles provided for the purpose.

8.1.3 *Manufacturer's Instructions* — The maintenance instructions and lists of spare parts should always be obtained from the manufacturer before the starter is installed, and made available to the maintenance staff in a form suitable for easy reference. These instructions should be followed as far as practicable. The information in the code is intended to supplement such instructions and a list of the information required from the manufacturer for maintenance work is given in Appendix D. When ordering replacement parts, the full nameplate particulars should be quoted and in any case the serial number or other manufacturer's identification number should be quoted.

8.1.3.1 A list of equipment which may be useful in connection with the maintenance work of motor starters is given in Appendix C.

8.1.4 *Changes in Service Condition* — The maintenance staff should always be on the look-out for, and should report immediately, any changes in service conditions which may have a detrimental effect on the starter. Such changes may either necessitate more frequent maintenance or the replacement of the starter. These changes may occur generally in load conditions, supply conditions, safety conditions and site conditions.

8.1.4.1 *Load conditions* — The following changes in load conditions should be reported:

a) A change of drive; this could result in an increase in the starting period or in the starting and accelerating torque required;

b) An increased duty, for example, day and night shift working;

c) Any addition of lead to the driven machinery, for example, the addition of a new length of line shafting to an existing system of shafting:

d) A change in the frequency operation or in the load cycle, for instance, if a centrifuge has only 300 seconds rest instead of 600 seconds between successive runs;

e) A change of speed; this can be particularly important for centrifugal fans and pumps and similar drives; and

f) Any increase in the frequency or more amount of inching.

8.1.4.2 *Supply conditions* — Any change in the supply condition should be taken care of. It is possible that the supply voltage may change due to increase of load on the system. This may require resetting of protective devices.

8.1.4.3 *Safety conditions* — Anything which adversely affects safety either permanently or temporarily, for men or machines, for instance, accumulation of split material in the well of a hoist which prevents the cage descending for enough to operate the ultimate limit switch.

8.1.4.4 *Site conditions* — Any change in the site conditions should be reported, for instance, plant or building alterations may make the area more dusty or damp than it originally was, may affect the ambient temperature or may introduce the risk of explosion.

8.1.5 *End of Useful Life of Components* — There comes a time with every starter when various components, such as contactor magnets, threaded rods, etc, become worn and require large-scale renewal. It is often difficult to decide when this moment has arrived, but when routine maintenance becomes costly the position should be reviewed and the equipment completely overhauled or replaced.

8.1.6 *Replacement Parts* — Care should be taken to see that all replacement parts are correct and suitable for the duty. A copy of the manufacturer's spare parts list should be kept readily available to maintenance staff. When ordering replacement parts, the full nameplate particulars should be quoted and in any case the serial number or other manufacturer's identification number should be quoted.

8.1.7 *Nameplate Particulars* — Full nameplate particulars should be kept in the office records, as plates may become damaged, defaced and painted over and may not even be in an accessible position.

8.2 Maintenance Procedure

8.2.1 *Frequency of Maintenance* (*see* **8.1.1.2**).

8.2.2 *Cleanliness* — For equipment to operate satisfactorily it is essential that it be kept clean. Before removing covers and opening doors, loose dirt and dust resting on the top of the enclosure should be removed with a brush.

8.2.2.1 When air is used for cleaning, a suction type device with dust receptacle should preferably be employed.

8.2.2.2 'Cotton waste' should not be used for cleaning. If clothes are used they should be chemically clean and free from loose fibres. This is particularly important in oil immersed equipment as the presence of loose fibres in the oil may lead to failure due to the alignment of the fibres under dielectric stress.

8.2.2.3 When solvents are used for cleaning or degreasing they should be of a non-flammable and non-toxic nature whenever possible, and at all times precautions against fire should be observed.

8.2.2.4 After maintenance work all covers and doors including those of instruments and relays should be securely replaced so as to exclude dust.

8.2.3 *Flameproof and Intrinsically Safe Equipment — (under consideration).*

8.2.4. *Marking of Covers and Connections.*

8.2.4.1 All covers, cables, shields, etc, should be marked carefully before removal to ensure correct replacement.

8.2.4.2 If connections are disturbed or temporary connections made for testing purposes, they should be clearly marked to facilitate reconnection and the permanent connection must be restored and the temporary connections removed before the unit is returned to service.

8.2.5 *Tightness of Connections*

8.2.5.1 After maintenance, the bolts, screws and locking devices of all current-carrying and earth connections should be securely replaced.

8.2.5.2 Connections which have not been disturbed should be checked for soundness. It is not sufficient for nuts and bolts to apear to be tight, sometimes a bolt will not be threaded quite far enough and give the impression of a tight connection when in fact, the connection is loose. A millivolt drop test will reveal bad connections and it may be possible to detect a bad connection by looking for signs of overheating.

8.2.5.3 Connecting aluminium to aluminium, copper or brass satisfactorily requires care, particularly if the joint has to be made and broken from time to time, and the use of proprietary compounds recommended for use with aluminium, copper or brass connections may be advantageous.

8.2.6 *Testing of Protective Devices*

8.2.6.1 Where practicable, test should be made for the correct operation and calibration of protective devices, periodically and particularly after faults. Readings should be recorded and compared with the figures obtained when commissioning the gear, the tests being carried out as far as possible under the same conditions on each occasion. It is essential that the settings be restored to the correct values after the test and verified that they are correct.

8.2.6.2 Care should be taken to ascertain whether calibrations marked are in terms of load current, or in terms of current required to trip the device (that is, load plus overload). It should be noted that protection against sustained overload may be lost in an attempt to cover a very long starting period.

NOTE — Where starters of identical type have different horsepower ratings, a suitable stock of overload units of different rating may be kept, so that there can be easy interchangeability of starters having different duties, and a starter can readily be altered if the size of the motor controlled is varied. If any such alterations are made, the overload calibration plate may require to be changed.

8.2.6.3 Where a single phasing protective device is fitted this should be checked when maintenance is carried out.

8.2.6.4 Where instruments and relays are fed from current transformers, it is essential to short-circuit the transformer secondary if the instrument or relay is disconnected, to safeguard against shock and against damage to the transformer.

8.2.7 *Maintenance of Insulation* — Reliable insulation is as important as conductors and contacts and with this in view close visual inspection and regular testing of insulation are most essential.

8.2.7.1 *Testing* — Visual examination usually suffices for porcelain insulation but other insulation, such as synthetic resin-bonded paper or fabric and impregnated or laminated wood, is particularly susceptible to the ingress of moisture, overheating or tracking and visual inspection should be supplemented by regular testing. Insulation resistance measurements are easily made and the most suitable for routine tests but, for their proper interpretation, systematic testing and recording methods are essential. It is only possible to judge the condition of insulation by comparing insulation resistance readings taken over a considerable period. If these show a steady decline in value, the danger is greater than if a steady low value is recorded. If humidity and/or temperature readings of the ambient air can be taken and recorded at the same time as the insulation resistance readings this may be advantageous.

8.2.7.2 Where possible the insulation to be tested should be allowed to reach ambient temperature before resistance tests are made.

8.2.7.3 Laminated insulation may be susceptible to the ingress of moisture, particularly through the edges of the laminae. High voltage resistance tests and visual examination should provide valuable indication of the dielectric quality of this type of insulation. If low insulation value of a laminated insulator due to moisture absorption is encountered, it may be overcome by heating the insulator to drive away the moisture and subsequent application of suitable moisture protection varnish over the insulator.

8.2.7.4 Porcelain insulation does not deteriorate in the manner of synthetic resin-bonded insulation but it may give low resistance reading under humid conditions.

8.2.7.5 Thorough visual examination for cracks or other mechanical damage is as important as electrical tests.

8.2.7.6 *Cleaning* — It is advisable when cleaning insulation to wipe across the likely tracking path and not in line with it. The use of a brush in conjunction with a suction cleaner is recommended and note should also be taken of the recommendations set out in **8.2.2**.

8.2.8 *Maintenance of Isolators and Isolating Switches*

8.2.8.1 Before working on isolators or isolating switches particular care is necessary to make sure that both sides of the device, and any auxiliary circuits, are 'dead'.

8.2.8.2 Many items of equipment are provided with isolators and isolating switches which may be of the knife switch pattern or of the plug and socket or some other form. The contacts of isolators and isolating switches are less frequently operated than others and are therefore particularly liable to failure arising from cumulative effects over a long period. Because of their position in the circuit, they tend to be neglected, and it is therefore important during maintenance to inspect them for signs of overheating and to replace parts where there is the slightest doubt.

8.2.9 *Switches and Composite Units of Switches and Fuses*

8.2.9.1 Maintenance procedure is similar to **8.2.8** with the following additional points to be borne in mind. Where cartridge fuses are used, replacements should be of the same pattern as the original. In no circumstances should attempts be made to rewire a non-rewireable fuse. In rewiring a semi-enclosed fuse, care should be taken to keep within the maker's designation of maximum fuse element size. The contacts should be examined for signs of overheating. Where a locking device holds the fuse in position, it should be replaced when the work is finished. It should be remembered that fuse-links incorrectly chosen or badly fitted may contribute to overheating. Switch contacts should require no more than cleaning with a smooth file or fine glass paper. Knife contacts should be lightly smeared with petroleum jelly or other suitable lubricant.

8.2.10 *Control Circuit Fuses*

8.2.10.1 The reliability of control gear will be seriously hazarded by control circuit faults and it is therefore most important to locate and correct immediately any fault which causes the operation of any control circuit fuse and to report the occurrence. Every fuse-link should be tested for continuity each time a routine inspection is carried out, where this is not an

inevitable part of the final running test. Clear labelling of fuses in agreement with connection diagrams is also desirable. Such labelling should also indicate the fuse ratings.

8.2.11 *Maintenance of Pushbuttons and Other Auxiliary Devices*

8.2.11.1 *Pushbuttons* — Local and remote 'stop' buttons are important components of many motor control installations. Failure to ensure proper maintenance of either operational or emergency 'stop' buttons may produce dangerous conditions. Maintenance work on motor control equipment should therefore always include careful inspection of and attention to 'stop' buttons; the fact that 'emergency stop' buttons may seldom be used makes it more necessary that there be regular inspection.

Any defects in local or remote 'start' buttons will generally be indicated at an early stage, but examination of contacts and insulation is an advantage, particularly as insulation failure may lead to inadvertent operation. The operation of 'inch' buttons should be checked to ensure that in no circumstances will a rapid release of pressure on the button cause the contactor to remain closed.

It is an advantage to list the location of all remote pushbuttons inside the door of the enclosure.

8.2.11.2 *Auxiliary devices* — i) Auxiliary devices include such items as press pressure switches, vacuum switches, limit switches, flow switches, speed sensitive switches, brakes, magnets and float switches. Safety of personnel and equipment depends largely on the reliability of auxiliary devices and it is essential that all such devices be regularly inspected and maintained. The recommendations set out in **8.2.12** should be followed regarding the maintenance of the contacts and **8.2.7** regarding the maintenance of insulation.

ii) Of the auxiliary devices mentioned above, operational and emergency limit and control switches should receive careful attention, particularly where protection against overhoisting is given or where one switch gives protection against more than one dangerous condition. Where it is necessary to disturb the mechanical devices which operate limit and control switches in the course of maintenance work, care should be taken to restore them correctly before returning the gear to service and to repair any mechanical defects in the mechanical devices, for example, a frayed operating wire rope.

iii) Satisfactory maintenance of the control circuits for brakes is essential for safety of personnel and plant as well as for proper operation. Deterioration of working parts or maladjustment may impose more arduous conditions on the control gear than those for which it was originally designed.

iv) For detailed recommendations regarding auxiliary devices reference should be made to the manufacturer's service sheet.

v) Tests for correct operation should always be made if possible before returning equipment to service.

8.2.12 *Air-Break Contactors* — It is good practice after an overhaul to disconnect the motor leads at the starter so that the correct operation of contactors and relays can be checked without the motor and, of course, the plant having to be run.

8.2.12.1 *Maintenance of contacts* — The correct treatment of contacts depends on the material of which they are made as well as on the duty of the equipment. Generally, copper contacts may be cleaned with a smooth file or fine glass paper (emery paper should not be used). This cleaning should be confined to removing projecting pieces of metal. Contacts should never be lubricated with either grease or oil unless the manufacturer recommends a proprietary lubricant which will not adversely affect the breaking performance. Silver or silver-plated contacts seldom require cleaning in spite of a frequent discoloured appearance.

8.2.12.2 The pressure and alignment of contacts should always be checked. Recommendations regarding the method of checking are usually included in the service sheet supplied by the manufacturer.

When new contacts have been fitted it is desirable to operate the equipment a few times to ensure that everything is satisfactory before it is put back into service.

Whenever contacts are replaced, it is recommended that they are replaced in pairs (that is, both fixed and moving contacts) and contact pressure should be checked after replacement. Contact pressure adjustment/replacement of contact springs may be necessary to achieve required contact pressure. The manufacturer's recommendations shall be followed as necessary.

8.2.12.3 *Replacement of contactor units* — It is recognized that it may be uneconomic to replace contacts or other small components in quantity-produced compact designs. For such equipment maintenance may well consist of replacement of the whole interior or even of replacement of the complete article.

8.2.12.4 *Flexible braids* — Flexible braids should be examined especially for fraying at the terminations, and renewed if necessary. In industrial situations subject to corrosive atmospheres the braids should be of tinned copper wire or alternatively, if of bare copper, should be treated with lanoline.

8.2.12.5 *Latched contactors* — These should have the latching features carefully tested since safety of personnel may depend on their correct operation.

8 2.12.6 *Arc-chutes* — The insulation of large arc-chutes should be cleaned, and any doubtful parts replaced. Care should be taken in assembly, as what might appear to be a minor change in the arc control arrangements may well be disastrous to the performance of the contactor. It is most important to ensure that arc-chutes are replaced in their correct position after maintenance, since a misplaced arc-chute may impede the moving parts of the contactor.

8.2.12.7 *Auxiliary contacts* — Auxiliary contacts are as important as main contacts: sometimes, from the safety standpoint, they are more so. They should therefore receive detailed attention similar to that recommended in **8.2.12.1.**

8.2.12.8 *Operating magnets* — The operating magnet should be checked for freedom of movement. Pole faces should be examined for the collection of material in the gaps, and care taken to remove any oil or grease without damaging the pole face; otherwise ' sticking ' may occur. If, with dc operated contactors, the magnet inadvertently remains closed when the coil is de-energized, the antiresidual device (or the pull-off spring, if fitted) should be checked.

With ac operated magnets the air gap should be checked when the magnet is closed and adjusted to the gap recommended by the manufacturer, where necessary.

Excessive humming in ac operated magnets may be due to a number of causes, of which the following are examples:

i) *Dirty magnet faces* — All dirt and grit should be removed from the magnet faces.

ii) *Excessive contact roll or excessive contact pressure* — Contact roll and spring pressure should be checked against the manufacturer's instructions.

iii) *Inadequate air gap in magnetic circuit* — Mechanical contact between the pole faces where an air gap is intended will result in a noisy magnet, and reduction of the air gap can result in the armature failing to drop out when the coil is de-energized.

The air gap should be checked by inserting a piece of thin paper between the pole faces. This paper should be easily removed when the contactor is energized. If the contactor appears sluggish in dropping out when de-energized and it is mechanically free, the air gap should be checked against the manufacturer's instructions.

iv) *Incorrect alignment of magnet faces* — This is unlikely to be the cause of noise on new installations, but after lengthy service or very severe operation uneven contact on the magnet faces may result in excessive noise.

The alignment of the faces may be checked by inserting a piece of thin paper between the surfaces and operating the contactor. The impression left on the paper will indicate any areas of uneven contact. It should be verified that there is no undue wear in other relevant parts.

Any high spots remaining on the surface should be carefully removed, and care should be taken to ensure that the air gap in the magnet circuit is not reduced unduly.

v) *Broken shading ring* — In all probability this will result in a very noisy chattering magnet. The manufacturer should be consulted regarding a permanent repair.

vi) Low voltage at the coil terminals or improper control transformer rating are also causes for humming of ac operated magnets.

8.2.13 *Pneumatically Operated Contactors*

8.2.13.1 In general the contacts and arc-chutes are treated as those on other air-break contactors.

8.2.13.2 The care of the magnet valve or valves and power operating cylinder varies according to construction, and the manufacturer's instructions should be followed.

8.2.13.3 The operation of the contactor should be checked for stiffness, air leakage or other defect. If air leakage is taking place the pipe runs should first be checked.

8.2.13.4 The bearings of the operating mechanism should be oiled at intervals, the cylinder walls should be lubricated, and the leather piston packing (if such is used) greased with a grease recommended for this application.

8.2.13.5 The magnet valve should be inspected for leakage or sluggish operation. Valve leakage is usually due to dirt on the valve seat but may be caused by wear. Sluggishness may be due to a sticky valve stem or insufficient travel. Suitable solvents may be used to clean valve parts when this is necessary.

8.2.14 *Oil-Break Contactors* — In general these are treated as air-break contactors but on heavy-duty they may need more frequent contact maintenance.

The oil should be examined and, if at all possible, a test in accordance with IS : 335-1978* should be carried out on a clean sample taken after sludge, etc, from the bottom of the oil has been removed. If breakdown value specified therein is not obtained, the oil should be reconditioned

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

or renewed. Small units rarely justify reconditioning. When in doubt the equipment should be refilled to the correct level with oil complying with IS : 335-1978*. The mainetnance of insulating oil is dealt with in greater detail in IS : 1866-1978†.

8.2.15 *High-Voltage Air-Break Contactors*

8.2.15.1 High-voltage air-break contactors require similar treatment to that described under ' Air-break contactors' above with particular attention being given to insulation and to arc-chutes. It is sometimes preferable to strip down, clean and re-assemble and arc-chute assembly both for routine and for post-fault maintenance. The correct reassembly of the arc-chute is most important.

8.2.16 *Switching Starters*

8.2.16.1 This type of starter may use contactors, but the following is intended to apply to manually-operated direct switching, star-delta, series parallel, pole changing, auto-transformer and similar starters. Manually-operated direct switching starters frequently take the form of air- or oil-break circuit-breakers: in this case the provisions of **4** and **5** will apply. More generally, however, maintenance similar to that for contactors will be required.

8.2.16.2 Oil immersed switching starters which depend on hydraulic buffers for cushioning may be damaged if operated during maintenance in the absence of the oil. Reference should be made to the maker's instructions.

8.2.16.3 Some oil-immersed switching starters have overload devices with oil dash-pots immersed in the oil. On first filling with oil or on re-filling after maintenance the device should be operated two or three times by hand to expel the air from the dash-pot and ensure that it is properly filled with oil.

8.2.17 *Under-Voltage Releases* — Under-voltage release features are often essential factors of safety provisions and should be checked for operation, if possible under conditions of steadily falling voltage.

8.2.18 *Drum Controllers* — Shaft bearings require adequate lubrication, checking and renewing where necessary. Notching arrangements are important since if they are defective, undue wear of the contacts may take place. Contacts should be carefully examined and lined up so that they register with the notching plate. Contact pressures should be checked and movement (drop) should be adjusted to the correct value in accordance

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

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

with the maker's instruction. Excessive drop of contact fingers is harmful. A trace of lubricant such as petroleum jelly, on the contacts will help when mechanical wear is predominated; an oil specially designed for contact lubrication is now available and in certain cases can be helpful. Carbon contacts should not be lubricated. All are control devices should be checked for operation by observing where possible, with suitable precautions, the behaviour of the controller with the cover removed. On dc controllers, shunt blow-out coils are often used and interturn short-circuits on these may give trouble. Thorough cleaning of finger and barrel (drum) insulation is essential, particularly where there is marked wear of the segments and fingers and deposition of conducting dust.

It is essential that the operation of a dead-man handle, if fitted, be checked since safety of personnel may depend upon its efficient operation.

8.2.19 *Cam Controllers* — Maintenance is similar to that of contactors and of the working parts of drum controllers. The cam profiles should be examined for undue wear leading to incorrect operation and the lubrication of the cams and rollers should be carefully carried out as recommended by the manufacturer; excessive lubrication is likely to cause electrical failure from accumulation of dust and dirt.

8.2.20 *Faceplate Starters* — These are either dry or oil-immersed. The latter pattern is usually associated with rotor starters. Contacts maintenance is generally similar to other gear, except that the smaller sizes of faceplate starters are usually not designed for renewal of the fixed contacts without dismantling the starter. It is important to clean thoroughly between contacts when cleaning faceplate starters.

9. MAINTENANCE OF PROTECTIVE DEVICES

9.1 Time Delay Devices

9.1.0 These are of many types and are employed for sequence operation and in connection with overload protection. The most important types are :

a) Magnetic devices,
b) Escapement and eddy current devices,
c) Oil dash-pot devices,
d) Air dash-pot devices,
e) Thermal devices,
f) Mercury switch devices,
g) Capacitor devices; and
h) Induction pattern devices with inverse time limit.

9.1.1 *Magnetic Devices* — These make use of the delaying action produced by a short-circuited turn surrounding an iron circuit. Maintenance is limited to ensuring that the movement is free and that the non-magnetic spacer is not excessively worn or damaged.

9.1.2 *Escapement and Eddy Current Devices* — These may either drive an escapement or an eddy current induction disc working as a brake in the adjustment field of a magnet. In the case of eddy current induction discs particular attention should be paid to removing dirt from the disc and the magnet air-gap. If not interfered with except for occasional drops of clock oil at the spindle bearings, and provided the duty is not severe and dust cannot enter, they should need no further attention. It should be realized that dust is the worst enemy of these devices.

9.1.3 *Oil Dash-Pot Devices* — The oil should be maintained at the correct level at all times. Oil dash-pot devices generally use only a small quantity of oil which may form a sludge of varying consistency fairly quickly. It is most important that only oil recommended by the manufacturer is used, both to give the correct delay and to minimize sludge formation. If the oil becomes cloudy or if any sludge is formed, the dash-pot should be cleaned out well with a solvent and fresh oil put to the correct level. If a hard sludge forms rapidly, the manufacturer should be consulted.

The use of silicon fluids may be advantageous where the variations of temperature occur or reduction of sludging and closer control of viscosity are needed.

9.1.4 *Air Dash-Pot Devices* — These are of two types:

a) Diaphragm type, and

b) Piston-in-cylinder type.

9.1.4.1 Where a dust-tight enclosure is provided, care should be taken during maintenance work not to impair the effectiveness of the enclosure. Types which have a piston moving in a cylinder, even if graphite lubricated, may require an occasional drop of light oil, but this should only be done with the manufacturer's approval.

9.1.5 *Thermal Devices* — These includes bimetallic strip, eutectic alloy and similar devices and should require little maintenance. The operating time of all thermal devices is considerably affected by ambient air temperature unless provided with a suitable compensator. Neglect of maker's instructions may adversely affect the device.

9.1.6 *Mercury Switch Devices* — The delay in switching is obtained by restricting the flow of mercury after the switch has been tilted by electrical or mechanical means. The angle of tilt is important and the levelling of the device when installed may be critical. A check should be made to see that the level had not been disturbed and that the column of mercury is

continuous, or broken completely, when the switch is at the appropriate position of its movement.

9.1.7 *Capacitor Devices* — If a capacitor fails it should be replaced by a new one. Except for cleaning and ensuring that the connections are sound, capacitors used as time limit devices require no maintenance.

9.1.7.1 Electrolytic capacitors deteriorate when out of use or in store. Spare capacitors of the continuously rated electrolytic type should be kept permanently charged at their rated voltage and should therefore be stored in a charging rack with suitable interlock to prevent shock when handling. Spare capacitors having paper dielectric need not be charged but should be kept dry.

9.1.7.2 If an insulation tester is used to test a capacitor it should be of the constant voltage type. It is essential to discharge the capacitor through a suitable resistor before handling.

9.1.8 *Induction Pattern Devices with Inverse Time Limit* — Such devices operate in a time inversely proportional to the current flowing, generally with a definite minimum time. These devices are usually housed in their own enlosure because of the importance of excluding dust. Care should therefore be taken not to admit dust when opening the cases and to replace the covers in such a way that dust cannot enter subsequently. The contacts should be adjusted only, if necessary, and then with extreme care and as little as possible. The induction disc should never be rotated by hand as this may result in damage to the device; instead, the time setting adjuster should be used.

9.2 Overload Devices

9.2.1 *Time Limit Fuses* — These should be examined for bad contacts and if necessary cleaned. Bad contact may cause premature tripping. Where semi-enclosed fuses are used they should be examined for deterioration or mechanical damage. Deteriorated or blown fuse elements should be renewed with identical elements, if of the renewable type, unless an alteration of the release current or of the time delay is required. The manufacturer's instructions should be followed if any alteration is made.

9.2.1.1 Where provision is made for adjustment of the release current by adjustment of the position of solenoid armature, the rated current of the fuse should exceed the operating current of the solenoid.

9.2.2 *Heat Sensitive Devices* — This type of device is mounted on the apparatus to be protected and operate when the apparatus itself attains a predetermined temperature. Owing to the dependence of such a device on its good thermal contact with the part to be protected, it should not be disturbed and maintenance should be confined to checking the device for electrical continuity. Arrangements should also be made for convenient

access to the device and suitable warnings given both to the motor and starter maintenance staff that such a device is in use.

9.2.3 *Latched Tripping Devices* — Overload devices may be required to trip a latch and in this case the mechanical condition of the tripping mechanism may affect the current at which the device operates; therefore lubrication and adjustment of the mechanism and renewal of worn parts are particularly important.

10. MAINTENANCE AND TESTING OF INSULATION IN SWITCHGEAR AND CONTROLGEAR

10.0 General — Close visual inspection and regular testing of insulation are most essential, since security of supply must always depend on the insulation quality of the switchgear. Visual examination usually suffices for porcelain insulation but other insulation, such as synthetic resin-bonded paper or fabric and impregnated or laminated wood, is particularly susceptible to the ingress of moisture, overheating or tracking, and visual inspection should be supplemented by regular testing. Insulation resistance measurements are easily made and the most suitable for routine tests, but for their proper interpretation systematic testing and recording methods are essential. Resistance tests are strictly comparative only, in that for each item tested a rejection value can only be fixed on the basis of experience, by comparison with earlier results. Test values obtained should be logged, together with the humidity and temperature at the time of the test, and in general, a steady fall of resistance over a period of time is a more reliable indication of deterioration than is a relatively low value which remains sensible constant.

On long pieces of insulation such as lift rods on large circuit-breakers, deterioration may not occur uniformly and resistance measurement taken over the entire length may not reveal localized deterioration. It is recommended that where possible an electrode be placed mid-way along the insulation, and the resistance to each end measured separately. If there is a marked difference between readings, the insulation should be rejected.

Particular attention should be paid to the lift rods of circuit-breakers where these are made of hickory or other natural wood. These should be examined for the wood shearing along the grain and for pulling out of the riveted end where this method of fixing is employed.

Where possible the insulation to be tested should be allowed to reach ambient temperature before resistance tests are made.

10.1 Condenser Bushings

10.1.1 Resistance measurement should indicate serious ingress of moisture though it may not reveal partial tracking or internal deterioration. Any

oil filling should be periodically checked for presence of moisture, and if this is suspected, the outer porcelain should be removed and the bushing examined for tracking. The joints should be examined to determine where the moisture, if any, has entered.

10.1.2 With compound-filled bushings, a resistance measurement will not necessarily indicate the presence of moisture, and once every five years, where practicable, the space above compound should be examined for signs of moisture ingress. If the presence of moisture is suspected the bushings should be returned to the manufacturer to be decompounded and subjected to a power factor test. Where covers have been removed care must be taken on reassembly to ensure that all joints are properly re-made. During inspection it is advised to check that the earth connection is sound.

10.1.3 Power factor measurements are difficult to make on site, and they should be confined to the testing of bushings at long intervals, or when suspect.

10.2 *Oil-Barrier Bushings* — Oil-barrier type bushings should have the bottom oil condition checked at least every five years and the bushing flushed and refilled with clean oil if necessary. If the oil is completely renewed the bushing must be allowed to stand for four hours before being made 'live' in order that the oil may de-aerate.

10.3 Laminated Insulation — Insulation of laminated type may be susceptible to the ingress of moisture, particularly through the edges of the laminae. Tracking which tends to commence at the sharp corners of adjacent metal end fixing, often occurs beneath the surface, and is indicated as a surface blister. Delamination or cracking of the material may result in mechanical breakdown or may allow the entry of moisture or carbon with consequent electrical breakdown. High voltage resistance testing and visual examination should provide valuable indication of the dielectric quality of this type of insulation.

10.4 Porcelain Insulation — Porcelain insulation does not deteriorate in the manner of synthetic resin-bonded insulation but it may give low resistance readings under humid conditions. Careful interpretation of test results is necessary and a thorough visual examination for cracks or other mechanical damage is as important as electrical tests.

10.5 Applied Voltages for Insulation Resistance Tests — These may correspond to the values stipulated in the relevant Indian Standards on equipment.

APPENDIX A

(*Clause* 4.0.2)

PREVENTIVE MAINTENANCE INSPECTION SCHEDULE OF POWER CIRCUIT-BREAKERS

What to Inspect	*What to Inspect For*	*Frequency*
Oil (for oil circuit-breakers)	At the time of the overhaul of switchgear, the oil should be tested. If oil shows signs of moisture, carbonization or dirt it should be filtered and tested, if necessary, replaced.	At the time of overhaul
	See that the oil level in the tanks is maintained at the proper height. Be sure the oil-level gauge is indicating properly the actual oil level.	Every 6 months
	Check all oil valves to be sure that they do not leak. Also check the condition of all gaskets, seeing that they seal properly to prevent the entrance of water and leakage of oil.	Every 6 months
Bushings	Clean the external surface to remove any accumulation of dirt or other deposit. In locations where abnormal conditions prevail, such as salt deposit, cement, dust, etc, it should be recognized that a special hazard exists and the surface should be cleaned at more frequent intervals to avoid accumulations which might cause a flashover. Carbon tetrachloride or liquid ammonia or any other suitable agent may be used to clean the porcelain.	Every 12 months

What to Inspect	*What to Inspect For*	*Frequency*
	Inspect the bushings to make sure that vibrations due to the breaker operation have not caused the bushings to move resulting in misalignment of the contacts. Be sure none of the porcelains are cracked or broken and that the oil (of oil-filled bushings) is at the required level.	Every 12 months
Internal insulating parts	See that the surface of bushings and other insulating parts within the tanks of oil circuit-breakers are thoroughly cleaned to remove all traces of carbon or sludges that may remain after the oil has been drained or the tank removed. All internal parts of the oil circuit-breaker should be cleaned before new or filtered oil is added.	At the time of overhaul
Contacts	See that the contacts are properly aligned, that contact surfaces bear with firm, uniform pressure and are adjusted in accordance with the breaker instruction book. Badly pitted or burnt contacts should be replaced before they cause damage to other parts. Otherwise, the following action may be taken:	Every 12 months

Type of Contact	*Action Required*
a) For plain finger	Surfaces, if burnt should be cleaned with smooth file.

What to Inspect	*What to Inspect For*		*Frequency*
	Type of Contact	*Action Required*	
	b) For rod and socket or contactor butt type with arc control chambers	Vent holes of arc chambers should be cleared. Contact surfaces should be trimmed with a fine file, if necessary.	
	c) Silver plated or with silver inserts	Silver plate should be cleaned with good quality polish. Current-carrying silver inserts should be cleaned with fine glass cloth; file shall not be used.	

NOTE 1 — Badly burnt contacts cause pre-arcing on the closing stroke, tend to slow down the operation on opening, and increase the heat losses.

NOTE 2 — Incorrect assembly of explosion pots and other arc-control devices may render them inefficient or completely ineffective.

Where the 'contacts' consist of separate main and arcing contacts, the main contacts require little maintenance but should be inspected for good condition and kept smooth and clean.

The arcing contacts, whether of the butt or finger type should be replaced if badly pitted and burned, before the main contacts are affected. Finger type arcing contacts because of their wiping operation against the bridging contact, require more maintenance than the butt type.

What to Inspect	*What to Inspect For*	*Frequency*
	The contacts of the air-break circuit-breaker should be inspected periodically to see that no excessive wear or scoring has taken place on the surface of the wiping contacts. If excessive scoring is evident, the contacts should be replaced.	According to the manufacturers' instructions or at the time of overhaul
	A good indication of the condition of the contacts within the arc chute may readily be obtained without any disassembly work by observing the appearance of the arcing tips on the moving-contact blades. Severe burning shall indicate a similar amount on the arc-chute contacts. Severely burned contacts and badly eroded fibre parts of the arc-chute should be replaced. Contacts should be adjusted as outlined in the instruction book.	
The breaker mechanism	See that the breaker mechanism operates smoothly and freely. Lubricate all bearing surfaces. Be sure all split pins are open and that all snap rings, locking plates, nuts, etc, are in place and properly tightened. Check the stop clearance against the dimension in the instruction book. Inspect the oil-filled dash-pots to ensure that they are filled with oil.	Every 12 months
	The length of the breaker stroke and its opening and closing speed should be measured or checked and adjusted in accordance with the breaker	

What to Inspect	*What to Inspect for*	*Frequency*
	instruction book. It should be ensured that there is no undue friction between the operating rod for the movable contacts and the guide.	
The operating mechanism	The mechanism should be checked to see that it is properly lubricated in accordance with the instruction book, and operates freely through the entire stroke. Parts which are scored or which show excessive wear should be replaced and adjustments should be within the tolerances listed in the instruction book.	At the time of overhaul
	Check the operating voltage at the mechanism terminals with full operating current flowing to see that it is adequate for current operation. This is especially necessary on solenoid-operated mechanisms. Check the air pressure of pneumatic mechanisms to be sure that it is adequate for proper operation, and that it is restored after each breaker's operation. See that there are no leaks in the air connections.	
	Check the closing relay to see that it is functioning properly and that its contacts are in good condition. Check that all electrically operated valves of pneumatic mechanisms function properly.	
	Check the tripping arrangement for positive tripping when	

What to Inspect	*What to Inspect for*	*Frequency*
	tripping is required. Auxiliary-switch adjustments should be checked and contacts examined to make sure that they are in good condition. Dress or replace damaged contacts.	
	Check the opening and closing speed, with an analyzer, if possible, to detect any changes in adjustments or improper operation.	
	Keep the air system clean by regular changing or cleaning of the compressor filter pads, regular blowing-off of water condensation and systematic overhaul and cleaning of the air strainer, check valve, unloader, and other critical parts which will eventually collect a certain amount of dirt. Replace the screen, if it is punctured or is rusting. Review the adjustment of all pressure switches and lockout devices. Consult the breaker instruction book for pressure settings.	
	Inspect to see that all bolts, nuts, pins, and coter pins are in place and that they are tight or opened properly.	

APPENDIX B

(*Clause* 4.0.2)

TROUBLE-SHOOTING CHART FOR POWER CIRCUIT-BREAKERS

Trouble	*Cause*	*Remedy*
Overheating	Poor condition of contacts. Out of proper alignment and adjustment.	Contacts should be lined up and adjusted properly.
	Burned and pitted due to lack of attention after many heavy operations, or too frequent operation.	Burned and pitted contacts should be dressed up, if practical, or replaced with new parts. (High pressure, butt type contacts usually do not require dressing.) Silver-to-silver contacts should be dressed very carefully and only when actually required.
	Breaker kept closed (or open) for too long a period (copper contacts)	Operate breaker more frequently to wipe contacts clean. It may be advisable to consider the installation of new silver-to-silver contacts.
	Overloading (continuous or prolonged current in excess of breaker rating)	If the breaker is overheating because of excess current, one of the two remedies can be followed: a) Replace with breaker having adequate rating for the present or future load. b) Arrange circuits so as to remove the excess load.
	Transmission of heat to the breaker from overheated or inadequate cables or connection bars	If the bars or cables overheat because of current in excess of their capacity, this can be remedied by: Increasing the current-carrying capacity (that is, increasing the size or number of conductors or by removing the excess current from the circuit).

Trouble	*Cause*	*Remedy*
	Loose connections or terminal connectors	Tighten
	Ambient temperature is too high	Relocate in a cooler place, or arrange some means of cooling
Failure to trip	Mechanism binding or sticking caused by:	
	a) Lack of lubrication	Lubricate mechanism
	b) Mechanism out of adjustment	Adjust all mechanical devices, such as toggles, stops, buffers and opening springs, according to instruction book.
	Failure of latching device	Examine surface of latch. If worn or corroded, it should be replaced. Check latch 'wipe', and adjust according to instruction book.
	Damaged trip coil	Replace damaged coil
	Blown fuse in control circuit (where trip coils are potential type)	Replace blown fuse
	Faulty connections (loose or broken wire) in trip circuit	Repair faulty wiring. See that all binding screws are tight.
	Damaged or dirty contacts on tripping device	Dress or replace damaged contacts or clean dirty contacts
Failure to close or to latch closed	Mechanism binding or sticking because of:	
	a) Lack of lubrication	Lubricate mechanism
	b) Improper adjustment of breaker mechanism	Adjust all mechanical devices, such as toggle, stops, buffers and opening springs, to specifications in breaker instruction book.

Trouble	*Cause*	*Remedy*
	Burn out of operating (closing) coil (of electrically operated breakers) due to operator holding control switch closed too long	Replace damaged coil and educate operator how to operate properly. A better remedy would be to change the connections to include an auxiliary switch, which automatically cuts off the closing coil as soon as the breaker closes.
	Closing relay sticking	Check or adjust closing relay
	Cut off switch operating too soon	Adjust operation of cut off switch to delay cut off so as to allow breaker to close fully
	Cut off switch operating too late, causing the breaker to ' bounce ' open	Readjust to reduce power at end of stroke, and eliminate ' bounce '
	Insufficient control voltage (of electrically operated breaker) caused by:	
	a) Too much drop in leads	Install bigger wires; improve contact at connections
	b) On ac control-poor regulation	Install larger control transformer. Check rectifier, and be sure it is delivering adequate dc voltage from adequate ac supply.
	c) On dc control — battery not fully charged or in poor condition	Give battery a sustaining charge, or repair according to instructions of battery manufacturer
	Blown fuse in control circuit, faulty connection or broken wire in control circuit, damaged or dirty contacts in control switch (electrically operated breaker)	Replace blown fuse; repair faulty connection or broken wire; dress or replace damaged or clean dirty contacts in control switch

Trouble	*Cause*	*Remedy*
Insufficient oil (in circuit-breaker tanks)	Leakage of oil	Locate point of leakage and repair. Tighten up joints in oil lines.
	Oil thrown during operation	Fill oil tanks to proper oil level
Dirty oil (in circuit-breaker tanks)	Carbonization from many operations	Drain poor oil and filter, or replace with new oil. Clean inside of tank and all internal parts of breaker
Moisture present in oil	Condensation of moist atmosphere	Drain and filter oil or put in new oil
	Entrance of water from rain or other source	Repair source of water entrance
Sludging of oil	Overheating	Filter or put in new oil. Remove source of overheating.
Gaskets leaking	Improper installation of gaskets at a previous inspection or repair. Oil saturation	Put in new gaskets, treated in accordance with breaker instruction book
Insulation failure	Absorption of moisture, accumulation of dirt, grime, carbon, etc, on bushing and insulating parts	Thoroughly clean all insulated parts. Bake or dry out water-soaked parts (or treat in accordance with directions in breaker instruction book).

APPENDIX C

(*Clause* 8.1.3.1)

LIST OF EQUIPMENT WHICH MAY BE USEFUL IN CONNECTION WITH MAINTENANCE OF SWITCHGEAR AND CONTROLGEAR

a) Wiring and schematic diagrams of circuits.

b) Maker's maintenance handbook and spare parts list.

c) Handlamp or torch (all-insulated type).

d) Mirror or an insulated handle.

e) Feeler gauges.
f) Cigarette paper for testing contact pressure.
g) Contact lubricant.
h) Oil can.
j) Clock oil, penetrating oil, dash-pot fluid.
k) Voltage indicator.
m) Insulation resistance tester.
n) Universal test set.
p) Millivolt drop tester.
q) Blower, cleaning cloth and small brush.
r) Suction cleaner.

APPENDIX D

(*Clause* 8.1.3)

INFORMATION AND PARTICULARS REQUIRED FROM THE MANUFACTURER FOR MAINTENANCE OF EQUIPMENT

a) Manufacturer's Identification number of the equipment.
b) General description of equipment.
c) Circuit wiring diagram and schematic diagrams.
d) Overload relay calibration curves.
e) Description of operation.
f) Spare parts list with illustration.
g) Instructions for maintenance and adjustment of all types of contactors, protective and operative relays forming part of the equipment with details of contact pressures, air-gaps, etc.
h) Lubrication instructions.
j) Values of all fixed resistances (if any) and tappings with current-carrying capacity and short-time rating.
k) Particulars of shunt regulator and starting resistance (if any) (ohms and current rating).
m) Capacitance of capacitors (if any) and its rated voltage.
n) Oil capacity of all oil-immersed equipment with grade of oil required.
p) Type of dash-pot fluid (if of oil dash-pot type).

q) Particulars of all coils.

r) Particulars of ammeter shunt or current transformer (if any),

s) Particulars of voltage transformers, including limiting resistances or fuses (if any).

t) Particulars of control circuit transformers (if any), including secondary voltage and rating.

u) Particulars of cartridge fuse links (if any).

v) Particulars of indicating lamps (if any), including cap size and wattage.

w) Particulars of rectifiers (if any).

(*Continued from page* 2)

Panel for Selection, Installation and Maintenance of Switchgear and Controlgear ETDC 20/P25

Members	*Representing*
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SHRI SYED KHADER MOHUDDIN	Karnataka Electricity Board, Bangalore
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