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Maintenance of electrical switchgear and controlgear for voltages above 36 kV – Code of practice

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Foreword

Publishing information

This British Standard is published by BSI Standards Limited, under license from the British Standards Institution and came into effect on 30 September 2013. It was prepared by Subcommittee PEL/17/1, *High-voltage switchgear and controlgear*, under the authority of Technical Committee PEL/17, *High-voltage switchgear and controlgear and HV-LV co-ordination*. A list of organizations represented on these committees can be obtained on request to their secretary.

Supersession

This British Standard supersedes BS 6867:1987, which is withdrawn.

Information about this document

This is a full revision of the standard, and introduces the following principal changes.

- The various types of maintenance approach are discussed, including preventative and condition based maintenance.
- Maintenance policies using PAS 55 philosophy have been introduced.
- Maintenance considerations for modern plant and equipment, like gas insulated switchgear (GIS) and capacitive charged motor drive mechanisms, have been added.
- The standard has been restructured to create a dedicated clause on mechanisms (Clause **31**).
- Text on use and handling of sulphur hexafluoride has been brought up to date.
- Recommendations for hard-gas interrupters are not given.

The purpose of this British Standard is to provide, in a convenient form, recommendations and guidance on those matters which technical knowledge and experience have shown to be important in keeping electrical switchgear and controlgear in an acceptable condition. It is intended for the guidance of those actually carrying out the maintenance work, as well as for administrative personnel.

The normally quiescent state of electrical switchgear and some controlgear does not automatically draw attention to incipient faults, deterioration or danger resulting from neglect and the consequent need for maintenance. It follows, therefore, that an organized system of maintenance is important to facilitate continued safe and acceptable operation of an electrical system with the minimum risk of failure and consequent interruption of supply.

Use of this document

As a code of practice, this British Standard takes the form of guidance and recommendations. It should not be quoted as if it were a specification and particular care should be taken to ensure that claims of compliance are not misleading.

Any user claiming compliance with this British Standard is expected to be able to justify any course of action that deviates from its recommendations.

It has been assumed in the preparation of this British Standard that the execution of its provisions will be entrusted to appropriately qualified and experienced people, for whose use it has been produced.

Hazard warnings

WARNING. Older switchgear might contain asbestos. Attention is drawn to the Control of Asbestos Regulations 2012.

Presentational conventions

The provisions in this standard are presented in roman (i.e. upright) type. Its recommendations are expressed in sentences in which the principal auxiliary verb is "should".

Commentary, explanation and general informative material is presented in smaller italic type, and does not constitute a normative element.

Contractual and legal considerations

This publication does not purport to include all the necessary provisions of a contract. Users are responsible for its correct application.

Compliance with a British Standard cannot confer immunity from legal obligations.

In particular attention is drawn to the statutory regulations listed in Annex A.

Section 1: General

1 Scope

This British Standard gives recommendations and guidance for the maintenance of electrical switchgear and controlgear having a rated a.c. or d.c. voltage above 36 kV.

NOTE This standard is not applicable to explosion protected switchgear and controlgear. Inspection and maintenance of electrical apparatus in explosive gas atmospheres is covered in BS EN 60079-17.

2 Normative references

The following documents, in whole or in part, are normatively referenced in this document and are indispensable for its application. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

BS 6423:1983+A1:1992, *Code of practice for maintenance of electrical switchgear and controlgear for voltages up to and including 1 kV*

BS EN 13306:2010, *Maintenance – Maintenance terminology*

BS EN 50110-1:2013, *Operation of electrical installations – Part 1: General requirements*

BS EN 60422, *Mineral insulating oils in electrical equipment – Supervision and maintenance guidance*

BS EN 60480, *Guidelines for the checking and treatment of sulphur hexafluoride (SF_6) taken from electrical equipment and specification for its re-use*

PD CLC/TR 62271-303, *High voltage switchgear and controlgear – Part 303: Use and handling of sulphur hexafluoride (SF6)*

3 Terms and definitions

For the purposes of this British Standard the terms and definitions given in BS EN 13306:2010, BS EN 50110-1:2013 and the following apply.

3.1 acceptable condition
condition in which an item is able to meet the requirements of the relevant specification and perform its required functions

3.2 controlgear
a general term covering switching devices and their combination with associated control, measuring, protective and regulating equipment, also assemblies of such devices and equipment with associated interconnections, accessories, enclosures and supporting structures, intended in principle for the control of electric energy consuming equipment [IEC 60050-441:1984+A1, **441-11-03**]

3.3 dead working
work activity on electrical installations, which are neither live nor charged, carried out after having taken all measures to prevent electrical danger [BS EN 50110-1:2013, **3.4.8**]

3.4 diagnostic test
comparative measurement carried out to monitor the condition of an item

3.5 examination
inspection with the addition of partial dismantling as required, supplemented by means such as measurement and non-destructive tests in order to arrive at a reliable conclusion as to the condition of an item

3.6 failure
termination of the ability of an item to perform a required function [BS EN 13306:2010, **5.1**]

NOTE Failure can be gradual or sudden and partial or complete.

3.7 high voltage
voltage in excess of 1 kV

3.8 inspection
examination for conformity by measuring, observing, or testing the relevant characteristics of an item [BS EN 13306:2010, **8.1**]

3.9 item
part, component, device, subsystem, functional unit, equipment or system that can be individually described and considered [BS EN 13306:2010, **3.1**]

3.10 live working
all work in which a worker deliberately makes contact with live parts or reaches into the live working zone with either parts of his or her body or with tools, equipment or devices being handled [BS EN 50110-1:2013, **3.4.4**]

3.11 low-maintenance equipment
equipment designed not to require frequent maintenance and, except when subject to very frequent operation, intended to need minimal examination or overhaul during the economic life of the equipment

3.12 maintenance
combination of actions carried out to retain an item in, or restore it to, an acceptable condition

3.13 manufacturer's handbook
written information issued by the manufacturer of the equipment which includes guidance and instructions concerning installation, commissioning, operation and maintenance of the equipment

3.14 non-routine maintenance
unplanned maintenance which is not the result of a failure

3.15 operational check
action carried out to determine whether an item functions correctly

3.16 overhaul
comprehensive set of preventive maintenance actions carried out in order to maintain the required level of performance of an item

NOTE 1 Overhaul may be performed at prescribed intervals of time or number of operations.

NOTE 2 Overhaul may require a complete or partial dismantling of the item.

[BS EN 13306:2010, **8.6**]

3.17 post-fault maintenance
maintenance which might be necessary after a specified number of fault clearance or making operations

3.18 preventive maintenance
maintenance carried out with the objective of preventing failure

NOTE It may include routine or non-routine maintenance.

3.19 routine maintenance
maintenance organized and carried out in accordance with a predetermined policy or plan to prevent failure or decide the likelihood of an item failing to be in an acceptable condition

3.20 servicing
work carried out to ensure that the equipment is kept in an acceptable condition, which usually does not involve any dismantling, and is typically limited to cleaning, adjustment and lubrication

3.21 switchgear
a general term covering switching devices and their combination with associated control, measuring, protective and regulating equipment, also assemblies of such devices and equipment with associated interconnections, accessories, enclosures and supporting structures, intended in principle for use in connection with generation, transmission, distribution and conversion of electric energy
[IEC 60050-441:1984+A1, **441-11-02**]

4 Maintenance policy

It is the asset owner's responsibility to ensure that there is an effective maintenance policy. An example of this is described in PAS 55. Whilst there is no legal requirement for maintenance at any particular interval, there is a legal requirement that the system and its parts continue to be safe.

NOTE Attention is drawn to the Electricity at Work Regulations 1989. See the Health and Safety Executive (HSE) publication HSR 25 Memorandum of guidance on the Electricity at Work Regulations 1989 *[1].*

There are several aspects of the risk assessment concerning the scope, content and timing of the maintenance. Evidence is necessary to make a judgement of what maintenance is required, ranging from functional checks to complete replacement. The performance of the system, operational history, environmental exposure, physical condition, age and consequences of failure all provide evidence. Experience from similar systems gives useful guidance on potential performance. Manufacturers can be expected to provide guidance about maintenance, but clearly different practical applications over the lifetime of the system can give rise to failure modes that the manufacturer might not be aware of. Further guidance is provided by competent organizations [e.g. the Health and Safety Executive (HSE) or electrical consultants], standards and industry recommendations. The initial maintenance interval and its content should be as advised by this guidance unless the owner has developed technical and risk assessments which justify an alternative interval.

Subsequent experience should be recorded and used to update maintenance policy. It is key to the continued safe operation of the system and its parts that there is adequate evidence to justify the maintenance policy. This may involve progressive sampling of the equipment to assess the continuing condition of equipment and understand potential failures. If the maintenance interval is extended and a system failure or fault can have significant consequences, then adequate precautions should be taken to ensure that such faults can be anticipated and the consequences prevented so far as is reasonably practicable. Thus it is essential that any maintenance policy takes into consideration the application of the equipment, its use, environment, changes in operation and consequences of failure.

Options for maintenance can be restricted by lack of available parts. Many original equipment manufacturers are no longer in business. Their equipment might be supported by other manufacturers, but such support can be limited. (See Clause **20**.)

5 Operational policy

A documented overall design, operation, maintenance, examination, inspection and testing scheme for the electrical installation, including fixed installations, switchgear, plant, machinery and equipment should be developed, with competent electrical workers employed to complete this work on site. A communications process should be established between the electrical workers employed to complete work on site and the organization's electrical engineering specialists. This should be reviewed periodically to ensure continued adequate installation, design, construction, integrity and operation and to confirm that the organization's policy, risk assessments and procedures are being complied with. This may include contingency planning in the event of the electrically competent workers being unavailable. Any identified remedial work should be completed in a prioritized programme, including inspection and testing. Clear instructions should be given, as appropriate, to site workers and contractors to ensure that they understand the job requirements, safe working procedures and their duties, limitations and responsibilities, all confirmed in writing as necessary. Appropriate training of staff, and supervision, monitoring and auditing of qualifications, competence and work should be undertaken.

6 Competence

Successful maintenance requires competent people. Training and experience sufficient for their tasks is essential for competent fitters and engineers. They should also be capable of recognizing danger and taking suitable action to prevent injury and damage to equipment. Those persons require appropriate information about the work and instructions about what to do. They should be familiar with the systems and equipment that they are responsible for. Changes in technology result in constant changes in the equipment and familiarity with the practical operational systems will require knowledge and experience of many different types of equipment from several generations using differing technologically diverse principles. As less experienced persons become responsible for maintenance, experience can be lost and this can adversely affect the quality of decisions and the condition of the equipment. This is particularly true where there are long intervals between interventions. Maintenance experience can become limited. It is important that relevant knowledge of maintenance and defects is documented such that staff experience is captured. This is particularly important to consider in instances of mergers, re-organization, redundancy and retirement.

According to their level of experience workers will require varying levels of supervision and support. Some form of recognition of competence and the extent of work that individual workers are expected to perform is usually necessary. This should be part of an authorization procedure, allowing the worker to challenge when work might exceed this expectation.

Experienced supervision capable of identifying procedural and technical failures is required to forestall potentially serious failures. Procedural drift and wilful neglect can result from inadequate assessment of policy and inadequate supervision to ensure compliance.

Section 2: Safety

7 Personal protective equipment and treatment of persons suffering from electric shock

A risk assessment should be carried out and the requirement for suitable personal protective equipment (PPE) should be considered before maintenance commences.

A notice giving instructions for the treatment of persons suffering from electric shock may be affixed in a prominent position in the vicinity in which work on electrical installations will be carried out. It is strongly recommended that all electrical maintenance personnel be trained in the application of resuscitation and know how to summon medical help.

NOTE A poster Electric shock. First aid procedures [2] *is available from the Health and Safety Executive.*

8 Operational experience

Equipment related issues identified through operational experience should be recorded to provide evidence for future consideration. A robust procedure for reporting and recording abnormal events and faults, and acting upon them, is important in justifying continued operation. It is essential that these actions and changes are effectively communicated. It is also essential that maintenance policies are frequently reviewed and revisions in procedures implemented. All round communication is a vital aspect of effective maintenance.

There might be experience available from elsewhere. There are commercially available databases which record incidents of equipment failures.

9 Safety rules and procedures for safe systems of work

It is recommended that for all premises, the dutyholder/asset owner should formulate, and update as necessary during the life of the equipment, a set of safety rules and procedures, appropriate to the type of electrical installation, covering safe access for the purposes of maintenance to, and operation of, the equipment on the premises. An example of the issues to consider when formulating a set of safety rules is given in Annex B. Where the dutyholder/asset owner is not competent to do this, the formulation of a set of safety rules may be contracted out to a competent authority.

It is extremely important that competent persons who have adequate technical knowledge and experience of maintaining the particular types of switchgear and controlgear carry out the maintenance and that it is done in accordance with documented maintenance procedures. This also applies to any authorized persons or subcontractors who may undertake the work.

Where switching or maintenance work has to be done on equipment fed directly from a source of supply not under the control of the asset owner or the persons actually carrying out the work special care is essential. It is necessary for all parties (including the owner of the source of supply not under the control of the asset owner) to mutually agree procedures and methods of work in order to ensure the safety of persons carrying out the work, and for these agreed procedures to be incorporated in the rules and procedures for the installation.

Care should also be taken to prevent equipment being worked on becoming energized due to the automatic or inadvertent starting of standby or emergency generators or other locally connected generation plant and sources of supply. In particular, the possibility of backfeeds from embedded generation should be taken into consideration.

In addition, the asset owner should ensure that safety rules and working procedures are based on the manufacturer's handbook, as applicable, and operational knowledge gathered over the lifetime of the asset, for the safe handling, maintenance and testing of the equipment. The asset owner should also make arrangements for monitoring to ensure that these procedures are performed effectively.

Those concerned with the organization of the maintenance of the equipment should familiarize themselves with the plant it controls and take account of any changes which might affect the operation or maintenance of the equipment. During maintenance work all personnel should pay particular attention to warning notices and/or instructions on the equipment or set up temporarily during the maintenance procedures.

10 Equipment location

Switchgear is generally located in substations. These locations are normally separated from the routine activity of the premises and visited infrequently. Such locations should be kept locked and access restricted to authorized personnel. Periodic inspection of such locations is considered good practice to ensure that deterioration is not occurring which could affect the equipment (e.g. water ingress, build-up of debris in the location, or presence of vegetation or vermin). Documented procedures should be in place to detect and rectify such faults as soon as possible.

11 Isolation and access for maintenance

11.1 General

The policy to be followed in making equipment available for maintenance should always be that it should be isolated (with a means of securing the isolation utilized), proved dead where possible and immediately earthed. Dead working procedures should be the normal practise. Where live working is to be carried out, attention is drawn to Regulation 14 of the Electricity at Work Regulations 1989.

NOTE See HSE publications HSG 85 Electricity at work – Safe working practices *[3] and HSR 25* Memorandum of guidance on the Electricity at Work Regulations 1989 *[1] for further information.*

11.2 Procedures

No electrical conductor should be regarded as being safe unless it has been isolated, proved dead where practicable, discharged to earth and, where necessary, earthed at all points of supply. It is essential that manually applied earth(s) are applied only after the conductor has been proved dead at the point of application.

Precautions should be taken to ensure that the isolated equipment cannot be re-energized from a high voltage or a lower voltage source of supply (e.g. backfeeds from transformers or other connected generation equipment). Precautions should be taken to ensure that any earth connection, applied as part of the safe system of work, is not inadvertently removed. This can be achieved with caution notices or, preferably, locks. If locks are used, they should have a unique key and the key should be under the control of the person carrying out the work.

If a circuit breaker is used to provide the earth connection, it is imperative that all trip facilities are disabled. This should include all facilities for remote operation.

Voltage indicators should be proved before and after use. This should the done by means of a proving unit with low power output. If live circuits are to be used to prove instruments, adequate precautions against electric shock and short circuits should be taken. A formal system of inspection and maintenance on all earthing harnesses and test bushings should be established. Such equipment should be inspected before every use. However, this might not be practicable for some devices where an integral earthing device is used. Earthing connections including leads and associated terminations need to be of adequate capacity for the duty at the point of application. The integrity of the earth connection should be verified before work commences.

Barriers preventing access to enclosures containing live conductors should normally be kept locked.

Where one person isolates and another does the work, the person responsible for isolating should demonstrate effectively to the other that the equipment is in fact dead and safe and that there are adequate safeguards to prevent re-energization.

Adequate quantities of suitable locks, cautionary notices and temporary barriers should be available for use to facilitate safe working and to prevent conductors from being accidentally electrically charged when persons are working on them, and also to warn of the presence of any live conductors. Such notices should be clearly legible, prominently displayed, made from durable material and kept up to date. Suitable precautions should be taken to identify circuits and equipment at the front and back of switchboards, where such identification does not already exist. Where locks are used as part of the safe system of work, they should have a unique key and the key(s) should be under the control of the person carrying out the work.

Any disconnectors used for isolation should be locked to prevent movement to the ON position. Any shutters giving access to live conductors should also be padlocked in the CLOSED position.

Equipment enclosures frequently contain circuits which have sources of supply different from that of the main circuit, such as interlocks, alarms, and heating and lighting circuits, and these secondary circuits are not always isolated when the main circuit is disconnected. Where reasonably practicable, separate isolation of these secondary circuits should be provided and used. Conductors and terminals associated with these circuits should be shrouded where necessary to prevent accidental contact and identified with warning notices. Particular care should be taken to avoid danger from reverse energization of voltage/control transformers or the open-circuiting of current transformer secondaries.

Removal and retention of fuse links or bolted links should only be used as a means of isolation when suitable precautions are taken to prevent duplicates being inserted.

Contactors and power electronic switching devices should never be considered as a means of isolation.

Where the component to be maintained is completely withdrawn from the equipment, and thus from all sources of electrical supply and discharged to earth, that component may be regarded as an electrically safe piece of equipment for maintenance purposes.

In the case where power capacitors are included in the component to be maintained, care should be taken to ensure that these are discharged to earth and are in a safe condition.

12 Preparing for maintenance work

Working space, entry ways and exit ways provided to apparatus and to equipment which is to be maintained should be kept clean and free from obstructions. Spare parts, tools, instruments, insulating screens, insulated tools, portable earthing devices and gloves associated with the equipment or the work to be performed should be housed in receptacles provided for the purpose, as necessary.

Adequate lighting, either fixed, portable, or a combination of both, should be provided as necessary to ensure safe access and working.

Portable electrical tools and inspection lamps should preferably be battery operated or operated from a system with a voltage no greater than 110 V with either the star point of a three-phase or the mid-point of a single-phase transformer low voltage winding earthed. If portable tools operating at a higher voltage need to be used, they should be of all-insulated or double-insulated construction and the use of a residual current device is recommended. All portable electrical equipment should be regularly inspected and tested.

NOTE 1 Further advice on maintaining portable tools is available in HSE publication HSG 107 Maintaining portable and transportable electrical equipment *[4].*

The ingress of moisture, vegetation, dirt, vermin, etc. into electrical equipment can cause malfunction and danger. Care should be taken to prevent such ingress whilst work is in progress, and covers should be replaced as soon as access to the particular part or the chamber is no longer required.

When work is being carried out with adjacent pneumatically operated or air-blast circuit breakers in service, precautions should be taken to protect personnel from the effects of noise caused by these circuit breakers should they operate. Consideration should be given to the use of ear protectors even where silencers are fitted.

NOTE 2 Attention is drawn to the Control of Noise at Work Regulations 2005.

13 Fire extinguishing equipment

All personnel carrying out maintenance on equipment where there is a fire risk, or using flammable materials in processes requiring flame or other sources of heat, should have suitable fire fighting equipment available for ready use. This equipment may be installed permanently by an asset owner for use in the premises or it may be temporary equipment provided for the period of work. Employees should be trained in the use of the fire fighting equipment and know how to summon further assistance.

If a fixed automatic fire extinguishing installation is installed, a prominent warning notice should be displayed at the entry to the protected area. The notice should also include instructions for preventing automatic operation when persons are working within the protected area. The prevention and restoration of automatic operation should be subject to appropriate safety procedures, for example by including a reference on the relevant safety documentation.

The type of fire extinguishers provided for use on or near electrical equipment should be compatible with the equipment and safe to use. Further advice on fire prevention and fire fighting may be obtained from the local Fire and Rescue Service.

14 Testing

14.1 General

Care should be taken when applying test voltages to ensure that they are the lowest value required for the purpose with the minimum current output and should not exceed the equipment capability. Where equipment is capable of storing a charge this should be safely discharged before and after every test.

NOTE 1 Further advice on electrical testing is given in HSE publications INDG 354 Safety in electrical testing at work – General guidance *[5] and EIS 37* Safety in electrical testing – Switchgear and controlgear *[6].*

NOTE 2 Electrical equipment can be damaged by the application of test voltages and currents of incorrect value and polarity. Some electronic equipment is particularly vulnerable.

14.2 Use of test instruments (oscilloscopes, etc.)

Instruments should be of a type suitable for the measurements that are to be made so that a malfunction or the introduction of transients and/or reversed polarities into the connected circuits is avoided. The manufacturer's instructions should be followed.

An earthed instrument lead can create danger if it is applied to an active signal circuit which is normally floating. It is recommended that the instrument casings are earthed at all times but, where the nature of the test precludes this, specific care should be taken by the operator to secure his or her own safety and that of others by the adoption of a safe system of work. Suitably protected test leads should be used at all times.

15 Disposal of scrap

In the UK there are statutory requirements for the disposal of waste products. These make the holder of the waste responsible for its fate even after it has left their premises. In particular, attention is drawn to the statutory requirements listed in Annex A. In case of doubt, the local authority should be consulted.

NOTE 1 Prior to scrapping materials it is recommended that the asset owner's agreement is sought.

NOTE 2 Consideration should be given to recycling materials where appropriate.

Section 3: Common recommendations relating to maintenance

16 Manufacturer's instructions

It is essential that personnel engaged on maintenance of equipment ensure that they have access to the relevant and up-to-date documentation for the task being undertaken. This may include work instructions and/or the manufacturer's handbook. These should be used as the principal reference guide to methods of working, dismantling, reassembly and restoring to service. It is good practice to liaise with the manufacturers to establish that the version of the instructions that they hold is still valid and is the latest version. Other trade bodies might have additional operational information.

17 Newly commissioned equipment

All newly installed equipment should have a full and detailed inspection and a complete range of tests and operational checks as part of the commissioning procedure. The manufacturer's handbook and other information supplied with the equipment should be consulted for details the procedures to be followed. From a subsequent maintenance point of view the most important factor is to keep careful records of the condition of the equipment, including values of essential settings. Reference to these notes at future maintenance operations can help in deciding what interval of time should elapse between such operations (see Clause **18**).

18 Frequency of maintenance

18.1 General

NOTE 1 Some items are not intended to be maintained and might have to be renewed periodically.

There are three approaches to maintenance:

a) maintenance based on failure;

b) preventive maintenance;

c) maintenance based on condition monitoring.

The most appropriate approach to maintenance should be chosen by the duty holder, who should develop and document technical and risk assessments to justify the approach taken.

NOTE 2 This may be determined as part of the risk assessment for the equipment. The risk of continued operation can be assessed using evidence from several sources. Inspection and test of the items and the system allows the condition to be assessed, provided appropriate observations are made. These can be compared with manufacturers' recommendations and previous observations and trends. Further guidance might be available from standards, fellow operators, industry associations and regulators. Key information can be obtained from internal operational reporting, including faults and operator reports of abnormal or fault events. Such evidence should be actively sought and acted upon. All of this evidence should be used when deciding on maintenance policy. It is vital that such decisions are made by competent persons who have appropriate knowledge and experience.

In any switchgear or controlgear installation, a distinction can be made between the device which carries out the switching operation (e.g. circuit breaker, contactor) and the rest of the equipment which performs a supporting role of connection, containment, etc. The latter components are only likely to need periodic inspection and servicing to ensure that the equipment is free from dirt, damp and deterioration, such as corrosion of metalwork and contamination of insulation. The switching device and its operating mechanism have moving parts subject to wear after extended use, and contacts, arc control devices and arc extinguishing fluids that are subject to deterioration at a rate depending on the design of the device and the frequency of switching operations.

Modern equipment, generally, is designed for lower maintenance and might be sealed for life. Depending on the design of the switchgear or controlgear, where frequent switching is required (e.g. several operations per day) it might be necessary to perform more frequent maintenance and the manufacturer should be consulted. This guidance should be checked and supplemented by keeping careful records of inspections and operational checks so that user experience can be built up in the operational environment. The manufacturer's handbook should also be consulted for information as to how essential settings should be checked and on the acceptable range of values for continuing service.

Whilst abnormally frequent operation might necessitate an increase in maintenance frequency, the converse is not necessarily true.

Semiconductors for power and control purposes and similar items and assemblies should be left undisturbed since they are easily damaged inadvertently.

18.2 Maintenance based on failure

When they fail, equipment and systems are repaired or replaced. This approach can be followed where failure does not result in danger and the consequences of failure are otherwise acceptable. Often failure maintenance is used in the belief that is the cheapest and least difficult to organize. It is also the default when maintenance is not adequately considered. It can lead to unplanned outages and undisclosed failures with potentially severe consequences. This can lead to further pressures to restore the failed system in an uncontrolled and potentially dangerous way. The financial and personal cost of such situations can far outweigh any short term financial gain. This lack of knowledge about the condition and risk of failure of the system can make planning difficult. Thus, failure maintenance is only suitable where the failure and its serious consequences can be prevented by effective reporting of the precursors of the failure and suitable remedial action. If this is not possible then a more formal maintenance procedure involving planned preventative and condition based maintenance is necessary.

As the items in the system age, various other faults and modes of failure can become likely that do not apply in the newly supplied system. Operational experience might highlight the need for modifications or alterations in their assigned capability.

Also, as time passes the items can be subjected to changes in the way that they are applied. The systems that utilize the items can change and they might have to operate in new ways or with extra duties that are possibly beyond the intention of their original design. There are likely to be changes in the loading of systems due to changes in the layout of connected loads and installation of new loads. Failure modes can be affected by environmental factors and operational stresses. Basic good practice such as keeping substations and switchrooms clean, tidy and free from condensation can have a beneficial affect on the performance of the systems.

18.3 Preventive maintenance

This is carried out before failure occurs. This normally means that maintenance is planned and carried out at specified intervals. Reliability centred maintenance (RCM) (see BS EN 60300-3-11) and failure modes, effects and criticality analysis (FMECA) (see BS EN 60812) may be used to determine optimum maintenance frequencies. The content, scope, timing, availability of alternative systems, finance, replacement parts and competent maintenance staff can all be planned and made available. Thus the planned outages can be better controlled, less disruptive and safer. There are fewer pressures and less stress on those involved. Key to the effectiveness of this type of maintenance is the evidence that justifies the policy. If the intervals or content are changed to reduce the amount of maintenance without supporting evidence then it is potentially another form of failure maintenance with the shortcomings of that type of maintenance. Checking, inspection and testing should inform the policy to highlight potential failures. However it can have the drawback of unnecessary maintenance that can lead to the introduction of errors due to poor standards of work, incorrect replacement parts, or reduction in reliability due to intrusion, albeit correctly executed. Irrespective of the maintenance process used, the use of competent maintenance personnel and appropriate supervision is essential.

Because of the widely varying conditions of operation of individual installations, it is not possible to give precise recommendations for the intervals between maintenance operations. These intervals can vary greatly depending upon the design of the equipment, the duty that it is required to perform and the environment in which it is situated. From experience and/or by consultation with the manufacturer, the person responsible for the maintenance strategy/policy should decide how long it would take for any item of equipment to deteriorate to an unacceptable state under normal conditions of use, and plan the maintenance schedule accordingly.

18.4 Maintenance based on condition monitoring

Maintenance based on condition monitoring requires the measurement of certain parameters of the equipment. Maintenance philosophies such as reliability centred maintenance (RCM) and failure modes, effects and criticality analysis (FMECA) may be used to determine optimum maintenance frequencies. It is very important that the switchgear and controlgear failure modes and degradation processes are understood. The role of condition based maintenance and condition monitoring in maintenance regimes to support maintenance decisions should be considered.

This type of maintenance does not rely on a policy of assessing a safe time interval for maintenance before failure. This extends the evidence available for the assessment by surveying the system and its parts to determine precursors of failures and faults. It assesses the reliability of systems and constituent parts. This might involve surveys using intrusive internal examination to assess the condition of equipment. Often periodic or continuous monitoring of relevant parameters is used to decide when some maintenance intervention is necessary. This monitoring can be non-invasive with sensors and instrumentation. The parameters measured can include temperature, leakage or operating currents, acoustics, partial discharge or thermographic surveys. The amount and effectiveness of maintenance can be better provided if the technique is effectively applied. It is essential that precursors of all significant failure modes are effectively monitored in this type of maintenance, even if they have not appeared yet. If the failure appears without sufficient warning to prevent its serious consequences then this type of maintenance is not suitable.

It is essential that the asset owner ensures that the designated condition monitoring parameters are measured by whoever undertakes the work. It is also essential that those undertaking the work follow the asset owner's requirements in order to ensure consistent application of the philosophy.

18.5 Routine maintenance

The appropriate maintenance approach for the equipment (see **18.1** to **18.4**) should be used when carrying out routine maintenance. Examinations should be carried out to determine whether undue damage or excessive wear has been sustained in the course of operations and whether there is a need for overhaul of the contact systems or servicing of mechanisms, together with a more detailed inspection and testing of insulation.

Diagnostic testing can be a useful aid in establishing the frequency of maintenance, because a comparison with previous similar tests can provide an indication of possible deterioration and might indicate a need to vary maintenance intervals under the particular service conditions.

18.6 Post-fault inspection and maintenance

The need for, and extent of, post-fault inspection and maintenance should be determined by consulting the manufacturer's handbook and by past experience; it depends on a number of factors such as the magnitude of the fault current, the number of fault operations, the condition and type of the arc extinguishing medium and the effectiveness of the arc-control devices.

Particular attention should be given to some older classes of switchgear (e.g. air blast and oil) which, experience has shown, need post-fault maintenance.

It is also desirable to include on the service record reference to the number of fault operations, together with an indication of the likely fault current, if known (see also Clause **19**). The cumulative fault current and duration of the fault (I^2t) is sometimes used to determine the requirement for post-fault maintenance.

19 Records and drawings

19.1 General

Records and drawings are of value in establishing the frequency of maintenance, therefore records should be updated each time maintenance is performed. It is recommended that records should be retained for the lifetime of the equipment.

19.2 Content of records and drawings

Records should be initiated, and initial drawings made, when the equipment is installed and should contain at least the following information:

a) network diagram showing all switchgear including earthing switches;

b) asset register – These records should also include operational information such as ownership schedules, interface agreements and cable records. Any master site electrical system and services diagrams should be checked and updated. Site installation, maintenance, inspection, test and examination records, including the system diagram, should be kept up to date and readily available on site for use at all times, along with relevant safety documentation and instructions for use of site equipment;

c) manufacturer's details, including nameplate particulars of the equipment installed, its serial number and manufacturer's order number (if known) and the date of installation;

d) place where the manufacturer's handbook and list of recommended spare parts can be found;

e) date of last maintenance operation and note of the operation counter reading at that time, or an estimate of the number of operations;

f) record of maintenance work carried out – Maintenance records should be kept for all of the systems. These provide the evidence needed to assess the condition of the system and its equipment, enabling the scope and effectiveness of maintenance to be assessed. Trends in precursor conditions and failures can be used to inform policy. The policy can be justified using this evidence about what is done, when and by whom. Changes in content and timing of maintenance can be made with more confidence, and the records can assist other similar asset owners. Subsequently, assessment of maintenance effectiveness is aided. The records should allow handover to new workers in the event of loss of experienced operational persons. There is no overall legal requirement to keep records but such evidence does allow legal compliance to be demonstrated. Regulators, insurers, asset owners and maintainers will all have an interest in the existence of such records. There are some more specific requirements about maintenance logs in the Provision and Use of Work Equipment Regulations (PUWER) Regulation 5(2);

g) record of any findings where the condition of the equipment varied from the expected, action taken and the condition of important components when the equipment was put back into service;

h) details of fuse-link type and ratings, and relay settings;

i) details of the maximum system fault levels, and any changes to them;

j) any updates to the maintenance instructions and the manufacturer's handbook and recommendations, where possible.

Every significant fault or failure should be recorded and analysed with a view to taking action to prevent its recurrence.

20 Replacement parts

Care should be taken to ensure that all replacement parts are correct and suitable for the duty they are to perform, particularly when these parts are not available from the original manufacturer. Consumable spare parts and copies of manufacturer's component lists with exploded view drawings, where provided, should be kept readily available to maintenance staff. Legacy equipment manufacturers and other specialist companies might have bought rights to manufacture replacement parts from the original equipment manufacturer (OEM).

Where replacement parts are not obtained from the OEM, parts should be obtained that meet the original manufacturer's specification. Where necessary a full engineering assessment of the part(s) should be carried out to ensure that this is the case. Care should be taken with asking non-specialists to fabricate parts.

When ordering replacement parts it is advisable that nameplate particulars are quoted, including the serial number or other manufacturer's identification number.

To prevent the use of defective or potentially defective replacement parts, parts should be used that have been manufactured and supplied in accordance with a suitable quality standard.

Spare parts should be stored in conditions that prevent corrosion/degradation.

21 Cleanliness

For equipment to operate satisfactorily it is essential that natural or forced ventilation is not restricted (see also Clause **28**). However, care should be taken to avoid needlessly disturbing equipment. Before removing covers, inserting test probes, breaking gasketted joints or opening doors, precautions should be taken to prevent ingress of dirt, dust and loose objects.

Where the recommended maintenance procedures permit the use of solvents for cleaning or degreasing, it is essential that the liquids used are compatible with the equipment. Non-flammable and non-toxic solvents are preferable and precautions should be taken against fire and toxic effects.

Wipes made of low linting manmade fibres should be used for cleaning.

Incorrect use and application of lubrication has been a major cause of mal-operation in switchgear and controlgear mechanisms. Some types of bearings should not be lubricated and can cause failure of the equipment if lubrication is applied.

If painting is necessary, care should be taken to avoid application of paint to pivots, bearings, insulating surfaces, labels and notices. It is essential to ensure that painting does not restrict the flow of air through ventilation openings.

22 Marking of covers and connections

All covers, cable terminations, etc., should be marked carefully before removal to enable correct replacement. Electricians tape should not be used for identification purposes because it has been found in the past to have contributed to dielectric failure, for example within cable compartments.

Disturbed connections or temporary connections made for testing purposes should be clearly marked to facilitate reconnection. It is essential that the service connections be restored and the temporary connections and markings removed before the unit is returned to service.

23 Quality of connections

It is recommended that connections that have not been disturbed be checked for soundness. It might be possible to detect a bad connection by looking for signs of overheating or by using a contact resistance test set. In-service thermal imaging surveys are being increasingly used to verify the quality of high current carrying connections.

If it is necessary to break bolted joints, the section of the manufacturer's handbook dealing with installation should be consulted for guidance on remaking the joint. A contact resistance test set should be used to confirm that a satisfactory joint has been made.

Moveable contacts, e.g. plugs and sliding connections, should be inspected, as far as is reasonably practical, for correct functioning, cleanliness and signs of overheating.

Flexible connections, e.g. braids, should be inspected for signs of fraying and loss of flexibility, and renewed if necessary.

24 Maintenance and testing of insulation

24.1 General

WARNING. Older switchgear might contain asbestos. Attention is drawn to the Control of Asbestos Regulations 2012.

It is important that insulation be inspected periodically. Modern insulation materials and systems are generally reliable and stable but when equipment is made available for maintenance, where practicable, the opportunity should be taken to inspect the insulation. Where practicable, porcelain and moulded insulation should be inspected for cracks and other defects. Bonded and laminated fibrous insulation and other organic insulation should be inspected for signs of tracking, treeing, delamination and mechanical damage. An insulation resistance test may be carried out to determine the condition of the insulation. Adjacent metallic surfaces should be examined for evidence of corrosion. In some cases this can be indicative of partial discharge activity.

24.2 Routine inspection and testing

Insulation resistance measurements between poles and between poles and earth are the most suitable for insulation testing under service conditions. In order to facilitate their proper interpretation, systematic testing and recording methods are essential. These tests are strictly comparative, in that for each item tested a judgement concerning any potential deterioration has to be made by experience based on earlier results. For this reason the test equipment and method used should be the same on each occasion, and the test values should be carefully logged, preferably on forms drawn up for this purpose, together with a record of the temperature and humidity conditions at the time of the test. Pass or fail criteria are sometimes stated by manufacturers.

The voltage which should be applied to primary insulation when making resistance tests varies according to the voltage rating of the equipment. Recommended test voltages are given in Table 1.

Table 1 **Recommended test voltages**

3-phase voltage rating of primary insulation of equipment kV	**Test voltage recommended for insulation resistance test (to earth and between phases)** kV (d.c.)
72.5	5
145	5
300	See Note
420	See Note

NOTE For higher voltages, Insulation testing is not routinely applied to the switchgear main current carrying components during normal maintenance. Electrical tests, such as capacitance, loss angle and partial discharge tests, can be carried for diagnostic purposes. There are considerable problems in achieving consistent accurate results on site owing to atmospheric conditions and adjacent live circuits.

After testing, conductors should be discharged to earth using an appropriate discharge rod.

The insulation resistance of small wiring and ancillary components should be tested at a voltage not exceeding 500 V d.c.

Certain types of equipment, e.g. apparatus incorporating semiconductors, might not withstand this test voltage and measures should be taken to protect these during the test.

Insulation media should be sampled and tested routinely and during maintenance (SF_6 only during normal maintenance). Thermal imaging and radio frequency interference (RFI) monitoring of equipment may be carried out during substation routine inspections. These checks provide indications of possible insulation degradation.

A steady fall in insulation resistance over a period of time is indicative of insulation deterioration. However, a relatively low value which remains reasonably constant might be acceptable.

Additional diagnostic insulation tests such as polarization index (PI) and step voltage (SV) may also be used. Such tests are not comparative and, therefore, do not rely upon earlier results.

Partial discharge measurements may be made. Where these are undertaken they should be made both before intrusive maintenance so that any detected source can be investigated, and after maintenance to ensure that a source has not been introduced during maintenance.

The types of insulation usually met with on switchgear comprise polymeric material, laminated material and porcelain. With all these materials, the results of the resistance measurements are mainly governed by the surface condition of the material and the humidity. Therefore, the insulation tests should be accompanied by a careful visual inspection of the insulation surface, as already indicated. In laminated insulation, tracking, which tends to start at the edges of metalwork, often occurs beneath the surface of the insulation, and is indicated as a surface blister.

24.3 Insulating oil

WARNING. Excessive handling of instulating oil can cause dermatitis. Precautions should be taken to protect personnel from contact with insulating oil.

Adverse environmental and operational conditions can have a detrimental effect on insulating oil and special attention should be paid to equipment operating under such conditions, for example by making checks initially at fairly frequent intervals until experience has been gained.

In normal use, the interval between tests of oil should be made dependent on the nature and frequency of use of the equipment. The optimum period between tests should be based on experience and/or consultation with the manufacturer.

The contamination of insulating oil can be a limiting factor on the allowable time between maintenance operations.

Testing in accordance with BS EN 60422 is recommended. These tests include testing of oil properties such as breakdown voltage, acidity, water content and flashpoint.

*NOTE 1 In equipment where the oil is used for arc extinction, the presence of carbon particles is a normal expectation in operation and does not necessarily indicate that the oil is in an unacceptable condition (see **35.2.2.1**).*

NOTE 2 To ensure satisfactory service, the utmost care in handling the oil is essential and guidance on this is given in BS EN 60422.

For oil handling it is good practice to segregate clearly the handling of clean oil and dirty oil, and for the arrangements to be clearly marked. All containers, pipework and pumps used with clean oil should be kept clean and free from moisture. Before use they should be carefully inspected and preferably flushed with clean oil.

24.4 Bushings on open-terminal equipment

The oil level on oil-filled terminal bushings should be periodically checked and if any marked change occurs, particularly if accompanied by signs of oil leakage, the manufacturer should be consulted.

With compound-filled bushings a resistance measurement will not necessarily indicate the presence of moisture. Where practicable, the space above the compound should be inspected for signs of moisture ingress. If the presence of moisture is suspected, the bushing should be returned to the manufacturer for checking. Where covers are removed, care should be taken on re-assembly to ensure that all joints are properly made. During inspection it should be verified that the earth connection is satisfactory.

Tan delta tests or partial discharge measurements may be used to assess the condition of the bushing insulation.

24.5 Sulphur hexafluoride (SF_6)

*COMMENTARY ON **24.5***

Sulphur hexafluoride is inert, colourless, tasteless, non-flammable, non-toxic, heavier than air (relative density = 5.11) and chemically stable in the normal conditions of use of electrical equipment.

At high temperatures (above 800 °C) and when exposed to an electric arc, sulphur hexafluoride is decomposed, with the formation of other SF compounds and, with the inevitable tiny traces of moisture and oxygen, with the formation of some oxyfluorides. In equipment where the gas is used for arc extinction, molecular sieves, activated alumina or charcoal are provided, which can easily absorb these decomposition products. The solid products resulting from the decomposition of sulphur hexafluoride exist in the form of a whitish powder which hydrolyses in the presence of moisture to form a sticky grey deposit. This powder has an irritating action on the skin, eyes and respiratory mucous membranes. However experience has shown that in the rare event of any of these products being present in the atmosphere within a substation, warning indications are likely to be apparent at very low concentrations in the form of a strong and nauseous odour. This is likely to be evident well before any toxic effects can take place.

Sulphur hexafluoride (SF_6) is listed as a fluorinated greenhouse gas in European Union Regulation EC 842/2006 [7] (on certain fluorinated greenhouse gases), the requirements of which are referred to in the Fluorinated Greenhouse Gases Regulations 2009. As such, SF_6 is subject to strict requirements governing its use, which are intended to prevent and minimize any release into the atmosphere.

EC Regulation 305/2008 [8], which is also referred to in the Fluorinated Greenhouse Gases Regulations 2009, requires individuals who carry out recovery of SF_6 gas from high voltage switchgear to be appropriately trained and assessed and to hold a written qualification issued by a certification body. The authorized certification bodies in the UK are listed in Schedule 2 of the Fluorinated Greenhouse Gases Regulations 2009.

24.5.1 General

Personnel working on equipment containing SF_6 should work in accordance with PD CLC/TR 62271-303.

24.5.2 Risks presented by sulphur hexafluoride leaks in normal operation

Gas loss from the equipment can lead to the introduction of air and moisture resulting in dielectric failure.

In the equipment covered by this British Standard the amount of gas present in the switching device can be substantial, but experience has shown that leakage is rare. Any arcing by-products are likely to be absorbed by the reagents mentioned in the commentary on **24.5**, so these are unlikely to leak from the container. However, if a pungent or unpleasant odour appears, personnel should quickly get into fresh air. In the unlikely event of a total loss of gas, the resultant layer of gas in the average indoor substation could present a risk of anoxia. Although SF_6 is non-toxic, it will not support life, and unprotected personnel entering an SF_6 filled enclosure, trench, etc., will be in danger of asphyxiation. It is essential that personnel be made aware of this danger and that equipment is adequately ventilated if it is to be entered without breathing apparatus. If there is any doubt, it is essential to verify the presence of sufficient oxygen using, for example, a portable oxygen analyzer.

For all substations (indoor and outdoor) special consideration should be given to extremely low lying confined areas e.g. cable trenches or substation basements where, for example, it might be necessary to install temporary or permanent SF_6 alarms.

24.5.3 Risks presented by sulphur hexafluoride leaks due to abnormal occurrences producing rupture

In the very unlikely event of a failure of a sulphur hexafluoride switchgear or controlgear enclosure as a result of an internal arcing fault there is a risk that some of the potentially toxic arcing products might be released into the substation. As mentioned in **24.5.2**, the presence of these products can be detected at levels of concentration well below the danger level and it is recommended that personnel who would be concerned with such a substation, but not be working on the equipment, be given the following advice.

a) If a disagreeable smell is detected on opening the door of the premises or near the place where the plant is installed, the area should be thoroughly ventilated.

b) As far as possible, entering the premises should be avoided until the ventilation has dispersed the nauseous products.

c) When the area has been ventilated, it is possible to proceed with the removal of the damaged equipment and the cleaning of the cubicle and its surroundings. The solid deposits to be removed can have an irritating effect on the skin, so it is imperative that suitable goggles, gloves and a mask fitted with an approved filter be worn. After use, the mask filter should be carefully disposed of, and the goggles and gloves should be washed and copiously rinsed using a solution of sodium carbonate/bicarbonate.

24.5.4 Prevention of release of gas to the atmosphere

As the venting of SF_6 to the atmosphere is strictly prohibited, if it is necessary to examine the interior of the equipment, all SF_6 should be removed and stored in a suitable cylinder using SF_6 gas handling equipment, in accordance with PD CLC/TR 62271-303.

24.5.5 Health and safety

On opening up equipment for inspection of the interior, personnel should take particular care to avoid exposure to possible breakdown products, and suitable personal protective equipment should be used. This should include suitable overalls, thin rubber gloves, chemical type box goggles and a respirator incorporating a dust filter and activated charcoal. Users should draw up a written procedure covering the opening and inspection of the equipment and this should be strictly followed. It is essential that this also includes decontamination processes for the equipment.

24.6 Arc gaps

Arcing horns should be secure and the gap dimensions correct.

25 Maintenance of safety earthing continuity

All exposed metal work should be effectively earthed. It is very important to ensure that earthing connections are mechanically and electrically sound and that all contact screws are tight and good contact is maintained. Particular care should be taken to reinstate fully all bolts and screws, together with any locking devices that might have been disturbed during the maintenance operation.

26 Shutters, locking devices, etc.

The mechanical features should be particularly checked for correct functioning and the inhibiting of incorrect actions under all conditions. Mechanisms should be free from corrosion and freely operating with all nuts, locking devices, etc. secure.

Unless otherwise stated in the manufacturer's instructions and only if deemed essential, lubrication should be applied to bearings, shafts, pivots, actuating levers and rollers.

27 Interlocks

27.1 Types and purpose

Equipment interlocks are of two types which are for different purposes, as follows:

a) standard interlocks incorporated in the design of the equipment and associated with its safe manipulation;

b) application interlocks associated with the safe operation of the connected plant.

27.2 Knowledge of interlocking requirements

The person, or persons, responsible for checking or maintaining any interlock system should have a thorough understanding of the extent, nature, function and purpose of the interlocks, together with the necessary knowledge and experience of the plant.

The manufacturer's handbook and any relevant plant diagrams should be available for reference.

27.3 Maintenance of interlock systems

Maintenance of interlock systems should include implementation of the following recommendations, depending on the types of interlock installed.

a) *Mechanical aspects*. All moving parts should be clean, adequately lubricated and be free to move as intended. Any evidence of wear or excessive free play should be investigated and, if necessary, reference made to the manufacturer. All fixing devices should be secure.

b) *Electrical aspects*. Where accessible, control wiring should be inspected for signs of damage, and terminations checked for tightness. If in doubt concerning the condition of the insulation it is recommended that an insulation resistance test be carried out (see **24.2**).

27.4 Functional test

Where it is reasonably practicable for the relevant busbar and/or feeder circuits to be made dead, all interlocks should be functionally tested before the equipment is restored to service. These checks should be carried out in both the positive and negative modes to ensure that the interlock system not only permits fulfilment of the intended operational sequence, but also prevents, when necessary, unintended or unsafe action.

When an interlock is found to be defective and remedial action cannot be implemented immediately, steps need to be taken to ensure safety by other adequate means.

28 Ventilation

Ventilated equipment should be examined and any restriction to the airflow removed. In the case of forced ventilation, the operation of any airflow interlock should be checked and corrected if necessary. Filters, if any, should be cleaned or renewed as necessary.

29 Equipment heating and lighting

WARNING. Circuits associated with equipment heating and lighting often remain live when the equipment is otherwise isolated.

Heaters, dehumidifiers, lights, emergency lighting installation and changeover equipment for alternative low voltage (LV) supplies, where fitted, should be checked for correct operation.

30 Lifting devices

The maintenance of lifting devices is covered by the Lifting Operations and Lifting Equipment Regulations 1998.

31 Mechanisms

WARNING. During inspection or examination of the mechanisms care should be taken to avoid injury from moving parts.

31.1 Main mechanism

The main operating mechanism should be carefully examined. Diagnostic tests and the verification of the setting dimensions will usually reveal any form of malfunction. Linkages should be inspected for free movement and attention given to any signs of catching on "passing" links. Circlips should be checked for correct seating and split pins opened. The mechanism should be cleaned and examined and worn parts renewed. Extreme care should be taken to verify that the adjustments comply with the manufacturer's handbook.

It is important that the tripping mechanism is free from congealed lubricant, particularly on rolling or sliding surfaces. Any dried lubricant should be removed and the mechanism re-lubricated in accordance with the manufacturer's instructions. These instructions should be very carefully followed where plastics bearings or components are used since in many cases the use of an incorrect lubricant can have a very serious effect.

The mechanism should be generally cleaned and lubricated in accordance with the manufacturer's instructions. The correct operation of heaters, where fitted, should be verified.

31.2 Tripping mechanisms (where applicable)

It is particularly important to ensure that rolling or sliding surfaces in the trip mechanism are free from dried up lubricant. Service with recommended lubricant, adjust as required and verify correct operation.

Opening release coil plungers should be inspected for free movement but should NOT be lubricated.

31.3 Closing mechanism (where applicable)

Clean, examine and renew worn parts, service as necessary and remove all surplus lubricant.

Examine the mechanical details and the closing mechanism and verify correct operation of damping devices where fitted. In the case of spring closing gear, special attention should be paid to ratchet wheels and pawls, which should be examined for broken or chipped teeth. Where motor wound springs are employed, the motor and its connections should be examined and the reduction gear treated with the prescribed lubricant. Recording of mechanism settings may indicate the progression of wear or relaxation.

31.4 Motorized drive mechanisms (where applicable)

Remove dried lubricant and inspect any clutch, spring, centrifugal switch or worm drive. Service these as required and top up gear box oil level.

31.5 Hydraulic drive mechanisms (where applicable)

Discharge the hydraulic energy accumulator, where fitted, and top up the reservoir with the recommended fluid using clean containers kept only for this purpose. Where recommended by the manufacturer, filter the hydraulic fluid, ensuring the system is refilled to the correct level and is free from air locks. Verify the operation of any pressure gauge or low pressure alarm. During service, periodically operate the accumulator fluid discharge lever to verify that the motor and pump are operating correctly.

31.6 Interpole linkages (where applicable)

In order to ensure minimum spread of the timing between poles, interpole linkages usually have carefully fitted linkage pins, etc. and minimum backlash mechanisms. It is important that these features are inspected. Any deterioration in this respect will usually be indicated in the timing test. When necessary, carefully verify the setting dimensions of the interpole linkages to the manufacturer' s handbook, but do not interfere with them unless essential adjustments are required. Verify that all nuts and bolts are tight and all pivot pins secure.

Malfunction of dashpots associated with interpole linkages is usually only shown up by an appropriate travel record during the timing test and unless such a record is available and indicates satisfactory operation, the dashpots should be carefully inspected. Oil type dashpots usually require no more than verification of the oil level but air type dashpots, depending on the type, will require verification of bleed holes and clearances, etc. On circuit breakers fitted with mechanical or pneumatic intertripping between poles, the correct function should be verified by initiating operations (close and open) of each pole in turn and ensuring that in each case the remaining two poles follow suit.

31.7 Auxiliary switches and interlocks

These should be inspected and cleaned or renewed if necessary. Particular attention should be paid to the required timing of auxiliary contacts controlling the trip circuit. They should be kept in clean and sound condition because upon them depends the correct functioning of other items of equipment, including protective gear.

Where possible, verify correct contact force, freedom of operating links and correct timing of auxiliary contacts in relation to the switchgear contacts. Particular attention should be paid to the required timing of the auxiliary contacts controlling the trip circuit. Indicating devices such as mechanical ON and OFF indicators, semaphores, etc., should be inspected to ensure that they are in good order and operating correctly.

Interlocks and locking devices should receive particular attention, especially those associated with earthing and testing facilities. A strained or worn device may result in a dangerous condition. It should be verified that any incorrect operation is satisfactorily inhibited. Service as necessary.

31.8 Isolating contacts (where applicable)

Examine for signs of overheating or corrosion and recondition as necessary. Verify correct engagement.

Contacts normally operating in air may have a film of contact lubricant applied sparingly.

31.9 Kinematic chains

The mechanical integrity of any kinematic chain between the moveable contacts and position indicating device should be visually checked and its accurate operation verified by ensuring that all the switchgear positions are adequately displayed, showing appropriate position indication.

31.10 Final verification

Before the switchgear and its auxiliary apparatus is returned to service, an operation check (see **35.1.3.1**) should be carried out.

32 Tripping and closing supplies

It is particularly important that tripping and closing supplies be maintained in good order. Compressed air plant and battery installations should be regularly maintained, including associated indicators and alarms, in line with the manufacturer's instructions. (See also BS 6423:1983+A1, Clause **63**.)

33 Equipment tools, spares and test instruments

Tools, spares and test instruments (including test probes) associated with a particular item of equipment should be regularly checked against an inventory. If calibration is required this should also be verified.

34 Conclusion of maintenance

After maintenance, equipment should be restored to a correct working condition, with particular attention to items and settings which have been disturbed, and it should be ensured that there is no potential hazard from loose or extraneous equipment, tools or wiring. Safety barriers and shrouds should be reinstated, all covers, including those of instruments and relays, replaced with all securing bolts properly tightened and all doors resecured and locked, where locks are fitted, to achieve the original degree of protection.

Any procedures required under plant safety rules should be carried out.

Section 4: Additional recommendations relating to the maintenance of specific items

NOTE For recommendations on maintenance of ancillary items operating at low voltage in control and auxiliary circuits see BS 6423:1983+A1.

WARNING. Care needs to be exercised with equipment containing old components which might contain asbestos. Attention is drawn to the Control of Asbestos Regulations 2012.

35 Circuit breakers

35.1 General

35.1.1 Safety

In addition to following the safety recommendations given in Section 2, the following precautions should be taken when working on circuit breakers.

a) Before work is commenced care should be taken to discharge and isolate all stored energy devices, e.g. closing and tripping mechanisms. Where power racking devices are provided these should be isolated. The manufacturer's handbook should be consulted for information as to how this is to be achieved in each individual case.

b) When maintenance opening and closing devices are in use, the manufacturer's instructions on their operation and application to the circuit breaker should be carefully followed.

c) No smoking or naked flames should be permitted where oil is, or has been, directly exposed to the atmosphere.

d) In the event of internal maintenance being considered necessary to any part of the equipment which is, or has been, in contact with sulphur hexafluoride (SF_6) or associated compounds, the use of personal protective equipment and special handling techniques are essential. Any sulphur hexafluoride taken from the equipment should be checked and treated in accordance with BS EN 60480, and reference should also be made to the manufacturer's handbook for instructions.

35.1.2 Diagnostic testing

Where reasonably practicable, the maximum use should be made of diagnostic testing techniques to indicate the condition of the equipment and to prolong the intervals between examinations and overhauls. It is important to keep detailed records of diagnostic test results so that comparisons can be made and trends estimated.

The following diagnostic tests should be used, as applicable.

a) Timing and travel tests, and the measurement of minimum operating voltages of both closing and tripping functions, should be carried out to indicate any deterioration in the operation of the mechanism. Valuable information can be derived from the first trip operation, which should be captured wherever possible. Sequence tests (close, open and close-open operations) should be carried out and the time from initiation (i.e. energization of coils) to the operation of the contact/contacts recorded. This timing should be arranged so that as many interrupters, or groups of interrupters, of the circuit-breaker as possible are timed at once so that comparisons can be made of timing between poles. It is advisable, where

relevant, for these tests to be carried out at normal and lockout pressure, and the pressure drop for each operation recorded.

b) Millivolt drop or resistance tests between the terminals of each pole or across individual series connected components, together with insulation resistance tests, should be used to detect any deterioration in contacts or connections.

c) Insulation tests should be carried out in accordance with **24.2**.

d) Measurements of contact engagement should be used to give information on the condition of the contacts in low-maintenance equipment.

e) Partial discharge testing, using couplers to detect ultra-high frequency (UHF) emissions, should be used to test for dielectric integrity. Thermal imaging should be used to help locate highly resistive connections.

f) Pneumatically operated circuit breakers should be tested at minimum close/trip lock-out pressures (i.e. just above pressure settings). A standard gauge should be fitted to the circuit breaker air system, where possible, or a calibrated replacement pressure gauge should be installed, to ensure accuracy of testing. Operation of close/trip lock-out relays should be tested by reducing the circuit breaker operating air pressure, and confirming that relays inhibit the electrical operation of the close/trip coils at recommended pressure settings (operate and reset).

Confirmation of the correct operation of associated detent mechanisms, or forced trip relays, where installed, should also be carried out at this stage. Following confirmation of correct operation of these devices, the air system pressure should be increased to allow the close/trip lock-out relays (and other protective devices where fitted) to reset. Timing and speed curve tests should be carried out at just above the appropriate close/trip lock-out relay reset settings. This procedure checks whether the circuit breaker operation is still within recommended limits at reduced air pressures. Further tests should be carried out to confirm that the minimum number of circuit breaker operations can be achieved, with the circuit breaker air system isolated from the substation air system, before close/trip lock-out occurs (e.g. typical ABCB – close/trip/close/trip OCB – trip/close/trip). Air consumption tests and air leakage tests should also be carried out.

Electrical operation of closing and tripping circuits should be carried out at reduced voltages to ensure circuit breaker operation can still be successfully carried out at minimum battery voltage levels (e.g. 6 h standby) following loss of battery charging supplies. Trip operation should be initiated with trip circuit supply voltage reduced to 60% of nominal voltage. Close operation should be initiated with close circuit supply voltage reduced to 80% of nominal voltage.

The results of these tests will provide an indication of the circuit breaker operating mechanism, and air system, condition. They might also provide an early indication of mechanism deterioration.

g) For pneumatically operated, air-blast and SF_6 circuit-breakers, leakage tests should be carried out on the complete circuit-breaker by isolating it from the source of air supply and recording the pressure drop for a given time. Unless the leaks are great (in which case they might be audible) the time allowed should be as long as possible so that more accurate figures can be obtained.

NOTE 1 Soap solution is very useful for detecting inaudible leaks or tracing the exact location of audible leaks.

NOTE 2 For pneumatically operated and air-blast circuit-breakers, information on the general condition of the air system can be obtained from a study of the number of compressor starts and hours run compared with circuit-breaker

operations and a knowledge of the pressure and temperature conditions in each of the systems. Pressure drops per operation, times to restore pressure, etc., should be recorded.

NOTE 3 SF_6 leaks can be detected with suitable commercial leak detection equipment but in general these are unsuitable for finding the exact location of large leaks owing to their extreme sensitivity.

35.1.3 Routine maintenance

35.1.3.1 Inspection and operation check

35.1.3.1.1 Operational check

It is recommended that, where reasonably practicable, every automatic circuit-breaker should be tripped and reclosed at regular intervals. The tripping should preferably be by the electrical operation of the opening release coil and associated relays.

35.1.3.1.2 Inspection

A general inspection should be made to detect signs of corrosion, leakage of oil or compound, any unusual smell which might denote overheating and any noise which might indicate electrical discharge or looseness of components. Where possible, any external insulation, trip mechanism, shutter mechanism, earth connection and other visible parts should be inspected for any signs of abnormality. The integrity of the enclosure should be checked to determine whether distortion of any component has reduced the degree of protection intended to apply to the equipment. Partial discharge detection may be used to indicate deterioration of insulation which could be potentially hazardous.

The inspection should include the cleanliness of the equipment and the surrounding area and, in particular, any fire resisting barriers or seals provided on cable access points and any other provision made to prevent the passage of flame, smoke, gas or liquid. When measures have been taken to contain possible oil spillage, the catchment area should be checked to determine whether it is effective and whether any porous bed is clear. Where arc relief vents are used it is recommended that the vent outlet is checked to ensure that it is not obstructed.

Following the inspection it is recommended that the circuit breaker be tripped and re-closed a number of times. The tripping should preferably be by the electrical operation of the release coil and the associated relays.

It is extremely important that gaskets are seated correctly, are not degraded and have the appropriate compression.

35.1.3.2 Servicing

With particular reference to low-maintenance equipment, recommendations from the manufacturer's handbook as applicable, and operational knowledge gathered over the lifetime of the asset should be used to define recommendations concerning the inspection, cleaning, adjustment and lubrication of the circuit breaker and its mechanism and these recommendations should be strictly followed.

35.1.3.3 Examination and overhaul

If the inspection procedures give rise to any doubts concerning the internal condition of the equipment, then an examination of the suspect part of the equipment should be carried out. This may include dismantling and the use of diagnostic testing procedures (see **35.1.2**).

The manufacturer's handbook and the maintenance instructions should be consulted as to how to gain access to the components in question and for guidance on the condition to be expected, allowable tolerances and the overhaul action that should be taken to rectify any deviation.

The following list gives operations which may be required to be carried out during maintenance of most types of circuit-breakers.

a) *Circuit-breaker enclosures*. Anti-condensation finishes should be inspected for signs of deterioration.

b) *Main/arcing contacts*. Inspect for burning or other damage and recondition or renew as required. Verify that any backing springs are exerting the correct force and that the contacts are in correct alignment.

   It is to be expected that the arcing contacts will show signs of burning and erosion, but this will not be harmful providing that it is not excessive and providing that the correct lead between the arcing and main contacts can be obtained. The secure fixing of any arc resisting tips should be verified.

   Hinge contacts should be examined for any signs of overheating, burning, welding or other damage, and should be reconditioned, adjusted or replaced as necessary. If such damage is found, the cause should be investigated.

   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 glass paper (emery or carborundum papers should not be used). The amount of material removed from contacts should be kept to a minimum as given in the manufacturer's handbook. It is important that the spring force 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 or opening should be removed.

   In the case of tipped or faced contacts, it is usually undesirable to attempt to clean or dress the contacts and the manufacturer's handbook should be followed. Silver contacts seldom require cleaning despite a black appearance.

   When contacts are refitted, renewed or refurbished, contact force, alignment and wipe should be verified.

c) *Arc-control devices and interpole barriers*. Where fitted, these should be inspected and cleaned or, if badly burned, renewed.

   Arc control devices made from compressed fibrous materials which cannot be cleaned without abrasion should be renewed. Other materials should be treated in accordance with the manufacturer's handbook.

   As far as is reasonably practicable, arcing tips and arc control devices should be inspected to ensure that they are securely fastened, correctly adjusted and electrically connected. All adjustments should be carried out in accordance with the manufacturer's handbook. It should be remembered that the normal duty of arcing tips is to carry the arc root but if excessive burning and/or erosion is present they should be renewed.

d) *Auxiliary switches, indicating devices and interlocks*. Auxiliary switches should be kept in clean and sound condition because upon them depends the correct functioning of other items of equipment, including protective gear.

Inspect the contacts and clean or renew if necessary. Where possible verify correct contact force, freedom of operating links and correct timing of auxiliary contacts in relation to the circuit-breaker contacts. Particular attention should be paid to the required timing of the auxiliary contacts controlling the trip circuit. Indicating devices such as mechanical ON and OFF indicators, semaphores, etc., should be inspected to ensure that they are in good order and operating correctly.

Interlocks and locking devices should receive particular attention, especially those associated with earthing and testing facilities. A strained or worn device may result in a dangerous condition. It should be verified that any incorrect operation is satisfactorily inhibited. Service as necessary.

e) *Isolating contacts*. Examine for signs of overheating or corrosion and recondition as necessary. Verify correct engagement.

Contacts normally operating in air may have a film of contact lubricant applied sparingly.

f) *Final verification*. Before the circuit-breaker and its auxiliary apparatus is returned to service, an operation check (see **35.1.3.1**) should be carried out.

35.1.4 Post-fault maintenance

Depending on the design and duty of the switchgear or controlgear, inspection might be necessary after operation on fault (see **18.3**). When such an inspection is necessary, particular attention should be given to the following points.

a) *Cleaning*. Insulation and other parts liable to deposition of metal vapour should be cleaned and inspected for signs of cracking, burning or other damage. An inspection for signs of tracking should also be made.

b) *Contacts and arc-control devices*. Where accessible, contacts should be inspected for burning or other damage and reconditioned or renewed if necessary. Adequacy of contact force, alignment and wipe should be checked. Contact wear should be checked either by direct examination or by means of wear indicators on sealed equipment such as vacuum or SF_6 circuit breakers.

c) *Mechanisms*. 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.

d) *General mechanical inspection*. A general inspection for mechanical damage or distortion of the general structure and mechanism should be made.

e) *Final verification*. Before the circuit breaker and its auxiliary apparatus is returned to service, an insulation resistance test should be carried out (see Clause **24**) followed by an operation check (see **35.1.3.1**).

35.2 Oil circuit breakers

*NOTE The following recommendations are specific to oil circuit breakers and are additional to those given in **35.1**.*

35.2.1 Routine examination and overhaul

35.2.1.1 Venting and gas seals

The venting system should be inspected, and cleared if necessary, to ensure that a free passage for oil and gases exists. Where there is a joint between fixed and moveable portions of the equipment, it should be ensured that it is in sound condition. In no circumstances should the vents be made larger than the design allows.

35.2.1.2 Mechanisms

Uncontrolled closing and opening operations with the tank removed or empty of oil are undesirable and should be avoided unless the manufacturer's instructions specifically indicate otherwise.

35.2.1.3 Insulating oil

A representative sample of oil should be taken and electric strength, water content and acidity tests should be carried out in accordance with BS EN 60422 with suitable variation for high viscosity oil. Oil that does not meet the recommendations given in BS EN 60422 should be replaced with oil that does. The oil level should be maintained at the level specified by the equipment manufacturer.

For internal cleaning high pressure spraying is recommended, using clean oil (several times) and removing it using a suction cleaner. Wipes should only be used if the contamination is difficult to remove. If using such wipes, it is advisable when cleaning insulation to wipe across the likely tracking path and not in line with it. Damage to insulating material should be avoided because surface damage can lead to early failure by making the insulation more susceptible to tracking.

Suitable proprietary wipes may be used when cleaning oil compartments. Cotton waste should not be used for cleaning. If cloths are used they should be chemically clean and free from loose fibres, metallic threads and similar particles. It is extremely important that wipes should be lint free and that they do not release fibres.

Before filling switchgear tanks with oil it is a good practice to clean the interior of the tank and the immersed part with clean oil. It is essential that the tank and the surfaces of conductors and insulators be kept free from fibres and from moisture as contamination lowers the dielectric strength of the oil. Exposure of internal tank surfaces to airborne contaminants and other foreign bodies should be minimized.

There should be as little aeration of the oil as possible during the filling of the tank, and a good practice is to fill from the bottom of the tank. A standing time should be allowed after the tank is filled before commissioning the equipment. Hot oil should not be used to fill switchgear or controlgear.

In addition to this routine maintenance, where practicable a more frequent inspection should be made of oil levels, or for signs of loss of oil.

35.2.1.4 Tank and tank linings

Tank linings should be inspected 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. Damp or damaged linings should be reconditioned or renewed as necessary. They should not be refitted until the tank has been thoroughly cleaned and dried using fibreless cleaning material.

Gaskets should be inspected for cracking, where they might allow moisture ingress, and for appropriate compressibility. They should be replaced with new gaskets where necessary.

It should be ensured that all tank bolts are properly tightened in the correct sequence when replacing the tank.

The tank compartment should, when practicable, be flushed with clean oil prior to filling.

Special care should be taken to avoid damage to interpole barriers when replacing tanks, since this could obstruct the opening of the circuit breaker.

35.2.2 Post-fault maintenance

WARNING. Fault operation of circuit breakers can produce quantities of smoke and flammable gases, and the isolation of withdrawable circuit breakers should be delayed to allow for dispersal of these.

35.2.2.1 Insulating oil

If the oil is badly discoloured or shows evidence of excessive contamination by carbon particles in suspension it might require changing. If the oil requires changing this should be done in accordance with the procedure given in **35.2.1.3**.

35.2.2.2 Joints and seals

All joints and seals should be inspected for tightness and particular attention should be paid to tank gaskets where these are fitted.

35.3 Air-blast circuit breakers examination and overhaul

*NOTE The following recommendations are specific to air-blast circuit-breakers and are additional to those given in **35.1**.*

35.3.1 Pre-maintenance recommendations and precautions

35.3.1.1 Adjacent unsilenced air blast circuit breakers

Where work is being carried out with adjacent unsilenced circuit-breakers in service, adequate precautions should be taken to protect personnel from the effects of noise caused by these circuit-breakers should they operate, e.g. by the use of hearing protection devices.

35.3.1.2 Air pressure reduction

In some designs of air blast circuit-breaker the air pressure in the air-conditioned sections cannot be reduced to atmospheric pressure by isolation and drainage of the air receiver. In these cases the manufacturer's maintenance and operational instructions on the operation of air conditioning during maintenance should be followed.

35.3.1.3 Hydraulic tests on air receivers

Inspections should be avoided as the introduction of any liquid into air-blast circuit breakers can be damaging.

NOTE Air receivers (pressure vessels) may be required to be inspected, tested and certified periodically and it is often convenient to schedule maintenance to coincide with these inspections. Attention is drawn to the Pressure Systems Safety Regulations 2000.

35.3.1.4 Conditioning air checks

Verification of conditioning air flow should be carried out.

35.3.2 Maintenance procedures

Maintenance should be carried out in accordance with the following recommendations.

a) *Main mechanism*. Valve gear in general should not be disturbed unless an inspection for leakage and correct operation shows this to be necessary. If it is necessary, the work should be done in clean surroundings, and the manufacturer's handbook closely followed. After the cleaning of control

valves in control units, ensure that components including 'O' rings are lightly lubricated in accordance with manufacturer's instructions before reassembly.

b) *Interrupters*. The interrupters usually comprise the fixed and moving main contacts, the nozzle and the associated valve gear. In some cases, particularly with fully pressurized types of circuit-breaker, the interrupter also houses the resistor.

At a suitable interval, one interrupter per pole should be examined to establish the rate of burning and erosion of the contacts and the general condition in order to assess the necessity for further maintenance, etc., of the other interrupters. This work needs to be carried out under reasonably dry weather conditions and precautions taken to avoid the ingress of any moisture or dirt into the compartment. The interrupter chambers of fully pressurised circuit breakers should be kept particularly clean and it may be that an industrial vacuum cleaner fitted with a non-metallic nozzle can be used. The internal insulation of air blast circuit breakers should be cleaned and examined for defects. Insulation tests will help show the condition of the internal insulation.

Slight burning of copper or copper-tungsten alloy contacts should not cause any trouble, but heavier burning should be removed with a fine file. (Emery or carborundum paper should not be used.)

Copper-tungsten alloy contacts should be examined for any signs of excessive erosion of the material; minor erosion is acceptable. It is important that the original profile of the main contacts is maintained and if they cannot be restored to condition with a fine file or without seriously changing the profile, the contacts should be renewed.

Any burning away from the arcing area should be noted and investigated as this will indicate that the arc is not positioning correctly. Silver plated contacts seldom require cleaning despite a black appearance, which may if desired be cleaned off with a silver polish. Transfer contacts should be examined for any signs of pick up or burning and cleaned as necessary. Resistor interrupter contacts should not show any excessive signs of erosion or burning and minor erosion can be left or cleaned up with a fine file.

The nozzle of the interrupter should be examined for excessive wear or cracking of the material and any signs of non-centralization of the arc.

This can best be carried out by comparison with a new nozzle and measurement. The profile as well as the size of the nozzle is important and if the size or profile or clearance to the contacts appears to be changed considerably, the manufacturer's handbook should be followed.

However, in general, nozzles will not need changing unless an increase in diameter of 5% or more has taken place. Minor irregularities in the nozzle surface can be removed with a fine file.

The insulation adjacent to the arcing area should be examined for any signs of contamination and, if necessary, cleaned. Charred insulation may indicate a misplaced arc and, if found, should be investigated. The interrupter chambers of fully pressurized circuit-breakers should be kept particularly clean. An industrial vacuum cleaner fitted with a non-metallic nozzle may prove to be suitable for this cleaning operation.

Where oil filled grading capacitors, resistors or bushings are fitted, these should be examined for signs of leakage, and remedial action should be taken as necessary. Air insulated capacitors and resistors or foil type capacitors incorporated within the pressure containing tube rarely give trouble and, provided an inspection shows nothing untoward, no action will be necessary.

The operating valve gear and linkages should not be disturbed unless diagnostic tests or visual inspection indicate that it is necessary. The setting dimensions should be verified and recorded and a leakage test carried out. Should it be necessary to dismantle the valve gear, this should be done in clean surroundings and the manufacturer's handbook closely followed.

The exhaust outlets and, where fitted, silencers, should be examined for signs of blockages, e.g. by birds' nests, and cleaned as necessary.

c) *Air receiver (high pressure air system).* The dew point of the operational air for fully pressurized air-blast circuit-breakers should be measured at regular intervals. The required dew point will depend on the environmental conditions in which the circuit-breaker is installed, but at the working air pressure it should not be greater than the minimum expected ambient temperature. The sample pipes used should preferably be of stainless steel, or failing this, of polyethylene or polytetrafluoroethene (PTFE). Sample pipes of nylon, polyvinylchloride (PVC) or rubber should not be used.

d) *Air conditioning*. It should be verified that the flow of conditioning air is adequate and dry. Where both input and output flow meters are fitted it is important that these should give the same readings. Failure to do this indicates leakage of air which should be traced. Where fitted, filters and orifices, etc. should be inspected.

e) *Local control kiosk*. Heaters should be checked for correct operation and any anti-condensation finishes inspected for signs of deterioration.

An emergency opening release facility is usually fitted in or on the local control kiosk and it should be ascertained that this correctly trips the circuit-breaker.

f) *Pressure gauges*. Correct operation and accuracy of pressure gauges should be verified.

g) *Pressure switches (including contact gauges)*. These should be verified and set for the correct operating pressure. The correct sequence of operation of the pressure switches should also be verified.

h) *Iterpole linkages*. The following activities are recommended:

1) interpole linkages should be examined and adjusted where necessary;

2) the manufacturer's instructions for the setting dimensions of the interpole linkages should be verified, and all nuts and bolts should be tight and all pivot pins secure;

3) on circuit-breakers fitted with mechanical or pneumatic intertripping between poles, the correct function should be verified by initiating operations (close and open) of each pole in turn and ensuring that in each case the remaining two poles follow suit.

i) *Sequence disconnector (where fitted)*. The fixed and moving contacts of the sequence disconnector should be examined for signs of overheating or burning and where necessary cleaned, refurbished or replaced. The contacts should be checked for freedom of movement within their housings as should the contact springs and connecting braids. Where circuit-breakers are mounted out of doors, signs of corrosion or contamination of the sequence disconnector should be looked for.

The fixed and moving contacts should be smeared with a suitable lubricant.

j) *Local air receivers and pressure vessels*. These should be kept clean and any damage to the paint surface should be made good to prevent corrosion taking place.

NOTE There are statutory obligations to inspect, test and certify air receivers (pressure vessels) periodically. Attention is drawn to the Pressure Systems Safety Regulations 2000.

The fusible plug should be inspected and in some cases it is recommended to replace it after a given period. Where fitted, safety valves should be inspected for freedom of operation and particularly for correct re-seating after operation.

35.3.3 Post-fault maintenance

The air-blast circuit-breaker should be capable of performing its rated operating duty at the rated level before examination is necessary. In most cases this duty may be exceeded but should only be so when the user, in consultation with the manufacturer, can show evidence in support of this based on operating experience or test. The number of operations at reduced fault may also be in excess of the rated number and the manufacturer should be able to provide information on the permissible number. However, following fault operation it is good practice to inspect a circuit-breaker at the earliest convenient opportunity. After the permissible number of fault operations at a given level items, a) to f) below should be examined and, depending on the results of the examination or the manufacturer's recommendations, overhauled:

a) insulation;

b) local control kiosk;

c) sequence isolator;

d) interrupters;

e) enclosures;

f) overload devices and protective relays.

After examination and any overhaul, the circuit-breaker should be subjected to an operational check and to any other relevant diagnostic tests.

35.3.4 Circuit breaker tank maintenance

35.3.4.1 Exterior condition

Inspect for defects in paintwork, missing or broken studs and for oil leaks. Carry out minor repairs to paintwork and report more serious deterioration.

All loose dirt should be cleaned off external surfaces and any joint or gasket should be cleaned prior to any dismantling, to avoid unwanted ingress of debris into the circuit breaker housings.

Where circuit breakers are mounted in enclosures, enclosures should be inspected for any signs of damage from the effects of air blast, ingress of water, etc. The correct operation of pressure relief vents and heaters where fitted, should be verified and any anti-condensation finishes inspected for signs of deterioration.

The exhaust outlets and, where fitted, silencers, should be examined for signs of blockages by birds' nests etc. and cleaned as necessary.

35.3.4.2 Loose handles and special tools

Condition and storage should be checked, and where applicable the locking facilities of maintenance handles.

35.3.5 Maintenance of control devices and auxiliaries

The circuit breaker manual CLOSE and TRIP devices should be checked for correct operation.

Any semaphore indicators should be checked for correct operation and that they and any associated windows (glass or plastics) are clean.

If possible, the trip coil(s), closing coil(s)and solenoid (if fitted) should be inspected but the moving parts should not be lubricated.

35.3.6 Operation and timing checks

35.3.6.1 General

Timing tests should be carried out to check the correct operation of the circuit breaker. The tests may be carried out from telecontrol and in accordance with the asset owner's procedures.

Where the timing tests do not show cause, valve gear should not be disturbed unless manufacturer's recommendations include routine replacement of components. If valves are to be stripped it is essential that they are removed to a clean environment for this work, to avoid contamination.

35.3.6.2 Interpole linkages

In order to ensure minimum spread of the timing between poles, interpole linkages usually have carefully fitted linkage pins, etc. and minimum backlash mechanisms. It is important that these features are inspected. Any deterioration in this respect will usually be indicated in the timing/travel tests.

When necessary, the setting dimensions of the interpole linkages should be carefully checked against the manufacturer's instructions, but they should not be interfered with unless essential adjustments are required. A check should be made that all nuts and bolts are tight and all pivot pins secure.

35.3.6.3 Dashpots

Malfunction of dashpots associated with interpole linkages is usually shown up by an appropriate travel record during the timing test and unless such a record is available and indicates satisfactory operation, the dashpots should be carefully inspected. Oil type dashpots usually require no more than verification of the oil level but air type dashpots, depending on the type will require verification of bleed holes and clearances, etc.

On circuit breakers fitted with pneumatic intertripping between poles, the correct function should be verified by initiating operations (close and open) of each pole in turn and ensuring that in each case the remaining two poles follow suit.

35.3.6.4 Isolating and earth switches

Isolating and earthing switches or selectors should be examined for correct operation and the contacts examined for signs of burning or overheating. Contact loading should be verified. The correct interlocking between these switches and the circuit breaker should be verified.

35.3.6.5 Earth connection

The main and secondary earth connections should be examined and it should be ensured that all joints and connections are tight and mechanically robust. At major overhaul periods the air receivers, pressure gauges, safety valves and reusable plugs will be subject to statutory inspection. The opportunity should be taken to check lock out device operating pressures.

35.3.6.6 Operational check before return to service

Before returning to service following overhaul, the circuit breaker should be subjected to a check for correct operation under "close", "open" and "close/open" conditions. The results should be recorded and compared with the manufacturer's recommendations.

35.4 Vacuum circuit breakers

*NOTE 1 The following recommendations are specific to vacuum circuit breakers and are additional to those given in **35.1**.*

NOTE 2 Vacuum circuit breakers are long life devices with a typical vacuum life of at least 20 years and typical switching capabilities of tens of short-circuit interruptions and thousands of load switching operations.

A vacuum interrupter is a sealed unit on which no internal maintenance can be carried out. For normal service applications contact wear is not usually a problem, however circuit breakers often have a method for indicating contact erosion. The minimum vacuum life of the vacuum interrupter can be expected to be stated by the manufacturer as this is specified in BS EN 62271-1 and is taken from the date of seal-off not the date of start of service. However, experience indicates that the actual lifetime is generally well in excess of the stated minimum value. During the specified life period vacuum integrity can be confirmed by methods recommended by the manufacturer. These normally consist of voltage withstand tests which can confirm the loss of vacuum but cannot predict future life expectancy. If a voltage withstand test confirms loss of vacuum it is essential that the unit is replaced.

In the case of gas insulted switchgear (GIS) where a vacuum interrupter is inside an SF_6 enclosure, in the case of a complete loss of vacuum the vacuum interrupter can fill completely with SF_6 and in this case a simple voltage withstand test might not be suitable. For vacuum interrupters in GIS the manufacturer should be contacted for the appropriate vacuum integrity test.

Once the vacuum life (also known as the shelf life) has expired, the continuing integrity of the vacuum interrupter should be determined by a revalidation process, e.g. by a risk assessment process and/or a vacuum assessment.

Where the recommended method involves the application of a high voltage to the vacuum interrupter, careful attention should be paid to the relevant instructions in the manufacturer's handbook for avoiding electric shock and possible emission of X-radiation.

35.5 Circuit breakers containing sulphur hexafluoride gas

*COMMENTARY ON **35.5***

Sulphur hexafluoride gas (SF_6) is an essential material used within high voltage electrical equipment because of its dielectric properties that are approximately 2.5 times better than that of air under the same pressure and temperature conditions. The gas is non-flammable, non-corrosive to metals at ambient temperatures and is non-toxic unless decomposed in electrical arcs. When SF_6 gas is subjected to electrical arcs, the gas molecules may be disrupted, but return to their original form. This tendency to repair itself is called "self-healing".

These qualities have made its use desirable within the UK market for over thirty years in circuit breakers, gas-insulated substations (GIS), and related equipment in electrical transmission and distribution systems, and has now progressed to be the main dielectric and insulator for new circuit breakers and gas insulated substations.

At transmission voltage levels, the quantities of SF_6 employed are significant. A typical 400 kV open terminal gas circuit breaker (GCB) would contain approximately 60 kg to 80 kg of SF_6 (filled to 7.0 bar at 20 °C approximately 1 100 L to 1 500 L of SF_6). GIS equipment contains significantly more SF_6.

*NOTE The following recommendations are specific to sulphur hexafluoride circuit breakers and are additional to those given in **35.1** (see also **24.5**).*

35.5.1 General

For SF_6 circuit-breakers, regular checking of gas pressure and temperature, with recording of the gas pressure and temperature together with reference to the manufacturer's handbook, should be used to indicate any gas leaks.

35.5.2 Analysis of SF_6

If recommended in the manufacturer's handbook, the oxygen content, acidity, dew point and hydrolyzable fluoride content of the SF_6 should be determined by testing in accordance with BS EN 60480 at the intervals recommended in the manufacturer's handbook.

35.5.3 Risks presented by SF_6 leaks in normal operation

For outdoor substations the risk of anoxia would be very low for general site access, except where building basements, or trenches in the vicinity of equipment, were to be accessed. GIS equipment contains significantly more SF_6, and there could be a significant anoxia risk where access is required to the GIS buildings, associated basements and trenches. Buildings containing GIS switchgear will usually have SF_6 detection systems installed, which give visual and audible alarms should leakage be detected. (See also **24.5.2**.)

35.5.4 Risks presented by SF_6 leaks due to abnormal occurrences producing rupture

The risks of exposure to SF_6 by-products following equipment failure are present in both indoor and outdoor substation environments. Secondary decomposition products may be created. As an example, sulphur fluorides and metal fluorides may react with moisture to yield hydrofluoric acid, which is extremely corrosive. (See also **24.5.2**.)

It is recommended that personnel who would be concerned with such a substation be given the following advice.

a) If a disagreeable smell is detected on opening the door of the premises or near the place where the plant is installed, proceed to ventilate the area thoroughly.

> **WARNING.** Where a fault has occurred in an installation and the cause has not been established, there might be danger in switching on gas extraction equipment or in leaving ventilating equipment running as the fault might be in oil filled equipment and any resultant fire made more dangerous by air movement.

b) Avoid, as far as possible, entering the premises, until the ventilation has dispersed the nauseous products.

Where entry cannot be delayed, personnel entering the premises should wear suitable protective clothing including respirator or breathing apparatus, goggles, boots and gloves. Such entry may be necessary for the closing of valves to prevent further loss of pressure.

NOTE Attention is drawn to the requirements of the Confined Spaces Regulations 1997 for entry into confined spaces. Where it is known that the total quantity of gas in the equipment on which an emergency has occurred is small the respirator may be worn instead of the breathing apparatus.

When the area has been ventilated, it is possible to proceed with the removal of the damaged equipment and the cleaning of the cubicle and its surroundings. Under the Fluorinated Greenhouse Gases Regulations 2009, personel undertaking decontamination are required to be appropriately trained and assessed and to hold a written qualification issued by a certification body (see Commentary on **24.5**). The procedures detailed in PD CLC/TR 62271-303 should be followed. The solid deposits to be removed can have an irritating effect on the skin, so it is imperative that suitable goggles, gloves and a mask fitted with an approved filter be worn. After use, the mask filter should be carefully disposed of, and the goggles and gloves should be washed and copiously rinsed.

If there is a possibility that gas may have accumulated in low lying areas, including trenches, or that gas may still be present around the equipment, personnel should work under the supervision of an authorized person and wear a respirator in addition to the protective clothing detailed above.

35.5.5 Examination and overhaul

Invasive maintenance should not be routinely carried out on GCBs or GIS switchgear, unless diagnostic checks are required when abnormalities have been identified.

The procedures detailed in PD CLC/TR 62271-303 should be followed when opening SF_6 filled chambers for examination and overhaul. On first opening up equipment for inspection of the interior, personnel should take particular care to avoid exposure to possible breakdown products, and suitable protective clothing should be worn. This would include suitable overalls, thin rubber gloves, chemical-type box goggles and a respirator incorporating a dust filter and activated charcoal. When all dust and breakdown products have been removed from the interior of the apparatus the respirator and goggles can be taken off. Users should lay down a code of practice covering the operations.

a) *Gas system*. Verify operation at the required pressure and, on dual pressure equipment, that the relationship between high pressure and low pressure is correct. The pressure/temperature conditions should be recorded at regular intervals and checked against the constant density characteristics.

   The oil level in the compressor should be verified, if applicable, as should the pumping time to raise pressure by a given amount. This latter information should be recorded.

   Special filters are fitted in certain equipment to absorb gaseous breakdown products. Filter material removed from the circuit-breaker should not be heated. Before attempting to remove such filters the operator should familiarize themselves with the manufacturer's handbook for doing this, together with the instructions for the treatment and disposal of used filter material, cleaning the container and recharging it with new material.

b) *SF_6 gas*. It is good practice to record the amount of gas used during filling and top-ups. This information can be used to identify equipment or individual chambers which have a high rate of leakage for remedial action. Testing of SF_6 gas should only be carried out:

   - on receipt of new gas supplies;
   - prior to use for filling/topping up of equipment;
   - for diagnostic testing where other maintenance activities have identified possible abnormalities (i.e. timing/speed curve tests, RFI/termovision/gas density monitoring);

NOTE SF_6 gas testing may be carried out on arcing chambers for switchgear above 72 kV as part of a condition based maintenance regime, but this is at the discretion of the user.

- on GCBs with high numbers of operations.

SF_6 gas should be sampled and tested in accordance with BS EN 60480.

Site gas testing should always start by sampling for decomposition products and/or toxic gases within the gas zone. This initial test gives an indication to the presence and quantity of SF_6 arcing by-products that can be associated with normal switching, partial discharging and/or full fault arcing. The results obtained, when combined with any existing local site information or knowledge, will act to warn site personnel and prepare them for any dangers that can be associated with the gas handling or access activities. The analysis also serves to warn site personnel and so avoid contamination of the gas handling equipment.

Tests should check for:

- bi-products (HF or SO_2 + SOF_2);
- air (N_2 + O_2) and CF_4;
- water (humidity);
- oil.

c) *Local control kiosk*. The correct operation of heaters should be verified. Other items are dealt with under separate headings.

d) *Pressure gauges*. The correct operation should be verified and periodically they should be calibrated against a dead weight tester or preferably a standard gauge.

e) *Pressure switches (including contact gauges)*. Correct operation should be verified and periodically they should be calibrated against a standard gauge, preferably while on the circuit-breaker. It should be noted that in some cases the pressure switches on SF_6 circuit-breakers are temperature compensated so that their characteristics follow a constant density curve. Where relevant, the switch should be calibrated to this curve.

f) *SF_6 gas heaters*. On dual-pressure circuit-breakers, gas heaters are usually fitted to the high pressure gas system to ensure that liquefaction does not take place. It is essential to verify the correct operation of these heaters regularly. It should be verified that the thermostats controlling the heaters operate within the required limits.

g) *Interrupters*. Interrupter units are usually returned to the factory for reconditioning/ replacement by the manufacturer.

The operating linkages should not be disturbed unless diagnostic tests or a visual examination indicate that this is necessary. The setting dimensions should be verified.

h) *Main mechanism*. Valve gear in pneumatically or hydraulically operated circuit-breakers in general should not be disturbed unless a diagnostic test shows this to be necessary. If it is necessary, the work should be done in clean surroundings and the manufacturer's handbook closely followed. Dashpots should be inspected for correct operation.

i) *Local air receivers and SF_6 enclosures*. Local air receivers and SF_6 enclosures should be kept clean and any damage to the paint surface should be made good with a suitable paint to prevent corrosion taking place. The interiors of air receivers should also be inspected for any signs of corrosion, flaking or blistering of the paint surfaces and appropriate action taken.

It should be noted that there are statutory obligations under the Pressure Systems Safety Regulations 2000 to inspect, test and certify air receivers (pressure vessels) periodically. It should also be noted that SF_6 pressure vessels in high voltage switchgear are excepted from the requirements of this legislation. However, it is recommended that, if a circuit-breaker is opened up for overhaul, the interior of the enclosure should be inspected for signs of corrosion, flaking or blistering of the paint surfaces and appropriate action taken.

The fusible plugs of air receivers, where fitted, should be inspected and in some cases it is necessary to replace them after a given period. Safety valves, where fitted, are also subject ot statutory obligations to inspect, test and certify.

36 Switches and switch disconnectors

The maintenance of switches and switch-disconnectors should generally be in accordance with Clause **35**.

NOTE They are not designed to break fault current and consequently arc control devices, where fitted, may be simpler than those used in circuit-breakers.

In addition, on open type outdoor switches, flexible connections should be inspected for fraying, especially at the terminations, and for deterioration of any protective oversheaths. Protective compound may be applied as recommended to protect bare copper flexible connections. Arcing horns should be inspected for damage and security of fixings verified. It should be ensured that the horns wipe lightly through the opening stroke and do not foul during the closing stroke.

37 Disconnectors and earthing switches

The maintenance of disconnectors and earthing switches should generally be in accordance with Clause **35**.

NOTE With the exception of some earthing switches which have a fault making rating, they are not designed to make or break any more than negligible currents. Consequently, contacts and mechanisms are simpler than for circuit-breakers.

Where open-type disconnectors and earthing switches are installed in an unfavourable environment, it might be necessary to use a dry type lubricant on contacts that would otherwise normally be greased in order to avoid a build up of contaminants.

Some types of disconnectors and fault-making earthing switches rely on contact friction to decelerate the moving parts without bounce. It is essential that contact lubricant is not applied in these cases.

38 Busbars and busbar chambers

Air insulated busbars and busbar chambers, and their supports, should be examined, as far as is reasonably practicable, for signs of overheating and for deterioration of the insulation. This could include use of a number of non-invasive techniques e.g. thermal, partial discharge. Open type busbars can be scanned with infra-red detection equipment in order to indicate any hot spots which are caused by high-resistance connections. Partial discharge detection may also be used to show early signs of dielectric breakdown. Sulphur hexafluoride filled busbar chambers which are giving satisfactory service should not be disturbed, as contamination might be introduced during examination. If examination is required, **24.5** gives advice on the handling of SF_6.

NOTE 1 Protective barriers, although they might be clear, can affect the transmission of infra-red and thus the reading of infra-red detection equipment.

Compound and oil filled busbar chambers should be inspected for leakage. Insulation should be checked as detailed in Clause **24**.

NOTE 2 Use of a leakage detection device may be considered.

Following maintenance, it is particularly important that an inspection is made to ensure that no loose equipment or wiring is left in the vicinity of the busbars which could subsequently cause a fault.

39 Relays

NOTE General purpose relays, such as contactor relays (maintenance of which is covered in BS 6423:1983+A1), overload protective devices and timing devices are not covered by the recommendations in this clause.

39.1 General

Particular note should be taken of any relay associated with plant safety (see also PD 5304). A periodic check should be devised to prove the operational capability of the device. Recommended tests should be incorporated in the maintenance programme including operational checking of protective and interlock features.

The following refers to special purpose relays, usually in their own protective enclosures and mainly used for system or plant protection purposes, sometimes via sensors for the particular parameters.

These relays are sensitive electromechanical or electronic devices and as such require careful treatment. It is important that dust should be wiped from relay covers before these are removed and equally important that these covers are replaced securely so as to exclude dust.

Any significant overhaul or repair work should therefore be carried out in suitable "clean room" conditions by suitably skilled persons and in strict accordance with the manufacturer's handbook, including recalibrating and testing.

39.2 Testing

Tests should be made on protective relays to verify the operating and resetting times or pick-up and drop-off current values, as applicable.

Static relays may require special test techniques and the manufacturer's handbook should be followed. See also Clause **29**.

Testing by primary injection or by injection into test windings where these are provided on the current transformer should be carried out whenever conditions permit and always after current transformer connections have been disturbed, in preference to secondary injection, which may however be used for routine tests. Secondary injection testing at regular intervals is, however, of much greater value than primary injection tests carried out infrequently.

Secondary injection tests should preferably be done using current injection devices suitable for the particular relay concerned or by means of test blocks forming part of the equipment. The disconnection of small wiring in order to carry out tests is not recommended.

When carrying out commissioning tests on protective apparatus, detailed records of the results should be made to provide a reference for comparison with future routine or post-fault tests. Up-to-date records of fuse-link ratings and the correct settings of all protective relays should also be maintained and care should be taken to restore the settings to their correct value if they are altered during tests. In addition to these records it is sometimes helpful to have the settings recorded in or on the relay case.

If it is necessary to disturb any connections or make temporary connections for test purposes, it is essential to ensure that these connections are correctly restored before returning the equipment to service. Attention is drawn to the dangerous voltages which may result if the secondary circuit of a current transformer is opened with the primary circuit on load.

The greatest care should be taken when carrying out routine tripping tests by manipulation of the relay, in order to avoid damage to the relay mechanism and contacts.

When voltage testing protective apparatus incorporating semiconductors or similar components, care needs to be taken that the test voltage level will not damage these components.

Some relays are manufactured for a very precise function and are used to monitor parameters that are liable to change, such as voltage (over, under), current (over, under, earth leakage), phase sequence, phase angle and power. The monitored parameters are often processed by sensors such as a temperature or pressure sensitive element or a level detector.

For all relays the manufacturer's handbook should be followed and any remedial action or adjustment only undertaken by appropriate personnel and only when this is clearly advised.

Electronic relays can be considered as either static or numerical. Static relays are likely to contain very large numbers of individual electronic components and generally use switches or dials to control relay settings and options. Numerical relays generally have few, if any, switches or dials and use a display screen to act as a man-machine communication (MMC), permitting a structured, menu-driven method of viewing and changing relay parameters. Communication with external devices such as personal computer and remote terminal is generally designed into numerical relays.

Maintenance testing of static relays can be treated in a similar manner to that for electromechanical relays, however the greater number of functions which tend to be present in static relays may necessitate the restriction of testing to those functions which are in use at the time.

Numerical relays generally employ many fewer discrete components than equivalent static relays and also employ inherent self-checking routines (known as a "watchdog"), therefore the risk of undetected failures is less than that of other relay types. Maintenance testing can be further restricted to proving the analogue or digital inputs and outputs and any other features which are not supervised by the relay watchdog systems.

40 Protective, measuring and control transformers

40.1 General

In general any maintenance on protective, measuring and control transformers should be carried out in accordance with the manufacturer's instructions.

40.2 Current transformers

Steps should be taken to ensure that a current transformer is dead and isolated and discharged to earth before it is examined. Attention is drawn to the dangerous voltage which could result if the secondary circuit of a current transformer is opened with the primary circuit on load. It is essential to ensure that any connection removed for the purpose of carrying out tests is correctly replaced and securely tightened.

When current transformers are installed in cells or other locations in which they are accessible, maintenance should consist of a general inspection and verification that all main and secondary connections are tight. All exposed insulation should be cleaned and examined thoroughly for any damage such as cracks or tracking marks.

On oil filled current transformers the oil level should be inspected and the required quantity of the correct oil added if necessary. At longer intervals the oil might require testing (see **24.3**). As the oil is used as a coolant, acidity and electric strength tests in accordance with BS EN 60422 might also be necessary.

Current transformers insulated by sulphur hexafluoride under pressure should be inspected to determine if the correct gauge pressure is being maintained. If attention is necessary, the manufacturer's maintenance handbook should be consulted.

Current transformers enclosed in metal clad gear or otherwise inaccessible are usually safe against mechanical damage and only electrical testing can determine whether they are in good order. Where test windings are provided, these tests can be carried out without difficulty. Where such provision is not made, however, special means might have to be devised; an insulation resistance and continuity test of the secondary winding should be regarded as an essential minimum.

40.3 Voltage and control transformers

Steps should be taken to ensure that a voltage transformer is dead and isolated and discharged to earth before it is examined. Where protective fuses are fitted, particular care should be taken to ensure that the voltage transformer is discharged to earth.

Particular care should always be taken to ensure that a voltage transformer is not liable to be made live inadvertently due to a feedback via the secondary side.

Maintenance as described in **40.2** for current transformers is appropriate to voltage transformers. In addition, the isolating contacts of withdrawable transformers should be cleaned, inspected for damage, reconditioned as necessary and a film of contact lubrication sparingly applied. The correct operation of any safety shutters should be verified.

Certain oil filled voltage transformers might be fitted with a gas/oil actuated (Buchholz) relay which should be maintained in accordance with the manufacturer's instructions.

Protective fuses and current-limiting resistors, if provided, should be tested for continuity and general soundness.

40.4 Non-conventional sensors

Some equipment is now being supplied fitted with non-conventional sensors in place of current and voltage transformers. These may include Rogowski coils or Hall probes instead of current transformers and capacitive or resistive voltage dividers instead of voltage transformers. At present there is insufficient long term field experience to give specific maintenance requirements or known weaknesses. Some equipment may contain hybrid sensors which combine some of all of the above techniques. These devices vary considerably in design and maintenance needs from manufacturer to manufacturer and should be maintained strictly according to the manufacturer's instructions.

41 Cable boxes and terminations

The security of mounting and of earthing, where appropriate, should be examined. Compound/oil filled boxes should be inspected for leakage. In the case of dry type terminations, exposed tails should be examined for the condition of insulation and freedom from moisture and tracking, particularly in the crutch area. This could include use of a number of non-invasive techniques e.g. partial discharge.

42 Compressed air plant

The Pressure Systems Regulations 2000 require compressed air plant to be inspected in accordance with a written scheme of examination drawn up by a competent person. Further guidance is given in HSE publication HSG 39 [9] and HSE Approved Code of Practice L122 [10].

43 Ancillary and auxiliary circuits

The low voltage equipment listed in Table 2 should be maintained in accordance with BS 6423:1983+A1.

Table 2 **Maintenance of ancillary and auxillary circuits**

Equipment	BS 6423:1983+A1 Clause
Fuses	**46**
Contactors	**47**
Overload protective devices	**48**
Timing devices	**50**
Instruments	**52**
Metallic resistors	**53**
Capacitors	**54**
Semiconductors	**55**
Cable boxes and terminations	**56**
Control switches	**57**
Liquid starters	**58**
Manual controllers	**59**
Sealed switches	**60**
Motorized items	**61**
Indicator devices	**62**
Batteries	**63**

44 Capacitive charged motor drive mechanisms

These are essentially digital systems, designed to be low maintenance. The required operating motions (trip and close) are digitally programmed into a control unit. Energy charging, buffering, release and transmission are essentially electrical and, as such, the mechanical system is reduced to one single moving part, the motor drive shaft.

Maintenance of these units should comprise visual and functional tests in accordance with the manufacturer's instructions. Built-in self-test facilities should be checked periodically for continued operation.

Annex A (informative)

Statutory requirements and related documents

Attention is drawn to the following statutory requirements.

NOTE This list is not exhaustive.

- Confined Spaces Regulations 1997
- Control of Asbestos Regulations 2012
- Control of Noise at Work Regulations 2005
- Control of Substances Hazardous to Health Regulations 2002
- Electricity at Work Regulations 1989
- Electricity Safety, Quality and Continuity Regulations 2002 (as amended)
- Environmental Protection Act 1990
- Factories Act 1961
- Fluorinated Greenhouse Gases Regulations 2009
- Gas Safety (Installation and Use) Regulations 1998
- Health and Safety at Work etc. Act 1974
- Lifting Operations and Lifting Equipment Regulations 1998
- Management of Health and Safety at Work Regulations 1999
- Pressure Systems Safety Regulations 2000
- Provision and Use of Work Equipment Regulations (PUWER) 1998
- Restriction of Hazardous Substances Regulations 2012
- Work at Height Regulations 2005

The following documents also offer further guidance.

- HSR 25 *Memorandum of guidance on the Electricity at Work Regulations 1989*, published by HSE Books [1].
- *Electrical maintenance*, published by the Institution of Engineering and Technology (IET) [11].
- MSA 19 *PCBs and you. Do you know how to work safely with PCBs?* Published by HSE Books, 1995 [1)] [12].

[1)] Available from http://www.hse.gov.uk/pubns/msa19.htm

Annex B (informative)

Example of items to be covered in safety rules

COMMENTARY ON ANNEX B

The information set out in this annex has been provided by the Energy Networks Association and is reproduced verbatim.

It is essential for every organization to have, and to work to, a detailed set of safety rules. This annex gives, as an example, some of the headings under which these rules need to be drafted and some of the principal topics which need to be covered.

The list of headings and topics is not exhaustive and asset owners/users should consider each element in turn and produce their own safety rules to suit their individual circumstances and the types of systems being worked upon.

NOTE Numbered paragraphs of text give advice which needs to be incorporated into the safety rules. The headings given are intended to be those under which safety rules specific to the particular organization can be drafted.

1. Introduction

1.1. Scope

1.1.1. Identify the full extent of the duty holder's electrical distribution system, including boundary points.

1.1.2. Safe systems of work must be established across boundary points.

1.2. Duties and Responsibilities (Generally)

1.2.1. The duty holder must allocate responsibility for the achievement of health and safety from the inherent dangers of the distribution system, plant and apparatus during the various stages of work or activity.

1.2.2. The duty holder must ensure effective systems and procedures are in place to safely manage the distribution network.

1.3. Training requirements

1.3.1. Duty holders must have in place:

(i) Adequate technical training;

(ii) Capability assessment;

(iii) Competency assessment;

(iv) Treatment of electric shock.

1.4. General 'safety rules housekeeping' requirements:

1.4.1. Change control process;

1.4.2. Ensure all relevant persons have copy of rules.

1.5. Identify which rules require approved plant and apparatus, and approved procedures (and/or Codes of Practice).

2. Definitions of terms

2.1. Terms used must be adequately defined to ensure correct application of the safety rules.

3. General Safety Rules

3.1. All tasks must start with a risk assessment.

3.2. Always assume apparatus is live.

3.3. Personal Protective Equipment shall be issued and worn.

3.4. If anyone is not sure, stop and seek clarification.

3.5. Don't do it unless you are suitably trained / competent / authorised.

3.6. What to do in unexpected situations while working e.g. failure of supply.

3.7. Confined Spaces.

3.8. Fire Protection.

3.9. Working above 2 metres:

3.9.1. Remain attached;

3.9.2. Unsound poles.

3.10. Do not patrol alone across country in darkness or poor weather conditions.

3.11. Voltage testing devices.

3.12. Use of mobile plant near overhead lines.

3.13. Restrictions for long objects and vehicles in substations.

3.14. HV Switching:

3.14.1. Assess the competency of persons;

3.14.2. Maintain control procedures.

3.15. Recording operational information.

3.16. Recording of accidents and incidents.

3.17. Every source of stored energy in the system to be worked on must be effectively controlled to minimise risk.

3.18. Equipment subject to the safety rules must be clearly and unambiguously identified.

3.19. Effective communication must be established and maintained between all relevant parties.

4. Precautions when working on or near HV systems

4.1. Work must not be carried out on an HV system unless it is dead, effectively isolated, efficiently earthed, screened to prevent danger, identified and released for work by the issue of appropriate documentation.

4.2. Isolation

4.2.1. Isolation must be controlled and co-ordinated in the context of the network.

4.2.2. Devices used to perform isolation must provide adequate physical separation between the isolated and non-isolated equipment.

4.2.3. Adequate precautions must be in place to reduce risk of interference with points of isolation.

4.3. Earthing

4.3.1. The positioning of earths relative to the zone of work.

4.3.2. Use lowest risk method to apply earths (via CB, switch, portable leads).

4.3.3. Check earthing lead equipment before use.

4.3.4. Use the lowest risk process to apply / remove portable earthing leads.

4.3.5. Control and recording of earths.

4.4. Safety distances and working and access clearances that must be maintained between exposed HV conductors and persons and / or objects.

4.5. Work in substations.

4.5.1. No one must work outside the delimited area.

4.6. Safety documentation.

4.6.1. Safety documents must match standard company proformas.

4.6.2. Safety documents must be legible, and clearly and unambiguously identify:

(i) The equipment that can be worked on;

(ii) What precautions have been taken;

(iii) Any other precautions that need to be taken, including any residual site hazards or risks;

(iv) The work that can be carried out.

4.6.3. Safety documents must be signed at each key stage in their lifecycle to indicate that the specified actions have been taken and responsibilities have been accepted.

4.6.4. Where safety documents are not used, effective precautions must be applied to ensure work can proceed safely. Clear, unambiguous instructions must be issued.

5. Working on specific items of plant, equipment, and apparatus

5.1. Specific precautions to be taken when working on or adjacent to high voltage open terminal apparatus in substations.

5.2. Specific precautions to be taken when working on fully enclosed (metalclad) apparatus in substations.

5.3. Specific precautions to be taken when working on transformers, capacitors and other equipment.

5.4. Specific precautions to be taken when working on or adjacent to overhead networks:

5.4.1. Lightning risk;

5.4.2. Soundness of poles.

5.5. Specific precautions to be taken when working on or adjacent to cable networks:

5.5.1. Always presume cables to be live unless identified and proved dead by approved means at the point of work;

5.5.2. Key points to deal safely with damaged cables.

6. Live Line working

6.1. Requirement for additional training and authorisation.

6.2. Tools and equipment must be approved and checked before use.

6.3. Control Engineer must be aware of work content.

6.4. Unauthorised re-energisation by manual, remote or automatic means is prohibited.

6.5. Apparatus must be checked before starting.

6.6. Precautions must be taken to prevent any steelwork becoming live.

6.7. Observe safe handling limits, including after conductors have been displaced.

6.8. Protect against out-of-control live conductor.

6.9. Defined weather restrictions.

6.10. Precautions for other members of the team and the public.

7. Safe working on LV systems

7.1. Personnel shall be adequately trained and authorised for the work to be done.

7.2. Apparatus shall always be presumed live unless proved dead by approved means.

7.3. Before starting work, always assess the risk.

7.4. If working dead:

(i) Apparatus shall be adequately isolated (including from consumers' generation), and;

(ii) Earthed where reasonably practicable, and;

(iii) Identified and proved dead at the point of work using approved means.

7.5. If working live:

(i) Adequate precautions shall be taken;

(ii) Approved procedures shall be followed;

(iii) Approved tools shall be used;

(iv) Electrical rubber gloves shall be worn;

(v) Only one live conductor in a cable shall be bared at a time, and;

(vi) When manipulating bare live conductors, the person must be accompanied.

7.6. Polarity and phase rotation shall be checked after working on a connection to a consumer.

7.7. Restrictions will apply when working on an LV overhead line in the vicinity of live HV overhead lines.

7.8. Identify precautions to ensure safe working on LV networks which are interconnected with HV networks.

7.9. Any unearthed steelwork supporting live LV overhead lines should be treated as live unless proved dead by approved means.

8. General precautions to be taken when testing HV Apparatus

8.1. Additional dangers require persons with special responsibilities.

8.2. Requirement for special processes with special proformas.

8.3. Requirement for maintaining clearances from live conductors.

9. Confirmation of the responsibilities of all persons who carry out duties under the safety rules

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Email: knowledgecentre@bsigroup.com

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Tel: +44 20 8996 7070
Email: copyright@bsigroup.com

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