MANUAL

FIELD COMMISSIONING AND MAINTENANCE OF ELECTRICAL INSTALLATIONS AND EQUIPMENT

DEP 63.10.08.11-Gen.

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DESIGN AND ENGINEERING PRACTICE

USED BY

COMPANIES OF THE ROYAL DUTCH/SHELL GROUP

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APPENDICES

1. INTRODUCTION

1.1 SCOPE

This DEP replaces that of the same number entitled "Field inspection of electrical installations and equipment" dated July 1982.

The DEP has been divided into three sections in recognition of the differing scope and timing of (pre-)commissioning and maintenance activities.

Part I gives requirements for the (pre-)commissioning of new electrical installations and equipment or the re-commissioning of equipment following a major overhaul.

Part II gives guidance on the scope and frequency of maintenance activities.

Part III is devoted to inspection forms and appendices in support of Parts I and II.

1.2 DISTRIBUTION, INTENDED USE AND REGULATORY CONSIDERATIONS

Unless otherwise authorized by SIPM, the distribution of this document is confined to companies forming part of the Royal Dutch/Shell Group or managed by a Group company, and to Contractors nominated by them (i.e. the distribution code is "C" as defined in DEP 00.00.05.05-Gen.).

This DEP is intended for use in oil refineries, chemical plants, gas plants, supply/marketing facilities and exploration and production installations.

If national and/or local regulations exist in which some of the requirements may be more stringent than in this DEP, the Contractor shall determine by careful scrutiny which of the requirements are the more stringent and which combination of requirements will be acceptable as regards safety, environmental, economic and legal aspects. In all cases the Contractor shall inform the Principal of any deviation from the requirements of this DEP which is considered to be necessary in order to comply with national and/or local regulations. The Principal may then negotiate with the authorities concerned with the object of obtaining agreement to follow this DEP as closely as possible.

1.3 SAFETY

The necessity for safety precautions during work on electrical equipment cannot be over emphasised. Attention is therefore drawn to the Shell Safety Committee publication "Recommendations for Electrical Safety", which should be used as a basis for formalising local safety codes and practices.

1.4 DEFINITIONS

1.4.1 General definitions

The **Contractor** is the party which carries out all or part of the design, engineering, procurement, installation, and commissioning or management of a project or operation of a facility. The Principal may sometimes undertake all or part of the duties of the Contractor.

The **Manufacturer/Supplier/Vendor** is the party which manufactures or supplies equipment and services to perform the duties specified by the Contractor.

The **Principal** is the party which initiates the project and ultimately pays for its design and construction. The Principal will generally specify the technical requirements. The Principal may also include an agent or consultant, authorized to act for the Principal.

The word **shall** indicates a requirement.

The word **should** indicates a recommendation.

1.4.2 Specific definitions/abbreviations

Authorized electrical person - a competent person, who is appointed by Management to supervise or to carry out specific work on electrical equipment and operations in power

systems. The appointment may include the authority to issue and cancel permits to work on electrical equipment.

Electrical **commissioning** - is the putting into service of a piece of equipment or system AND the demonstration that the equipment or system is fit for the purpose for which it was intended. It is the last verification point prior to the official acceptance of that portion of the installation. Commissioning therefore consists of on-load, on-line performance and functional tests.

Electrical **pre-commissioning** - consists of those activities which are carried out after equipment erection and prior to energising and performance checks. Pre-commissioning is therefore concerned with the verification of the state of the equipment, quality of installation work and compliance with requirements and codes.

Essential service - a service which, when failing in operation or when failing if called upon, will affect the continuity, the quality or the quantity of the product.

Inspection - to ascertain the general running condition of a piece of equipment by sight, sound, smell and touch. (This may involve the opening of covers).

Restoration - to carry out work to maintain or restore the performance or functionality of an equipment by:
- the replenishment of consumed materials,
- the replacement of worn parts,
- the repair or replacement of damaged parts.

SF6 - sulphur hexafluoride gas

Test and measurement - to verify by means of instruments and tools the condition and the functioning of an item of equipment and to measure its parameters. (This may include re-calibration).

Vital service - a service which, when failing in operation or when failing if called upon, can cause an unsafe condition of the process and/or electrical installation, jeopardise life, or cause major damage to the installation.

1.5 CROSS-REFERENCES

Where cross-references to other parts of this DEP are made, the referenced section number is shown in brackets.Other documents referenced in this DEP are listed in Part II, section (9).

PART I FIELD COMMISSIONING

2. PROCEDURES, RESPONSIBILITIES AND DOCUMENTATION

2.1 PROCEDURES AND RESPONSIBILITIES

Electrical installations and equipment in plants engineered and/or erected by contractors and, in general, any equipment which has been completed and is ready for operation, shall be subject to certain take-over procedures which shall have been agreed between the Contractor and the Principal well before the pre-commissioning stage.

Furthermore, the take-over procedure should state clearly the relevant responsibilities of Contractor and Principal.

The organisation and execution of pre-commissioning and commissioning activities shall be the responsibility of the Contractor. Unless otherwise agreed by the Principal, complex electrical systems (e.g. HV/LV switchgear, generators, AVRs, VSDSs, UPSs) shall be commissioned with the assistance of the Manufacturer.

The steps required prior to the initial energising of an electrical system so that it becomes connected to an existing electrical network, shall be jointly agreed by the authorized electrical persons responsible for each electrical network.

Where site conditions prevent full performance tests (e.g. power output, temperature rise), agreement should be reached between the Principal and Contractor on the need for such tests at a later date.

If applicable, the Principal should have internal procedures for equipment acceptance by Operations/Maintenance departments from Engineering/Construction departments.

2.2 DOCUMENTATION

The Contractor shall complete the Inspection Forms found in Part III. For (pre-) commissioning, 'Form 1' is applicable to all equipment; subsequent forms shall be used as required.

The Contractor shall develop additional inspection forms for equipment not covered, or not fully covered, by Part III.

All deviations from requirements shall be documented on an "exception list" which shall be presented to those responsible for the installation work for their agreement and action.

The above documentation shall form part of the official hand-over of plant and equipment.

3. TESTING AND COMMISSIONING METHODS

For suitable test instruments refer to DEP 70.08.10.13-Gen.

3.1 INSULATION TESTING

Insulation tests shall be carried out at the pre-commissioning stage and prior to the energising of equipment and cables.

The following two methods shall be used:

a) insulation resistance (IR) testing for motors, generators, transformers, LV switchgear and all equipment other than those items susceptible to damage by over voltage (e.g. electronic components).
b) high voltage a.c. or d.c. testing for HV switchgear and HV cables.

Refer to Appendices 11 and 12 for recommended test voltages and insulation resistance values.

3.1.1 Insulation Resistance (IR) Tests

IR testing shall be carried out by applying a d.c. voltage from an insulation tester at voltage levels given in Appendix 11.

For correct comparative interpretation of test data, subsequent IR tests should be carried out at the same voltage level as the initial test.

The measured resistance value is also dependent on the temperature of the insulation and shall be corrected with the use of the nomogram in Appendix 1.

As a guide, the IR of windings reduces by approximately 50% for each 10 °C rise in temperature.

3.1.2 High voltage tests

Prior to executing high voltage tests, insulation resistance tests shall be carried out.

High voltage testing can be carried out either by applying a.c. (power frequency), very low frequency (VLF) or d.c. voltage at a level above the operating voltage.

There are distinct differences in the nature and practicality of these tests. Whilst testing at power frequency is preferable, the a.c. test equipment must be capable of supplying the capacitive current requirement of the item under test. Thus physically large test equipment is frequently called for which is impractical for field commissioning use.

For on-site commissioning, d.c. test equipment may be used.

High-voltage testing of electrical equipment, except LV cables, shall have been carried out at the manufacturer's works with a.c. at voltage levels in accordance with the relevant DEP or International standards.

Repeated high voltage pressure tests may introduce weak points in the insulation of windings, and therefore such tests shall **not** be applied at site to generators, motors or transformers.

If, however, for special reasons these tests are considered to be necessary, they shall be carried out only after consultation with the Manufacturer.

3.1.3 Polarisation Index (PI)

The PI is the ratio between the insulation resistance measured after one minute and after 10 minutes of continuous testing at the appropriate voltage ($PI = R_{10\ min} / R_{1\ min}$).

After 10 minutes the capacitive current, the leakage current over the surface of the insulation and the dielectric absorption current will have stabilised.

The PI obtained gives an indication of the condition of the winding insulation with regard to its dryness and cleanliness; the PI will be lower for a dirty, wet or chemically contaminated winding insulation.

The PI, being a ratio, is practically independent of winding temperature and test voltage.

Appendix 2 shows typical curves for variations of insulation resistances and the values for the Polarisation Index.

3.1.4 Interpretation of results

Should the obtained IR or PI values fall below the minimum values given in Appendix 12, then the equipment should not be energised or subjected to high voltage testing.

Appropriate action should be taken, e.g. drying, to normalise the figures.

Should 'flash-over' occur during high voltage testing then the test shall be deemed to have failed and appropriate measures taken (e.g. cleaning, drying, repair) to eliminate the cause, following which re-testing shall take place.

3.1.5 Insulating oil tests

High voltage withstand tests shall be carried out using a standard oil testing apparatus, with 25 mm diameter mushroom-shaped electrodes placed at a distance of 2.5 mm from each other.

The minimum withstand voltage shall be 30 kV. The test sample shall be tested 6 times without breakdown using the same cell filling. Reference Appendix 16 for additional requirements.

3.1.6 Bearing insulation tests

The method of insulating bearings as a means of controlling shaft current depends upon the type of construction and methods employed to support the bearings.

In the case of pedestal bearings or sleeve bearing housings that are completely insulated from the body of the machine, the insulation may be checked with the machine coupled and running at normal speed to establish an oil film in the bearing which will prevent electrical contact between shaft and bearing. An ohmmeter applied across the insulation should indicate a resistance of > 10kΩ; figures below this shall be investigated.

In the case of bearings having internally insulated 'shells' or having insulated shafts, measurements shall be carried out with the machine uncoupled (and stopped). If however only one bearing is insulated (contrary to DEP requirements for motors and generators), verification is limited to the inspection of manufacturers QC documentation.

Where double insulation is applied to pedestal bearings, i.e. insulated around the bearing 'shell' and at the pedestal base, IR measurement of the 'mid section' with respect to earth will indicate if either insulation is bridged.

3.2 CONDUCTIVITY AND EARTH RESISTANCE TESTS

3.2.1 Conductivity tests

Conductivity tests shall be carried out on switchgear busbar connections and switchgear earth system joints in order to establish their tightness and condition. Conductivity testing shall be carried out with a low-resistance test set, e.g. a 'Ducter' with a 20 A (d.c.) output.

For identical connections the measured values shall not differ by more than 20% from each other.

3.2.2 Earth resistance tests

For values and method of earth resistance tests see section (4.9) and Appendix 13.

3.2.2.1 Earth electrodes

All earth electrodes shall be tested by the measurement of electrode (or electrode group) resistance against the mass of earth, using a purpose made test set as outlined in Appendix 14.

3.3 WIRING AND TERMINAL CHECKS

Electrical wiring shall be checked against the schematic diagrams. Factory tested assemblies such as switchgear, should require only sample checks.

The tightness of all terminals shall be verified.

3.4 FUNCTIONAL TESTS

Functional tests shall be carried out to demonstrate the correct operation of complete systems.

Particular attention should be paid to equipment interfaces, where there is a greater likelihood of functional discrepancies.

In cases where complicated control and/or interlock systems are used, the Contractor shall demonstrate compliance with the design requirements using special case-by-case functional check lists and system logic diagrams.

4. TESTING AND COMMISSIONING PROCEDURES

4.1 HAZARDOUS AREA EQUIPMENT

(Form 1 and applicable equipment forms)

4.1.1 Installation

All items of electrical equipment (except bulk ordered equipment) installed in a hazardous area shall be inspected in accordance with the above forms.

Spot checks shall be carried out on bulk ordered material such as light fittings, junction boxes and RCUs. One form type 1 per plant area is sufficient for each 'bulk material' type.

Particular care shall be taken to ensure that correct cable glanding has been carried out.

4.1.2 Certification

Certificates and declarations relating to the application of equipment for use in hazardous areas are called for in DEP 33.64.10.10-Gen. and are outlined below.

Certificates shall be examined to ensure that the installation is in compliance with the certification requirements.

- For electrical apparatus in Zone 0, Zone 1 and Zone 2 areas, a Certificate of Conformity shall be obtained from the Manufacturer.
- For electrical apparatus in Zone 2 areas, which has type of protection 'n', a Declaration of Compliance may be accepted instead of a Certificate of Conformity, subject to the Principal's approval.

Refer to:

Appendix 4 for degree of protection standards,
Appendix 5 for explosion protection standards,
Appendix 6 for certification standards and bodies.

4.2 MOTORS

(Forms - 1, and 14 or 16)

It should be noted that the scope of motor testing depends upon the motor type and size, this being indicated on the inspection forms.

Motor vibration shall be measured in a tri-axial direction, i.e.:

point x axis - side of bearing housing at shaft height
point y axis - top of bearing housing
point z axis - axial of bearing housing at shaft height

The measurements shall be carried out with an instrument conforming to ISO 2954 (10-1000 Hz frequency range). With the motor at normal operating temperature, the vibration velocity shall not exceed 2.8 mm/s RMS, or 4 mm/s PEAK, in any direction.

For bearings fitted with proximity probes, the unfiltered peak-to-peak value of vibration (including shaft 'run-out') at any load between no load and full load, shall not exceed the following values:

- 50 µm for two-pole motors
- 60 µm for four-pole motors
- 75 µm for six-pole or higher motors

Bearing temperature rise limits as given in DEP 33.66.05.31-Gen. following a 'heat run' of 3.5 - 4 hours are as follows :

Rolling bearings :
- outer ring measurement max. 90 °C
- temperature rise from ambient max. 50 °C

Sleeve bearings :
- oil temperature max. 90 °C
- bearing temperature rise by RTD max. 50 °C

- luboil temperature rise from ambient max. 30 °C
  (for forced luboil systems).

When commissioning or re-commissioning motors, precautions shall be taken to avoid excessive vibration caused by the phenomenon known as 'soft foot'; i.e. feet which do not have solid **flat** contact with the base **prior** to the tightening of the holding-down bolts.

This may be measured and rectified during installation or detected during running by the loosening of each holding-down bolt in turn while measuring motor vibration.

See Appendix 9.

4.3 GENERATORS

(Forms - 1, 16 and 17)

4.3.1 Base load generators

A detailed commissioning plan should be developed prior to commencing tests. Details of a test programme shall be agreed between the Principal and the Contractor/Manufacturer.

NOTE: A switching plan should form part of this procedure.

The following tests shall be carried out in order to prove the satisfactory performance of the generator, its governor, automatic voltage regulator, and synchronising and protection systems.

4.3.1.1 Pre-commissioning checks (prior to running)

All electrical pre-commissioning work shall have been satisfactorily completed, i.e. all possible tests shall have been carried out, prior to the equipment being run and energised.

Protection relays should be tested in accordance with (4.5); however some tests may only be possible with the generator running. See (4.3.1.2.4).

4.3.1.2 Pre-synchronising checks (generator running, no-load)

4.3.1.2.1 Open circuit tests

Verify the excitation system and generator characteristics by gradually increasing excitation and plotting generator output voltage against excitation current.

4.3.1.2.2 Generator phase rotation

Verify phase rotation of generator by means of an LV phase rotation meter connected as shown in Appendix 3 to generator VTs, the VTs being fed either from the busbars (test 1) or the generator (test 2).

4.3.1.2.3 Synchronising circuit checks

During above test 2, verify that operation of the synchroscope, voltmeter, auto and check synchronising relays follows the 'beat frequency', i.e. the difference between generator and network frequency and voltage.

During above test 1, verify in-phase indication on all of above devices and verify synchronising relay operating parameters and close command.

As a last check, using high voltage 'phasing sticks' across the open generator breaker spouts, verify that the synchronising relay 'close' command coincides with the in-phase condition on the phasing stick.

4.3.1.2.4 Protection tests

- In the absence of suitable 3 phase primary injection test sets, differential relay in-zone operation and out-of-zone stability may be verified by using the generator as a current source.

- Differential relay stability check:

  A 3 phase short circuit shall be applied at a suitable point **outside** of the differential protection zone.

  The generator shall subsequently be run up to speed and excited.

  The generator excitation shall be adjusted from zero to a low figure (ref. manufacturer's test data) such that no more than full load current may flow.

- Differential relay sensitivity check:

  A 3 phase short circuit is applied at a suitable point **inside** the differential protection zone. Proceed further as for the stability check.

- Other items of protection and indication equipment may also be verified at this time if not already done by primary current injection, e.g. overcurrent, neutral displacement, negative sequence relays.

- Overspeed check:

  Operation of mechanical and electronic overspeed trip devices shall be verified.

4.3.1.3 Post synchronising checks (generator running, loaded)

4.3.1.3.1 Synchronise to Grid

The network to which the generator will be initially synchronised should be configured such that the risk of a disturbance to normal plant operations is minimised.

4.3.1.3.2 Function tests

The following shall be confirmed:

- Auto and Manual synchronising.
- Control of power factor over full range of power generation.
- Control of load.
- 'Bumpless' change-over from Auto AVR to Manual and vice versa.
- The change over of AVR from power factor to voltage control (when changing from coupled to 'island operation')

4.3.1.3.3 Protection tests

The operation of the Reverse Power relay shall be verified by decreasing the governor setting.

The operation of the Field Failure relay shall be verified by decreasing the excitation at minimum load.

4.3.1.3.4 Dynamic tests

(see test form 17)

Dynamic tests shall comprise:

- Active load rejection, reactive load acceptance, active load sharing and reactive load sharing tests as well as 'island' proving tests if applicable.

  The following parameters shall be measured on a suitable recorder:

  Generator voltage/time, current/time and speed (or frequency)/time.

  The test acceptance criteria shall be:
  - no tripping of any protection device,
  - no parameter shall exceed 80% of the difference between nominal value and trip set points,
  - transient response shall be within the design parameters.

- Governor Tests

a. Load acceptance and rejection: transient response shall be measured by the switching IN and OUT of active load blocks.

b. Droop settings in "island condition": speed change between zero and full load shall be measured.

c. Active load sharing: it shall be verified that the load is shared equally (or for different ratings, pro rata) between the generator being commissioned and all other combinations of generators. It shall be verified that the load continues to be shared during changes in total load.

d. It shall be verified that electrical load variations are within agreed limits during the change-over of fuels.

- AVR Tests

a. Transient response: the recovery of generator voltage shall be measured, during the reactive load acceptance and the load rejection tests to verify that it is within the limits of time and terminal voltage.

b. Voltage droop*: it shall be verified that voltage droop is proportional to reactive load or is according to design.

c. Reactive load sharing: the ability of the generator being commissioned to run at the same power factor as parallel connected generators shall be verified. It shall also be verified that the power factor remains equal during changes in reactive load.

d. Current boost*: (for AVRs whose supply is derived from own terminal voltage), it shall be verified from design data that generator terminal voltage is sufficiently maintained to allow operation of protective devices in the event of a short circuit.

NOTES: 1. For items marked *, factory test results are acceptable.
2. 'block load' values shall be such as to demonstrate the equipment's compliance with its design.

4.3.1.5 Load trials

Load trials shall be carried out as agreed between Contractor and Principal and will normally follow satisfactory completion of all the above tests and the completion of construction and testing of the various systems and sub-systems peripheral to the generator and prime mover.

These final tests should be a series of load tests culminating in a protracted run under design conditions at designed maximum power output

These final tests will demonstrate that the generator, prime mover and all ancillary equipment meet the designed performance levels while running continuously at full rated load.

For temperature rise and vibration limits reference is made to DEP 33.65.11.31-Gen.

Proof of the unit's performance during tests should be in the form of a running log.

The log sheets should be formally drawn up and the parameters to be recorded agreed between Principal and Contractor/Vendor.

4.3.2 Emergency and standby generators

Where relevant, the tests described in sections 4.3.1.1 to 4.3.1.5 shall be carried out. The testing methods, however, shall be subject to agreement between the Principal and the Contractor.

Generators of the 'automatic mains failure' type shall be tested with associated switchgear as a complete unit. Additional functional tests shall be carried out to prove that the unit functions as intended.

Where an emergency generator system is designed to withstand severe accident conditions of fire, explosion and strong vibration, this capability shall be verifiable from tests and inspection.

4.4 SWITCHGEAR

(Forms - 1, 3, 4, 10, 10a and 11)

4.4.1 Conductivity tests

All bolts and nuts in the power current carrying circuits shall have been tightened with a torque wrench to the factory recommended figures before conductivity tests are carried out. Random checks shall be carried out to verify compliance with factory torque figures.

Switchboard 'droppers' shall be considered as part of the busbar system.

Conductivity tests shall be carried out between adjacent cubicle spouts. See 3.2.1.

The measured values shall be interpreted on a comparative basis.

4.4.2 Insulation tests

High voltage switchgear components (busbars, contactors and circuit breakers) shall be subjected to high-voltage tests at the pre-commissioning stage.

In general high voltage tests are carried out with d.c. and the test voltage shall be limited to 70% of the peak value of the relevant a.c. voltage levels given in IEC 694. Refer to Appendix 11 for test voltages and durations.

For HV cast resin insulated switchgear the Manufacturer shall recommend appropriate testing methods.

Low voltage switchgear components (busbars, contactors and switches) shall be subjected to IR tests at the pre-commissioning stage.

4.4.3 Functional tests

In addition to carrying out all checks as given in the appropriate test forms, a full check shall be carried out to demonstrate that all features of the switchboard function as intended.

For complex installations the Contractor shall develop specific functional check lists based upon control schematic diagrams in order to demonstrate compliance with the design requirements.

4.5 PROTECTION

(Forms - 5, 6, 7, 8, 9 and 12)

4.5.1 Testing general

Relays should be tested and commissioned in accordance with the Manufacturer's instructions. Use should be made of the standard test forms but where these prove to be inadequate, specific forms shall be developed.

All CT ratios shall be verified by primary current injection. CT connections once proven by primary injection should not be removed without retesting. Break-in to CT circuits should subsequently only be made at test links provided for the purpose. Under no circumstances shall a CT primary be energised while the secondary is open circuited.

All protection relays shall be tested by means of primary current injection at (wherever possible) the normal settings to verify their operating parameters.

Where it is impractical to use a primary injection test set because of extreme current requirements relays may, subject to the Principals approval, be tested by secondary injection.

For generators and generator/transformer combinations, use may be made of the generator as a current source, refer to (4.3.1).

Overload relays of Ex'e' motors shall be tested to verify that the tripping time of a 'warm' relay is less than the t_E time shown on the motor rating plate when injected at a current equivalent to the motor starting current.

Relay testing shall include verification of the operation of the switching device's tripping mechanism and all alarms and intertrips.

Motor restart relays and systems shall be tested to verify that their settings are as recommended by a "motor restart" study.

After each test it shall be verified that the actual relay setting is in accordance with the setting as laid down in the overall protection scheme of the power system.

The last test date shall be indicated on the relay.

4.5.2 Equipment

The use of voltage source current injection test sets to test relays which have a non-linear characteristic can give rise to timing errors of more than 30% and, for attracted armature types, to relay chattering.

Many electromechanical overcurrent relays have a non-linear load impedance - the relay impedance usually reducing as the injected current increases (caused by saturation of the relay magnetic circuit).

Also, relays of the attracted armature type change their inductance at the point of operation which could cause a drop in injected current from a 'voltage source' set and subsequent relay chattering.

Current source secondary test sets shall therefore be used for the calibration of the above relays.

4.5.3 Electronic relays

Printed circuit boards and modules of electronic relays are susceptible to damage by electrostatic discharge if incorrectly handled. Failure to take adequate precautions could result in components being damaged or over stressed by static discharges which could lead to premature failure.

Care shall therefore be taken that electronic relay components are only touched under controlled conditions, i.e. in a workshop equipped with anti-static facilities.

Components are usually delivered in anti-static bags or packing, and they should not be removed from the packing until required.

Electronic relays shall be removed or short circuited during IR tests on connected circuits.

4.6 CABLES AND POWER TRANSFORMERS

4.6.1 Cables

Form 18, (HV cables)
11, (Lighting and power cables)
14, (LV motor cables)
19, (Heat tracing cables)

Testing of all power cables shall be carried out whilst isolated from both supply and load circuits.

Refer to Appendices 11 and 12 for values of test voltage, method and acceptable insulation resistance values.

Underground cables should be tested prior to cable trench back-filling.

All unterminated and exposed cable ends shall be sealed against moisture ingress.

Heat tracing cable ends shall be kept sealed under all circumstances to prevent moisture ingress which may destroy the temperature regulating characteristic of the cable.

4.6.2 Power transformers

(Forms 1 and 13)

Windings of transformers shall not normally be subjected to high voltage testing. Refer to Appendices 11 and 12 for test voltages and acceptable insulation resistance values.

Refer to Appendix 16 for transformer oil tests.

Before parallel operation of the transformer is attempted, 'phasing-out' operations shall be carried out to verify that the two supplies are in-phase. Refer to Appendix 15.

Refer to Appendix 15 for examples of Delta/Star Transformer connections.

4.7 POWER ELECTRONICS

4.7.1 General

Power electronic equipment (i.e., items such as UPS, VSDS, excitation controls, heater controls) shall be commissioned fully in accordance with the Manufacturer's instructions. Specific test forms shall be developed for the commissioning of power electronic equipment in the absence of the Manufacturer's procedures.

Electrical protection 'relays' of the conventional type shall be tested in accordance with (4.5); however some devices form an integral part of the systems central processor unit whose parameters have already been factory tested, and these may be functionally tested on site.

All protection devices which perform a trip, alarm or control function shall be functionally tested up to and including the operation of the final 'device'.

At the completion of commissioning a listing of all equipment set points and parameters shall be recorded.

4.7.2 Variable speed drives

(Forms 1, 13, 14, 16 and forms specific to the VSDS type)

A full 'string' test shall be carried out on site, comprising all items supplied, e.g. transformer, converter, motor and load, with particular attention being paid to items not factory tested. For example:

- setting of site specific parameters,
- full load trials, including auto-restart,
- full load noise tests throughout the speed range,
- full load vibration tests throughout the speed range.

4.7.3 UPS

(Forms - 1 and 15)

The commissioning procedure shall follow the Manufacturer's instructions and shall include tests designed to confirm the static and dynamic performance of the equipment, including:

- Rectifier float charge voltage level,
- Rectifier boost charge voltage level,
- Battery discharge capacity test,
- Battery cell voltage and specific gravity measurements,
- Operation of Inverter and By-pass in synchronism,
- Transfer of load from Inverter to By-pass and return,
- Switching off rectifier the battery accept load and UPS output, remains within limits,
- Oscilloscope checks on the equipment's output waveform.

4.8 LIGHTING

(Forms 1 and 11)

One Inspection Form 1 per equipment type, per area shall be completed.

Inspection Form 11 shall be completed for all circuits.

Spot checks on 5% (minimum) of the population shall be carried out to confirm that correct installation work has been carried out.

The operation and autonomy time of all Emergency and Escape lighting systems shall be verified.

The activities shall include a record of measured illumination levels. Luxmeter readings shall be taken at the working plane or 1 m above the floor level in a horizontal plane and entered on a suitable plot or building plan.

The illumination levels shall be as specified in Appendix 4 of DEP 33.64.10.10-Gen. or as specified by the Principal.

4.9 EARTHING AND BONDING

(Forms 20, 21 and, (partly) Forms 3, 10, 13, 14)

Refer to Appendices 13 and 14 for testing methods. The test numbers mentioned below are illustrated in Appendix 13.

4.9.1 Electrical system earthing (ESE)

All earth electrodes shall be measured (with the earth cable disconnected from the electrode), and the resistance value of each electrode (group) shall not exceed 4Ω (test 1).

All earth connections between the electrode and the supply neutral and the plant earth loop shall be tested for continuity (tests 2 and 3).

All earth connections between Switchboards, Transformers and the Substation earth bar shall be tested for continuity (test 11).

The earth loop impedance of all power and convenience outlets shall be measured using an appropriate 'earth loop tester'.

4.9.2 Clean earth (CE)

All earth electrodes shall be measured (with the earth cable disconnected from the electrode), and the resistance value of each electrode (group) shall not exceed 4Ω (test 4).

All earth connections between the electrode and the instrument clean earth bar and the substation earth bar shall be tested for continuity (tests 5 and 6).

4.9.3 Equipment external earth (EE)

- Process Plant Non-Electrical Equipment

  Sample measurements shall be made (5% of the population) to verify the continuity of the equipment's external earthing cable (with the cable disconnected from the equipment) and any adjacent earthing cable (also disconnected from its equipment) (test 7).

- Process Plant Electrical Equipment, (Motors, Heaters etc.)

  Sample measurements shall be made (10% of the population) on the earth return path of electrical equipment having an external earth connection (test 8).

  Measurements shall be made with the equipment in operational condition and all cables connected. The earth return impedance shall be measured between the body of the equipment and the substation earth bar using a conductivity meter and a calibrated cable.

  Results shall be evaluated on a comparative basis.

4.9.4 Earth for lightning and static discharge (LPE)

All earth electrode systems used for lightning or static discharge shall be measured with the main earth grid disconnected, and the resistance value of each electrode (group) shall not exceed 10 Ω (test 9).

All earth connections between the electrode and the plant earth loop shall be verified for continuity (test 10).

4.10 BUILDINGS

(Forms - 1, 2, 11, 20, (Form 2 for Electrical Buildings only))

Plant buildings and non-plant buildings (i.e. offices, warehouses, gatehouses, workshops etc.) shall be treated in the same manner as plant equipment and be subject to (pre-) commissioning procedures.

The scope of the (pre-)commissioning activities shall cover all electrical equipment and systems, including the following :

- Lighting shall include normal, emergency and escape lighting systems, refer to section (4.8).
- Switchboards, convenience outlets, refer to Inspection Form 11.
- HVAC electrical equipment, refer to sections on Motors, Switchgear etc. Functional testing and commissioning of HVAC systems is covered in DEP 31.76.10.11-Gen.
- Earthing, refer to section (4.9).

4.11 HIGH VOLTAGE OVERHEAD LINES

(Forms - 22, 23, and 24)

Inspection criteria and responsibility should be clearly defined at the time of contract award. It is now common practice for the Contractor responsible for erection to also carry out the inspection measurements required during erection. Such measurements include:

- conductor tension (during and after pulling),

- conductor sag,
- conductor to ground clearance at critical points (e.g. road crossings),
- resistance across line compression joints and termination fittings,
- structural alignment (poles in line and upright),
- resistance to earth of static earth wires, guys, structures, lightning arrestors etc.

The measurement shall be recorded in a suitable tabular format.

The Contractor should be required to submit for the Principal's approval a procedure for stringing/tensioning the line.

Prior to energisation, the entire line and associated equipment shall be checked visually. (See check list Form 22 item 7), and the insulation resistance of the line recorded. It is often not possible to arrange for high potential testing of the line and in this case insulation resistance measurements may be made using a 5 kV insulation tester.

PART II MAINTENANCE

5. SCOPE

The purpose of maintenance is to ensure that installed equipment remains fit for purpose throughout its designed lifetime.

A successful maintenance regime is one that minimises operating cost, whilst maximising equipment availability and ensuring that installed equipment retains its designed safety features. It is not possible to provide definitive statements regarding the interval between maintenance on equipment in all locations, as these will depend on factors such as environmental conditions, degree of criticality of service, timing of plant shutdowns, and Manufacturer's recommendations. Furthermore the process should be one of continual feedback and fine tuning based on information on equipment condition found during the early years of any new scheme.

Many potential problems can be avoided by the most simple of checks. As a general principle all electrical equipment rooms and plant areas should be visited on a weekly basis. Personnel should pay attention to the equipment's normal operating characteristics, i.e. load, sound, temperature, smell, vibration, etc., in order to identify oncoming problems at an early stage.

Such visits will not be covered in the following text, but it must be recognised that a quoted interval of say 2 years between inspections does not imply that an item of equipment should not be visually inspected at all during this period.

Where equipment is situated in remote locations and the above policy is impractical then such visits that are made should be structured by the use of prepared check lists.

This section provides guidelines on the essential elements for building up a maintenance and inspection schedule. It does not, however, address the detail of organisation of maintenance sections, or the systems to be used for work control and data collection. Inspection periods quoted are based on general practical experience and Manufacturer's recommendations, and should be seen as a starting point for refinement in the light of local conditions.

The need to retain records of both the maintenance work that is carried out and the frequency with which it is carried out cannot be over-emphasised. Such records should comprise the results of inspections, measurements and tests that are performed, details of the specific replenishment or remedial work carried out, and the dates on which the work is done. The recording of this data is necessary to monitor rates of deterioration, failure rates, the general adequacy of the remedial work performed etc. It serves also as evidence in support of any decision to perform the work at a greater or lesser frequency at a particular site. For example, no decision should be taken to decrease the frequency of test and measurement work on protective relay systems unless the number of relays failing such tests at the previous test frequency are sufficiently low. The information should also be retained for possible inspection by third parties e.g. factory inspectors.

It is emphasised also that nothing in this document is intended to overrule the statutory regulations that exist at OpCo sites. It goes without saying that the latter must always be complied with.

6. ORGANISATION

The activities of electrical personnel should be carried out within a well established and Management approved framework of Company Rules which contain the following:

- ELECTRICAL SAFETY RULES,
- STANDING INSTRUCTIONS,
- AUTHORISATION PROCEDURES,
- MAINTENANCE MANAGEMENT SYSTEM.

1. Electrical Safety Rules should be drawn up based upon applicable local regulations and the Shell publication 'Electrical Safety'.
2. Local Standing Instructions should cover those items that cannot be or have not been covered in the Electrical Safety Rules or in the Maintenance Management System and which require clarification, explanation, or standardisation of methods and aims.
3. Authorisation procedures should be in place which define for each person who works on electrical equipment (including process operators) a clearly defined level of knowledge/skill required for authorisation at each level.

   The Authorisation should state:
   - The level of authorisation.
   - The activities the person is allowed to perform under both normal and emergency conditions.
4. Maintenance Management Systems should be used to plan activities, prepare work orders, and be so designed as to accept feedback of results, so that equipment records can be updated.

7. DOCUMENTATION AND SYSTEMS

7.1 GENERAL

An essential requirement for a maintenance department is the keeping of up to date records of inspections, tests, and work carried out on each item of equipment.

This will provide :

- information on the condition and reliability of the equipment,
- comparative values for the correct interpretation of test data,
- information required for the preparation of maintenance schedules, for example feedback on the period required between routine replenishment or replacement of consumables.

A documentation and history/test record filing system shall therefore be implemented.

7.2 DOCUMENT FILE

The document file shall contain all Manufacturer's documentation of the equipment including Factory test and inspection reports, requisitions, purchase orders/data sheets, certificates and drawings.

7.3 HISTORY/TEST RECORD FILE

For the history/test record filing system, a computerised data base should be used to record all information, and programmed to prepare maintenance schedules based on test and inspection intervals. This system may be part of an overall computerised maintenance management program.

The system shall basically contain the following information for each item of registered equipment:

- Registration or tag number, location and type of equipment;
- Basic data of the equipment and inspection/test interval;
- Last inspection date, commissioning date and commissioning test results, subsequent test results and history of major failures;
- Repairs, modifications and drawing number reference.

7.4 LOCATION OF FILES

Depending on the type and size of plant, its maintenance organisation, and the presence of a computer network, the maintenance filing systems should be centrally located or located in the offices of the diverse maintenance units. Where the size of the location warrants an independent test and inspection section, it shall have its own document and inspection/test record filing system.

In general if the Electrical workshop carries out the maintenance of Electric motors, the records for these shall be retained in the workshop. When a computerised system with a network is used, access (info only) shall be possible from other locations.

Refer to Appendices 17 and 18 for specimen equipment record cards.

8. MAINTENANCE RECOMMENDATIONS

8.1 ELECTRICAL EQUIPMENT IN HAZARDOUS AREAS

Effort should be directed towards detecting any changes in condition which may invalidate the certification of a piece of equipment. As such, most inspections are of a visual nature which can be carried out with the equipment running. The time interval quoted relates to the period between formal, recorded inspections.

TYPE	DESCRIPTION	INTERVAL	EXTENT
1a. INSPECTION (EXTERNAL): *Motors, Generators, Switchboards, Lighting, RCUs, Boxes, Sockets*	No visible unauthorised modifications. Bolts, cable entry devices and blanking elements are of correct type, complete, in good condition and tight. No obvious damage to cables. Sealing of trunking, ducts, pipes and/or conduits is satisfactory. Earthing and bonding connections are in good condition and tight. No undue accumulation of dust and dirt. Enclosure, glasses, sealing gaskets and/or compounds are satisfactory.	3 y	All Ex 'd' Ex 'e' Ex 'n' Ex 'p' Ex 'i'
	Circuit identification present and correct.	3 y	All controls and major equipment
	Ducts, pipes and enclosures are in good condition. Protective gas is substantially free from contaminants (water, oil, dirt). Protective gas pressure and/or flow is adequate.	3 y	All Ex 'p'

TYPE	DESCRIPTION	INTERVAL	EXTENT
1b. INSPECTION (INTERNAL)	Earth connections maintain integrity of type of protection. Safety barrier units, relays and other energy limiting devices are of the approved type, installed in accordance with certification requirements and securely earthed where required.	3 y	All Ex 'i'
	Motors, Generators, Switchboards RCUs, Boxes, Sockets: General condition, and tightness of electrical connections.	3 y	10% Ex 'd' Ex 'e' Ex 'n' Ex 'p Ex 'm'
2. TEST and MEASUREMENT	Protection devices operate within permitted limits.(4).	3 y	All Ex 'e' motors.
	Alarms.	3 y	All Ex'p'

NOTES :

1. Prior to the replacement, repair, modification or adjustment of hazardous area equipment, it should be confirmed that the equipment will remain suitable for use in the area in which it is installed.

2. Special Requirement for Moveable Apparatus.

   Moveable electrical apparatus (hand held, portable and transportable) is particularly prone to damage or misuse and therefore the interval between formal inspections needs to be reduced, see section (8.11).

3. Type of protection 'd'.

   When re-assembling flameproof enclosures, all flameproof joints should be thoroughly cleaned and lightly smeared with a suitable grease to prevent corrosion and to assist weatherproofing. Blind holes should be kept free of grease. Only non-metallic scrapers and non-corrosive cleaning fluids should be used to clean flanges.

   It is normally not necessary to check the diametrical clearances of spigot, shaft, spindle and thread joints, unless there is evidence of wear, distortion, corrosion or other damage, in which case reference should be made to the Manufacturer's documents.

4. Type of protection 'e'.

   Motor protective devices are selected so that the tripping time from hot when carrying the locked rotor current of the motor, with the motor in the stalled condition, is less than the stated time t_E on the motor nameplate.

8.2 ELECTRIC MOTORS AND GENERATORS

Motors are inherently highly reliable, requiring little routine maintenance. This remains true for most duties but may not be so where environmental conditions are aggressive, the starting duty is onerous, or high structural vibration is present. The same may be said of generators, with the exception that, as with all synchronous machines, particular attention needs to be paid to the excitation system.

In general smaller motors of less than 5 kW and MOV motors should only receive breakdown maintenance. However, MOVs shall be functionally tested at suitable intervals and it shall be confirmed periodically that their condition remains suitable for use in the area in which they are installed. Motors may, depending on their duty or criticality, be selected for regular monitoring of bearing vibration.

Particular attention should be paid to the Manufacturer's recommendations for the lubrication of bearings. Roller bearings should not be overgreased, oil mist systems should be checked for correct atomisation of the mist, oil quality cleanliness and oil levels on white metal bearings should be maintained. Bearing replacement should be on condition, but may be timed to coincide with shutdowns depending on an assessment of the consequences of an unplanned outage. Bearing insulation should be checked in accordance with the Manufacturer's recommendation.

Internal inspection of motors will not normally be necessary, except for frequently started motors, essential motors, and synchronous machines where checks on the excitation system will be detailed by the manufacturer. Checks on the condition of induction motor rotor bars and end rings should normally be scheduled to be carried out during bearing replacement. Coolers should be checked for leaks and blockages at plant shutdowns.

Winding insulation tests need only be carried out infrequently at a period based on site conditions, and timed to coincide with plant shutdowns. Such tests are best carried out from the associated switchgear to include the connecting cable.

8.2.1 Induction motors

TYPE		DESCRIPTION	INTERVAL	EXTENT
1.	INSPECTION	General condition external.	3 y	All
		Winding and rotor condition. (2)	4 - 6 y	frequently started motors, essential motors.
2.	TEST and MEASUREMENT	Vibration. (1) (8)	1 month	selected
		Insulation resistance (with cable). (9) (8) Polarisation index.	2 - 4 y	
		Bearing insulation.	2 - 4 y	All
		White metal bearing clearance and condition.	4 - 6 y	
3.	RESTORATION	Bearing lubrication. (5)	as specified	All
		Rolling bearing replacement. (4 and 6)	4 - 6 y	selected and essential drives.
		Cleaning/reinsulating/rewinding. (3)	as determined by inspection and tests	

8.2.2 Synchronous machines

TYPE	DESCRIPTION	INTERVAL	EXTENT
1. INSPECTION	General condition external.	2 y	All
	Excitation equipment Internal check for component integrity, loose connections, cleanliness, overheating, corrosion.	2 y (or at appropriate shutdown)	
	Winding and rotor condition. (2)	4 - 6 y	
	Remove rotor end bells. (10)	12 - 14 y	
2. TEST and MEASUREMENT	Vibration. (1)	1 month	All except standby.
	Insulation resistance (with cable). (9) Polarisation index. Bearing insulation.	2 - 4 y	All
	White metal bearing clearance and condition.	4 - 6 y	
	Excitation equipment Verification of settings and tolerances.	4 y	
3. RESTORATION	Bearing lubrication. (5)	as specified	All
	Rolling bearing replacement. (4 and 6)	4 - 6 y	
	Cleaning/reinsulating/rewinding. (3)	as determined by inspection and tests	
	Excitation equipment Component replacement (11).	as necessary	All

NOTES:
1. For selected drives without integral vibration probes, bearing vibration may be monitored at the prescribed interval using portable instruments, e.g. Shock-Pulse-Meters for rolling-element bearings.
   For vibration velocity recommendations see Appendix 10.
2. Inspection should be performed of sample of HV machines, concentrating on those with the highest number of starts. Visual checks should cater for loose, cracked, or overheated components (including rotor bars, end rings, end bracings) and for leaks and blockages in cooling circuits.
3. Rewinding should only be carried out where economically and technically justified, insulation quality tests shall be carried out following a rewind in accordance with DEP 33.66.05.31-Gen. and consisting of at least a HV pressure test at (2 x Vn) + 1 kV for 1 minute on each winding.
4. Bearings which have indicated reduced life spans during monitoring or by experience should be replaced on a time scale commensurate with their known service life. Such replacements may be accelerated to coincide with plant shutdowns.
5. Regreasing should be carried out in accordance with the Manufacturer's recommendations.
6. Replacement ball and roller bearings should be C3 fit (clearance greater than normal) unless otherwise specified.
7. Plant operations should ensure that HV motors equiped with rolling element bearings are alternated at regular intervals in order to forestall the brinelling of bearings and to ensure the availability of the spare unit.
8. Test intervals/extent should be determined by the importance of the equipment and local conditions.
9. For recommended minimum acceptable insulation values see Appendix 12. For suggested action criteria see Appendices 7 and 8 (note that IR values are not necessarily indicative of winding remnant life).
10. End Bells should be removed and inspected for cracks, and rotor end windings checked for condition and tightness. This requirement only applies to steam turbines with end bells manufactured from type 8/8/5 Mn/Ni/Cr or 18/4 Mn/Cr steel, which are prone to stress corrosion due to the combination of humid conditions and type of steel.
11. Components nearing the end of their expected lifetime (e.g. electrolytic capacitors) should be replaced during the appropriate test and inspection activity.

8.3 SWITCHGEAR

Installed in clean, well ventilated or air-conditioned locations, switchgear will require little routine maintenance. An early verification (after say 1 year) following initial commissioning that bolts remain tight on busbar and dropper connectors should be planned. Subequently major inspection should be scheduled for Plant Shutdowns and concentrate for LV Switchboards on identifying contact wear, correct operation of interlocks, correct overload settings and fuse sizes, signs of overheating, and undue dirt or corrosion.

For HV Switchgear similar considerations apply although more extensive checks on protective devices, circuit breaker oil, vacuum bottle contact distances are required as specified by the Manufacturer.

Exceptions to the above rule are devices which operate frequently, where inspection/overhaul may need to be based on the number of operations. Also, HV isolating devices which have cleared a short circuit will require confirmation that the insulating medium and the circuit contacts are fit for continued service.

8.3.1 LV Switchgear

TYPE	DESCRIPTION	INTERVAL	EXTENT
1. INSPECTION	General condition external.	1 y	All
	Motor starters and outgoing feeders, internal. Incomers, internal.	4 y	
	Busbar compartments. (1)	8 y	
	Metering: Correctness main voltmeters. Correctness main ammeters.	4 y	
	General internal condition of outdoor equipment. (5)	2 y	
2. TEST and MEASUREMENT	*Incoming feeders, bus section, switches:* Operating mechanism. Interlocks. Control equipment. Electrical protection/tripping.	4 y	All
	Busbar systems: Torque bolts. (1) Insulation resistance. Continuity (ductor).	8 y	
	Motor feeders: Draw-out system/interlocks. Cable connection tightness.	4 y	
	Thermal and earthfault protection.	4 y	10%
	Certified Ex'e' thermal protection.	3 y	All
	Restart system.	4 y	10%
	Insul. resistance motor + cable.	4 y	selected
	Plain feeders: Draw-out system/interlocks. Cable connection tightness.	4 y	All
	Protection/tripping.	4 y	10%
	Socket outlets.	1 y	All
	R.C.D. for fixed load (e.g. trace heating).	4 y	

NOTES:
1. Access to modern, high integrity, insulated/segregated busbar systems may be difficult. In this case other test and measurements as indicated should give sufficient information on the actual condition.
2. CT connected protection relays should be tested by means of secondary injection.
3. Testing of change-over systems of emergency switchboards should coincide with the testing of the emergency generator/system.
4. Type of protection 'e'.
   Motor protection devices are selected so that the tripping time from hot when carrying the locked rotor current of the motor, with the motor in the stalled condition, is less than the time t_E on the motor nameplate.
5. Internal inspection should be limited to contactor/control equipment installed out of doors in boxes, e.g. MOV control panels.

8.3.2 HV Switchgear (up to 36 kV)

TYPE	DESCRIPTION	INTERVAL	EXTENT
1. INSPECTION	General condition external.	1 y	All
	Cable boxes internal. Circuit breakers internal. Fused contactors internal.	4 y	
	Busbar compartments (1) internal.	8 y	
	Metering: Correctness main voltmeters. Correctness main ammeters. Correctness of other measuring systems.	4 y	All
2. TEST and MEASUREMENT	*Circuit breaker in/outgoing and fused contactors:* Operating mechanism. Draw-out system/interlocks. Control equipment. Insulation resistance.	4 y	All
	Dielectric strength across open contacts.	8 y	
	Ductor test across closed contacts. Electrical protection/tripping.	4 y	
	Certified Ex'e' thermal protection.	3 y	
	Contact distance.	4 y	vacuum, SF_6
	Dielectric test oil.	4 y	oil immersed
	Insulation resistance cable (incl. motor if applicable).	4 y	All
	Restart system.	4 y	motors
	Busbar systems: Torque bolts. (1) Insulation resistance. Dielectric strength. Continuity (ductor).	8 y	All
	Correctness of kW, kVAr, max. demand measuring systems. (5)	4 y	
3. RESTORATION	Greasing of operating mechanisms.	4 y	All
	Oil filtering/replacement. Component replacement.	as necessary	

NOTES:
1. Access to modern, high integrity, insulated/segregated busbar systems may be difficult. In this case other test and measurements as indicated should give sufficient information on the actual condition.
2. CT connected protection relays should be tested by means of secondary injection.

3. After operation of the circuit breaker/contactor following a short circuit, the proper operation of switching device and its protection shall be tested.
4. Type of protection 'e'.
   Motor protection devices are selected so that the tripping time from hot when carrying the locked rotor current of the motor, with the motor in the stalled condition, is less than the stated time t_E on the motor nameplate.
5. Where used for tariff purposes.

8.4 PROTECTION SYSTEMS

This section includes all protection devices and systems installed on HV and LV generation, grid intake and distribution circuits. Typical examples are overcurrent, earth fault, differential, under/overvoltage, load shedding. For motor protection requirements see (8.3).

In general it should not be necessary to functionally test relays more frequently than every 4 years. Site conditions may dictate, however, a shorter timing where humidity, airborne pollution, or excessive heat are shown by experience to be a problem.

See Part 1 ("Commissioning") for guidance on relay testing.

TYPE	DESCRIPTION	INTERVAL	EXTENT
1. INSPECTION	Settings as per protection report. Visual check for mechanical integrity, accumulation of dust and signs of corrosion.	2 y	All
2. TEST and MEASUREMENT	Function testing at relay setting. Function test tripping circuit. Check CT winding continuity.	4 y	
	Insulation testing of relay wiring.	8 y	spot check
	Insulation testing of current transformers. Insulation testing of voltage transformers.	8 y	All

NOTES:
1. Inspection, Test and Measurement of protection systems should be combined and, where possible, shall coincide with plant or equipment overhaul activities.
2. Function testing of protection relays shall be understood to mean testing by secondary injection, at the selected relay setting, as detailed by the Manufacturer's literature.
   The results should be checked against those obtained during the pre-commissioning tests.
3. Protection relays should also demonstrate a trip of their circuit breakers.
4. Where a protection scheme comprises an integrated system made up of a number of relays e.g. differential, bus zone, load shedding schemes, it is vital to ensure that a preplanned programme of testing is carried out which can demonstrate correct performance of the scheme.
5. Spot checks should be understood to cover at least 5% of the population.
6. The last test date should be indicated on the relay.

8.5 CABLES AND POWER TRANSFORMERS

8.5.1 Cables and Cable support Systems

TYPE		DESCRIPTION	INTERVAL	EXTENT
1.	INSPECTION	Conditions of cable support systems. Check earth bonding of cable trays. (4)	4 y	All
		Cable terminations as part of the inspection of the connected equipment.	see relevant sections	
2.	TEST and MEASUREMENT	Insulation resistance of cables together with the connected equipment, e.g. motors.	see relevant sections	

NOTES:
1. Routine HV pressure testing is not considered necessary and will cause unwanted ageing of the cable; it should however be done as part of the re-commissioning of repaired HV cables.
2. Special cables, e.g. oil cooled, need to be tested in accordance with the Manufacturer's recommendations. This also applies to single core cable systems with cross bonded metallic sheaths.
3. In order to aid future fault finding on long and/or important cables it is recommended to obtain the cables 'signature' in the healthy condition using 'time domain reflectometer' equipment.
4. Cable trays/ladders should be connected to the plant earth ring at one end. The individual lengths should be bonded by the manufacturer's standard fishplate joint.

8.5.2 Power Transformers

TYPE		DESCRIPTION	INTERVAL	EXTENT
1.	INSPECTION	General condition external (oil leakage, cable connection, corrosion, colour of silica gel in breather, oil level).	1 y	All
		Automatic, on-load tap changer contacts, mechanism.	6 - 8 y (2)	
2.	TEST and MEASUREMENT	Buchholz relay. Temperature alarm/trip. IR primary and secondary.	4 y	All
		Test oil. (1)	4 y	not sealed types
		Contact resistance tap changer. Automatic on-load tap changer control equipment.	4 y	All
		Correct operation cooling fans.	1 y	
3.	RESTORATION	Repaint/touch-up. Fill up with oil. Filter/replace oil. Replace silica gel.	as necessary	

NOTE:
1. For oil sampling and testing methods see Appendix 16.
2. Also dependent upon the number of operations.

8.6 POWER ELECTRONICS

Power electronic equipment may be associated with:

Variable Speed Drive systems.

Rectifiers, and Inverters associated with UPS systems.

Electric Heaters.

Excitation systems.

If operated in a clean environment, at design temperature these systems will require minimal maintenance. Routine checks as detailed below may also be supplemented by an occasional full inspection and test by the Manufacturer for critical duties (say every 5-6 years).

8.6.1 Uninterruptible Power Supply (UPS) Systems

This section includes rectifiers and inverters associated with a.c. and d.c. UPS systems. Batteries of UPS systems are included in section (8.10.1).

TYPE	DESCRIPTION	INTERVAL	EXTENT
1. INSPECTION	Internal visual check for signs of overheating, corrosion, and accumulation of dust. Check ventilation system is clean, free from blockages, and operational. Check that cables are securely terminated, and that earth bonds are in place and secure.	1 y (1)	All
2. TEST and MEASUREMENT	Function tests and verification of settings.	2 y (2)	All
	Battery autonomy.	(refer to 8.10.1)	

NOTES:
1. Internal visual check and test/measurement activities should be combined and, where possible, shall coincide with plant or equipment overhaul activities.
2. Tests and measurements should be as per Manufacturer's recommendations, but as a minimum should include :
   a) Check that battery float and boost charge voltage levels remain correctly set.
   b) For AC UPS systems functional testing of the static switch by transferring the load from UPS to bypass and back to UPS by manual initiation of uninterrupted transfer.
   c) Record the output waveform of rectifier and if applicable inverter using oscilloscope. This should be done during plant shutdown or with load fed from another UPS.
3. Components which may require replacement (such as electrolytic capacitors) and fans should be replaced as per Manufacturer's recommendation during the appropriate two yearly inspection/test and measurement activity.

8.6.2 Variable Speed Drive Systems.

This section includes rectifiers, d.c. links and inverters associated with Variable Speed Drive Systems.

	TYPE	DESCRIPTION	INTERVAL	EXTENT
1.	INSPECTION	Internal visual check for mechanical integrity of components, loose connections, accumulation of dust and signs of corrosion, noisy auxiliary drives, signs of overheating, blocked filters, cooling circuit temperature and pressure, deposits/deformation in plastic cooling water piping.	1 y (1)	All
2.	TEST and MEASUREMENT	Function tests and verification of settings.	2 y (2)	All
		Vibration checks on cooling-circuit pumps.	2 y	

NOTES:
1. Internal visual check and test/measurement activities should be combined and, where possible, shall coincide with plant or equipment overhaul activities.
2. Tests and measurements should be carried out with the aim of verifying the equipments electrical performance and operation of stand-by systems e.g. cooling pumps.
3. Consumables including cooling circuit filters, de-ionisation compounds, auxiliary equipment bearings, and batteries in memory cards, should be planned for replacement as per Manufacturer's recommendation.
4. Components nearing the end of their expected lifetime, e.g. electrolytic capacitors, and fans should be replaced during the appropriate two yearly inspection/test and measurement activity.

8.7 LIGHTING

	TYPE	DESCRIPTION	INTERVAL	EXTENT
1.	INSPECTION	*Plant:* As indicated for hazardous area equipment (Section 8.1).		All
		Buildings, Street and area lighting: Visual inspection when carrying out necessary lamp changing.	as and when necessary	
2.	TEST and MEASUREMENT	Check operation over the designed operating period of the battery backed up emergency and escape lighting.	1 y	All

NOTES:
1. Replacement of lamps in bulk should be considered in certain installations. Some criteria are:
   a) Availability of personnel to change out lamps during their day to day work.
   b) Does Operations Department accept that a (limited) number of luminaries do not operate, until the bulk changing takes place.
   c) Is it economically attractive to change-out in bulk. Factors such as location and nature of the facilities, i.e. on or offshore, manned or unmanned, should be taken into account.
   d) The use of long life lamps, which are expected to give a reliable service over a prolonged time, could make bulk changing combined with cleaning attractive.
2. Depending on the site conditions, battery packs of self contained emergency fitting should be replaced every 4 to 6 years.
3. Portable lighting - see (8.11).

8.8 EARTHING

Earthing systems can be subdivided into the following categories:

Electrical System Neutral earthing (ESE)

Equipment External earth (EE)

Earthing for Lightning and Static Protection (LPE)

"Clean" earthing systems (CE)

TYPE		DESCRIPTION	INTERVAL	EXTENT
1.	INSPECTION	*For all categories:* General condition of visible connections (earthing bosses, connection of earth wires, bonding strips, terminations, etc.).	1 y	5%
2.	TEST and MEASUREMENT	*Earth Electrode (ESE):* Test (1) earth electrode resistance. Test (2) continuity earth electrode to transformer star point. Test (3) continuity earth electrode to substation earth bar.	8 y	All
		Clean Earth (CE): Test (4) earth electrode resistance. Test (5) continuity earth electrode to clean earth bar. Test (6) continuity clean earth bar to substation earth bar.	8 y	All
		Equipment External Earth (EE): Test (7) continuity earth cable to plant earth ring.	4 y	5%
		Test (8) continuity equipment body to substation earth bar.	4 y	10%
		Earthing For Lightning and Static (LPE): Test (9) earth electrode resistance.	4 y	20%
		Test (10) continuity earth termination to plant earth ring.	4 y	5%

NOTES:
1. The earth electrodes may serve more than one of the categories listed above.
2. Testing of earth connections should coincide with the test/measurements done on the connected equipment.
3. For test methods and values see Appendices 13 and 14.
4. Individual earth electrodes may also be measured using purpose-made clamp-on current injection/measurement equipment. However use of such equipment is restricted to multiple earthed systems.

8.9 BUILDINGS

The electrical installation can be considered as made up of:

a) Main Power Distribution cabling and switchgear which should be treated as in sections (8.3 and 8.5).
b) Lighting and small power circuits. See note (2).
c) User installed electrical appliance. See note (3).

8.9.1 Substations and Switchhouses

TYPE	DESCRIPTION	INTERVAL	EXTENT
1. INSPECTION	Housekeeping internal and external.	1 month	All
	'Station' operating/safety equipment. (1)	1 y	
	Electrical equipment.	see sections 8.3, 8.5, and note (2)	
2. TEST and MEASUREMENT	Electrical equipment.	see sections 8.3, 8.5, and note (2)	

8.9.2 General buildings

TYPE	DESCRIPTION	INTERVAL	EXTENT
1. INSPECTION	Electrical equipment (switchboards etc.).	see sections 8.3, 8.5.	
	Condition of appliances fed from convenience socket outlets. (3)	ongoing by user	All
2. TEST and MEASUREMENT	Electrical equipment (switchboards etc.).	see sections 8.3, 8.5.	
	Lighting and small (2) power circuits.	Max 4 y	All
	Appliances fed from convenience socket outlets. (3)	spot checks	

NOTES:
1. See check list in Form 2.
2. Residual current devices should be tested periodically by means of the test button. A full test and inspection, in line with local wiring regulations, should be carried out periodically to confirm the correct functioning of RCDs earth loop impedance of protective conductors, and insulation resistance measurement between each live (including neutral) conductor and earth. The period between full inspections should not exceed 4 years.
3. In general the electrical appliances installed in buildings should be monitored routinely by the occupant or prime user. Occupants should be encouraged to report immediately any malfunctioning device, damaged electrical equipment, or signs of overheating.
   Periodic audits by electrical personnel should be considered to confirm the general condition of appliances.

8.10 EMERGENCY AND STANDBY SYSTEMS

Emergency and stand-by systems are designed to support vital and essential services in the event of a power interruption.

By their nature they will seldom be called upon, so it is critical that such systems be inspected, tested and maintained with the aim of ensuring the equipment's electrical and mechanical performance, operational availability and reliability.

This section describes the tests required on batteries and standby generators, but the principles apply equally to any emergency equipment such as fire pumps which rely on a secure source of electricity.

8.10.1 Batteries

TYPE		DESCRIPTION	INTERVAL	EXTENT
1.	INSPECTION	Terminals, electrolyte level.	3 months	vented types
		Terminals, general condition.	1 y	valve regulated
2.	TEST and MEASUREMENT	Float voltage is correctly set.	6 months	All
		Cell voltages on float charge.	2 y	
		Cell specific gravity.	2 y	All (vented types)
		Battery discharge capacity (1) (Ni Cd).	2 y	All
		Battery discharge capacity (1) (Lead acid).	2 y	
3.	RESTORATION	Top-up electrolyte.	as necessary	vented
		Clean and grease terminals.	as necessary	All
		Boost charge. (2)	1 y	Ni Cd.
		Boost charge. (3)	2 y	Lead Acid vented.
		Replace electrolyte. (4)	6 to 10 y	Ni Cd.
		Replace battery.	7 to 10 y	valve regulated

NOTES:
1. Battery capacity measurements are made with the rectifier 'off' and with a suitable load connected to prove that the system voltage/time parameters remain acceptable. During this test defective cells can be readily located by measurement of cell voltages.
2. Boost charging of nickel cadmium cells is required in order to reverse the voltage depression of the negative electrode which occurs after a period on float charge reducing cell capacity.
3. For vented lead-acid batteries boost charging is required to ensure a proper mix of the electrolyte, and to equalise the charge and capacity among the battery cells.
4. NiCd battery electrolyte should be changed when the specific gravity drops to 1.17 or when carbonate content reaches 75 g/l.

8.10.2 Emergency Generators and electrically started/controlled machines

TYPE	DESCRIPTION	INTERVAL	EXTENT
1. INSPECTION	General condition, battery and fuel level, fluid leaks, cleanliness.	1 month	All engine driven
	Control/protection relays and equipment (internal). Internal condition of rotating equipment.	1 y	All
2. TEST and MEASUREMENT	Start and run up to speed for min 1/2 hr, confirm satisfactory operation. (1)	1 month	All engine driven
	Full simulated on-load test. (2)	6 months	All
	Function test control/protection relays. Winding IR test.	2 y	
3. RESTORATION	Battery.	see section (8.10.1)	
	Change filters, brushes, bearings.	In accordance with Manufacturer's recommendations.	

NOTES:
1. Wherever possible diesel generators should be run at least 50% loaded. In order to prove system security it is advised to stop the machine using a safety device (engine or electrical) at the end of a test run.
2. A full load test should as far as possible simulate an emergency situation to a planned programme in co-operation with the Operations Dept.

8.11 MOVEABLE ELECTRIC TOOLS AND EQUIPMENT

A formal system of test and inspection should be set up to ensure the safety of portable and mobile electric tools and equipment and temporary electrical installations. Such a system may include an equipment registration procedure, but should as a minimum ensure that all equipment is clearly tagged to show that it has been tested, and the date of the next test.

TYPE	DESCRIPTION	INTERVAL	EXTENT
1. INSPECTION	*Certified Equipment:* No visible unauthorised modifications. Bolts, cable entry devices and blanking elements are of correct type, complete, in good condition and tight. No damage to cables or plugs/sockets. Earthing and bonding connections are in good condition and tight. No undue accumulation of dust and dirt. Enclosure, glasses, sealing gaskets and/or compounds are satisfactory.	6 months and after the return of the material	All
	Industrial Equipment: No damage to cables or plugs/sockets. Earthing and bonding connections are in good condition and tight. Degree and condition of enclosure is adequate. General condition external.		
2. TEST and MEASUREMENT	*Distribution equipment:* Test earth-leakage protection devices.	1 month	
	Measure insulation resistance.	6 months	
	Tools. Class I, II and III: Measure insulation resistance to casing. (3)	6 months	
	Tools. Class I: Confirm earth continuity.		

NOTES:
1. See Appendix 12 for insulation values.
2. Classification of equipment:
   Class I Conductive body with earth connection.
   Class II Double insulated with non-conductive body, or conductive body over double and reinforced insulation.
   Class III Extra low voltage.
3. For Class II the insulation resistance should be measured between the conductors and exposed metalwork of the apparatus, e.g. drill chuck, fixing screws, nameplate.

8.12 HIGH VOLTAGE OVERHEAD LINES

The work required to maintain condition of overhead lines is largely determined by the enviromental conditions. In dry areas there may be no requirement to clean insulators even though dust deposits are formed (these in themselves are not a cause for a breakdown). In areas where humidity is high and the insulators accrue deposits such as salt or dust such that flashovers occur then cleaning should be carried out. If cleaning times are unacceptable in terms of plant outage and there is no redundancy in supply then live line washing should be considered. In this case only suitably qualified and experienced contractors should be used. The economics of insulator cleaning should also be considered against the economics of alternative remedial work - e.g. treating the insulators to improve performance.

TYPE	DESCRIPTION	INTERVAL	EXTENT
1. INSPECTION	Visual general inspection of overhead line route to check that insulator strings are intact; line, fittings and poles, are in good condition; earth connections secure etc.	6 months	All
	Survey outdoor substation bus and switchgear connections using thermo vision type equipment. Investigate anomalies.	1 y	
2. TEST and MEASUREMENT	Operate isolator switches. Check for freedom of movement and positive action during contact closure. Measure impedances of critical connections to earth. Follow Manufacturer's instructions concerning maintenance of outdoor switchgear - e.g. (where fitted) measure hydraulic system pressure in close and open states, system cut off pressure, control functions etc.	2 y	
3. RESTORATION	Cleaning and restoration of condition of outdoor switchgear as determined by inspection and tests. Cleaning and restoration of insulators.	As required	

9. REFERENCES

In this DEP, reference is made to the following publications:

NOTE: Unless specifically designated by date, the latest edition of each publication shall be used, together with any amendments/supplements/revisions thereto.

SHELL STANDARDS

Index to DEP publications and standard specifications	DEP 00.00.05.05-Gen.
Installation testing and balancing and commissioning of HVAC systems	DEP 31.76.10.11-Gen.
Electric engineering guidelines	DEP 33.64.10.10-Gen.
Synchronous AC generators 1250 kVA to 50 000 kVA	DEP 33.65.11.31-Gen.
Electric motors cage induction and synchronous type	DEP 33.66.05.31-Gen.
Equipment and tools for maintenance and inspection Part 4 - Electrical Workshop - Test equipment and Tools	DEP 70.08.10.13-Gen.
"Electrical Safety" Shell Safety Committee Publication	

INTERNATIONAL STANDARDS

Rotating electrical machines, classification of degrees of protection	IEC 34-5
Electrical apparatus for explosive gas atmospheres	IEC 79
Method for the determination of the electric strength of insulating oils	IEC 156
Maintenance and supervision guide for insulating oils in service	IEC 422
Classification of degrees of protection provided by enclosures	IEC 529
Common clauses for high-voltage switchgear and controlgear standards	IEC 694

Issued by:
Central Office of the IEC
3 Rue de Varembé
1211-Geneva 20
Switzerland.

Mechanical vibration of rotating and reciprocating machinery	ISO 2954

Issued by:
International Organisation for Standardisation
1, Rue de Varembé
1211-Geneva 20
Switzerland.

PART III FORMS AND APPENDICES

FORMS

Form Number 1	Basic inspection - electrical equipment
Form Number 2	Inspection of switch houses (including transformer yard)
Form Number 3	Inspection of busbar assembly - HV switchgear
Form Number 4	Inspection switching units - HV switchgear
Form Number 5	Voltage transformer (and UV relay) test
Form Number 6	Current transformer (and ammeter) test
Form Number 7	Overcurrent/earth-fault protection relay (induction type) test
Form Number 8	Overcurrent/earth-fault protection relay (thermal type) test
Form Number 9	Differential protection relay test
Form Number 10	Inspection of LV switchboard (including incoming and sectionalizer units
Form Number 10a	Inspection of switchboard, busbar continuity.
Form Number 11	Inspection of outgoing unit - LV switchboard
Form Number 12	LV overcurrent and earth-fault protection relay test
Form Number 13	Inspection of power transformer
Form Number 14	Inspection of electric motor - cage-induction type (including control unit)
Form Number 15	Inspection of static supply unit
Form Number 16	Inspection of synchronous machines (including exciter)
Form Number 17	Synchronous A.C. generator dynamic tests load acceptance/rejection test results
Form Number 18	Inspection of high voltage cable
Form Number 19	Inspection list trace heating installation
Form Number 20	Inspection of earth systems
Form Number 21	Inspection of earthing electrodes
Form Number 22	Inspection of overhead line
Form Number 23	Overhead line sag record
Form Number 24	Overhead line compression joints

FORM NUMBER 1 BASIC INSPECTION - ELECTRICAL EQUIPMENT

Type of equipment: ..... Location: .....

NOTE: Commissioning, bulk ordered material (light fittings, boxes etc.) one Form per type, per area.

System voltage: ..... Unit No.: .....
Size/rating: ..... Registration No.: .....

1. Compare nameplate information with equipment record. .....
   Note any deviations under remarks.

2. Establish and record the following:
   1. Equipment/circuit identification .....
   2. Area classification .....
   3. Type of Ex-protection/gas group/temperature class .....
   4. Degree of enclosure protection .....
   5. Electrical protection setting/rating .....
   6. Actual maximum load/ammeter reading .....

3. Check the following items and report any deviations/defects under remarks:
   1. Labelling correct .....
   2. No unauthorized modifications .....
   3. Enclosures and glasses satisfactory .....
   4. Seals and gaskets satisfactory .....
   5. Bolts and glands complete and tight .....
   6. No undue accumulation of dust and dirt .....
   7. No leakage of oil/compound .....
   8. No damage to aboveground part of connected cables .....
   9. Adequate protection of equipment and cables against corrosion, the weather, vibration and other adverse factors .....
   10. Motor fans and couplings not rubbing on cowls/guards .....
   11. Earthing in good condition .....
   12. Oil levels in sight glasses correct .....
   13. Padlock facilities correct .....
   14. Silica gel in breathers satisfactory .....
   15. Pressurisation system correct & tested .....

4. Suitable for use in area as classified Y/N

5. Remarks Inspector: .....
   Date: .....

6. Equipment Accepted Y/N Supervisor: .....
   Date: .....

FORM NUMBER 2 INSPECTION OF SWITCH HOUSES (INCLUDING TRANSFORMER YARD)

1. Report on tidiness and general condition of station and yard:
   .....
   .....

---

2. Check the following items:

   - **Station exterior:**
     1. Has the station been numbered and fire fighting instructions and danger signs provided .....

   - **Is the station equipment complete with:**
     2. First aid/electric shock treatment directions .....
     3. Instructions required by local authority .....
     4. Key diagram of main power system (wall mounted) .....
     5. Single line drawing of station switchboards (wall mounted) .....
     6. Schematic/wiring diagrams of station equipment .....
     7. Blackboard and/or log book .....
     8. Sufficient caution and danger notices and spare fuses .....
     9. Telephone and telephone list .....
     10. Fire extinguisher - state type: $C0_2$/BCF .....
     11. Special operating tools/earthing equipment .....

   - **Proper operation of:**
     12. Safety locks .....
     13. Doors, door locks and panic bars .....
     14. Lighting, socket outlets, emergency lighting .....
     15. H.V.A.C. .....

---

3. Remarks Inspector: .....
   Date: .....

---

4. Equipment Accepted Y/N Supervisor: .....
   Date: .....

FORM NUMBER 3 INSPECTION OF BUS-BAR ASSEMBLY-HV SWITCHGEAR

Location: .....

Switchboard No: ..... Section: .....

Manufacturer: ..... Purchase No: .....

System voltage: ..... Rating: .....

NOTE: Tests marked (C) are required for pre-commissioning inspection only.

---

1. Insulation resistance test - bus-bar system

   test voltage ..... V Tester used: .....

   phase L1 ..... L2 ..... L3 .....MΩ

---

2. HV pressure test - bus-bar system (C)

   test voltage dc ..... kV Tester used: .....

   leakage current - mA L1 ..... L2 ..... L3 .....

---

3. Conductivity test - bus-bar system(C)
   Spout to spout **Use Form 10a**

4. Earthing system:
   Check the condition of earthing bar and connections .....
   Measure the continuity of earthing bar to main earth .....mΩ

---

5. Voltage transformer test (**Form No. 5**)
   (including UV-relay and voltmeter) Sheet No. .....

---

6. Basic inspection completed (**Form No. 1**) .....
   Sheet No. .....

---

7. Remarks Inspector: .....
   Date: .....

---

8. Equipment Accepted Y/N Supervisor: .....
   Date: .....

FORM NUMBER 4 INSPECTION SWITCHING UNITS - HV SWITCHGEAR

Location: .....

Switchboard No: ..... Function: .....

Manufacturer: ..... Switching device type: .....

Panel No.: ..... Rating: .....

---

1. Record the reading of the operation counter .....

---

2. Check the following items and report any deviations/defects under remarks:

   1. Circuit labelling correct .....
   2. Operation of safety shutters .....
   3. Padlocking facilities .....
   4. Interlocking facilities, mechanical/electrical .....
   5. Mechanical position indicators, indicating lights .....
   6. Insulating bushings and barriers .....
   7. Cable box and terminations .....
   8. Alignment of main and auxiliary contacts .....
   9. Mechanical closing and tripping .....
   10. Electrical closing local/remote .....
   11. Electrical tripping local/remote .....
   12. Alarm indications local/remote .....
   13. Anti-condensation heater working .....

       - test insulation resistance at 500 V .....MΩ

   14. Secondary and auxiliary wiring .....

       - test insulation resistance at 500 V .....MΩ

---

3. Earthing:
   Check the condition of earthing bar and connections .....

---

4. Record fuse type/rating .....

---

5. Insulation resistance - circuit breaker/contactor main contacts:

   test voltage ..... V Tester used: .....

   phase L1 ..... L2 ..... L3 .....MΩ

FORM NUMBER 4 INSPECTION SWITCHING UNITS - HV SWITCHGEAR (cont'd)

6. HV pressure test - (for pre-commissioning inspection only)

   test voltage dc ..... kV Tester used: .....

   leakage current - mA L1 ..... L2 ..... L3 .....

---

7. Conductivity test:

   Ducter used: .....

   Phase L1 ..... L2 ..... L3 .....mΩ

---

8. For oil circuit breakers:
   check the oil condition, oil test result .....

   For vacuum/SF6 circuit breakers/contactors: SF6 pressure: .....

   check for loss of vacuum/SF6 by high-voltage test
   across open contacts (refer to manufacturer's instructions)

   test voltage ..... kV leakage current ..... mA

---

9. Current transformer test completed .....

   Sheet No. .....

---

10. Protection relay test completed .....

    Sheet No. .....

---

11. Restart relay tested ..... result: ..... s

---

12. Remarks Inspector: .....

    Date: .....

---

13. Equipment Acceptable Y/N Supervisor: .....

    Date: .....

FORM NUMBER 5 VOLTAGE TRANSFORMER (AND UV RELAY) TEST

Location: .....

Switchboard No.: ..... Section/panel No.: .....

Voltage transformer: Function: .....

Type: ..... Serial No.: ..... Class: .....

Ratio: ..... Vector group: ..... VA rating: .....

NOTE: Tests marked (C) are required for pre-commissioning inspection only.

---

1. Record the fuse rating ..... A

---

2. Check the following items, note deviations/defects under remarks:
   - mechanical damage ..... - alignment of contacts .....
   - tight connections ..... - star-point earthing .....
   - locking arrangement ..... - core marking .....
   - for oil-immersed transformers, oil test result: .....

---

3. Insulation resistance tests:
   - secondary wiring .....MΩ
     at 500-V:
   - secondary winding (primary winding earthed)
     at 500-V:
     phase to phase L1-L2 ..... L2-L3 ..... L3-L1 .....MΩ
     phase to earth L1-E ..... L2-E ..... L3-E .....MΩ
   - primary winding (secondary winding earthed)
     up to 4.6 kV; at 2500 V - above 4.6 kV; at 5000-V:
     phase to phase L1-L2 ..... L2-L3 ..... L3-L1 .....MΩ
     phase to earth L1-E ..... L2-E ..... L3-E .....MΩ
     Temperature .....°C

---

4. Test VT polarity by battery flick test (C)
   L1 ..... L2 ..... L3 .....

FORM NUMBER 5 VOLTAGE TRANSFORMER (AND UV RELAY) TEST (cont'd)

5. After energizing:
   - measure the VT secondary voltage

   phase to phase L1-L2 ..... L2-L3 ..... L3-L1 V

   phase to earth L1-E ..... L2-E ..... L3-E V
   - check phase rotation .....(C)
   - voltmeter reading:

     sec. voltage ..... V meter reading .....kV

---

6. Undervoltage relay:

   Manufacturer ..... Type .....

	drop-off		pick-up
setting range	.....	V	V
selected setting	.....	V	V
measured value	.....	V	V

---

7. Remarks Inspector: .....
   Date: .....

---

8. Equipment Accepted Y/N Supervisor: .....
   Date: .....

FORM NUMBER 6 CURRENT TRANSFORMER (AND AMMETER) TEST

Location: .....

Switchboard No: ..... Panel No.: .....

Current transformer: Function: .....

Serial No.: ..... Class: .....

Type: bar/wound Ratio: ..... VA rating: .....

NOTE: Tests marked (C) are required for pre-commissioning inspection only.

---

1. Check the following items:
   - mechanical damage ..... tight connections .....
   - star-point connection and earth link .....

---

2. Insulation resistance test,
   secondary winding at 500 V:
   phase to earth L1-E ..... L2-E ..... L3-E .....MΩ

---

3. Resistance test secondary circuit (C)
   (including transformer winding and all secondary loads)
   L1 ..... L2 ..... L3 .....W

---

4. Test CT polarity by battery flick test (C)
   L1 ..... L2 ..... L3 .....

---

5. Ratio test (C)
   (to be combined with relay testing, if required)

Phase	L1	L2	L3	
Primary current	.....	.....	.....	A
Secondary current	.....	. .....	.....	A
Ammeter reading	.....	.....	.....	A

---

6. Remarks

   Inspector: .....
   Date: .....

---

7. Equipment Accepted Y/N

   Supervisor: .....
   Date: .....

FORM NUMBER 7 OVERCURRENT/EARTH-FAULT PROTECTION RELAY (INDUCTION TYPE) TEST

Location: .....

Switchboard No.: ..... Panel No.: .....

Relay:Overcurrent inverse time.

Manufacturer: ..... Type: ..... CT ratio: .....

Current setting range: ..... Selected setting: ..... A

Time setting range: ..... Selected setting: ..... %

Test setting		Injection current			Trip time seconds		Remarks
current A	time %	Is	Primary A	Secondary A	Curve 2)	Actual	Phase.....
			Secondary injection				
S	100	1)	NA	.....	NA	NA	Measure and inject minimum relay
S	100	1.3x	NA	.....	.....	.....	operating current at 1)
S	100	2x	NA	.....	.....	.....	NOTE: the trip time curve will be supplied by the manufacturer 2)
S	100	4x	NA	.....	.....	.....	
			Primary injection				
S	S	1.3x	.....	.....	.....	.....	For pre-commissioning
S	S	2x	.....	.....	.....	.....	inspection only

Check correct reset action .....

Check correct trip action .....

Check correct flag operation .....

NOTES: S = preferably at selected setting NA = not applicable

Values to be filled in for each overcurrent and earth-fault element

---

Relay setting after test:

Instantaneous element ..... A

Current setting ..... A

Time setting ..... %

Adhesive label provided .....

Remarks Inspector: .....

Date: .....

---

8. Equipment Accepted Y/N Supervisor: .....

Date: .....

FORM NUMBER 8 OVERCURRENT/EARTH-FAULT PROTECTION RELAY (THERMAL TYPE) TEST

Location: .....

Switchboard No.: ..... Panel No. .....

Relay: Overcurrent inverse time Relay:

Manufacturer: ..... Type: ..... Rated current: .....

Trip setting range: ..... Selected setting: .....%

Tap setting: ..... Selected setting: .....%

Motor FLC: ..... A CT ratio: .....

Secondary injection test

Nominal injection current Is = tap setting x rated current = ...A

Injection current x Is	A	Operating temperature	Trip time Curve	Actual	All three phases connected in series
4x	.....	cold	.....	.....	load to trip
2x	.....	warm	.....	.....	setting 105%
4x	.....	warm	.....	.....	
1x	.....	warm	running load indication ..... %		

Instantaneous elements: Short circuit/earth fault

Fuse rating ..... setting .....x In = ... A

measure pick-up current .....A

Primary injection test (for pre-commissioning inspection only)

Injection current = 100% FLC = ... A

Running load indication = ... %

Relay setting after the test:

Tap setting ..... % Adhesive label provided .....

Load to trip ..... %

Inst. setting ..... x In

NOTE: Trip time curve will be supplied by the manufacturer

Remarks Inspector: .....

Date: .....

Equipment Accepted Y/N Supervisor: .....

Date: .....

FORM NUMBER 9 DIFFERENTIAL PROTECTION RELAY TEST

Location: .....

Switchboard No.: ..... Panel No.: .....

Relay:

CT ratio: side 1 .....

Interposing CT: .....

Manufacturer: ..... Type: ..... CT ratio: side 2 .....

Interposing CT: .....

Current setting range: ..... Selected setting: .....

Time setting range: ..... Selected setting: .....

---

1. Secondary injection test
   - sensitivity test

   at max. setting ..... A

   at min. setting ..... A

   at selected setting ..... A
   - stability test

     at 100% nom. current ..... A

     at 500% nom. current ..... A

---

2. primary current tests:
   - sensitivity test (supply from test set) ..... A

     at selected setting
   - stability test (supply from system) ..... A

     at actual load or 100% nominal current for generators

Check correct reset action .....

Check correct trip action .....

Check correct flag operation .....

Relay setting after test:

Current setting ..... A

Time setting .....

Adhesive label provided .....

Remarks

Inspector: .....

Date: .....

Equipment Accepted Y/N

Supervisor: .....

Date: .....

FORM NUMBER 10 INSPECTION OF LV SWITCHBOARD (INCLUDING INCOMING AND SECTIONALIZER UNITS) (Outgoing unit use Form No. 11)

Location: .....

Switchboard No.: ..... Section: .....

Manufacturer: ..... Purchase No.: .....

System voltage: ..... Rating: .....

NOTE: Tests marked (C) may be waived for small lighting and power boards in safe areas.

---

1. Insulation resistance test - bus-bar system at 500-V Tester used:

   Phase L1-E ..... L2-E ..... L3-E ..... MΩ .....

   Anti-condensation heaters working .....

   Test insulation resistance at 500 V ..... MΩ

---

2. Conductivity test - bus-bar system (C) **Use Form 10a**

---

3. Earthing system

   Check the condition of the earthing bar and connections .....

   Measure continuity of switchboard to main earth ..... mΩ

---

4. Current transformer test (incl. ammeter)

   completed (**Form No. 6**) Sheet No. .....

---

5. Basic inspection completed (**Form No. 1**) Sheet No. .....

---

6. After energizing

   Check voltmeter reading: .....

   Check phase rotation (C): .....

---

7. Remarks Inspector: .....

   Date: .....

---

8. Equipment Accepted Y/N Supervisor: .....

   Date: .....

FORM NUMBER 10a INSPECTION OF SWITCHBOARD BUS-BAR CONTINUITY (INCLUDING INCOMING AND SECTIONALIZER UNITS)

Circuit designation		Busbar conductivity, mΩ					
From	To	L1	L2	L3	N	E	Ducter #

NOTES:
1. Conductivity measurements shall be carried out between adjacent outgoers or adjacent outgoer and incomers in order to verify the entire bus-bar path including 'droppers/risers'.
2. For identical connections the measured values shall not differ by more than 20% from each other.

FORM NUMBER 11 INSPECTION OF OUTGOING UNIT - LV SWITCHBOARD

Location: .....

Switchboard No: ..... Function: .....

Manufacturer: ..... Switching device type: .....

Panel No.: ..... Rating: .....

NOTE: Complete page 2 for lighting circuits, (one form per board).
Complete page 2 for convenience circuits, (one form per board).

---

1. Check the following items and note any deviations/defects under remarks:
   - Circuit labelling .....
   - Mechanical damage .....
   - Door interlock .....
   - Mechanical position indication .....
   - Electrical closing local/remote .....
   - Electrical tripping local/remote .....
   - Alarm indication local/remote .....
   - Wiring connection and marking .....
   - test insulation resistance wiring at 500 V ..... MΩ

---

2. Earthing
   Check the condition of the earthing bar and connections .....

---

3. Insulation resistance test - switching device at 500 V
   Phase L1-E ..... L2-E ..... L3-E ..... MΩ

---

4. Protection relay test (**Form No. 12**) Sheet No. .....

---

5. Restart relay tested ..... result: ..... s

---

6. Check and record the fuse:
   Class ..... Rating ..... Condition .....

---

7. Remarks Inspector: .....
   Date: .....

---

8. Equipment Accepted Y/N Supervisor: .....
   Date: .....

FORM NUMBER 11 INSPECTION OF OUTGOING UNIT - LV SWITCHBOARD (cont'd)

LIGHTING CIRCUITS INSULATION RESISTANCE TEST *
(fittings disconnected).

Circuit Number	Value MΩ	Date	Circuit number	Value MΩ	Date

CONVENIENCE OUTLETS *

Circuit Number	IR MΩ	Residual current device	Earth loop impedance	Polarity	Date

* for the physical inspection of fittings use one Form 1 per Plant area.

FORM NUMBER 12 LV OVERCURRENT AND EARTH-FAULT PROTECTION RELAY TEST

Location: .....

Switchboard No.: ..... Panel No.: .....

Relay: Motor protection relay

Manufacturer: ..... Type: ..... Contactor rating: ..... A

Trip setting range: ..... A Motor FLC: ..... A

Primary injection test

at selected trip setting ..... A
all three phases connected in series

Test current in % setting	300	300	120	105
current, A	.....	.....	.....	.....
relay condition	cold	warm	warm	warm
relay time, seconds	.....	.....	.....	no trip
curve time, seconds (supplied by manufacturer)	.....	.....	.....	after .... min

earth-fault relay

setting ..... A
measured pick-up current ..... A

---

relay setting after test:
thermal relay ..... A
earth-fault relay ..... A
setting sealed .....

Remarks

Inspector: .....

Date .....

Equipment Accepted Y/N

Supervisor: .....

Date: .....

FORM NUMBER 13 INSPECTION OF POWER TRANSFORMER

Location: .....

Transformer No.: ..... Manufacturer: .....

Enclosure: ..... Serial No.: .....

Rating: ..... kVA Voltage: ..... / V

Vector group: ..... Current: ..... / ..... A

---

1. Inspection of the switchgear transformer feeder unit

   completed: ..... Sheet No.: .....

   protection relay setting .....

---

2. Insulation resistance tests:

	Cable incl./excl.	Test voltage	MΩ	Meter used
HV winding to earth	.....	.....	.....	.....
LV winding to earth	.....	.....	.....	.....
HV winding to LV winding	.....	.....	.....	.....

---

3. Continuity test - tap changer:

   after moving tap changer, switch set at tap. No. .....

   Continuity test - HV winding:

   L1-L2 ..... L2-L3 ..... L3-L1 ..... mΩ

---

4. Earthing:

   Check the condition - neutral earthing .....

   measure: - neutral earthing continuity ..... mΩ

   - equipment earthing continuity ..... mΩ

---

5. For breathing type transformers:

   - check the position of the conservator valve .....
   - check the silica gel condition/colour .....
   - result of the oil test main tank .....

     conservator .....

- test gas/oil relay (Buchholz) alarm .....

  trip .....

   - check thermometer ..... reset max. indicator .....

FORM NUMBER 13 INSPECTION OF POWER TRANSFORMER (cont'd)

6.	Check single core cable bonding (for pre-commissioning inspection only)		
7.	Inspection of the electrical system of cooling fans/pumps:		
8.	Basic inspection completed (**Form No. 1**)	Sheet No.:	.....
9.	Remarks	Inspector: Date:	....
10.	Equipment Accepted Y/N	Supervisor: Date:	....

FORM NUMBER 14 INSPECTION OF ELECTRIC MOTOR - CAGE-INDUCTION TYPE (INCLUDING CONTROL UNIT)

Location: .....

Motor No.: ..... Driven equipment: .....

Manufacturer: ..... Serial No.: .....

System voltage: ..... V Rating: ..... kW

NOTE: Tests marked (A) may be waived for motors below 30 kW rating.

Tests marked (B) may be waived for motors below 100 kW rating driving centrifugal pumps.

* Delete as necessary.

---

1. Motor record sheet - Equipment Record Card completed. .....

---

2. Inspection of the switchgear motor supply unit completed:
   (**Form No. 4 or 11**) Sheet No.: .....

---

3. Insulation resistance tests:
   before connecting cable: test voltage V
   - insulation resistance of motor cable (phase to earth + phases)
     L1-E ..... L2-E ..... L3-E ..... MΩ
   - insulation resistance of motor (phases to earth)
     after 1 min. ..... MΩ after 10 min. ..... MΩ(A)
     Polarizing index. ..... (A)

   after connecting cable:
   - check cable connection .....
   - insulation resistance motor + cable (phases to earth) ..... MΩ
   - insulation resistance control unit + cable to earth ..... MΩ

---

4. Earthing
   - check the condition of earthing connections at: motor .....
     control unit .....
   - continuity measurement earth
     return path on (20% of motors) test #8 Appendix 13 ..... Ω

---

5. Special items:
   - check anti-condensation of heater installation working .....
   - test insulation resistance of heater at 500V ..... MΩ
   - test insulation resistance of temperature detectors ..... MΩ
   - inspect system aux. motors .....
   - test bearing insulation (if fitted) ..... MΩ
   - check magnetic centre .....

FORM NUMBER 14 INSPECTION OF ELECTRIC MOTOR - CAGE-INDUCTION TYPE (INCLUDING CONTROL UNIT) cont'd

---

6. Basic inspection completed
(**Form No. 1**) Sheet No. .....

---

7. Test/record the following items in uncoupled condition:
   - record rotation from NDE: CW/CCW * (confirm correct).....
   - measure vibration - refer sheet No. ..... (A)
     max. reading .....mm/s RMS DE/NDE * (A)
   - record:
     ° starting current ..... A (A) (B)
     ° no load current ..... A
     ° bearing temperature (A) (B)

time	min	0	20	40	60
temp. DE	°C	.....	.....	.....	.....
temp. NDE	°C	.....	.....	.....	.....
ambient temp.	°C	.....	.....	.....	.....

---

8. Test/record the following items in full load condition:
   - measure vibration - refer sheet No. ..... (A)
     max. reading ..... mm/s RMS DE/NDE * (A)
   - record bearing temperature (A)
     (motors >30 kW < 100 kW, for 60 min)
     (motors >100 kW and factory tested, for 60 min):

time	min	0	30	60	90	120	150	180	210
temp. DE	°C	.....	.....	.....	.....	.....	.....	.....	.....
temp. NDE	°C	.....	.....	.....	.....	.....	.....	.....	.....
ambient temp.	°C	.....	.....	.....	.....	.....	.....	.....	.....

---

9. Record in coupled condition:
   - starting time (if over 1 s) ..... s (A)

---

10. Remarks Inspector: .....
Date: .....

---

11. Equipment Accepted Y/N Supervisor: .....
Date: .....

FORM NUMBER 15 INSPECTION OF STATIC SUPPLY UNIT

Location: .....
Unit No.: ..... Manufacturer .....
Rectifier/inverter: ..... Serial No.: .....
Battery type: ..... No. of cells/volts: .....

NOTE: Tests marked (C) and (M) are required for pre-commissioning and maintenance inspections only.

---

1. AC/DC distribution board.

   Check: good condition - no mechanical damage .....
   correct labelling .....
   correct earthing

   Test: insulation resistance at 500-V
   bar 1 - earth ..... MΩ
   bar 1 - bar 2 ..... MΩ bar 2 - earth ..... MΩ

   Test earth-fault indication and detection .....
   Record: fuse size: ..... type: ..... actual load: .....

---

2. Check the following items:

   - correct earthing ..... - cable connections .....
   - operating temperature ..... - cleanliness .....
   - no abnormal noise ..... - no leaking capacitors .....
   - all parallel capacitors at same temperature .....

---

3. Check correct operation of:

   - forced cooling fan ..... - interlock system .....
   - indicating lights/meters ..... - common alarm .....

---

4. Check operating set points

4.1 Rectifier:

   - float charge voltage ..... V - boost charge voltage V

   (indicate if trip or alarm function)
   - AC failure ..... V ..... s - rectifier failure .....
   - low DC voltage ..... V - high DC voltage V
   - earth fault ..... - fuse failure .....
   - .... - ....
   - .... - ....

   - rectifier output oscilloscope check at normal load .....

FORM NUMBER 15 INSPECTION OF STATIC SUPPLY UNIT (cont'd)

4.2 Inverter:

- inverter output voltage & frequency ..... V ..... Hz
- inverter in synchronism .....
- auto change-over:
  a. from inverter to by-pass ..... b. from by-pass to inverter .....
- inverter output oscilloscope check at normal load .....

(indicate if trip or alarm function)

- low DC input	 V	- high DC input	 V
- low AC output	 V	- high AC output	 V
- inverter fail	.....	- load on bypass	.....
- fuse failure	.....	-	.....
-	.....	-	.....

5. Batteries

Check that all connections are tight and that anti-corrosive coating (vaseline) is provided .....

Check the liquid level of each cell .....

Check the cells for leakage .....

- cell voltage and specific gravity tests .....
- battery discharge capacity test .....

6. Basic inspection completed (**Form No. 1**) Sheet No. .....

7. Remarks Inspector: .....
Date: .....

8. Equipment Accepted Y/N Supervisor: .....
Date: .....

FORM NUMBER 15 INSPECTION OF STATIC SUPPLY UNIT (cont'd)

BATTERY DISCHARGE CAPACITY TEST

Unit No.: ..... Test Date: .....

Normal load: ..... A

Time	DC Volts	DC Amps	AC Volts	AC Amps	Hz
0 min					
5 min					

Meter No:

Test guidelines:

1. Discharge load current to be equal to normal load current +/- 10%.
2. Simulate a rectifier power failure and discharge to the point of inverter trip or the specified minimum voltage.
3. Cell voltages may be measured during battery discharge, to detect defects.
4. Upon completion of the test carry out boost charging.

Remarks

Inspector: .....

Date: .....

FORM NUMBER 15 INSPECTION OF STATIC SUPPLY UNIT (cont'd)

BATTERY CELL TESTS

Unit No.: .... Test Date: ....

Temperature: ....°C

Cell No.	Volts	S.G.	Cell No.	Volts	S.G	Cell No.	Volts	S.G.

Meter No:

Remarks

Inspector: ....

Date: ....

FORM NUMBER 16 INSPECTION OF SYNCHRONOUS MACHINES (INCLUDING EXCITER)

Location: .....
Tag No.: .....
Manufacturer: ..... Serial No.: .....
System Voltage: ..... V Rating: ..... kW

NOTES: - Tests marked (A) may be waived for units < 100 kW.
- HV cables tested using Form No. 18.

---

1. Inspection of the switchgear unit complete: (**Form No. 4 or No. 11**) .....
   Basic inspection complete: (**Form No. 1**) .....

---

2. Insulation resistance tests:
   Insulation resistance test of stator (phase to earth):
   after 1 min: . ..... MΩ test voltage: V
   after 10 min: ..... MΩ Polarisation index: .....
   Insulation resistance test of stator + cable: ..... MΩ
   Insulation resistance test of rotor circuit (diodes short circuited): ..... MΩ
   Insulation resistance test of exciter field: ..... MΩ
   Insulation resistance test of exciter field + cable: ..... MΩ

---

3. Earthing, check the condition of earthing connections at:
   machine: ..... exciter: ..... neutral: .....

---

4. Special items:
   - check anti-condensation heater installation working .....
   - test insulation resistance of heater at 500 V ..... MΩ
   - test insulation resistance of temperature detector ..... MΩ
   - inspect system aux. motors .....
   - test bearing insulation (if fitted) ..... MΩ
   - check magnetic centre .....

---

5. Vibration, measure at full load condition:
   refer sheet No.: .....
   Maximum readings DE ..... mm/s RMS
   NDE ..... mm/s RMS

FORM NUMBER 16 **INSPECTION OF SYNCHRONOUS MACHINES (INCLUDING EXCITER) (cont'd)**

GENERATOR LOAD TRIALS

DATE:	TIME, HOURS				
LOAD:					
Voltage					
Current					
PF					
MW					
MVAR					
EXCITATION:					
Current					
Voltage					
TEMPERATURE:					
Windings:					
(if fitted					
with RTDs)					
Air:					
Ambient					
In					
Out					
Water:					
In					
Out					
Bearings:					
DE					
NDE					

Remarks

Inspector: .....

Date: .....

Equipment Accepted Y/N

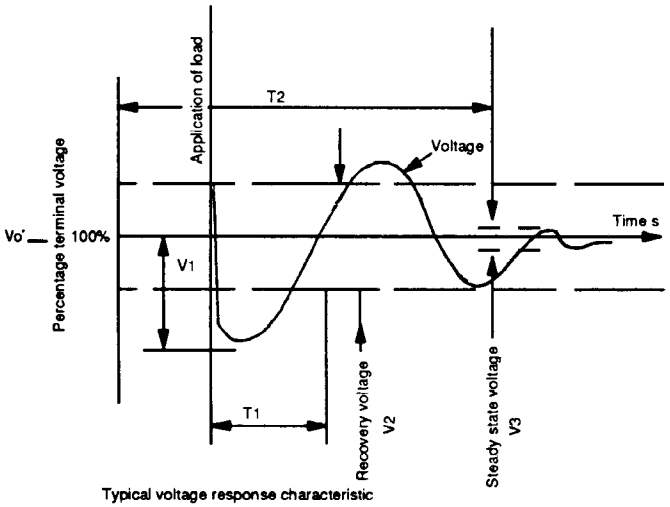
Supervisor: .....

Date: .....

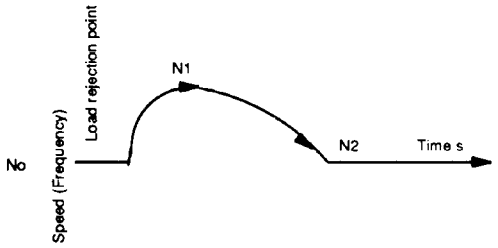
FORM NUMBER 17 SYNCHRONOUS A.C. GENERATOR DYNAMIC TESTS
LOAD ACCEPTANCE/REJECTION* TEST RESULTS

TIME & DATE						
GENERATOR INITIAL LOAD		kW				
LOAD ACCEPTED/REJECTED *		kW/kVA *				
GENERATOR: - FREQUENCY	Before (N0)	Hz				
	Transient (N1)					
	Steady State (N2)					
- TIME	To N1 Max. */Min. Hz	s				
	To Steady State (N2)					
GENERATOR: - VOLTAGE	Initial Voltage (V0)	V				
	Transient " (V1)					
	Recovery " (V2)					
	Steady State " (V3)					
- TIME	Recovery T1 (to V2)	s				
	Steady State T2 (to V3)					
GOVERNOR INDICATION	Initial	%				
	Transient					
	Steady State					

* Delete as applicable



Typical voltage response characteristic
(Load Acceptance)



Typical speed response characteristic
(Load rejection)

Refer to Specification for applicable Transient and Steady state voltage parameters

Refer to Specification for applicable Steady state speed parameters

FORM NUMBER 18 INSPECTION OF HIGH VOLTAGE CABLE

Location: .....

Cable No: ..... System voltage: V

Cores: ..... Size: ..... mm^2 Cable rated voltage: V

NOTES: - Cable to be isolated at both ends during following tests.

- Tests marked (C) are required for commissioning only.

---

1. Establish and record the length of cable (C): .....

---

2. Insulation resistance test, phase to earth + remaining phases:

   Phase L1 ..... MΩ L2 ..... MΩ L3 ..... MΩ

   Test voltage: ..... Meter No.: .....

---

3. High Voltage tests (C) (and after repair).

   Leakage current:

   Phase L1 ..... mA L2 ..... mA L3 ..... mA

   Test voltage: ..... kV Time ..... s Meter No.: .....

   (refer Appendices 11 and 12)

---

4. Cable terminations correct: .....

---

5. Remarks Inspector: .....

   Date: .....

---

6. Equipment Accepted Y/N Supervisor: .....

   Date: .....

FORM NUMBER 19 INSPECTION LIST TRACE HEATING INSTALLATION

Location	.....	Distribution board No.	.....
Type Heat trace cable	.....	Heating temperature	.....
Make	.....		
Voltage	.....	Area classification	.....

Check that the installed equipment is suitable for the classified area.

Type of protection:
Connection box .....
Local switches .....
Thermostats .....
Indication lamps .....

Circuit No.								
1. Test insulation resistance to earth Heat trace cable only (MΩ)								
2. Check earth continuity								
3. Check cold junction/interconnection box for correct connections/glands								
4. Check the cable, junction boxes and thermostats for correct mounting. (Refer manufacturer's recommendations)								
5. Check local switches for correct rating, connection, and mounting								
6. Check thermostats for contact rating, and correct operation at set point								
7. Check circuit labelling and warning signs								
8. Check that conduit pipes are plugged off and pull wires installed (Cryogenic tanks)								

Remarks

Inspector: .....

Date: .....

Equipment Accepted Y/N

Supervisor: .....

Date: .....

FORM NUMBER 20 INSPECTION OF EARTH SYSTEMS

(Use Form No. 21 for earth electrode measurements)

PLANT: .....

From (Equipment)	To	Ω	Test No. *

* Refer to Appendix 13 for test number

Remarks Inspector: .....

Date: .....

Equipment Accepted Y/N Supervisor: .....

Date: .....

FORM NUMBER 21 INSPECTION OF EARTHING ELECTRODES

Location: ..... Reference number: .....

Type of Earthing: ..... Type of Electrode: .....

---

1. Electrode Tests:

   Earthing electrodes are to be tested individually and finally as a 'group' (if installed as a group for the purpose of obtaining a sufficiently low ohmic value); by means of a test set and test electrodes.
   (Refer to Appendices 13 and 14 for method and values).

	No. 1	No. 2	No. 3	No. 4
Individual Electrode resistance, (ohm)	.....	.....	.....	.....

   Electrode Group resistance, (if applicable) ..... Ω

---

2. Cable/connection Tests:

   Check connections earth cable/electrode .....

   Check for corrosion on the exposed part of the electrodes .....

   Check continuity electrode - earth bar/Plant earth ring .....

---

3. Remarks Inspector: .....

   Date: .....

---

4 Equipment Accepted Y/N Supervisor: .....

   Date: .....

FORM NUMBER 22 INSPECTION OF OVERHEAD LINE

Location: .....

Drwg Ref. No.: .....

Operating voltage: ..... kV Conductor size: .....

---

1. Insulation resistance test:

   Test voltage: ..... V Tester used: .....

   phase L1 ..... L2 ..... L3 ..... MΩ

---

2. HV pressure test: Duration: ..... min

   Test voltage: ..... kV Tester used: .....

   Leakage current mA

   L1 to L2+L3 ..... L2 to L1+L3 ..... L3 to L2+L3 .....

   L1+L2+L3-E .....

---

3. Line resistance (complete line):

   L1-L2 ..... L2-L3 ..... L1-L3 ..... Ω

---

4. Earthing system:

   Earth pits tested: ..... Static earth wire: .....

   Earth connections: ..... Structure/guys: .....

---

5. Line joints:

   All line joints tested (**Form No. 24**) .....

---

6. Line sag:

   Sag measurement satisfactory (**Form No. 23**) .....

---

7. Pole check list completed (p.t.o.) .....

---

8. Remarks Inspector: .....

   Date: .....

---

9. Equipment Accepted Y/N Supervisor: .....

   Date: .....

FORM NUMBER 22 INSPECTION OF OVERHEAD LINE (cont'd)

7. Pole check list:

Work commenced Date: ..... Work completed Date: .....

1.	Foundations correctly installed	.....
2.	Poles are vertically installed	.....
3.	All wooden poles impregnated with creosote	.....
4.	All pole unused holes plugged	.....
5.	Backfilling, compacting, levelling complete	.....
6.	Cross arms and supports straight	.....
7.	All damage to galvanizing repaired	.....
8.	All fixings tightened to spec and painted	.....
9.	All insulators are clean	.....
10.	Line correctly phased and phase discs fitted	.....
11.	Line conductors are correctly clamped/strapped	.....
12.	Anti-climbing devices, danger and reflector plates fitted	.....
13.	No strand damage to conductors	.....
14.	Sagging correct (records submitted)	.....
15.	All clearances correct to specification	.....
16.	Stay anchors checked for tightness	.....
17.	Installation of isolators, surge diverters, post insulators, ball and socket insulators and drop-out fuses satisfactory	.....
18.	Isolators operated for ease of movement and ability to lock-out	.....
19.	Expulsion fuses correct size and spring tension	.....
20.	All temporary earths removed	.....
21.	All excess material removed	.....
22.	All pole areas shaped to eliminate water-ponding	.....
23.	Ramming and levelling around foundations and guys completed, all excess earth removed	.....
24.	Earthing	.....

Remarks

Inspector: .....

Date: .....

FORM NUMBER 23 OVERHEAD LINE SAG RECORD

Location: .....

Sagging/Tension Drwg Ref. No.: .....

---

1. Record:

Pole No. ..... to Pole No.		Pole No. ..... to Pole No.	
Span length:	..... m	Span length:	..... m
Ambient temperature	.....°C	Ambient temperature	.....°C
Conductor temperature	.....°C	Conductor temperature	.....°C
Midspan joints Y/N	Line	Midspan joints Y/N	Line .....
Conductor repair Y/N	Line	Conductor repair Y/N	Line .....
Shortened pole Y/N	No.	Shortened pole Y/N	No. .....
Dynamometer Y/N	..... N	Dynamometer Y/N	..... N
Method of measuring sag:	.....	Method of measuring sag:	.....
Sag measured:	..... m	Sag measured:	..... m

Pole No. ..... to Pole No.		Pole No. ..... to Pole No.	
Span length:	..... m	Span length:	..... m
Ambient temperature	.....°C	Ambient temperature	.....°C
Conductor temperature	.....°C	Conductor temperature	.....°C
Midspan joints Y/N	Line	Midspan joints Y/N	Line .....
Conductor repair Y/N	Line	Conductor repair Y/N	Line .....
Shortened pole Y/N	No.	Shortened pole Y/N	No. .....
Dynamometer Y/N	..... N	Dynamometer Y/N	..... N
Method of measuring sag:	.....	Method of measuring sag:	.....
Sag measured:	..... m	Sag measured:	..... m

---

2. Remarks

Inspector: .....

Date: .....

---

3. Equipment Accepted Y/N

Supervisor: .....

Date: .....

FORM NUMBER 24 OVERHEAD LINE COMPRESSION JOINTS

Location: .....

Drwg Ref. No.: .....

Operating Voltage: ..... Conductor size: .....

---

1. Measure all line joints and record:

Pole No.	mΩ			Date
	L1	L2	L3	Tested

---

2. Remarks Inspector: .....

Date: .....

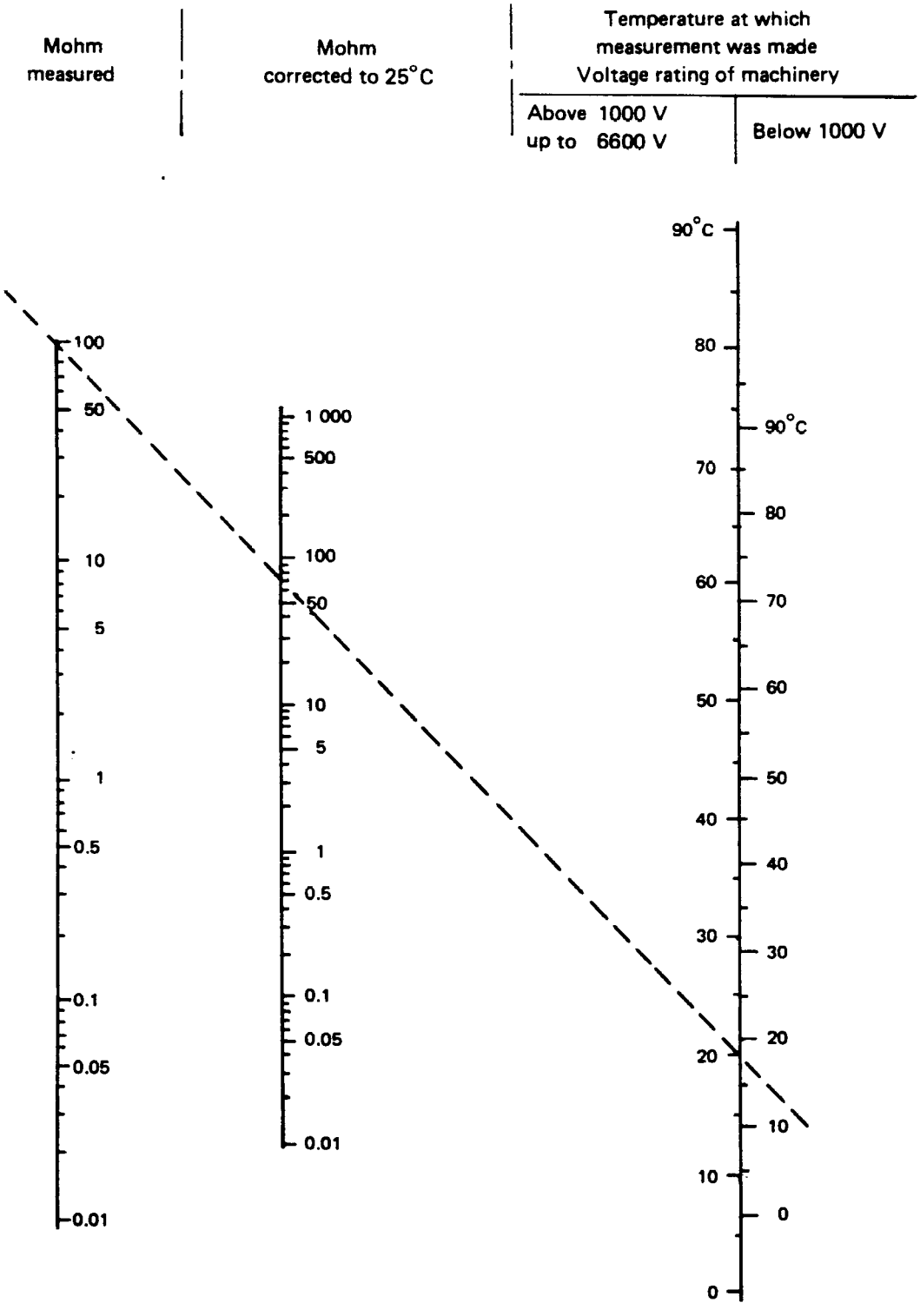
---

3. Equipment Accepted Y/N Supervisor: .....

Date: .....

APPENDICES

APPENDIX 1 NOMOGRAM FOR TEMPERATURE CORRECTION



Example: Measured resistance: 100 Mohm

Temperature at measurement: 20 °C (1000-6600 V)

Corrected resistance: 70 Mohm

APPENDIX 2 TYPICAL CURVES FOR VARIATION OF INSULATION RESISTANCES

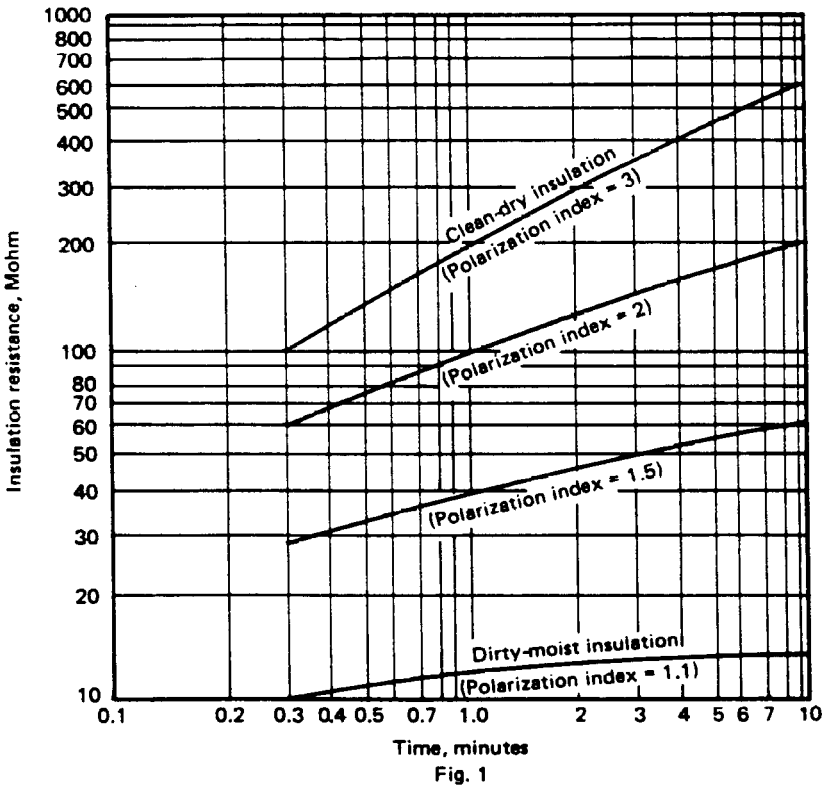


Fig. 1
Typical curves showing variation of insulation resistance with time for class B insulated alternating current armature windings.

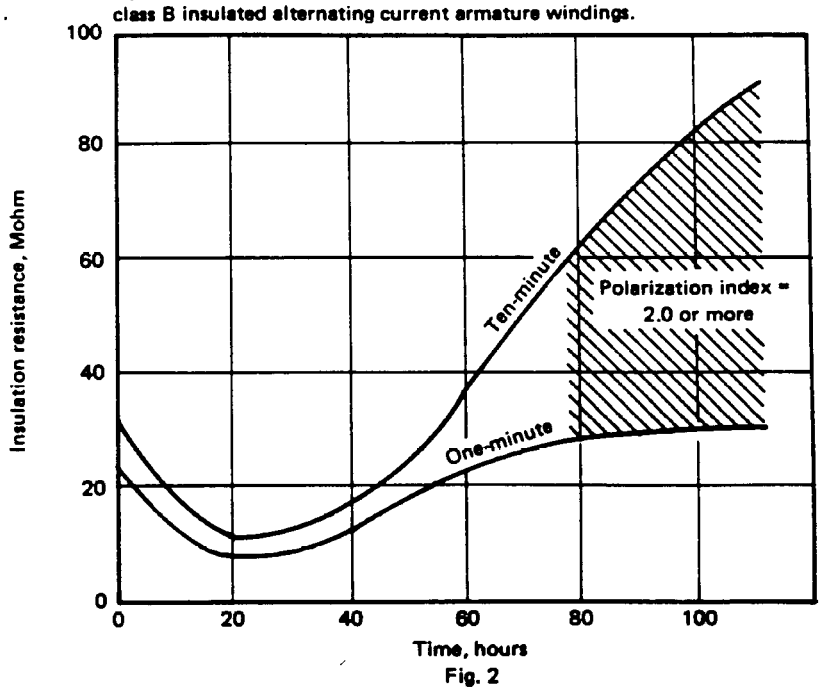
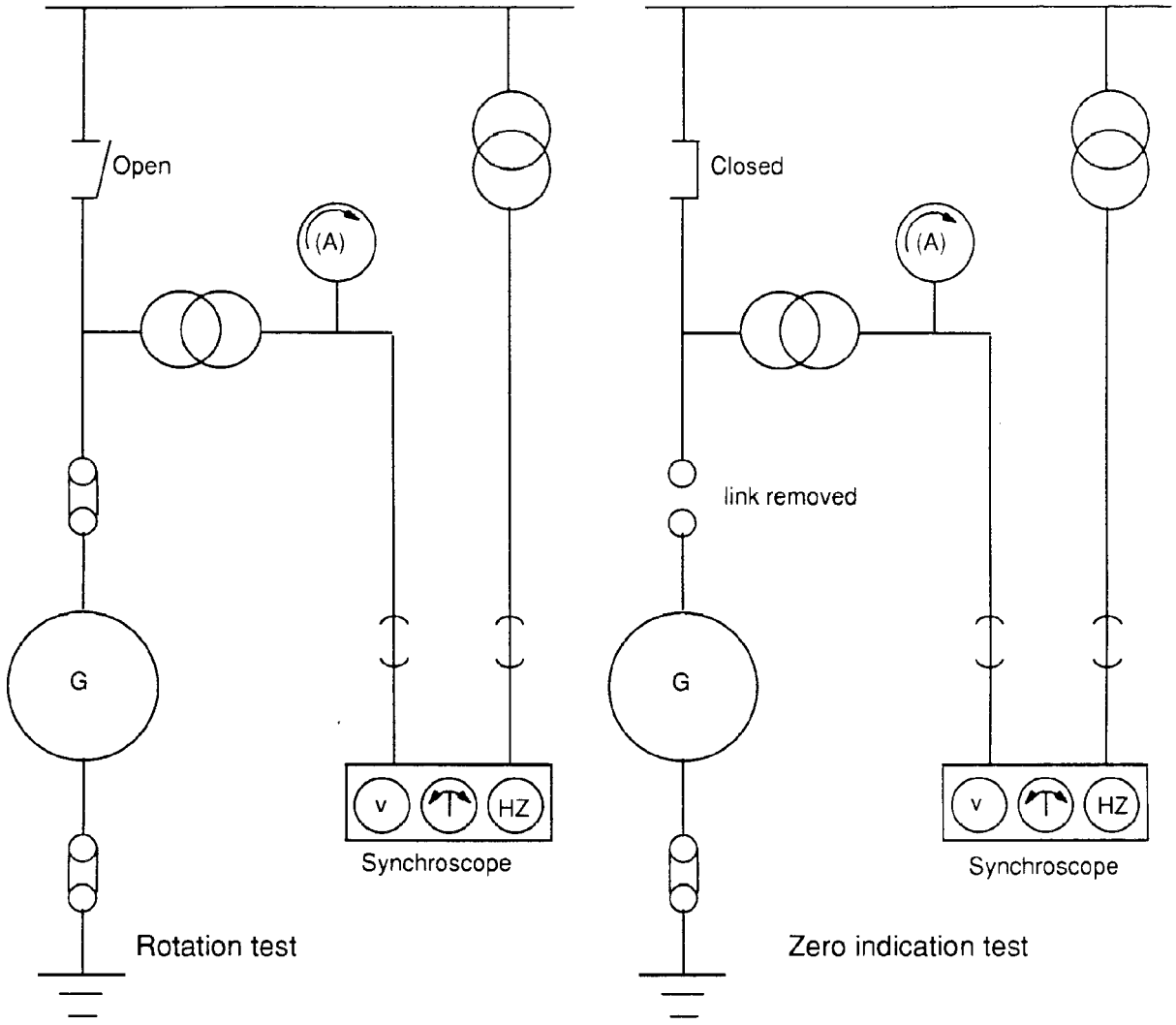


Fig. 2

Change in one-minute and ten-minute insulation resistance during the drying process of a class B insulated alternating current armature winding.
Initial winding temperature 25 °C.
Final winding temperature 75 °C.

APPENDIX 3 GENERATOR SYNCHRONIZING SYSTEM TESTING



test 2 test 1

NOTES:
1. Test 1, verify in-phase indication of synchroscope, check sync and voltmeter.
2. Using a phase rotating meter (A), verify identical phase rotation for tests 1 and 2.
3. Test 2 with generator energized, verify that synchroscope, voltmeter, auto and check sync relays follow the 'beat frequency'.

APPENDIX 4 ENCLOSURES - DEGREE OF PROTECTION

Characteristic letters: I P

FIRST characteristic numeral		SECOND characteristic numeral	
a) protection against ingress of foreign bodies b) protection of personnel against contact with live or moving parts		protection against ingress of water	
0	no protection	0	no protection
1	a) no ingress of solid bodies ≥ 50 mm	1	against vertical drops
	b) no accidental contact by hand	2	against drops falling under 15° from vertical
2	a) no ingress of solid bodies ≥ 12.5 mm	3	against rain up to 60° from the vertical
	b) no deliberate contact by fingers	4	against splashing from any direction
3	a) no ingress of solid bodies ≥ 2.5 mm	5	against water jets from any direction
	b) no contact by tools ≥ 2.5 mm	6	against ship's deck condition
4	a) no ingress of solid bodies ≥ 1 mm	7	against immersion effects in water
	b) no contact with wires ≥ 1 mm	8	against indefinite immersion in water
5	a) no harmful deposits of dust		
	b) no possible contact at all		
6	a) no ingress of dust		
	b) no possible contact at all		

See IEC 34-5 and 529 for exact descriptions.

APPENDIX 5 EXPLOSION PROTECTION

Area classification	Zone 0	Zone 1	Zone 2	Non-hazardous 2)
Presence of explosive atmosphere	Continuous or for long periods	Likely to occur under normal operation	Not likely and if present for short time only	Virtually excluded
Presence of electrical ignition sources	Should never occur, even under fault conditions	Practically excluded	Not present under normal operation; may occur by faults	May be present under normal operation
Minimum type of protection of electrical equipment	Ex (i a) Ex (s) for Zone 0	Ex (e) 1) Ex (i b) Ex (d) Ex (o) Ex (p) Ex (s) for Zone 1	Ex (n) Industrial non-sparking	Normal industrial equipment

TYPE MARKING OF EQUIPMENT (IEC 79)

General symbol		Protection type	Use	Explosion group	Temperature class
Flameproof enclosure	(79-1)	d			
Increased safety	(79-7)	e			
Pressurized enclosure	(79-2)	p			
Oil-immersed apparatus	(79-6)	o			
Intrinsically safe	(79-3)	i			
Special protection	(-)	s			
Non-sparking	(79-15)	n			
For use in mines (methane)			I		
For use in other industries			II		
Representative gas		i.e. - propane		A	
		- ethylene		B	
		- hydrogen		C	
Limiting temperature		max. 450 °C			T1
		max. 300 °C			T2
		max. 200 °C			T3
		max. 135 °C			T4
		max. 100 °C			T5
		max. 85 °C			T6

NOTES: 1) LV equipment and HV terminal boxes only.

2) It is preferred to use Zone 2 equipment in process plant non-hazardous areas.

APPENDIX 6 STANDARDS TO WHICH APPARATUS MAY BE MANUFACTURED

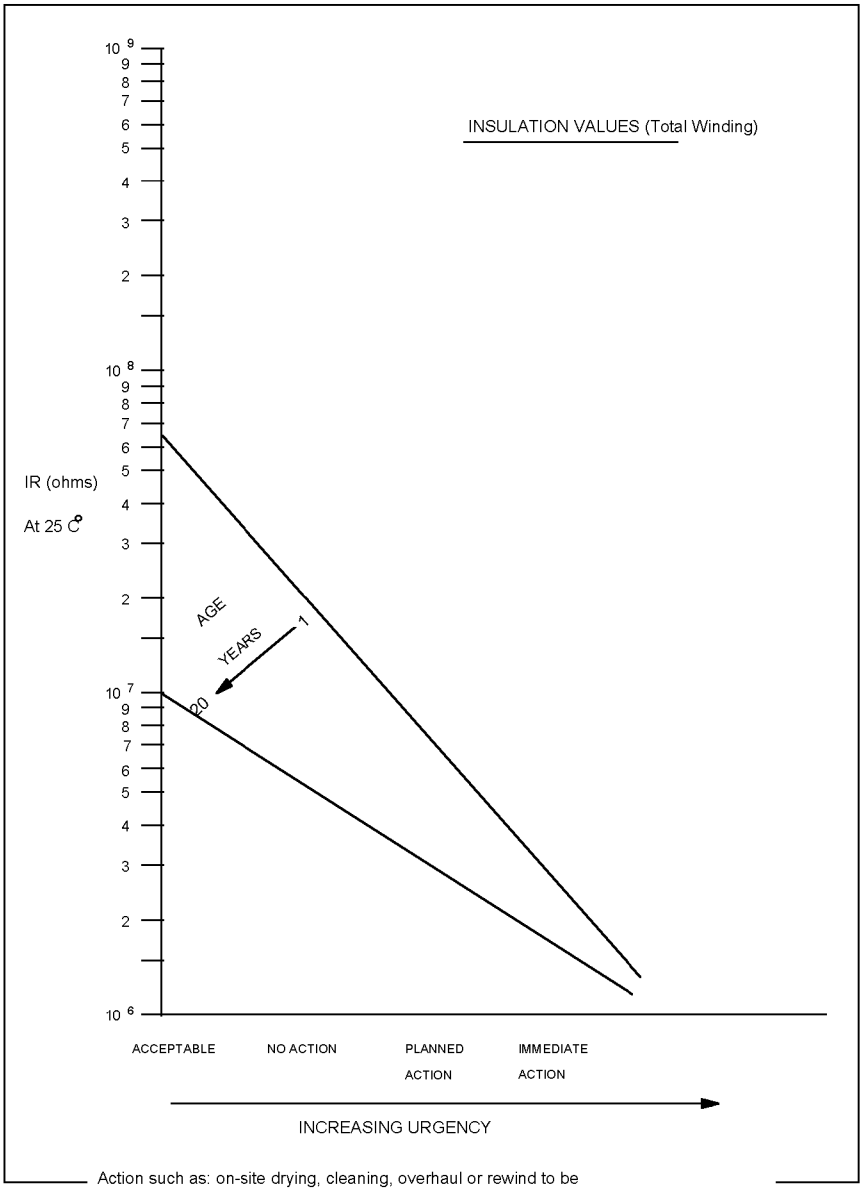
PROTECTION METHOD	CODE	IEC	CENELEC	U.K.	NETHERLANDS	GERMANY OIL	USA	CANADA
FLAMEPROOF PROTECTION	EEx d		EN50 018	BS 5501 Part 5	NEN 50018	VDE 0170/0171-5	-	-
	Ex d	79-1	-					
	Ex d	-						
INCREASED SAFETY	EEx e		EN50 019	BS 5501 part 6	NEN 50019	VDE 0170/0171-6	-	-
	Ex e	79-7	-					
							-	-
NON-SPARKING	Ex N		-	BS 6941				
	Ex n	79-15	-					
INTRINSIC SAFETY	EEx 1a / 1b		EN50 020	BS 5501 Part 7	NEN 50020	VDE 0170/0171-7	FM 3610	CSA 22.2 - 157
	Ex 1a / 1b	79-11	-	SFA 3012			UL 913	
	Ex 1a / 1b		-					
PRESSURIZED	EEx p		EN50 016	BS 5501 Part 3	NEN 50016	VDE 0170/0171-3	NFPA	Use NFPA 496
	Ex p	79-2	-				496	
ENCAPSULATION	EEx m		EN50 028	BS 5501 Part 8	NEN 50028	VDE 0170/0171-8	-	-
SPECIAL PROTECTION	Ex s		-	SFA 3009			-	-
OIL FILLING	EEx o	79-6	EN50 015	BS 5501 Part 2	NEN 50015	VDE 0170/0171-2	UL698	
SAND/POWDER FILLING	EEx q	79-5	EN50 017	BS 5501 Part 4	NEN 50017	VDE 0170/0171-4		
EXPLOSION PROOF	-		-	-	-	-	UL 698	CSA 22.2 - 30
							UL 886	
							FM 3165	
NON - INCENDIVE	-		-	-	-	-		CSA 22.2 - 157

NOTE: The above table does not necessarily imply that the Standards are identical.

EXAMPLES OF AUTHORISED CERTIFICATION BODIES:

U.K.	FRANCE	ITALY	SPAIN	NORWAY	DENMARK	GERMANY	BELGIUM	U.S.A.	CANADA	JAPAN
BASEEFA	LCIE	CESI	LOM	NEMKO	DEMKO	PTB	IMIEX	F.M.	CSA	RIIS
	CHERCHAR						ISSeP	U.L.		

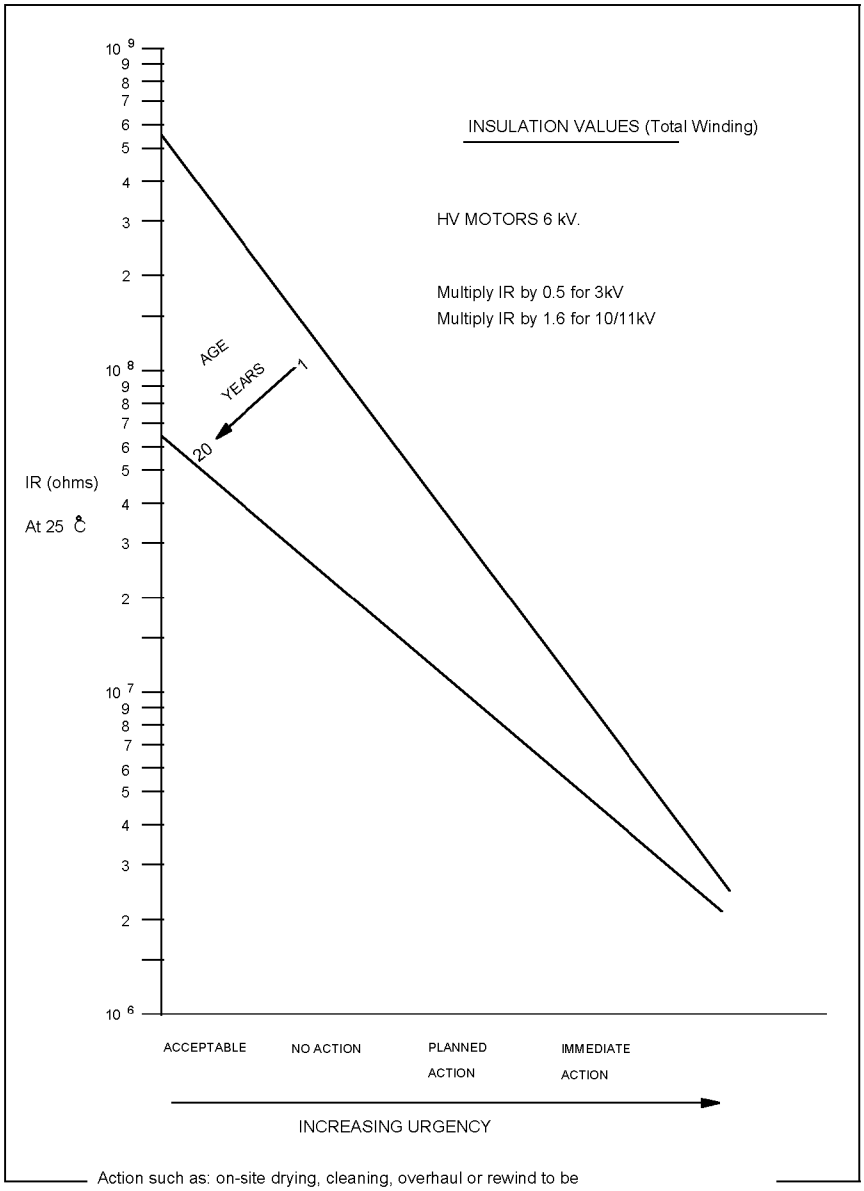
APPENDIX 7 MAINTENANCE URGENCY FOR INSULATION VALUES (LV MOTORS)



Action such as: on-site drying, cleaning, overhaul or rewind to be determined on a case-by-case basis.

31###N7

APPENDIX 8 MAINTENANCE URGENCY FOR INSULATION VALUES (HV MOTORS)



APPENDIX 9 MOTOR 'SOFT FOOT' CONDITION

'Soft feet' are those which do not have solid flat contact with the base prior to the tightening of the holding-down bolts; one or more feet may be 'soft' as shown in Figures 1 to 3.

The profile of the foot contact area may be as shown in Figures 4 to 6.

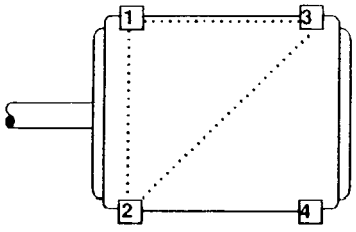


Figure 1
Machine resting on 3 feet, foot 4 is raised or 'soft'

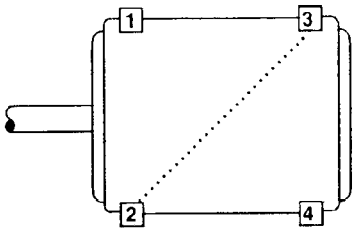


Figure 2
Machine resting on diagonal formed by feet 3 and 4, feet 1 and 4 are 'soft'

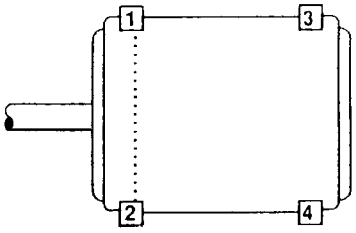


Figure 3
Bottoms of all 4 feet are not parallel with base, feet 3 and 4 are 'soft'

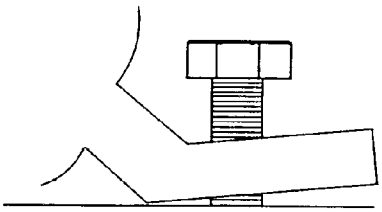


Figure 4

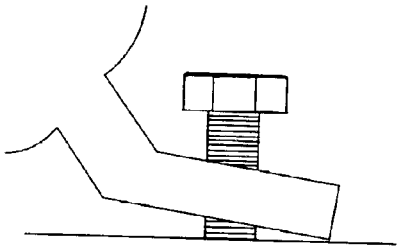


Figure 5

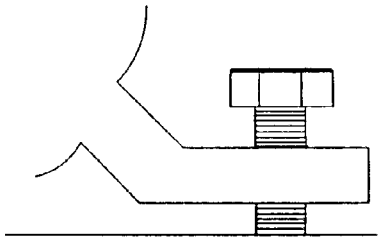


Figure 6

Profile of 'soft foot' contact area

NOTE: Re-machining of rotor feet is required in Figures 4 and 5; temporary use of wedge-shaped shims may be acceptable (maintenance).

APPENDIX 10 MOTOR VIBRATION MAINTENANCE RECOMMENDATIONS

Measurements should be carried out with an instrument conforming to ISO 2954 (10-1000 Hz frequency range), with the motor at normal operating temperature and at full load.

For equipment (re)commissioning the vibration velocity should not exceed 2.8 mm/s RMS, or 4 mm/s PEAK in any direction.

It is prudent to judge vibration severity on a trend basis, thus a step change of 2.5 times in vibration velocity should be considered as significant and worthy of further investigation.

Vibration levels on non-running machinery should be substantially below those for a running machine to avoid deterioration of the bearings by 'brinelling'. Values > 0.4 mm/s should be attended to.

As a guide to acceptable vibration levels during plant operations the following table may be used.

<table>
<tr><td>VELOCITY RANGE</td><td colspan="4">MACHINE TYPE</td></tr>
<tr><td>Upper Range Limit, mm/s rms 600-12,000 rpm</td><td>Type 1</td><td>Type 2</td><td>Type 3</td><td>Type 4</td></tr>
<tr><td>0.28</td><td colspan="4" rowspan="3">GOOD TO VERY GOOD</td></tr>
<tr><td>0.45</td></tr>
<tr><td>0.71</td></tr>
<tr><td>1.12</td><td colspan="4" rowspan="3">USABLE</td></tr>
<tr><td>1.8</td></tr>
<tr><td>2.8</td></tr>
<tr><td>4.5</td><td colspan="4" rowspan="2">IMPROVEMENT DESIRABLE TO NECESSARY</td></tr>
<tr><td>7.1</td></tr>
<tr><td>11.2</td><td colspan="4" rowspan="3">UNUSABLE</td></tr>
<tr><td>18</td></tr>
<tr><td>28</td></tr>
</table>

Type 1 - Small industrial machines, e.g. electric motors below 15 kW.

Type 2 - Medium size electric motors, 15-75 kW without special foundations.

Type 3 - Large motors or machines consisting largely of rotating masses, mounted on rigid foundations having high rigidity in the direction of measurement.

Type 4 - Type 3 but without rigidity in the direction of measurement.

APPENDIX 11 RECOMMENDED TEST VOLTAGES FOR COMMISSIONING AND MAINTENANCE

A11.1 CABLES

Insulation resistance tests and High voltage tests shall be carried out between each phase and earth with the remaining phases connected to earth and loads disconnected.

A11.1.1 High voltage tests:

Duration: 3 minutes

High voltage tests: Duration: 3 minutes	Newly laid cables	Recommissioning of repaired cables
Cable voltage designation kV-(a.c.) U_O/U (U_m)	Test voltage kV-(d.c.)	Test voltage kV-(d.c.)
< 1.0	IR test only	IR test only
1.8/3 (3.6)	6.5	4
3.6/6 (7.2)	11	7
6/10 (12)	15	12
8.7/15 (17.5)	22	17
12/20 (24)	30	24
18/30 (36)	45	36

NOTES:
1. Cables specifically manufactured for unearthed systems, i.e. U_o = U, shall be tested at the value given above for U_o. E.g. cable type 3/3 (3.6) should be tested at 11 kV.
2. - U_o is the rated power-frequency voltage between conductor and earth or metallic screen, for which the cable is designed.
   - U is the rated power frequency voltage between conductors, for which the cable is designed.
   - U_m is the maximum value of the 'highest system voltage' for which the equipment may be used.

A11.1.2 Insulation resistance tests:

System voltage	Test voltage
LV 50 V - 1 kV	500 V (d.c.)
HV up to 4.6 kV	2500 V (d.c.)
HV above 4.6 kV	5000 V (d.c.)

A11.2 MOTORS, GENERATORS, TRANSFORMERS (coil wound equipment).

A11.2.1 Insulation resistance tests:

System voltage	Test voltage
LV below 1 kV	500 V (d.c.)
HV up to 4.6 kV	2500 V (d.c.)
HV above 4.6 kV	5000 V (d.c.)

APPENDIX 11 RECOMMENDED TEST VOLTAGES FOR COMMISSIONING AND MAINTENANCE (cont'd)

A11.3 SWITCHGEAR

High Voltage tests and insulation tests on busbar systems shall be carried out between each phase and earth with the remaining phases connected to earth (voltage transformers and load disconnected).

High Voltage tests and insulation resistance tests on circuit breakers and contactors may be carried out together with or separately from the busbar and shall be carried out with the breaker/contactor closed, with loads disconnected.

A11.3.1 High Voltage test voltages:

Duration: 1 minute

max system voltage kV	3.6	7.2	12	17.5	24	36
test voltage kV (d.c.)	10	20	28	38	50	70

A11.3.2 Insulation resistance test voltages:

- LV systems : 500 V (d.c.)
- HV systems up to 4.6 kV : 2500 V (d.c.)
- HV systems above 4.6 kV : 5000 V (d.c.)

A11.4 CAPACITORS

High Voltage tests on capacitor units shall **exclude** the cable and be carried out between each phase to earth with the remaining phases connected to earth.

A11.4.1 High Voltage tests:

(commissioning only)

Duration 10 s, after stabilisation of charge current.

highest system voltage kV (a.c.)	1.0	3.6	7.2	12	17.5
test voltage kV (d.c.)	1.0*	10	20	28	38

NOTE *: LV capacitor banks and cables shall not be HV tested, but insulation resistance tests shall be carried out.

A11.4.2 Insulation resistance tests:

Use values given in this Appendix 1.2.

APPENDIX 12 RECOMMENDED INSULATION VALUES FOR EQUIPMENT

	Minimum maintenance value (NOTE 1)	Minimum for acceptance at commissioning
A12.1 SWITCHGEAR		
Insulation resistance:		
HV bus	100 MΩ	200 MΩ
LV bus	10 MΩ	20 MΩ
LV wiring (NOTE 2)	0.5 MΩ	5 MΩ
A12.2 CABLES		
Insulation resistance: HV and LV * minimum length 100m (NOTE 3)	$\frac{kV}{km}$ MΩ	$\frac{10 \times kV}{km}$ MΩ
A12.3 MOTORS and GENERATORS		
A12.3.1 Polarisation Index: (9) LV and HV machines Class B and F	1.5	2.0 (6)
A12.3.2 Insulation resistance (at 25 °C) LV and HV machines: (NOTES 4, 5, and 7)	2(kV+1) MΩ	10(kV+1) MΩ
A12.4 POWER TRANSFORMERS (max 36 kV)		
A12.4.1 OIL IMMERSED Insulation resistance :	30 MΩ	75 MΩ
A12.4.1 DRY TYPE Insulation resistance:		
HV side:	25 MΩ	100 MΩ
LV side:	2 MΩ	10 MΩ
A12.5 EQUIPMENT and COMPONENTS		
A12.5.1 FIXED INSTALLATIONS Insulation resistance :	1 kΩ/volt	5 kΩ/volt
A12.5.2 MOVABLE EQUIPMENT.		
A12.5.2.1 Hand Tools.		
Insulation resistance Class I:	2 MΩ	2 MΩ
Class II:	7 MΩ	7 MΩ
Class III:	2 MΩ	2 MΩ
A12.5.2.2 Distribution Equipment (cables, distribution boards, transformers)		
Insulation resistance :	1 MΩ	5 MΩ

APPENDIX 12 RECOMMENDED INSULATION VALUES FOR EQUIPMENT (cont'd)

NOTES:

1. These values are considered the lowest acceptable to allow energisation of existing equipment. Corrective action must be taken where lower values are found.

2. The above figures are to be used unless local regulations are more stringent in which case the latter shall prevail.

3. IR to be measured with load disconnected.

   Example: Required value for maintenance (MΩ) is kV rating/length in km.

4. Minimum insulation resistance values are given for 25 °C equipment temperature, apply corrections for differing temperatures.

5. For machines < 10MVA energisation is possible if IR or PI is above the minimum given.

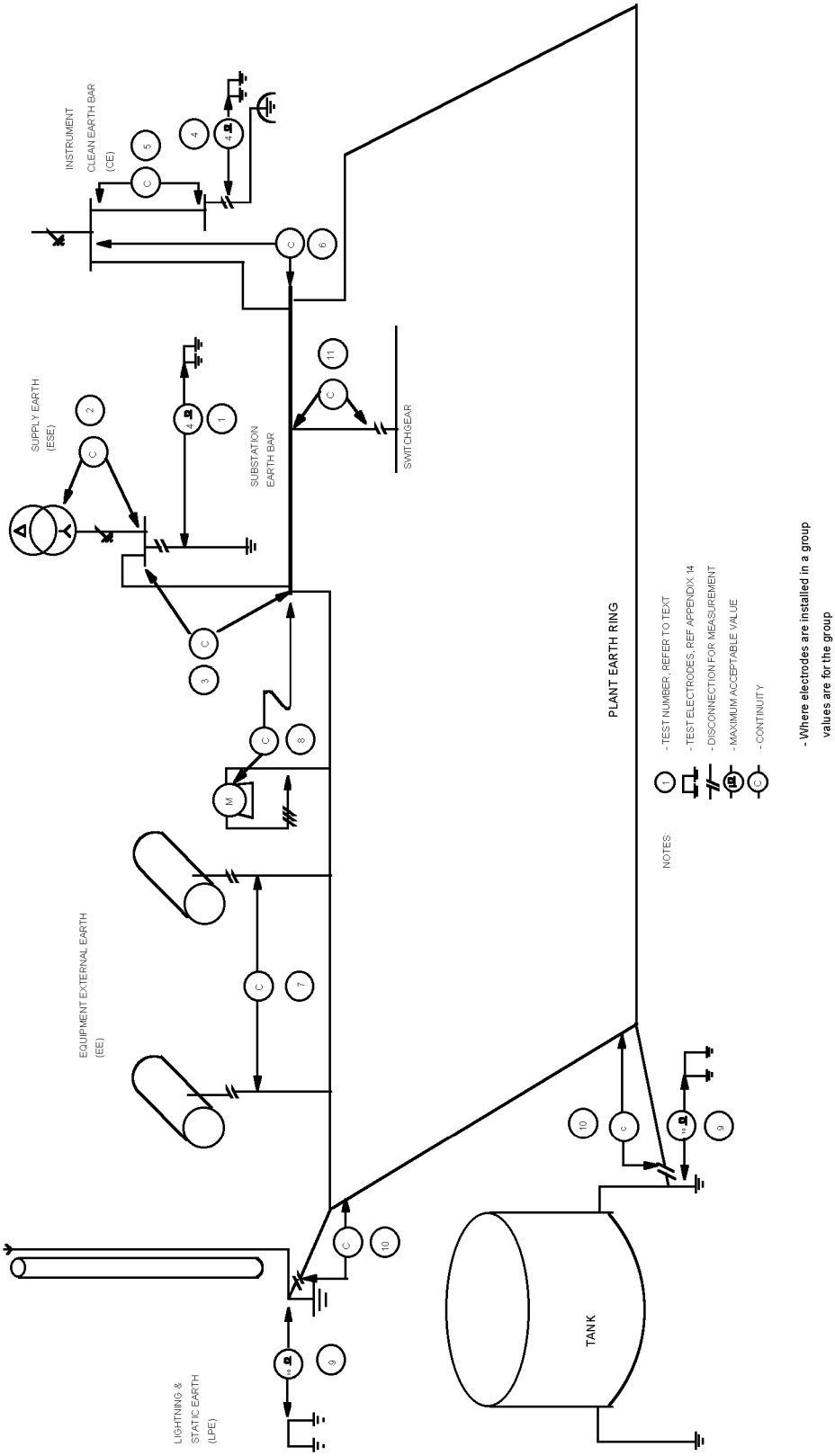
6. PI values below those given can be accepted if IR is > 100(kV+1) MΩ.

7. For insulation values during a machines lifetime see Appendices 7 and 8.

8. For test method and voltage see Appendix 11.

9. PI measurements on insulation class 'F' machines with IR in the GΩ range may be difficult to obtain due to meter scale compression.

APPENDIX 13 TEST METHOD EARTHING SYSTEM

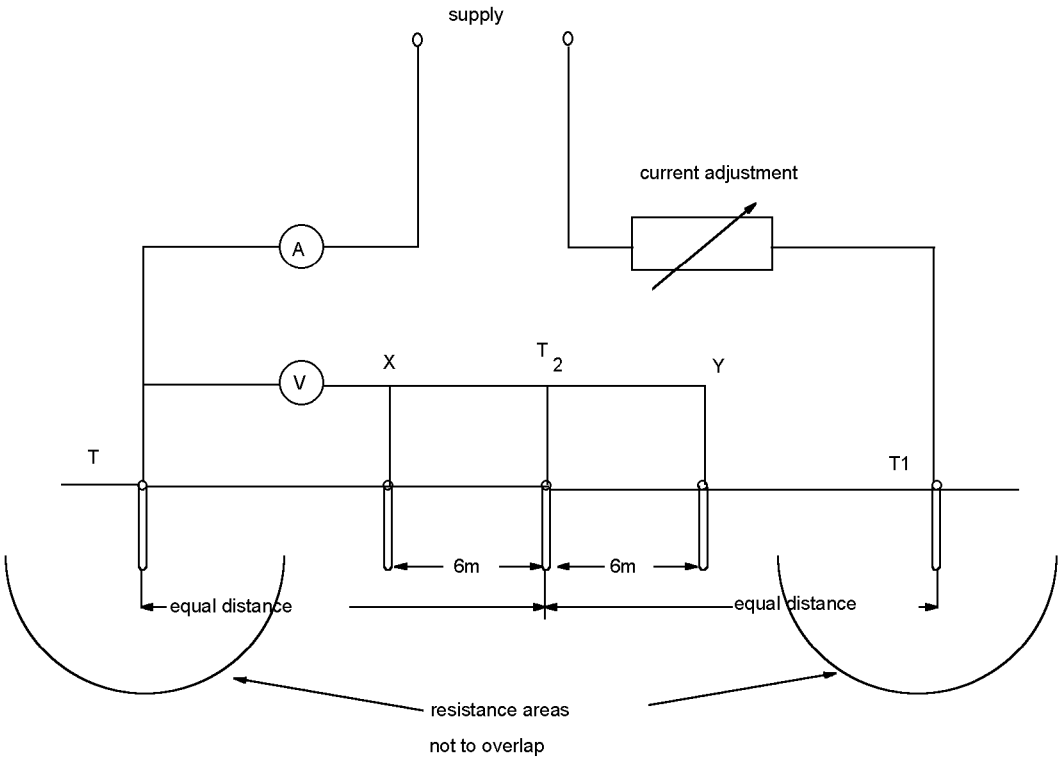


APPENDIX 14 EARTH ELECTRODE RESISTANCE

An alternating current of a steady value is passed between the earth electrode T and an auxiliary earth electrode T_1 placed at such a distance from T that the resistance areas of the two electrodes do not overlap. A second auxiliary earth electrode T_2, which may be a metal spike driven into the ground, is then inserted half-way between T and T_1 and the voltage drop between T and T_2 is measured. The resistance of the earth electrodes is then the voltage between T and T_2, divided by the current flowing between T and T_1, provided that there is no overlap of the resistance areas. To check that the resistance of the earth electrodes is a true value, two further readings are taken with the second auxiliary electrode T_2 moved 6 m further from and 6 m nearer to T respectively. If the three results are substantially in agreement, the mean of the three readings is taken as the resistance of the earth electrode T. If there is no such agreement the tests are repeated with the distance between T and T_1 increased.

The test is made either with current at power frequency, in which case the resistance of the voltmeter used must be high (of the order of 200 ohms per volt), or with alternating current from an earth tester comprising a hand-driven generator, a rectifier (where necessary), and a direct-reading ohmmeter.

If the tests are made at power frequency the source of the current used for the test is isolated from the mains supply (e.g. by a double-wound transformer), and in any event the earth electrode T under test is disconnected from all sources of supply other than that used for testing.



- Measurement of earth electrode resistance

T - earth electrode under test, disconnected from all other sources of supply.

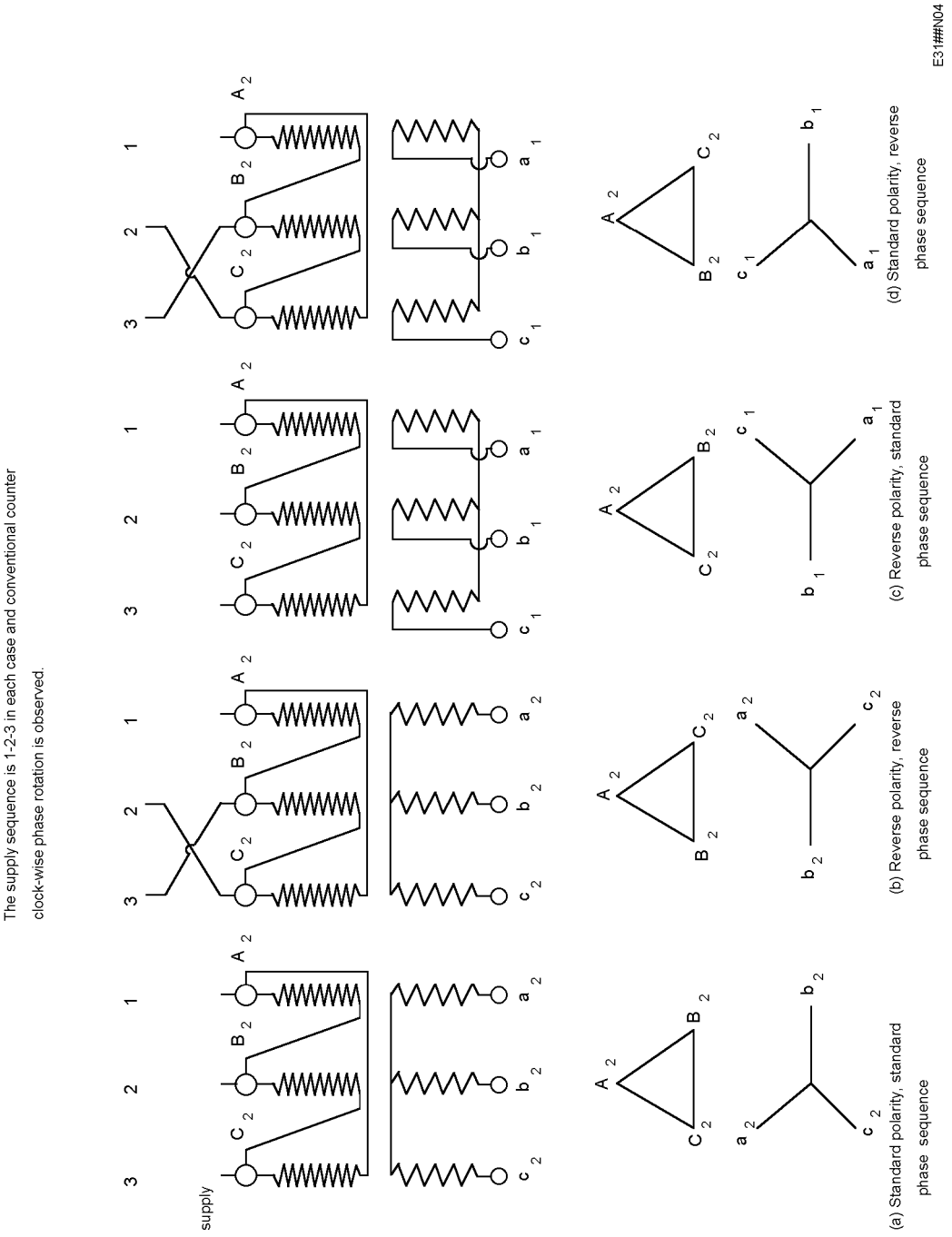
T_1 - auxiliary earth electrode.

T_2 - second auxiliary earth electrode.

X - alternative position of T_2 for check measurement.

Y - further alternative position of T_2 for check measurement.

APPENDIX 15 EXAMLES OF DELTA/STAR TRANSFORMER CONNECTION



APPENDIX 16 TRANSFORMER OIL

GENERAL

The oil in a transformer operating under normal load conditions adequately ventilated and free from moisture, will show little oil deterioration after years of service. If, due to overload or inadequate ventilating conditions, the oil temperature is high for prolonged periods, deterioration of the oil will be accelerated. Routine oil sampling and testing should be carried out so that it may be possible to determine whether the oil is suitable for further service.

OIL SAMPLING

Samples taken on-site are frequently contaminated owing to a lack of cleanliness.

It is important that the valve be first thoroughly cleaned externally and then wiped with a clean material reasonably free from fibre, followed by a similar material soaked in oil.

Finally the valve should be flushed by draining off a sufficient quantity of oil to ensure that the sample obtained is representative of the oil at the bottom of the tank.

Stoppered glass sampling bottles are recommended. They must be absolutely clean and dry and should be rinsed with the first sample drawn.

Tests should be carried out as soon as possible after drawing a sample.

INSPECTION OF SAMPLES

Cloudiness in the oil may be due to suspended moisture or solid matter such as iron oxide or sludge.

A very dark coloured oil may have suffered oxidation; however; the coloration may be due to its contamination for example with bituminous compound.

A green colour may indicate the presence of copper soaps, and it may be expected that rapid deterioration of the oil will occur.

A strong acid smell is indicative of the presence of volatile acids which can cause tank corrosion above oil level.

A smell of gas may indicate a low flash point due to an internal fault.

ELECTRIC STRENGTH

Tests shall be carried out using equipment with a gap of 2.5 mm between electrodes, each sample shall be tested 6 times to breakdown voltage level using equipment and methods in accordance with IEC 156 and 422.

The electric strength of the oil shall be the arithmetic mean of the 6 tests and shall not be lower than 30 kV.

TEST FOR MOISTURE

If the oil sample fails the Electric Strength test it may be due to moisture content, which can be simply tested by means of the 'crackle test', whereby a metal rod is heated to a dull redness and lowered into the oil sample and stirred. Audible crackling will occur during the stirring if moisture is present in unacceptable quantities.

ACIDITY

The first indication of acidic oil may be its pungent odour, and steps should then be taken to ascertain the acidity value

High levels of acidity can precipitate the formation of sludge and corrosion of metal surfaces above the oil level.

Suggested acidity limits are as follows :

1.	< 0.5 mg KOH/g	-	no action necessary if oil is satisfactory in other respects.
2.	≥ 0.5 < 1.0 mg KOH/g	-	increase testing frequency and filter oil.
3.	≥ 1.0 mg KOH/g	-	change oil; if condition is serious and is combined with heavy sludging then further treatment of the windings and core may necessary.

SLUDGING

Sludge formation is uncommon in transformers; however, should it occur in sufficient quantity, internal restriction of cooling may result in local overheating.

If severe sludging is present, then washing of the windings and core by means of a pressure jet of clean warm oil may be required.

APPENDIX 17 SAMPLE GENERAL EQUIPMENT RECORD CARD

LOCATION AND DUTY					
No	LOCATION	LOC No	DUTY	MEDIUM	DATE

REGISTRATION No

GENERAL INFORMATION			
Purchase order	No	Date	
Maker		Type	
Year of fabrication		Serial No	
Design book page	No	Size	
Fabrication report	No	MESC No	
		Mass	kg
		Date in operation	

INFORMATION COMPILED BY	DATE	CHECKED ON SITE BY	DATE
CHECKED BY	DATE	REFINERY	

APPENDIX 18 SAMPLE ELECTRIC MOTOR RECORD CARD

Variable working conditions at site				HV	LV	ELECTRIC MOTOR		REGISTRATION No
Method of starting	Starting current ampere	Max ambient temp °C	LOCATION	DRIVEN UNIT Type	Reg. No	TYPE OF MOTOR Remarks	Date	GENERAL INFORMATION
								Purchase order No
								Maker
								Date / Frame size
								Year of fabrication / Serial No
								MESC No / Mass kg
								Rated output kW
								Type of enclosure
								Date in operation
								Standards

ENGINEERING DATA		
Supply system	volts / phase	Hz
Shaft speed at full load		rpm
Stator winding connection	star / delta /	
Direction of rotation (seen from non-driving end)		cw / ccw / reversible
Rated line current at full load		ampere
No load line current		ampere
Power factor	full load	
	¾ load	
	½ load	
Efficiency at	full load	%
	¾ load	%
	½ load	%
Starting current as percentage of full load current		%
Starting torque as percentage of full load torque		%
Min. running/up torque as percentage of full load torque		%
Break/down torque as percentage of full load torque		%
Allowable number of starts in 4 min		
Starting time of uncoupled motor		s
Min. air gap		mm
Cooling medium		
Max. temp. rise		°C
Class of insulation		
Drain device	yes / no	
Space heater	yes / no	

BEARINGS	
DRIVING END	NON DRIVING END
Maker	Maker
Type: ball / roller / sleeve	Type: ball / roller / sleeve
Dimensions	Dimensions

TERMINAL BOX	
Location of terminal box (seen from non-driving end)	
Clock position	
Type of cable	core / mm²

LUBRICATION	DRAWING REFERENCE	
Type of lubricating system	General arrangement	No.
Type of bearing lubricant	Requisition	No.
	Data sheet	No.

DEVIATIONS FROM ABOVE MENTIONED ORIGINAL MOTOR DATA	GENERAL REMARKS

INFORMATION COMPILED BY	DATE	CHECKED ON SITE BY	DATE
CHECKED BY	DATE	REFINERY	