TECHNICAL SPECIFICATION

POWER TRANSFORMERS
(AMENDMENTS/SUPPLEMENTS TO IEC 76 AND IEC 726)

DEP 33.65.40.31-Gen.

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DESIGN AND ENGINEERING PRACTICE

USED BY

COMPANIES OF THE ROYAL DUTCH/SHELL GROUP

PREFACE

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Shell International Exploration and Production B.V. (SIEP)
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The Hague, The Netherlands,

and other Service Companies.

They are based on the experience acquired during their involvement with the design, construction, operation and maintenance of processing units and facilities, and they are supplemented with the experience of Group Operating companies. Where appropriate they are based on, or reference is made to, national and international standards and codes of practice.

The objective is to set the recommended standard for good design and engineering practice applied by Group companies operating an oil refinery, gas handling installation, chemical plant, oil and gas production facility, or any other such facility, and thereby to achieve maximum technical and economic benefit from standardization.

The information set forth in these publications is provided to users for their consideration and decision to implement. This is of particular importance where DEPs may not cover every requirement or diversity of condition at each locality. The system of DEPs is expected to be sufficiently flexible to allow individual operating companies to adapt the information set forth in DEPs to their own environment and requirements.

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NOTE: In addition to DEP publications there are Standard Specifications and Draft DEPs for Development (DDDs). DDDs generally introduce new procedures or techniques that will probably need updating as further experience develops during their use. The above requirements for distribution and use of DEPs are also applicable to Standard Specifications and DDDs. Standard Specifications and DDDs will gradually be replaced by DEPs.

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APPENDICES

PART I GENERAL

1. INTRODUCTION

1.1 SCOPE

This DEP gives the minimum technical requirements for power transformers for use in oil refineries, chemical plants, gas plants, exploration and production and supply/marketing.

Transformers shall comply with IEC 76 and/or IEC 726, as relevant and as amended by this specification.

This specification gives SIPM/SICM amendments/supplements to the following IEC publications.

IEC Publication 76-1 1976

IEC Publication 76-2 1976

IEC Publication 76-3 1980 1)

IEC Publication 76-3-1 1987

IEC Publication 76-4 1976

IEC Publication 76-5 1976 2)

IEC Publication 726 1982 3)

1) as amended by amendment No. 1 of 1981.
2) as amended by amendment No. 1 of 1979.
3) as amended by amendment No. 1 of 1986.

Part II of this specification covers oil-immersed power transformers.

Part III covers the additional requirements for dry-type transformers, which shall also comply with the relevant parts of Part II.

Part IV covers the requirements for Korndorfer Starting Transformers, and shall be read in conjunction with all relevant clauses elsewhere in this specification.

Part V covers the documentation requirements and references.

The corresponding requisition DEP 33.65.40.93-Gen has been extended to cover more project specific transformer requirements. The requisition shall be completed and returned by the Manufacturer as part of his quotation.

1.2 DISTRIBUTION, INTENDED USE AND REGULATORY CONSIDERATIONS

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

This DEP is intended for use in oil refineries, chemical plants, onshore and offshore oil and gas production facilities, loading terminals, tank farms and interconnecting piping between such 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 DEFINITIONS AND ABBREVIATIONS

For the purposes of this DEP, the following terms and abbreviations are defined.

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

The **Manufacturer/Supplier** 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, authorised to act for, and on behalf of, the Principal.

The word **shall** indicates a requirement.

The word **should** indicates a recommendation.

The **Requisition** is DEP form 33.65.40.93-Gen.

PART II REQUIREMENTS FOR OIL-IMMERSED POWER TRANSFORMERS

(AMENDMENTS/SUPPLEMENTS TO IEC 76-1)

2. SERVICE CONDITIONS

(supplement to IEC clause)

Transformers shall have a lifetime of at least 25 years, when delivering rated output under the service conditions specified and maintained according to the manufacturer's recommendation.

Transformers shall be suitable for continuous operation at full load for at least 30 000 hours without maintenance requiring the transformer to be de-energised.

The system supply voltage and frequency will not vary more than:

Voltage : plus or minus 10%

Frequency : plus or minus 5%

The Requisition identifies the maximum site ambient temperature, for either outdoor or indoor transformer installations. Unless otherwise specified in the Requisition, the maximum average daily temperature shall be 10 °C less than the maximum site ambient temperature, and the maximum average annual temperature shall be 20 °C less than the maximum site ambient temperature. The relative humidity shall be taken to be 90% maximum.

The atmosphere shall be regarded as dusty, sulphurous, saliferous and corrosive, as commonly encountered in petrochemical installations in close proximity to the sea.

4. RATING

(supplement to IEC clause)

The Requisition identifies the duty of the transformer, e.g. generator transformer.

All "general service" transformers may be used to feed groups of motors and shall be capable of withstanding infrequent restarting loads of up to 1.8 times the transformer rated current. Five such restarts may take place in succession at 5 second intervals.

Motor unit transformers (i.e. transformers supplying individual motors) and Korndorfer starting transformers shall be capable of withstanding three successive motor starts and a further two successive starts after a half-hour cooling-off period. Motor data are stated on the Requisition.

The transformer shall be capable of delivering rated current at applied voltages up to 105% of rated voltage continuously.

NOTE: Preferred ratings are given in Appendix 1.

5. RATING PLATE

(supplement to IEC clause)

Rating plates shall be of stainless steel or other corrosion resistant metal. They shall be permanently fixed to a readily accessible and non-removable part of the transformer.

5.1 INFORMATION TO BE GIVEN IN ALL CASES

(supplement to IEC clause)

The Customer purchase order number shall be stated on the rating plate.

5.2 INFORMATION TO BE GIVEN IN CERTAIN CASES (supplement to IEC clause)

The CT ratios shall be stated on the rating plate.

6. MISCELLANEOUS REQUIREMENTS

6.1 DIMENSIONS OF NEUTRAL CONNECTION

(supplement to IEC clause)

The LV neutral conductor and terminal of polyphase general service transformers shall be located next to the phase terminals and be dimensioned to carry not less than 50% of the load of the phase conductors and terminals.

6.3 LIGHTNING IMPULSE WITHSTAND VOLTAGE

(new clause)

The rated withstand voltages shall comply with IEC 76-3, Table II. "List 2" - rated lightning impulse withstand voltage levels - shall apply.

6.4 CONSTRUCTIONAL REQUIREMENTS

(all sub-clauses under 6.4 are new clauses)

6.4.1 General

Tanks shall be constructed of steel.

Oil-immersed transformers rated 1600 kVA and below shall be hermetically sealed. Transformers rated above 1600 kVA and up to and including 3150 kVA, may be either hermetically sealed or of the conservator type.

Oil-immersed transformers above 3150 kVA shall have a conservator. Transformers with conservators shall be fitted with Buchholz relays, having both alarm and trip contacts.

If recommended by the manufacturer, pressure relief devices (e.g. Qualitrol) shall be fitted to transformers above 1600 kVA. They shall be fitted on the tank cover.

6.4.2 Windings and tappings

Windings shall be uniformly insulated. Transformer windings should be either copper or aluminium. However, the design and construction of transformers having aluminium windings shall be subject to Principal's approval.

Full-power tappings shall be provided in the high voltage windings.

Winding connections inside transformers shall be brazed or crimped.

The winding arrangement shall be Dyn11, unless otherwise stated in the Requisition.

6.4.3 Core Construction

For three-phase transformers, in-line, three-limb cores shall be used.

6.4.4 Core Earthing

All metal parts of the core, frame and tank etc., shall be maintained at earth potential.

The magnetic circuit of conservator type transformers exceeding 10 MVA shall be bonded to the clamping structure through one removable core-insulation-test link or strap only. It shall be placed in an accessible position beneath an inspection opening in the main tank cover. With the bond removed, the magnetic circuit shall be insulated from the clamping and supporting structure and all structural parts.

6.4.5 Cooling

Unless otherwise specified on the Requisition, the transformers

a) shall be naturally air cooled (ONAN),

b) if rated over 10 MVA shall be naturally air cooled (ONAN), but designed and equipped so that fans can be fitted at a later date to allow a minimum increase in rating of 25% (ONAF). The manufacturer shall submit calculations to substantiate temperature rises for both the ONAN and ONAF ratings. All components shall be rated to meet this requirement.

Where forced air cooling is specified, the manufacturer shall provide the associated control cubicle mounted on the transformer. The auxiliary power supply shall be as specified in the Requisition.

Oil-immersed transformers shall be cooled by means of bolted, flange-mounted radiators. Welded or other non-detachable cooling tubes shall not be used. For sealed transformers, corrugated tank walls are acceptable.

Oil-immersed transformers shall be filled with the oil specified on the Requisition. Where environmental and/or fire protection requirements prohibit the use of mineral oil, a synthetic substitute may be used. The manufacturer shall stipulate in his quotation the characteristics of the liquid proposed. The liquid shall not contain, nor be contaminated with, polychlorinated biphenyls (PCBs).

6.4.6 Temperature measurement

A tubular pocket shall be welded into the tank cover plate to accommodate either a thermometer or a thermocouple probe. The pocket shall be 120-150 mm deep with an inside diameter of approximately 20 mm and be capable of being closed with a screwed sealing cap. The pocket shall be oil-filled to provide proper heat transmission. The location shall be such that "top oil/liquid" temperature can be measured even when the transformer is in a "cold" condition.

If specified on the Requisition, transformers rated over 3150 kVA shall be provided with a hot oil temperature indicator. The indicator shall be a dial-type calibrated in degrees Centigrade and fitted with two adjustable setting contacts, for remote alarm and trip purposes, and a hand-reset pointer to register the highest temperature attained. The location shall be such that "top oil/liquid" temperature can be measured even when the transformer is in a "cold" condition.

6.4.7 Cable connecting boxes

6.4.7.1 General

Cable connecting boxes shall be made of steel and shall be dimensioned to allow termination of the cables specified on the Requisition.

The enclosures shall offer a minimum degree of protection IP54, in accordance with IEC 529.

Separate cable connecting boxes shall be provided for the connection of the specified cables to:

a) the high-voltage side of the transformer

b) the low-voltage side of the transformer

c) the transformer auxiliary circuits (direct measuring alarm/trip devices, CT secondaries, etc.)

d) the forced cooling installation, if applied

e) the on-load tap changer, if applied

NOTE: Items (c) and (d) may be combined.

Auxiliary cable boxes shall be mounted on the side of the transformer in an accessible position.

Cable connecting boxes shall be air-insulated. They shall be designed to prevent deterioration or failure due to the accumulation of condensation.

The covers of all cable boxes shall be secured, using non-loosening bolts or screws.

The cover of all cable boxes shall not be removable without the use of tools.

On transformers for outdoor use water shedding metal sun/rain canopies with an overhang of at least 50 mm on all sides shall be fitted over all cable connecting boxes. An air space of at least 50 mm above the top cover shall be provided for ventilation.

6.4.7.2 Main cable connecting boxes

The design of the main cable connecting boxes shall meet the following requirements:

a) The dimensions of H.V boxes shall not be less than those stated in Appendix 2.

b) Connection boxes for multicore cables shall be of a type which minimises the cable bending requirements (e.g. split type box).

c) They shall allow single-core conductors to be connected straight on to the terminating point without the need to bend the conductors. Gland plates shall be constructed from a non-magnetic material.

d) When top mounted cable connecting boxes are provided and/or when two or more parallel conductors are to be connected, straight conductors, e.g. copper bars or flags of adequate dimensions, shall be provided and adequately supported, so that each cable conductor can be separately terminated.

e) All connections shall be sized to carry the maximum continuous current, (including overloads, where relevant), and also the prospective through-fault currents. Test certificates or calculations shall be available for all main cable connecting boxes to confirm short circuit withstand capability.

f) Removable cover access plates shall be provided with handles or, when having a mass of 25 kg or more, shall be provided with lifting lugs.

6.4.8 Cable terminations

6.4.8.1 Main cable terminations

Cable types and sizes shall be as indicated on the Requisition.

Single core phase and neutral cable terminations shall be provided with brass or bronze compression type cable glands, mounted on a non-magnetic gland plate.

For earthing the neutral point of star-connected transformers, an additional compression-type cable gland shall be installed for an insulated single-core cable.

6.4.8.2 Auxiliary cable termination

Undrilled gland plates shall be provided at the bottom of the cable box(es) for all external cables. These gland plates shall be separate from those used for the cabling interconnecting the on-skid auxiliary equipment.

6.4.9 Cable screen and armour earthing

Facilities shall be provided for the earthing of each cable protective screen and/or armour inside each cable connecting box, including those for secondary or auxiliary circuits.

Earthing bolts, nuts and washers shall be provided in each box.

For earthing the screens and/or armour of single-core cables a copper earthing bar shall be provided complete with an earthing bolt, nuts and washers for each cable.

6.4.10 Terminals

6.4.10.1 Main terminals

Terminals (and lugs where appropriate) shall be suitable for the cable conductors, specified on the Requisition.
For LV single core cable terminations clamping methods shall be used in order to avoid cable alignment problems associated with lugs.

All terminals shall be clearly and indelibly marked to identify the phase connections in accordance with the connection diagram on the rating plate.

6.4.10.2 Auxiliary terminals

Individual terminals shall be provided for each external cable core.

Terminals shall be of the non-loosening wedge type, obviating the need for cable lugs, and constructed in such a way that direct contact between screw, bolt or nut and conductor is avoided.

The terminals shall be logically arranged, circuit by circuit, with adequate barrier shields and spacers in between them.

Terminals shall be clearly and indelibly marked in accordance with the transformer auxiliary wiring diagrams.

6.4.11 Cable supports and clamps

Suitable cable supports and clamps for the main cables shall be provided to within 500 mm of the bottom of the cable boxes. The mounting of the cables shall not obstruct the transformer cooling system.

The spacing between supports/clamps for the main cables shall not exceed 500 mm.

6.4.12 Bushing insulators

The internal winding ends shall always remain under the oil/liquid level.

6.4.13 Surge arrestors

If specified in the Requisition, transformers shall be equipped with suitable surge arrestors, complying with IEC 99-1. This equipment shall be mounted on the transformer.

6.4.14 Auxiliary wiring

Conductors shall be stranded copper and shall have a cross-section of at least 1.5 mm^2.

All auxiliary wiring and cabling shall be ferruled in accordance with the manufacturers wiring diagram.

All external auxiliary cabling shall either be wire braided or wire armoured.

6.4.15 Frame earthing

Transformers shall be provided with two earth terminals on the outside of the transformer mainframe or tank wall, for connection to an external earthing grid. Each earth connection shall consist of a brass or stainless steel M 10 bolt with nuts and washers. They shall be located on opposite sides of the transformer, preferably near the main cable boxes.

All metallic components, such as cable boxes and their internal earthing bars or studs, shall be bonded to the transformer mainframe or tank.

6.4.16 Electric motors

Motors shall have a minimum degree of protection of IP54, as per IEC 529 and shall have winding insulation class F. Maintenance intervals shall meet the requirements of section (II-2).

6.4.17 Current transformers

When current transformers are included with the transformer, they shall be in accordance with IEC 185, and comply with the requirements as specified on the Requisition.

All secondary terminals of current transformers shall be wired to a terminal block in the transformer auxiliary cable connecting box. The terminals shall be provided with short-circuiting links. one side of the secondary winding of each current transformer circuit shall be earthed at this terminal block.

The current transformer for the neutral-earth connection of low voltage transformer windings shall be of the bar primary type and be located in the main terminal box.

The current ratings shall be as specified on the Requisition. The current transformer shall have a minimum rating of 10 VA and an accuracy class 5P10.

6.4.18 Off-circuit tap changer

Except where an on-load tap changer is specified on the Requisition, a manually operated off-circuit tap changer shall be provided. It shall meet the following requirements:

a) The tapping range shall be $\pm$ 5% in $2^1/_2$% steps.

b) The tapping switch shall be positively located in each tap position and shall be lockable only in those positions.
The operating handle shall be provided with padlock facilities to lock the tap changer in each position.

c) Mechanical end stops shall be provided.

d) The operating handle shall be metal and sized to allow operation without the need for tools. It shall be located in a directly accessible position (i.e. not requiring the removal of any covers).

e) Tap positions shall be clearly marked in line with the data given on the rating plate.

g) One handle shall operate all phases simultaneously.

6.4.19 On-load tap changing equipment

6.4.19.1 On-load tap changer

The on-load tap changer and its motor drive mechanism shall comply with the requirements of IEC 214 and IEC 542, and the details on the Requisition.

The tap changer shall be a polyphase unit with a single drive mechanism.

The insulation level and short circuit rating shall not be less than that of the winding to which the tap changer is connected.

The diverter switch oil compartment shall be connected to a separate conservator or segregated section of the main conservator of the transformer and shall be provided with the following facilities:

a) Suitable Buchholz relay.

b) Oil sampling connection at bottom of compartment.

c) One filling/filter connection valve and one drain/filter connection valve.

d) A dehydrating breather.

The motor drive mechanism shall be supplied complete with the following features:

a) Padlockable incoming supply switch.

b) Local control facilities.

c) Manual operation facilities.

d) Direction of rotation protection.

e) Remote control facilities including a local/remote selector switch, remote tap position transmitter and "Tap change in progress" indication, whether or not remote control facilities are provided initially.

f) Individual fault indications with two sets of common voltage-free changeover contacts.

g) Terminals for all related cables.

6.4.19.2 Remote control panel

When specified on the Requisition, a remote control panel shall be supplied by the manufacturer for each tap changer, for installation in a nearby control room or substation.

The remote control panel shall comply with the requirements of IEC 439 and the door shall be lockable. The degree of protection shall be IP 41, and IP 2X with its door(s) open.

The master/follower method of controlling two or more transformers operating in parallel shall be applied.

The following control features shall be supplied:

a) Automatic, solid state voltage regulator relay with adjustable setpoint, selectable time characteristics and undervoltage and overcurrent blocking.

b) Manual control facilities.

c) Tap position indicator.

d) "Tap change in progress" indicating lamp (white).

e) "Tap changer fault" indicating lamp (red).

f) Anti-condensation heater.

The control panel shall be prepared, painted and finished in accordance with the manufacturer's standard for indoor installations. The manufacturer shall submit details of the proposed surface protection with the quotation.

6.4.20 Mounting and handling facilities

The transformers shall be skid-mounted.

The transformer skids shall have rounded off beam ends and be provided with pulling lugs/holes to enable site movements.

Transformers, and associated cooling equipment, when transported separately, shall each be provided with adequate lifting lugs to facilitate transport to, and assembly at, site. If lifting lugs are fitted on the tank walls, additional lugs on the tank covers shall be provided for lifting the cover, if this is removable.

Transformers with an assembled mass of more than 2000 kg shall be provided with jacking pads.

6.4.21 Noise

6.4.21.1 Measuring method

Measurement of noise levels of transformers and associated equipment shall comply with IEC 551.

6.4.21.2 Noise limits

The maximum sound pressure level (SPL) developed by the transformer with ONAN cooling at a distance of 0.3 m shall not exceed the value given by the following equation:

$SPL = 46 + 5 \log_{10} P \quad dB(A)$

where P is stated in kVA.

Compliance with the noise limits shall be achieved by methods other than the provision of sound attenuation enclosures.

The manufacturer shall submit with his quotation the maximum sound pressure level of a transformer with forced cooling in operation.

The manufacturer shall state the guaranteed maximum sound pressure level with zero positive tolerance.

6.4.22 Surface preparation, galvanising and finishing

Transformers shall have a surface finish which complies with the manufacturers standard for enhanced protection against corrosion in outdoor climates. The paint system applied shall provide adequate protection against the adverse effects of the climate specified in (II-2).

The finish of internal walls of tank, covers, connecting boxes and cooling systems shall effectively protect against the effects of corrosion and the influence of the oil or synthetic liquid used in the transformer.

External surface preparations, prior to the overall paint finish, shall comprise at least the following:

a) Radiators and corrugated tanks shall be hot-dip galvanised

b) Tanks and other parts shall be hot-dip galvanised, or zinc sprayed if too large for the hot-dip process. The surface preparation of tank walls shall include grit blasting to surface preparation SA 2.5-3 in accordance with ISO 8503.

c) Welded areas, such as the tank cover rims of hermetically sealed transformers, shall be painted with zinc-rich paint.

The manufacturer shall provide, with the quotation, details of all surface treatments, galvanising, base, intermediate and final painting systems, including the minimum thickness of each application, and an assurance of suitability to meet the specified requirements.

The external paint finish colour shall be light grey.

6.4.23 Special tools

Special tools required for erection, commissioning and maintenance shall form part of the order and be shipped together with the transformer.

6.4.24 Packaging for transport

Transformers and their accessories shall be clearly marked to facilitate assembly and erection at site.

Items supplied loose required for erection at site shall be packed together with the transformer.

For packaging for transport, reference is made to Conditions of Purchase - General No. MA 01, and Supplement No. MA 06.

The Principal will identify any particularly onerous transport and/or site storage conditions. The onus shall rest with the manufacturer to suitably package the transformers to avoid damage. Consideration shall be given to the provision of vibration pads where appropriate.

6.5 ADDITIONAL REQUIREMENTS FOR SEALED TRANSFORMERS

The tank cover shall be welded to the tank with a continuous weld. Filling and drain orifices shall also be sealed and rendered tamper-proof.

The use of bolted covers shall be subject to approval by the Principal.

The tank, cover and cooling system assembly shall have the mechanical strength to withstand without permanent distortion, the internal pressures caused by the contraction or expansion of the oil/liquid and gas/air volumes under the specified service conditions (II-2).

6.6 ADDITIONAL REQUIREMENTS FOR CONSERVATOR-TYPE TRANSFORMERS

The capacity of the oil conservator tank shall be such that it will amply cover the expansion of the oil volume of the transformer under the extremes of ambient temperatures and for all operating conditions specified. It shall be equipped with a sealed oil level indicator gauge.

At its lowest part the oil conservator shall have provision to collect and remove water and sludge.

A breather shall be provided with a silica gel dehydrating capsule and an air lock.

If specified in the Requisition, a split conservator tank, utilising a method of avoiding air/oil contact and moisture contamination of the oil, shall be provided.

The radiators shall be provided with isolating valves fitted at the oil inlet(s) and outlet(s) and with an oil filling plug and oil drain valve. This valve shall be provided with cap and padlock facilities or alternatively designed to require the use of special tools to operate.

Each transformer shall be fitted with one filling/filter connection valve near the top of the tank and one drain/filter valve near the bottom of the tank. The filling and drain valves shall be fitted with sealing caps and padlock facilities, or alternatively designed to require the use of special tools to operate.

A Buchholz relay shall be provided, complete with an air relief valve, flanges and valves to enable its removal without the need to drain the oil.
A cable connection shall be installed between the relay and a terminal box, located on the lower part of the tank wall, for the alarm/trip functions.

8. TESTS

8.1 GENERAL REQUIREMENTS FOR TYPE, ROUTINE AND SPECIAL TESTS

(supplement to IEC clause)

Before leaving the manufacturer's works, each transformer shall be inspected and tested. All transformers shall be subjected to the "routine tests" as modified by this specification. All on-load tapchangers shall be subjected to the "routine tests" as specified in IEC 214.

The test results shall be recorded in a test report.

Whether the Principal or his nominee will inspect the transformer(s) and witness the required tests shall be indicated on the Requisition or order and confirmed or waived at the time the equipment is offered for final inspection. Notification of final inspection shall reach the Principal at least two working weeks before the inspection is to take place.

Generally the requirements for type and special tests will be waived if corresponding certification is made available for equipment of identical design and rating. Inability to meet this requirement shall be made known to the Principal in writing at the quotation stage. It shall rest with the manufacturer to demonstrate to the Principal that the equipment offered is identical, or directly equivalent.

The requisition shall specify the requirements for the special tests.

In any instances where satisfactory type and special test certification cannot be made available to the Principal, then the manufacturer shall quote separate prices for the execution of all such tests on one of a series of each type and rating of transformer.

If a transformer forms part of a motor unit transformer system, then the performance test requirements detailed in DEP 33.66.05.31-Gen shall apply.

The type, special and routine tests are summarised in Appendix 4 - Additional tests for dry-type transformers are given in (III-5), and for Korndorfer starting transformers in (IV-5).

8.10 INSPECTION AND TESTS

(new clause)

Inspection and tests shall be carried out on the completely assembled transformer(s).

Checks shall be made to verify:

- the correct type and make of the insulation/cooling liquid.
- the oil-tightness of the tank, conservator, cooling system, interconnecting piping, flanges, valves and fittings.
- the arrangements for oil sampling, cleaning and filtering.
- the transportability, skid, lifting, pulling lugs, jacking pads, temporary seals, etc.
- the suitability of cable connecting boxes and support clamps for type of cable(s) specified.
- the sun/rain canopies of cable connecting boxes.
- the layout of the auxiliary cable boxes and the external cabling system on the transformer interconnecting operating and measuring devices to the connecting box.
- the off-load tap changer.
- the on-load tap changer equipment and its remote control panel, if specified.
- the earth connections.
- the completeness of the nameplates.
- the proper terminal markings.
- the finish of the transformer and its components.

- the adequacy of results of the "routine tests".
- the adequacy of results of the "type tests".
- the adequacy of results of the "special tests".

The manufacturer shall compile the complete records of the above inspection and tests in one inspection document.

9. TRANSFORMER LOSSES AND TOLERANCES

9.1 LOSSES

(new clause)

If specified on the Requisition, the Manufacturer shall submit with the quotation the calculation of the Net Present Value (NPV) of the losses of the transformer offered.

The manufacturer shall in this case guarantee the values of the no-load and load losses with tolerances as stated in (II-9.2).

The manufacturer shall carry out the calculations, using the formula given below, and using the factors and cost data stated in the requisition:

$NPV = (P_o + a^2.P_k) \times 8760 \times b \times c$

where:
- P_o = no-load loss (kW)
- P_k = load loss (kW)
- a = loading factor (% of transformer rating/100)
- b = energy unit cost (cost/kWh)
- c = capitalisation factor from annuity table in Appendix 3

The manufacturer shall provide details of the no-load and load losses, together with alternative values for alternative designs, where appropriate. Any forced cooling system electrical load consumption shall be declared separately.

9.2 TOLERANCES

(new clause)

The tolerances of the losses on which the calculation of the NPV as stated in (II-9.1) is based, shall be reduced from those normally allowed by IEC 76-1, Table III, as follows:

total loss	:	+ 5% instead of 10%
component loss	:	+10% instead of 15%

These more demanding tolerances shall be guaranteed.

PART III ADDITIONAL REQUIREMENTS FOR DRY-TYPE TRANSFORMERS

(AMENDMENTS/SUPPLEMENTS TO IEC 726)

1. GENERAL

1.1 SCOPE

(supplement to IEC clause)

The transformers shall have cast resin encapsulated windings.

Transformers shall also fully comply with all other relevant Sections of this DEP specification.

1.2 SERVICE CONDITIONS

(supplement to IEC clause)

The transformers will be installed indoors. All other requirements stated in (II-2) apply.

1.4 TAPPINGS

(supplement to IEC clause)

Tap changing should be effected by the use of bolted links.

1.101 CORE CONSTRUCTION

(new clause)

The core laminations shall be specially treated to avoid moisture ingress and consequent core corrosion.

2. RATING

2.7.1 General

(supplement to IEC clause)

The statements on rating in (II-4) shall apply.

IEC 905 shall apply, also to transformer accessories.

2.8 RATING PLATES

(supplement to IEC clause)

The statements on rating plates in (II-5.1 & 5.2) shall apply.

3. COOLING METHODS AND TEMPERATURE-RISE

3.10.1 Normal temperature-rise limits

(supplement to IEC clause)

Insulating materials in the range Class B to H inclusive may be used in accordance with the temperature rises stated in IEC.76-2, Table III.

3.101 TEMPERATURE MEASUREMENT

(new clause)

The temperature of each winding shall be determined by one set of measurements per phase by means of thermistors or Pt 100 resistance type temperature detectors. These measuring elements shall be interchangeable. The leads shall be brought out to a terminal box located on the outside of the transformer enclosure.

The thermistors shall be of the positive temperature coefficient (PTC) type.

The thermistors or resistance elements shall be supplied complete with the auxiliary equipment necessary to initiate remote alarms/trips via voltage-free changeover contacts.

The thermistors or resistance elements shall be designed and located in such a manner as to avoid the transfer of over-voltages to auxiliary or external connections.

4. INSULATION LEVELS

4.11.1 General

(supplement to IEC clause)

The insulation levels shall comply with Table V of IEC 726. "List 1" -rated lightning impulse withstand voltage levels- shall apply.

5. TESTS

5.20 PARTIAL DISCHARGE MEASUREMENTS

(supplement to IEC clause)

Partial discharge test shall be included as a routine test.

5.20.5 Partial discharge acceptance levels

(supplement to IEC clause)

The partial discharge measured shall not exceed 20 pC.

6. ENCLOSURES

6.25 DEGREES OF PROTECTION PROVIDED BY ENCLOSURES

(supplement to IEC clause)

With the cables connected, all connections and live parts shall be insulated.

Requirements for separate enclosures shall be as stated on the Requisition. This enclosure shall have a degree of protection of at least IP21

7. NOISE LIMITS

(new clause)

The maximum sound pressure level (SPL) at a distance of 0.3m shall not exceed the value given by the following equation:

$SPL = 45 + 8 \log_{10} P \quad dB(A)$

where P is stated in kVA.

PART IV ADDITIONAL REQUIREMENTS FOR KORNDORFER STARTING TRANSFORMERS

1. SCOPE

This part of the specification covers the additional requirements for motor starting auto-transformers for use with Korndorfer closed transition motor starters.
The auto-transformers shall be either oil-immersed transformers complying with Part II or dry-type transformers complying with Part III of this specification, but modified as indicated in this Part IV.

The auto-transformers shall be suitable for use in conjunction with the type(s) of motor and switching device specified on the Requisition.

2. DEFINITIONS

2.1 CHARACTERISTICS

2.1.1 Auto-transformer mode

The mode of connection whereby the neutral end of the auto-transformer is connected in star and the motor is connected to the tapping point.

2.1.2 Reactor mode

The mode of connection whereby the neutral end of the auto-transformer is open circuit and the winding section between the 100% terminal and the tapping point is employed as a reactor in series with the motor.

3. RATINGS

The manufacturer shall define a short-time rating in auto-transformer mode, which shall be used as the base for characteristics and as a reference for tests.

The motor full load current and the motor full voltage starting current shall be subject to the normal tolerances specified in IEC 34.

Tappings other than the principal tapping shall be provided to take account of the preliminary nature of the design data.

4. DESIGN AND CONSTRUCTION

4.1 DESIGN COORDINATION

The overall design parameters of the transformer, in particular the percentage tapping and the impedance voltage, shall be coordinated with the motor manufacturer and the Principal, as required to provide a satisfactory starting system.

4.2 REACTOR VOLTAGE DROP

The transition from the auto-transformer mode to the reactor mode shall not produce a rate of change of flux in the auto-transformer core which is capable of generating peak transient voltages, either across the windings, between phases or with respect to earth, which exceeds the value stated in (IV-4.3). Surge suppressors shall be fitted where required.

4.3 INSULATION

In addition to being able to withstand the electrical stress produced by self-generated transient voltages, the auto-transformers shall be capable of withstanding the transient voltages associated with periodic disturbances on the power system, infrequent fuse operation and repeated contactor operation. In the latter two cases, the peak transient voltage shall not exceed 3 times the rated insulation voltage.

4.4 MECHANICAL STRENGTH OF WINDINGS

The winding sections shall be ampere-turn balanced to minimise the axial electromagnetic forces.

The manufacturer shall state in his quotation the dynamic and thermal withstand capability during normal motor starting condition and under symmetrical three-phase short circuit condition.

5. TESTS

5.1 TYPE TESTS

5.1.1 Temperature Rise Test

With the transformer connected in auto-transformer mode on principal tap, a load equal to the motor starting load shall be applied to the tapping. Rated voltage shall be applied to the line terminals for a period equal to three times the motor starting period, followed by a de-energised period of 30 minutes and finally rated voltage shall be re-applied for a period equal to twice the motor starting period.

The peak winding temperature shall be determined after the first and second applications of voltage, in accordance with IEC 76-2 Clause 3.

The maximum temperature reached during the above test may exceed the limits stated in IEC 85 by not more than 20 °C.

5.2 ROUTINE TESTS

5.2.1 Impedance Voltage and Reactance Test

The impedance voltage shall be measured on each tapping, using a current in the range of 100% - 300% of motor full load current.

The reactance of the series winding in reactor mode shall be measured on each tapping, using a current in the range of 100-300% of motor full load current. The neutral terminals shall be left open circuit.

PART V DOCUMENT REQUIREMENTS AND REFERENCES

1. DOCUMENTS

1.1 GENERAL

All documents shall show the relevant order number, item and manufacturer's references, and be distributed as specified in DEP 40.10.01.93-Gen., which forms part of order documents.

The language used shall be as specified in the Requisition.

1.2 MANUFACTURER'S DRAWINGS AND DOCUMENTS

The following drawings/documents shall be submitted as a minimum, in the quantities and at the times stated in DEP 40.10.01.93-Gen.:

- General Arrangement showing masses, main dimensions, arrangement of auxiliary components and the minimum clearances required for ventilation and safety during operation and maintenance.
- Drawings of nameplate and all termination arrangements.
- Foundation plan, including foundation loading.
- Schematic and connection diagrams covering all equipment pertaining to the transformer.
- Type and special test certificates.
- Instrument Schedule.
- Schedule of recommended spare parts.
- Technical Manual giving installation, operation and maintenance instructions.

1.3 TEST REPORTS

Test reports, giving the results of all tests carried out on the transformers and its auxiliaries, shall be provided by the manufacturer.

2. 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 DEPs and Standard Specifications	DEP 00.00.05.05-Gen.
Requisition for power transformers	DEP 33.65.40.93-Gen.
Electric motors, cage-induction and synchronous type	DEP 33.66.05.31-Gen.
Requisition for engineering documents	DEP 40.10.01.93-Gen
Conditions of Purchase (SIPM Materials Function)	General No. MA 01, and Supplement No. MA 06

INTERNATIONAL STANDARDS

IEC standard voltages	IEC 38
Insulation co-ordination	IEC 71
Power transformers	
Part 1 - General	IEC 76-1 (1976)
Part 2 - Temperature rise	IEC 76-2 (1976)
Part 3 - Insulation levels and dielectric tests	IEC 76-3 (1980 +AMD 1, 1981)
Part 3-1 - External clearances in air	IEC 76-3-1 (1987)
Part 4 - Tappings and connections	IEC 76-4 (1976)
Part 5 - Ability to withstand short circuit	IEC 76-5 (1976 +AMD 1, 1979)
Thermal evaluation and classification of electrical insulation	IEC 85
Lightning arresters Part 1 : Non-linear resistor type arresters for a.c. systems	IEC 99-1
Current transformers	IEC 185
On-load tap-changers	IEC 214
Standard frequencies for centralised network control installations	IEC 242
Partial discharge measurements	IEC 270
Low voltage switchgear and controlgear assemblies	IEC 439
Degrees of protection provided by enclosures (IP Code)	IEC 529
Application guide for on-load tap-changers	IEC 542

Determination of transformer and reactor sound levels	IEC 551
Dry-type power transformers	IEC 726
Loading guide for dry-type power transformers	IEC 905

Issued by:
Central Office of the IEC (Sales Dept.)
3, Rue de Varembe,
1211 Geneva 20,
Switzerland.
(also obtainable through National Standardisation Institutes)

Preparation of steel substrates before application of paints and related products: surface roughness characteristics of blast-cleaned steel substrates	ISO 8503

Issued by:
Central Secretariat of the ISO,
1, Rue de Varembe,
1121 Geneva 20,
Switzerland.
(also obtainable through National Standardisation Institutes)

APPENDIX 1 PREFERRED RATINGS, IMPEDANCES AND VOLTAGES

1. PREFERRED RATINGS

Values of rated power should be selected from the following series and their decimal multiples:

100, 125, 160, 200, 250, 315, 400, 500, 630, 800, 1000

2. IMPEDANCE VOLTAGE

Unless there is an overriding design requirement, the percentage impedance voltage based on rated power shall be selected from the following values:

Rated Power (kVA)	Impedance Voltage (%)
Up to - 630	4.00
631 - 1250	5.00
1251 - 3150	6.25
3151 - 6300	7.15
6301 - 12500	8.35
12501 - 25000	10.00

Impedance voltages for transformers rated above 25000 kVA shall be specified in the requisition, depending on the system design criteria.

3. CORRELATION BETWEEN TRANSFORMER AND SYSTEM VOLTAGES

The rated voltage of the high voltage winding is, in general, equal to the system nominal voltage, to which the high voltage winding is connected.

The correlation between the rated voltage (at no-load) of the low voltage winding of the transformer and the corresponding system voltage, is shown below.

System nominal voltage (V)	Transformer secondary rated voltage (V)
380	400
400	420
415	433
440	460
3000	3150
3300	3450
6000	6300
6600	6900
11000	11500
33000	34500

APPENDIX 2 DIMENSIONS OF H.V. CABLE CONNECTING BOXES

The minimum electrical clearances and creepage distances shall be as stated in Table 1, but may need to be increased to provide adequate mechanical clearances.

Table 1

Rated voltage Um (kV)	Minimum clearance between live metal of different phases (mm)	Minimum clearance between live metal and earth (mm)	Minimum creepage distance over insulator (mm)
12	127	76	127
17.5	165	102	153
24	242	140	203
36	356	222	305

APPENDIX 3 ANNUITY TABLE

PERIOD	*INTEREST RATE, R (%) per annum*														
t (yr)	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**
	CAPITALISATION FACTOR, c														
1	0.990	0.980	0.971	0.962	0.952	0.943	0.935	0.926	0.917	0.909	0.901	0.893	0.885	0.877	0.870
2	1.970	1.942	1.913	1.886	1.859	1.833	1.808	1.783	1.759	1.736	1.713	1.690	1.668	1.647	1.626
3	2.941	2.884	2.829	2.775	2.723	2.673	2.624	2.577	2.531	2.487	2.444	2.402	2.361	2.322	2.283
4	3.902	3.808	3.717	3.630	3.546	3.465	3.387	3.312	3.240	3.170	3.102	3.037	2.974	2.914	2.855
5	4.853	4.713	4.580	4.452	4.329	4.212	4.100	3.993	3.890	3.791	3.696	3.605	3.517	3.433	3.352
6	5.795	5.601	5.417	5.242	5.076	4.917	4.767	4.623	4.486	4.355	4.231	4.111	3.998	3.889	3.784
7	6.728	6.472	6.23	6.002	5.786	5.582	5.389	5.206	5.033	4.868	4.712	4.564	4.423	4.288	4.160
8	7.652	7.325	7.02	6.733	6.463	6.210	5.971	5.747	5.535	5.335	5.146	4.968	4.799	4.639	4.487
9	8.566	8.162	7.786	7.435	7.108	6.802	6.515	6.247	5.995	5.759	5.537	5.328	5.132	4.946	4.772
10	9.471	8.983	8.53	8.111	7.722	7.360	7.024	6.710	6.418	6.145	5.889	5.650	5.426	5.216	5.019
11	10.368	9.787	9.253	8.760	8.306	7.887	7.499	7.139	6.805	6.495	6.207	5.938	5.687	5.453	5.234
12	11.255	10.575	9.954	9.385	8.863	8.384	7.943	7.536	7.161	6.814	6.492	6.194	5.918	5.66	5.421
13	12.134	11.348	10.635	9.986	9.394	8.853	8.358	7.904	7.487	7.103	6.75	6.424	6.122	5.842	5.583
14	13.004	12.106	11.296	10.563	9.899	9.295	8.745	8.244	7.786	7.367	6.982	6.628	6.302	6.002	5.724
15	13.865	12.849	11.938	11.118	10.380	9.712	9.108	8.559	8.061	7.606	7.191	6.811	6.462	6.142	5.847
16	14.718	13.578	12.561	11.652	10.838	10.106	9.447	8.851	8.313	7.824	7.379	6.974	6.604	6.265	5.954
17	15.562	14.292	13.166	12.166	11.274	10.477	9.763	9.122	8.544	8.022	7.549	7.120	6.729	6.373	6.047
18	16.398	14.992	13.754	12.659	11.690	10.828	10.059	9.372	8.756	8.201	7.702	7.250	6.840	6.467	6.128
19	17.226	15.678	14.324	13.134	12.085	11.158	10.336	9.604	8.950	8.365	7.839	7.366	6.938	6.550	6.198
20	18.046	16.351	14.877	13.590	12.462	11.470	10.594	9.818	9.129	8.514	7.963	7.469	7.025	6.623	6.259

$$c = [1/r] - 1/[r(1+r)^t] \quad \text{where } r = R/100$$

APPENDIX 4 SUMMARY OF TESTS

1 ROUTINE TESTS

a) Measurement of winding resistance (IEC 76-1)

b) Measurement of voltage ratio and check of voltage vector relationship (IEC 76-1)

c) Measurement of impedance voltage (principal tapping), short-circuit impedance and load loss (IEC 76-1)

d) Measurement of no-load loss and current (IEC 76-1)

e) Dielectric tests: Induced overvoltage withstand test and separate-source voltage withstand test (IEC 76-3)

f) Tests on on-load tap changers, where appropriate (oil-immersed transformers only) (IEC 76-1)

g) Partial discharge test (dry-type transformers only) IEC 726)

2. TYPE TESTS

a) Temperature-rise tests (IEC 76-2)

b) Dielectric tests : Full-wave impulse-voltage withstand test (IEC 76-3)

3. SPECIAL TESTS

a) Dielectric tests : Impulse-voltage withstand tests including chopped waves (IEC 76-3)

b) Measurement of zero-sequence impedance on three-phase transformers (IEC 76-1)

c) Short-circuit test (IEC 76-5)

d) Measurement of acoustic sound level (IEC 551)

e) Measurement of the harmonics on the no-load current (IEC 76-1)

f) Measurement of the power taken by the fan and oil pump motors (IEC 76-1)

If special tests other than those listed above are required, the test method shall be subject to agreement between the manufacturer and the Principal.