WATER SUPPLIES DEPARTMENT

STANDARD SPECIFICATION E-60-04

POWER TRANSFORMERS WITH EPOXY-ENCAPSULATED WINDINGS FOR A RATING OF 50 to 1000 kVA

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This specification shall be read in conjunction with WSD Standard Specification EM-00-01.

1. GENERAL

1.1 Scope

This specification covers the design, manufacture, inspection and testing of distribution type transformer with epoxy resin encapsulated windings in a free-standing enclosure.

For a rating of 50 to 1000 kVA and primary voltage of 3.3 kV, 6.6 kV or 11 kV as specified in the Particular Specification, the secondary voltage at principal tapping shall be 380V.

1.2 Standards

The transformer supplied shall comply with the latest editions and amendments of the relevant International Electrotechnical Commission (IEC) Standards and British Standards (BS).

In particular, the transformer shall comply with the following standards:

IEC 60076	Power Transformers
IEC 60076-11	Power Transformers - Part 11 : Dry-type transformers
IEC 60076-12	Power Transformers - Part 12 : Loading guide for dry-type power transformers
IEC 60085	Electrical Insulation - Thermal evaluation and designation
BS 2562	Specification for Cable Boxes for Transformers and Reactors
BS 3816	Specification for Epoxy Resin Casting Systems used for Electrical Insulating Applications at Power Frequencies

2. PERFORMANCE PARAMETERS

2.1 Technical Particulars

Transformers supplied shall comply with the following specific requirements.

(a) Type : Three phase, two winding, epoxy resin encapsulated, floor mounted, indoor and natural air-cooled

(b) Rating : Maximum continuous rating

(c) Vector Grouping : Dyn 11 with star point solidly earthed

(d) Insulation : Class F design for Class B operation

(e) Tap changer : Off-load, fitted on HV winding, +15% to -5% in 2.5% steps

(f) Noise level : Sound power level not to exceed 60 dB(A) with transformer enclosure and measurement to IEC 60076 Part 10

2.2 Site Operating and Storage Conditions

(a) Ambient temperature :

Average over 24 hours	: 35^{o}C
Peak for any 4 hours continuous	: 40^{o}C

(b) Minimum ambient temperature : 0^{o}C

(c) Average yearly temperature : 30^{o}C

(d) Relative humidity : 0-98%

(e) Altitude above sea level : Not greater than 1000 metres

2.3 Electricity Supply

(a) Normal limits of voltage fluctuation : +10%, -2.5%

(b) Normal limit of frequency fluctuation : 50 Hz ± 2%

2.4 System Fault Level

Nominal system voltage (kV)	11	6.6	3.3	0.38
Symmetrical 3 phase short circuit current (kA)	20	20	25	43.1

2.5 Rating

The values of rated power shall be chosen from the recommended values as specified in IEC 60076 Part 1.

2.6 Load Pattern

The transformer load shall comprise induction motors, variable speed drives and steady loads such as lighting. The total load from 3-phase motors may vary between 0-95% of the transformer kVA rating. The maximum unbalance current of the total load connected to the transformer shall not exceed 15%. Transformers supplied shall be suitable for such load variations and unbalance.

2.7 Overload Capacity

The windings shall be designed and constructed for operation within the specified limits of temperature rise under the following cyclic overload conditions:

Loading	Preloading	Duration	Occurrence in 24 hours
120% rated kVA	100%	5 minutes	once during every 60-minute period
200% rated kVA	100%	20 sec.	once during every 5-minute period
225% rated kVA	75%	8 sec.	once during every 5-minute period

The thermal withstand curve of the transformer is shown in Appendix I.

2.8 Service Life

The equipment shall be designed for a 25-year service life based on the conditions and loading as given in this specification. The Contractor shall verify with calculations showing that the transformer insulation life is 25 years or more when operating under any of the overload conditions as specified in Clause 2.7 above. The average annual ambient temperature used for the calculations shall be 30°C.

2.9 Insulation

2.9.1 Class

The high voltage winding, low voltage winding and common components of the transformer supplied shall be provided with Class F insulation with the temperature rise limit of the transformer winding at full load limited to Class B. Where this is not a standard feature of the manufacture, type tests shall be conducted or detailed design calculations shall be provided to verify that adequate derating has been allowed for.

2.9.2 Impulse Voltage Test Level

Windings and connected parts shall be designed for the following impulse voltage test levels.

System highest voltage (kV r.m.s.)	Power frequency withstand voltage for 1 minute (kV r.m.s.)	Lightning impulse withstand voltage 1.2/50 μs (kV peak)
3.3	10	40
6.6	20	70
11	28	75

2.10 Transformer Parameters

The values of transformer voltage impedances at 115°C and principal tapping shall fall within the limits given in the following table, including the tolerance limits allowed in Clause 2.11 below.

Rating (kVA)	Min. Impedance (%)	Max. Impedance (%)
50-160	4.0	4.5
200-315	4.2	4.7
400-630	4.5	5.0
800-1000	4.7	5.2

2.11 Tolerance Limits

Tolerance limits on guaranteed values shall be as follows:

(a) Maximum load loss at full rated power (maximum continuous rating), principal tap and 115°C : no positive tolerance permitted.

(b) Maximum no-load loss at rated voltage, principal tap, 50 Hz and 115°C : no positive tolerance permitted.

(c) Impedance voltage at full rated power (maximum continuous rating), principal tap and 115°C : ± 5%.

The above parameters shall be guaranteed by the manufacturer and verified in the routine tests.

Due allowance shall be made by the Contractor for the design and measurement tolerances of the transformer losses. The tolerances shall be deemed to have been included in the guaranteed maximum loss figures quoted in the tender.

The tolerance limits of other parameters shall comply with IEC 60076. Where it is not specified in IEC 60076, the permissible tolerance limit of the parameters shall be taken as ± 5%.

3. DESIGN AND CONSTRUCTION

3.1 Transformer Windings

The windings of the transformers shall be of uniformly insulated copper or aluminium.

The windings shall be encapsulated with epoxy resin cast under vacuum. Suitable fillers shall be mixed in the resin to provide high mechanical strength and resilience.

The rated output of the transformer shall be achieved under natural ventilation only. The high and low voltage spools shall not require coolant air channels.

Embedded temperature detectors (ETD) shall be moulded into the low voltage winding. A solid state temperature monitoring unit shall be supplied for the ETDs.

3.2 Core Assembly

Steel sheets and strips for magnetic circuits of transformer shall comply with IEC 60404 with insulation on both sides. The core assembly shall be coated with resin based paint for protection against corrosion.

The assembled core shall be braced in frames with suitable lifting facilities provided. The core assembly shall enable the removal of the coils in the field if necessary.

Coil-assembles shall be acoustically insulated from each other and from the core/base-frame to minimize noise emission.

The earthing of transformer core shall comply with Clause 3.5 of this specification.

3.3 Enclosures

The transformer shall be enclosed in a rectangular enclosure, with a degree of protection of IP 32 to IEC 60529, suitable for natural air ventilation. The enclosure shall be made of sheet steel of minimum thickness 2 mm, suitably braced to form a rigid structure. Exterior corners and edges shall be rounded to give a smooth overall appearance.

Removable, hinged access doors incorporated with limit switches for electrical interlocks with the H.V. switchboard shall be provided. Double-leaf doors shall be fitted where the width of the opening exceeds 450 mm.

The enclosure shall be bolted to the transformer frame and shall be easily removable when required. Access doors and openings shall be provided to facilitate changing of the transformer tapping, routine inspection and maintenance without the need for dismantling the enclosure.

A warning label shall be provided adjacent to the access doors to warn against any attempt at opening the doors without switching off the HV supply. Mechanical interlock shall be provided per Clause 4.3 of this specification.

The transformer enclosure shall be fitted with a 30 x 6 mm solid copper earth bar which shall run the full length of the enclosure on the outside at the bottom.

The transformer enclosure including the cable boxes, where fixed, shall not incur damage as a result of a through short circuit. The results of short circuit type tests carried out on the transformer shall be provided to verify this capability.

3.4 Transformer Connections

Cables shall be terminated within the transformer enclosure.

All external cable connections to the high voltage side shall be of insulated, screened plug and-socket arrangement. The plugs and all termination accessories shall be supplied with the transformer suitable for termination of copper cables. The connections to the low voltage side shall be through a set of busbar stubs. If several parallel cables per phase are specified, sufficient space and fixing hardware shall be provided for their connections. The busbar stubs for cable connections shall be tinned and suitable for connection to tinned copper cable lugs.

All terminals shall be clearly and permanently marked to IEC 60076.

Busbars/Jumpers external to the transformer winding shall be either encapsulated in epoxy resin or encased heat-shrinkable PVC sleeving of appropriate grade such as Scotchtite or Raychem. All live parts shall be shrouded after cable termination. Insulating shrouds or sleeving for this purpose shall be supplied with the transformer.

Where the enclosure is fitted with detachable type cable boxes for termination of the power cables, cable boxes to BS 2562 shall be supplied. If separate short circuit type tests have been carried out on the cable boxes, results of the type tests shall be submitted with the equipment supplied.

3.5 Leakage Protection and Earthing

Provision shall be made to protect the low voltage components from contact with or leakage from high voltage components.

The neutral point of the secondary winding shall be brought out to an insulated neutral terminal and, where specified in the Particular Specification, shall be suitable for fitting a neutral current transformer. In addition, an insulated earthing terminal and a removable solid copper link for connecting it to the neutral terminal shall be provided. The link shall be removable independent of the connection between the earth terminal and the system earth. The neutral bars shall be insulated with heat-shrinkable PVC sleeving of appropriate grade such as Scotchtite or Raychem.

The transformer core shall be earthed at one point only through a removable earthing terminal stud and link so as to allow the insulation between the core and earth to be tested. The insulation shall withstand a test voltage of 2000V rms for 1 minute.

Connections or links for earthing shall be insulated and shall have a current carrying capacity of not less than that of the phase connections. Metalwork other than current carrying conductors shall be effectively bonded to the earth bar.

Provision shall be made for bonding cable glands to the earth bar. Drawings showing the internal and external earthing of the transformer shall be submitted for approval prior to manufacture.

3.6 Electrical Clearances

Air insulated busbars and terminals shall have the following minimum electrical clearances:

Nominal voltage between phases (kV)	11	6.6	3.3	0.38
Min. clearance between live conductor and earth (mm)	205	140	106	19
Min. clearance between live conductors of different phases (mm)	255	180	140	25
Min. clearance between live conductors of different voltage systems (mm)	405	-	-	-

3.7 Finishes

3.7.1 Surface Preparation and Painting

Steelwork shall be suitably treated, cleaned, degreased, primed and given at least two stoved undercoats and two stoved top coats of paint. Undercoats shall be epoxy based and easily distinguishable in shade or colour from the priming and finishing coats. The two final coats shall have a total minimum dry film thickness of 0.075 mm with each coat separately stoved in an air-circulating oven.

The final paint coating shall be of semi-matt finish and the colour shall be BS 4800 shade 18B21 (light grey).

Manufacturers shall ensure that components having the same colour finish and mounted on the transformer enclosure shall be of the same texture and colour match.

Alternative finishing process, if used, shall be detailed in the tender and approved in writing before being used.

3.7.2 Painting - Internal Surfaces

Internal surface finish of enclosures, with the possible exception of the colour of the final coat of paint, shall be identical to that of the external surfaces. The finishing colour shall be identical to the external colour or white.

3.7.3 Painting - External Components

Externally mounted accessories shall be coated with air-drying paints by cold airless spray to a minimum total dry film thickness (DFT) of 0.125 mm. Colour of the components shall be agreed by the Engineer before manufacture.

3.8 Fittings and Accessories

Transformer shall be mounted on a mild steel skid frame complete with lifting and haulage accessories such as rollers that can be removed after installation.

Stainless steel rating and connection plates to IEC 60076 shall be provided.

4. AUXILIARIES

4.1 Embedded Temperature Detectors (ETD)

ETDs supplied shall be of positive temperature coefficient type (PTC). At least three detectors shall be installed with one for each phase and positioned at points where the highest temperatures are likely to occur.

A monitoring/control unit shall be provided to monitor the winding temperature and to initiate alarm and trip functions at excessive temperatures. Relays shall be suitable for operation at 110V d.c. and their contacts shall be rated at 0.5A 110V d.c. Alarm and trip relays shall be set for operation at 120°C and 140°C respectively. The trip relay shall be de-energized when auxiliary power supply fails. Terminals shall be provided for external cables in an auxiliary cable termination box.

Detailed diagrams indicating the exact position of each detector shall be provided. Full particulars of the detectors with the name of the manufacturer, model no. and installation method shall be provided to facilitate renewal of transformer rewinding if required at a later date. Relevant diagrams and technical manual for the monitor unit shall be supplied.

4.2 Tap Changers

An off-load tap changer fitted on H.V. winding shall be provided. The tap range shall be +15% to -5% in 2.5% steps.

An off-load tap changing switch or a set of links housed behind a transparent protective screen shall be provided for the changing of the transformer tapping. The tap-changer shall be accessible only through the lockable doors of the transformer enclosure and shall not be obstructed by the incoming supply cables. The selected tap position shall be clearly indicated.

4.3 Mechanical Interlocks

(a) A lock and key for each leaf of the access door which shall be coded with symbols “Tl”, “T2”, “T3” etc. for transformers no. 1, 2, 3 etc. respectively. The key shall remain trapped in the lock at all times when the associated door is not fully closed

and secured. The door shall not be capable of being opened until the correct key is inserted.

(b) A key exchange box for each transformer with a Master Key and Lock coded with symbols "MR", "MS", "MT" etc. for the corresponding transformers no. 1, 2, 3 etc. respectively. The Master Key shall remain barred until all of the individual access door keys of that particular transformer are inserted into the key exchange box. Similarly, all the individual access door keys shall remain barred until the Master Key for that particular box is inserted.

(c) The Contractor shall ensure that the Master Key will match with the lock fitted to the Transformer Supply Circuit Breaker. The Contractor shall submit the manufacturer type and coding symbols of the keys to the Engineer for approval prior to ordering.

4.4 Cable Accessories

The following accessories shall be provided for the termination of external cables.

(a) Terminal Bases
Terminal base and insulators shall be of epoxy resin or glass-fibre polyester high-pressure mouldings. Porcelain insulators are not acceptable.

(b) Terminal Studs
Studs shall be of hard-drawn cadmium copper or hard-drawn copper.

(c) Terminal Sockets
Cable terminal lugs shall be of hard-drawn cadmium copper with their socket portion locally annealed for crimping.

Compression type cable sockets shall be manufactured from tin plated seamless copper tubing with single hole palm terminals. Each socket shall be supplied with a piece of heat shrinkable tubing of sufficient length to cover, when shrunk, the socket portion and an adequate length of cable entering the socket.

Stud holes in the palm of cable lugs shall have nominal diameters compatible with the bolts.

(d) Mechanical Cable Glands
Insulated glands shall be used where terminations of single core cables are specified. A removable bonding link to enable the cable sheath and armour to be earthed to the cable box shall be provided. The gland insulation shall withstand a test voltage of 2000V rms for 1 minute. The armour clamp shall be suitable for gripping aluminium wire armour.

Each cable gland shall be supplied with a brass gland backnut for plain hole fixing, slip-on copper earth tag with galvanized bolt and nut for earth strip and a polychloroprene (PCP) outer gland shroud.

Cable glands for unarmoured cables with elastomer or plastic outer sheath shall be made of brass to BS 6121 Type A4. Cable glands for armoured cables with elastomer or plastic outer sheath shall be made of brass to BS 6121 Type E1W.

(e) Cable Gland Plates and Split Boards

The gland plates and split boards shall be non-magnetic metal such as brass. Split boards shall be provided for cables entering the transformer enclosure to prevent entry of vermin.

The size and height of gland plates shall permit a smooth run of the incoming supply cables to the terminals.

(f) Ferrule Number for External Wirings

The ferrule number for external wirings shall be as follows:

(i)	Contacts for winding temperature high trip initiation (WTT)	K121, K123
(ii)	Contacts for winding temperature high alarm initiation (WTA)	K121, K125
(iii)	Contacts for enclosure door open limit switches	K121, K127
(iv)	Terminals for 110V d.c. auxiliary power supply for temperature monitor	K121, K122
(v)	Neutral C.T. (where fitted)	A141, A142

5. INSPECTION AND TESTING

5.1 Inspection and Testing in Manufacturer's Works - General

The transformer supplied shall be inspected and tested at the manufacturer’s works by an Independent Inspection Body (IIB) in compliance with WSD Standard Specification EM-00-01 in the manufacturer’s works. The qualification and experience of IIB shall comply with requirements stipulated in WSD Standard Specification EM-00-01.

Tolerance limits shall be in accordance with Clause 2.11 of this specification.

5.2 Test Requirements

All tests listed in Clauses 5.3 - 5.4 of this specification shall be performed on the transformers in accordance with IEC 60076.

5.3 Type Tests

The following type tests to IEC 60076 shall be carried out.

(a) Lightning impulse test

(b) Short circuit withstand test

(c) Temperature rise test

(d) Noise level test.

Type test certificates of the transformer, if available, shall be provided after award of contract to prove that the relevant type tests have been performed on a representative transformer. Any outstanding test requirement on the type test certificate including no type test certificate submitted shall be conducted on one of the transformers supplied for the contract. The tests shall be witnessed by an IIB unless prior agreement has been obtained from the Engineer for not doing so. However, short circuit type tests must not be carried out on the transformer supplied for the contract.

A transformer is considered to be representative of others if it is identical in rating and construction. Type tests on a transformer which has minor deviations in rating or other characteristics may be acceptable subject to agreement of the Engineer.

Furthermore, if the secondary voltage of the transformers which undergo the type tests is different from those supplied under the contract, detailed calculations shall be provided to prove that the flux densities of the respective transformers are identical.

Submission of the above type test certificates will not exempt the manufacturer from carrying out the transformer routine tests as specified in Clause 5.4 of this specification.

5.4 Routine Tests

The following tests shall be carried out on each transformer supplied except the temperature rise test and noise level test which are only required to be carried out on one transformer of each rating. These tests shall be carried out in compliance with IEC 60076 and the requirements as specified below. These tests shall be witnessed by an IIB.

(a) Winding Resistance Test for determination of the D.C. resistance of all the transformer windings.

(b) Ratio, Polarity and Vector Grouping Test which shall include the checking of the connections and the voltage ratios of all tappings.

(c) Open Circuit Loss Test for determination of the values for core loss, dielectric loss and I^2R loss due to excitation current. The losses shall be determined at rated frequency, with rated voltage applied to one winding and the other winding being open circuited.

(d) Load Loss Test for proving compliance with the guarantee of load losses at maximum continuous rating.

(e) No Load Current Test for determination of no load or magnetising current at rated frequency with rated voltage applied to one winding.

(f) Impedance Voltage Test for determination of impedance voltage at the maximum, minimum and normal tappings.

(g) High Voltage Tests including induced overvoltage withstand test and separate source power frequency voltage withstand test.

(h) Partial Discharge Test for measurement of partial discharge after the dielectric tests are completed.

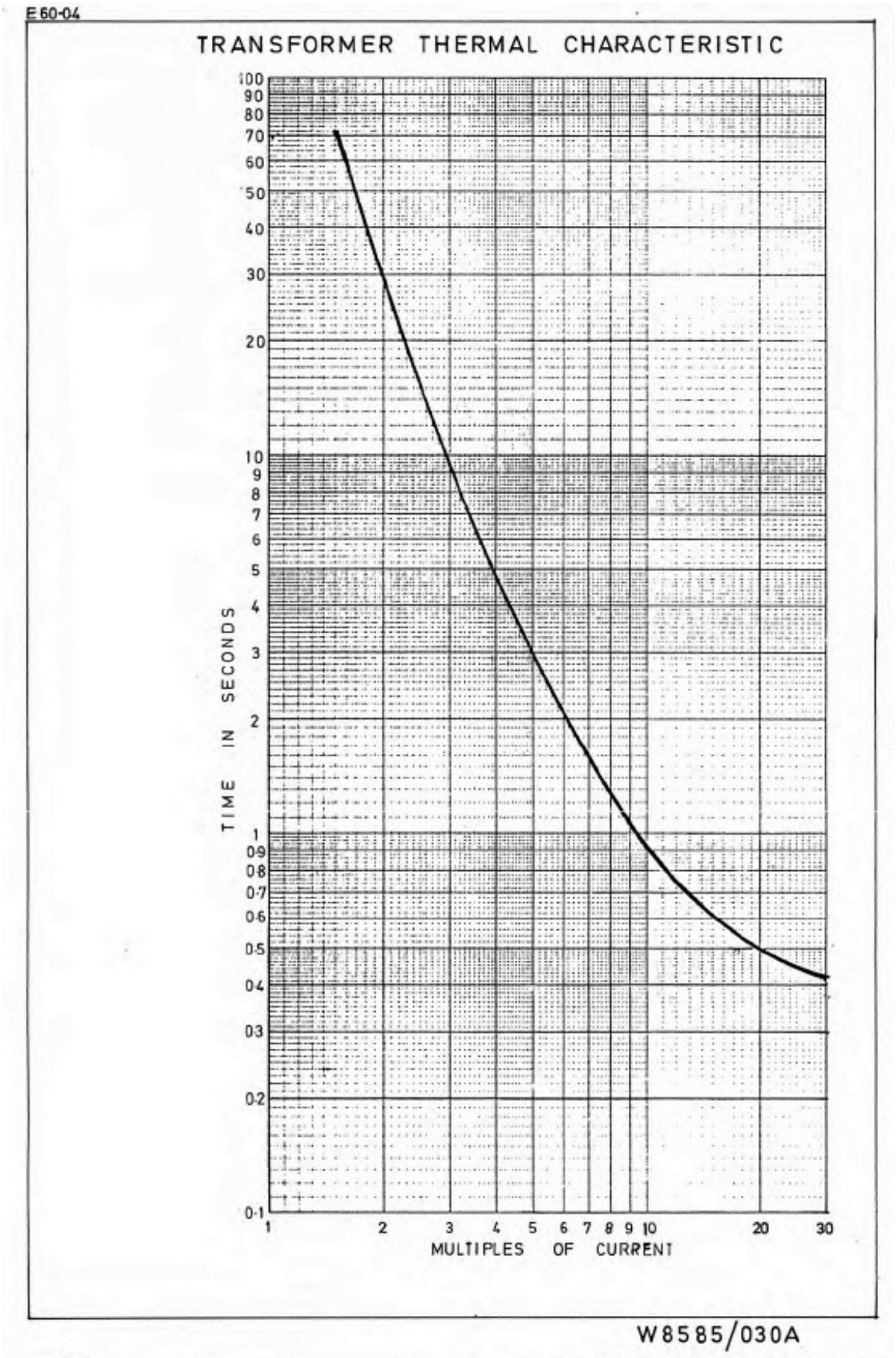
(i) Test on Tap Changer for operation of tap changer.

(j) Magnetic Circuit Insulation Test for pressure testing of each core after assembly for one minute at 2000 volts A.C. between all bolts, side plates and structural steelwork. The magnetic circuit shall be pressure tested for one minute at 2 kV 50 Hz between the core and earth immediately prior to the despatch of the transformer from the manufacturer's works. Alternatively, a 2500 volt megger test would be accepted providing that a reading higher than 5.0 megohms is obtained.

(k) Temperature Rise Test for measurement of temperature rise in its own enclosure with the winding on its principal tapping. During this test the accuracy of the winding temperature indicators shall also be determined.

(l) Noise Level Test for determination of noise level on the transformer, complete with the enclosure, with measurements made at a distance of 0.3 m.

Appendix I



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