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BRITISH STANDARD 3399 : 1961

SPECIFICATION FOR TRANSFORMERS FOR USE IN SHIPS

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B.S. 3399: 1961

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THIS BRITISH STANDARD, having been approved by the Electrical Industry Standards Committee and endorsed by the Chairman of the Engineering Divisional Council, was published under the authority of the General Council on 31st July, 1961.

The Institution desires to call attention to the fact that this British Standard does not purport to include all the necessary provisions of a contract.

In order to keep abreast of progress in the industries concerned, British Standards are subject to periodical review. Suggestions for improvements will be recorded and in due course brought to the notice of the committees charged with the revision of the standards to which they refer.

A complete list of British Standards, numbering over 9,000, fully indexed and with a note of the contents of each, will be found in the BSI Catalogue which may be purchased from BSI Sales Department. The Catalogue may be consulted in many public libraries and similar institutions.

This standard makes reference to the following British Standards:

- B.S. 148. Insulating oil for transformers and switchgear.
- B.S. 171. Power transformers.
- B.S. 2562. Cable sealing boxes for oil-immersed transformers.
- B.S. 2757. Classification of insulating materials for electrical machinery and apparatus on the basis of thermal stability in service.
- CP 1009. Maintenance of insulating oil (with special reference to transformers and switchgear).

British Standards are revised, when necessary, by the issue either of amendment slips or of revised editions. It is important that users of British Standards should ascertain that they are in possession of the latest amendments or editions.

The following B.S.I. references relate to the work on this standard:
Committee reference ELE/51 and ELE/51/5
Draft for comment A(ELE) 5025.

CONTENTS

	Page
Co-operating organizations	6
Foreword	7
Section One: General	
101. Scope	7
102. Definitions	7
103. Additional definitions	9
Section Two: Type of cooling and classification	
201. Types of cooling	10
Section Three: Rating	
301. Rated kVA	10
302. Rated voltage and current	11
303. Rated frequency	11
304. Phase factors	11
305. Rating of additional windings	11
306. Preferred kVA ratings	11
307. Regulation	12
Section Four: Service conditions	
401. General	12
Section Five: Constructional requirements	
501. General	13
Section Six: Tappings	
601. General	13
602. Principal tapping	13
603. Output at any tapping	13
Section Seven: Insulating materials	
701. General	14
702. Solids	14
703. Liquids	14
Section Eight: Insulation levels	
801. General	14
Section Nine: Temperature rise limits	
901. General	15

Section Ten: Performance under external short-circuit conditions	Page
1001. General	16
1002. Series current-limiting reactors	16
 Section Eleven: Assignment of designating letters to windings and of numbers to winding ends and tappings	
1101. Designating letters	17
1102. Subscript numbers for winding ends and tappings	18
 Section Twelve: Marking of terminals	
1201. Terminal and sub-terminal markings for transformers	18
1202. Terminal markings for series current-limiting reactors	20
 Section Thirteen: Position of terminals	
1301. General	20
 Section Fourteen: Vector diagrams and symbols	
1401. Vector diagrams and symbols	21
 Section Fifteen: Terminal marking plates and rating plates	
1501. Terminal marking plates	23
1502. Rating plates for transformers	24
1503. Rating plates for series current-limiting reactors	25
 Section Sixteen: Fittings	
1601. Provision of fittings	27
 Section Seventeen: Performance and tolerances	
1701. Efficiency	30
1702. Performance and tolerances	30

Section Eighteen: Tests	Page
1801. Conditions for tests	31
1802. Tests of transformers	32
1803. Test certificates	32
1804. Measurement of winding resistance	32
1805. Ratio measurement, check of polarity and phase relationship	33
1806. Measurement of impedance voltage	33
1807. Measurement of load loss	33
1808. Measurement of no-load losses and no-load current	34
1809. Measurement of insulation resistance	35
1810. Induced overvoltage withstand test	35
1811. Separate-source voltage withstand test	35
1812. Test of temperature rise	35
1813. Series current-limiting reactors	41

APPENDICES

A. Information required with enquiry and order	43
B. Additional fittings for oil-immersed type transformers	45
C. Three-phase vector diagrams	46
D. Connection diagrams	48
E. Method of declaring efficiency	48
F. Calculation of inherent regulation	48
G. Supplementary high-voltage tests	50

CO-OPERATING ORGANIZATIONS

The Electrical Industry Standards Committee under whose supervision this British Standard was prepared, consists of representatives from the following Government departments and scientific and industrial organizations:

- *Admiralty
- *Air Ministry
 - Associated Offices' Technical Committee
- *Association of Consulting Engineers (Incorporated)
 - Association of Supervising Electrical Engineers
- *British Electrical and Allied Industries Research Association
- *British Electrical and Allied Manufacturers' Association
 - British Electrical Development Association
- *British Railways, The British Transport Commission
- *Cable Makers' Association
 - Crown Agents for Oversea Governments and Administrations
 - Electric Lamp Industry Council
 - Electric Light Fittings Association
 - Electrical Contractors' Association (Incorporated)
 - Electrical Contractors' Association of Scotland
- *Electricity Council, Generating Board and the Area Boards in England and Wales
 - Electronic Engineering Association
- *Engineering Equipment Users' Association
 - Independent Cable Makers' Association
- *Institution of Electrical Engineers
 - Ministry of Aviation
 - Ministry of Labour (Factory Inspectorate)
 - Ministry of Power
 - Ministry of Works
 - Municipal Passenger Transport Association (Incorporated)
 - National Inspection Council for Electrical Installation Contracting
- *National Physical Laboratory (D.S.I.R.)
 - Oil Companies Materials Association
 - Post Office
 - Public Transport Association (Incorporated)
- *South of Scotland Electricity Board
 - War Office

The Government departments and scientific and industrial organizations marked with an asterisk in the above list, together with the following, were directly represented on the committee entrusted with the preparation of this standard:

Chamber of Shipping of the United Kingdom
Engineer Surveyors' Association
High Commission of India
Institute of Marine Engineers
Lloyd's Register of Shipping
London Transport Executive, The British Transport Commission
Ministry of Transport
National Coal Board
North East Coast Institution of Engineers and Shipbuilders

BRITISH STANDARD SPECIFICATION FOR TRANSFORMERS FOR USE IN SHIPS

FOREWORD

This British Standard has been prepared at the request of the Institution of Electrical Engineers and under the authority of the Electrical Industry Standards Committee to meet the need for a specification for transformers for marine use.

During preparation of the standard every effort was made to align it as far as possible with B.S. 171: 1959, 'Power transformers'.

SPECIFICATION

SECTION ONE: GENERAL

SCOPE

101. This British Standard applies to single-phase and polyphase double wound power transformers and reactors, for use in ships, having windings insulated with Class A, B, H and/or C materials, rated from 1kVA to 1000 kVA inclusive, and having a rated voltage not exceeding 3300 volts line-to-line. This standard does not apply to rectifier transformers.

DEFINITIONS

102. For the purposes of this standard, the following definitions apply:

1. Transformer. A piece of apparatus without moving parts which, by electromagnetic induction, transforms alternating or intermittent voltage and current in one winding into alternating or intermittent voltage and current in one or more other windings.

2. Drip-proof transformer. A transformer in which the core, windings and connections are protected by a covering arranged to exclude vertically falling water or dirt when the transformer is tilted at an angle of $22\frac{1}{2}$ degrees from the vertical in any direction.

3. Dry-type transformer. A transformer having the core and windings directly exposed to air or to a gas substantially at atmospheric pressure.

4. Oil-immersed type transformer. A transformer having the core and windings immersed in either a natural mineral oil or a synthetic insulating liquid.

5. Higher-voltage winding and lower-voltage winding. Terms used in reference to two-winding transformers to distinguish the winding or group of windings associated with the higher operating voltage from that associated with the lower operating voltage.

(Clause 102 continued).

6. *Primary winding(s)*. The winding (or windings) which receives the energy from the supply circuit(s).

7. *Secondary winding(s)*. The winding (or windings) which receives energy from the primary winding(s) by electromagnetic induction and delivers it as output energy to the load circuit.

8. *Principal tapping*. The tapping which corresponds to the rated voltage of the winding.

9. *Plus tapping*. A tapping so located as to introduce into the active part of the winding concerned a greater number of turns than those corresponding to the principal tapping.

10. *Minus tapping*. A tapping so located as to introduce into the active part of the winding concerned fewer turns than those corresponding to the principal tapping.

11. *Turns ratio*. The ratio of the number of turns associated with one winding to the number of turns associated with another winding.

12. *Voltage ratio*. The ratio of the voltage between line terminals of one winding to the voltage between line terminals of another winding.

13. *Phase displacement*. The angular difference between the vectors representing the voltages induced between the higher-voltage and lower-voltage terminals having the same marking *letter* and the corresponding neutral points (real or imaginary), expressed with reference to the higher-voltage side.

14. *Rating*. The whole of the electrical quantities assigned by the manufacturer to define operation under specified conditions.

15. *Rated primary voltage(s)*. The terminal voltage(s) applicable under normal operating conditions to the full primary winding(s) if there are no tapplings, or to the principal tapping on a tapped primary winding. It is the voltage(s) specified by the purchaser.

16. *Rated secondary voltage(s)*. The voltage(s) developed between the output terminals at no-load by the full secondary winding(s) if there are no tapplings, or in a tapped winding, by that part of the winding up to the principal tapping when rated primary voltage is applied. It is the voltage(s) specified by the purchaser.

17. *Rated current*. The current, marked on the rating plate, derived from the rated kVA and the rated voltage.

18. *Rated kVA*. The product of the rated voltage in kilovolts, the rated current in amperes and the appropriate phase factor.

19. *Rated frequency*. The frequency at which the transformer is designed to operate.

(Clause 102 continued).

20. *Cooling-medium temperature.* The temperature of the cooling medium (e.g. air or water) above which the temperature rise is measured.

21. *Thermal time constant.* The time which would be required for a transformer to reach a temperature rise equal to that which would be attained under steady-state specified loading conditions in a cooling medium of constant temperature, if the initial rate of temperature rise (when no heat was being dissipated) were maintained.

22. *Impedance voltage**. That voltage which, applied to a winding of the transformer when another winding is short-circuited, will cause rated current to flow in the winding to which the voltage is applied.

NOTE. The impedance voltage is the vector sum of the resistance voltage and the reactance voltage. The values for resistance, reactance and impedance voltages apply only to the pair of windings tested.

23. *Resistance voltage**. The component of the impedance voltage in phase with the current.

24. *Reactance voltage.* The component of the impedance voltage in quadrature with the current.

25. *Inherent regulation.* The difference between rated secondary voltage and the voltage developed at the terminals of the secondary winding when, with rated primary voltage applied to the terminals of the primary windings, rated current is delivered at a stated power factor.

NOTE. For the calculation of inherent regulation see Appendix F.

26. *Off-circuit tapping switch or link.* A device for changing the voltage ratio of the windings, only suitable for operation when the transformer is not energized.

27. *Routine tests.* Tests made by the manufacturer on each transformer.

28. *Type tests.* Tests made by the manufacturer to verify a design characteristic not covered by routine tests.

ADDITIONAL DEFINITIONS

103. For the purpose of this standard, the following definitions, additional to those in Clause 102, apply for series current-limiting reactors only:

29. *Rated current.* The current which the reactor will carry continuously without the temperature rise exceeding the limits specified in Section Nine.

30. *Over-current factor.* The ratio of the symmetrical r.m.s. value of the through-current under system fault conditions which the reactor is designed to carry, to the rated current.

* These quantities, after correction to the appropriate reference temperature, specified in Clause 1807, are usually expressed as a percentage of the rated voltage of the winding supplied during the test.

(Clause 103 continued).

31. *Ohmic reactance*. The inductive reactance expressed in ohms per phase at rated frequency.

32. *Reactive kVA*. The product of the number of phases, the ohmic reactance and the square of the rated current, divided by 1000.

SECTION TWO: CLASSIFICATION OF COOLING METHODS

TYPES OF COOLING

201. The classification of transformers according to different methods of cooling, and the recognized abbreviation for each class is given in Table 1. In the table the symbol 'O' is used to indicate mineral oil complying with B.S. 148, 'Insulating oil for transformers and switchgear', and the symbol 'S' is used when a synthetic liquid is employed.

TABLE 1. CLASSIFICATION OF METHODS OF COOLING

1 Type of transformer	2 Oil circulation	3 Cooling method	4 Abbreviation		
			Dry	Mineral oil	Synthetic liquid
Dry	—	Natural	AN	—	—
	—	Blast*	AB	—	—
Oil-immersed	Natural thermal head only	Air natural	—	ON	SN
		Air blast	—	OB	SB
		Water	—	OW	SW
	Forced, by pump	Water	—	OFW	SFW

* This term includes forms of construction in which the air or gas is recirculated in a closed circuit.

SECTION THREE: RATING

RATED kVA

301. Rated kVA shall be declared as the product of the rated voltage in kV, the corresponding rated current and the appropriate phase factor, taken from Table 2. It shall be such that the transformer can deliver its rated current under steady loading conditions without exceeding the limits of temperature rise

specified in Section Nine, when the rated primary voltage at the rated frequency is applied to the principal primary tapping. The rated kVA so assigned shall envisage service conditions not less favourable than those specified in Section Four.

NOTE 1. When the transformer is operated with the rated primary voltage applied to the terminals of the primary windings, the apparent power (kVA) at the terminals of the secondary winding, when carrying the rated secondary current, differs from the rated kVA by an amount corresponding to the regulation of the transformer and is the product of the actual secondary voltage, the rated secondary current and the appropriate phase factor.

NOTE 2. If the output voltage is specified at full load, the corresponding no-load voltage should be taken as the basis of rated kVA.

RATED VOLTAGE AND CURRENT

302. Values shall be marked on the rating plate. Where tapplings are provided, the values shall be those applicable to the principal tapping.

RATED FREQUENCY

303. Rated frequencies of 50 cycles per second and 60 cycles per second are each recognized as standard.

PHASE FACTORS

304. The factors to be used to inter-relate rated kVA with rated voltage and rated current are given in Table 2.

TABLE 2. PHASE FACTORS

Number of phases	Phase factor
1	1
3	1.73

RATING OF ADDITIONAL WINDINGS

305. Where more than one primary or secondary winding is provided, the kVA rating of each winding shall be marked on the rating plate and the temperature rise of each winding under the specified loading conditions shall comply with the limits stated in Section Nine.

PREFERRED kVA RATINGS

306. For guidance, preferred kVA ratings are listed in Tables 3 and 4, but compliance with this standard does not require the adoption of only those values given.

**TABLE 3. PREFERRED kVA RATINGS FOR 3-PHASE TRANSFORMERS
OR 3-PHASE GROUPS**

kVA	kVA
10	200
15	250
25	300
50	400
75	500
100	750
150	1 000

**TABLE 4. PREFERRED kVA RATINGS FOR SINGLE-PHASE
TRANSFORMERS**

kVA	kVA	kVA
1	75	500
2	100	750
5	150	1 000
10	200	
15	250	
25	300	
50	400	

REGULATION

307. The inherent regulation at 0·8 power factor shall not exceed the values given below. (For calculation of inherent regulation see Appendix F.)

kVA rating	Percentage regulation
1 to 10	5
above 10 to 100	4½
above 100	4

SECTION FOUR: SERVICE CONDITIONS**GENERAL**

401. The service conditions envisaged in specifying the limits of temperature rise referred to in Clause 301 are as follows:

Group 1. Transformers installed in ocean-going ships and all ships operating in tropical waters.

Continuous cooling air temperature 45°C

Continuous cooling water inlet temperature 30°C

Group 2. Transformers installed in all ships other than Group 1 ships (e.g. ships solely for use in temperate waters, on duties such as coastal and harbour services, inland waters, and cross-channel services).

Continuous cooling air temperature 40°C

Continuous cooling water inlet temperature 25°C

SECTION FIVE: CONSTRUCTIONAL REQUIREMENTS

GENERAL

501. Unless otherwise specified, transformers shall be drip-proof. When filled with oil or other liquid coolant, these liquids shall not seep or spill from the transformer, nor shall any live parts normally immersed become exposed when the transformer is tilted at an angle of $22\frac{1}{2}$ degrees in any direction from the normal, unless some greater angle is specified.

Transformers shall be capable of withstanding the vibration and shock normal to ships, and provision shall be made for bolting down to resist movement.

For dry-type transformers, the insulation, windings, etc., shall be treated to resist the effects of moisture, sea air and oil vapour.

SECTION SIX: TAPPINGS

GENERAL

601. Where 'off-circuit' tapplings are specified, but the size and the number of the steps is not stated, voltage adjustment of plus and minus 5 per cent of the rated voltage in the steps indicated below, is assumed:

25 kVA and below: 5 per cent steps

above 25 kVA: $2\frac{1}{2}$ per cent steps

PRINCIPAL TAPPING

602. If the rated voltage is not otherwise specified, the principal tapping shall be as follows:

a. Where the number of tapplings is odd: the mean tapping.

b. Where the number of tapplings is even: that tapping, of the two middle tapplings, associated with the higher number of turns.

OUTPUT AT ANY TAPPING

603. Where primary or secondary tapplings are used to compensate for variation of either the primary or the secondary voltage, the transformer shall be capable

of operation at its rated kVA without injury on any tapping and at any applied voltage which does not vary from the voltage for which the tapping is rated by more than plus 5 per cent.

SECTION SEVEN: INSULATING MATERIALS

GENERAL

701. The recognized insulating materials shall be suitable for use in the service conditions specified in Section Four.

SOLIDS

702. Four of the classes of insulating material listed in B.S. 2757*, A, B, H and C, are recognized in this standard for dry-type transformers. For transformers immersed in oil or synthetic liquid, Class A only is recognized.

LIQUIDS

703. a. Oil. Mineral oil, when provided, shall comply with B.S. 148, 'Insulating oil for transformers and switchgear'.

NOTE. Attention is drawn to the fact that sustained operation of transformers at the maximum temperatures permitted by this standard may cause the oil to deteriorate more rapidly than the other components [see CP 1009 'Maintenance of insulating oil (with special reference to transformers and switchgear)].

b. Synthetic liquids. In the absence of British Standards covering synthetic insulating liquids the provision of such liquids is a matter for arrangement between manufacturer and purchaser.

NOTE. Oil and synthetic liquids should not be interchanged.

SECTION EIGHT: INSULATION TESTS

GENERAL

801. The test voltages shall be as follows:

**TABLE 5. TEST VOLTAGES FOR DRY-TYPE TRANSFORMERS
AND OIL-IMMERSED TYPE TRANSFORMERS**

1	2
Rated voltage	Power-frequency test voltage
kV r.m.s.	kV r.m.s.
Less than 1.0	2.5
1.0	3
3.3	8

NOTE 1. Where the rated voltage of a transformer is an intermediate value, the test voltage should be the next higher value.

NOTE 2. Transformers for use in ships are not designed for impulse testing.

* B.S. 2757, 'Classification of insulating materials for electrical machinery and apparatus on the basis of thermal stability in service'.

SECTION NINE: TEMPERATURE RISE LIMITS

GENERAL

901. The temperature rises of transformer windings, oil and cores shall not exceed the limits specified in Tables 6 and 7, when tested in accordance with Section Eighteen.

For water cooled transformers, the temperature rise given is that measured above the inlet water temperature. For other types of cooling, the temperature rises given are those measured above the temperature of the cooling air.

**TABLE 6. TEMPERATURE RISE LIMITS FOR
DRY-TYPE TRANSFORMERS**

1	2	3	4	
Part	Cooling classification (see Table 1)	Class of insulation	Temperature rise (measured by resistance)	
			Group 1 ships	Group 2 ships
Windings	AN or AB	A	deg C 50	deg C 55
		B	70	75
		H (in air)	115	115
		H (in inert gas)	145	145
		C (Silicone material only)	145	145
Cores	The temperature rise shall in no case reach such a value that there is risk of injury to any insulation material on adjacent parts.			