

Recommendation 6A

*Technical regulations etc. for 10-20 kV
oil-immersed distribution transformers*

5th Edition, May 2007

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1. SCOPE

This recommendation applies to three-phase, oil-immersed distribution transformers with normal equipment

The transformers are used to transmit power from resonant earthed or isolated 10-20 kV systems to solidly earthed low voltage systems.

The recommendation is published in Danish and English. In case of discrepancy between the two versions the Danish version shall prevail.

2. GENERAL REQUIREMENTS

The general requirements and test instructions laid down in CENELEC-, CEN- and IEC standards and valid at the tender invitation date shall be met.

With regard to the terminology used in this recommendation, reference is made to the definitions given in the above mentioned standards.

The transformer shall meet the requirements laid down in current environmental legislation.

2.1 Temperature

The transformer is designed for installation at ambient temperature in the range of:

$$-25^{\circ}\text{C} \dots +40^{\circ}\text{C}$$

Furthermore the monthly average temperature may not exceed 30°C and the annual average temperature may not exceed 20°C.

3. PRINCIPAL ELECTRICAL DATA

3.1 Rated frequency

50 Hz

3.2 Rated power

Recommended rated power:

50, 100, 200, 400, 500, 630, 800, 1000, 1250, 1600, 2000 and 2500 kVA.

3.2.1 For the load current applies, cf. HD 428.4, that the total harmonic factor¹ and the even harmonic factor shall be limited to respectively 5% and 1%. If these limits are exceeded, the harmonic content in the load current must be taken into account.

Account may be taken to the harmonic content in the load current by specifying in invitations to tender that the transformer shall accommodate to loads pursuant to CENELEC HD 428.4.

Invitations to tender may also specify that the transformer shall be dimensioned to accommodate 100 % of its rated current plus the harmonic content in the load current.

If required, see DEFU report RA 532 "Transformere udsat for harmoniske strømme" in Danish for a detailed description of the load limit of the transformers, when they are exposed to harmonic currents.

3.3 Dimensioning of neutral connection of the low-voltage winding

The neutral terminal and conductor on the low voltage side shall be dimensioned for rated current of the low voltage winding.

3.4 Overload capacity

The overload capacity of the transformer shall be in compliance with IEC 60076 - 7.

For hermetically sealed transformers without gas cushion a maximum allowable oil temperature that is lower than the in IEC 60076-7 stipulated value of 115 °C, shall be described in the tender and on the rating plate.

¹ The harmonic factor is determined by :
$$H[\%] = 100 \cdot \left[\sum_{h=2}^{h=H} \left(\frac{I_h}{I_1} \right)^2 \right]^{\frac{1}{2}}$$

3.5 Rated voltages

Nominal voltage , U _r	Primary [kV]			Secondary [V]	
	10	15	20	400	690
System voltage	10.50 ²	15,75	21	420	690 ³

3.6 Tappings

The high voltage winding shall have five tappings, corresponding to the rated voltage $\pm 2.5\%$. A tap-changer for switching between tappings must be provided, cf. 4.1. The transformer shall accommodate a load according to para. 3.4 in all switching positions.

3.7 Vector group

Dyn 5 or Dyn 11. Alternatively, at power ratings lower than or equal to 200 kVA, the vector group may be Yzn 5 or Yzn 11.

3.8 Short-circuit impedance

The transformer shall be designed for the following short-circuit impedance:

Rated power [kVA]	< 500	500...630	> 630... 1600	>1600... 2500
Short-circuit impedance, e _k [%]	3 ... 4	4 ... 5	5 ... 6	6 ... 10

3.9 Short-circuit withstand requirements

The transformer must withstand the thermal and mechanical loads arising from external short circuits and earth faults in all switching positions.

The short-circuit power of the system shall be provided in invitations to tender. It is presupposed that the short-circuit power of the 10 – 20 kV network is 500 MVA (standard procedure in Europe pursuant to CENELEC EN 60076 – 5, if the short-circuit power is not known).

3.10 Insulation level

The transformer shall be provided with uniform insulation layer and be designed for the following voltages:

Nominal voltage , U _r [kV]	Highest voltage for the equipment, U _m [kV]	1 min. AC voltage [kV]	Lightning impulse 1.2/50 μ s [kV]
0.4	1.1	3	-
0.69	1.1	3	-
10	12	28	75
15	17.5	38	95
20	24	50	125

3.11 Loss and sound power level

Max load loss, no-load loss and sound power level shall be specified in invitations to tender.

3.11.1 Max. load loss, no-load loss and sound power level may be specified in invitations to tender from the four lists D_k, C_k, B_k and A_k, in the table below.

Rated power [kVA]	List D _k P _k [W]	List C _k P _k [W]	List B _k P _k [W]	List A _k P _k [W]	e _k [%]
50	1350	1100	875	750	4
100	2150	1750	1475	1250	
200*	3400	2700	2250	1900	
400	6000	4600	3850	3250	
500	7200	5500	4600	3900	
630	8400	6500	5400	4600	
630	8700	6750	5600	4800	
800	10500	8400	7000	6000	6
1000	13000	10500	9000	7600	
1250	16000	13500	11000	9500	
1600	20000	17000	14000	12000	
2000	26000	21000	18000	15000	
2500	32000	26500	22000	18500	

*Determined by Interpolation.

3.11.2 The max. no-load loss and sound power level may be specified in invitations to tender from the five lists E₀, D₀, C₀, B₀ and A₀ in the table below.

For transformers for noise-sensitive placing it may be relevant to specify lower values than those mentioned in the table below.

The sound power level shall be documented, cf. EN 60076-10. If the sound power level ex-

² 10.75 kV transformers with a fixed transformer value.

³ Unless otherwise agreed.

ceeds the value specified in the tender, the purchaser reserves the right to reject the transformer.

Rated power [kVA]	List E _o		List D _o		List C _o		e _k %
	P _o [W]	L _{wa} [dB]	P _o [W]	L _{wa} [dB]	P _o [W]	L _{wa} [dB]	
50	190	55	145	50	125	47	4
100	320	59	260	54	210	49	
200*	520	62	420	57	340	52	
400	930	68	750	63	610	58	
500	1100	69	880	64	720	59	
630	1300	70	1030	65	860	60	6
630	1200	70	940	65	800	60	
800	1400	71	1150	66	930	61	
1000	1700	73	1400	68	1100	63	
1250	2100	74	1750	69	1350	64	
1600	2600	76	2200	71	1700	66	
2000	3100	78	2700	73	2100	68	
2500	3500	81	3200	76	2500	71	

Rated power [kVA]	List B _o		List A _o		e _k %
	P _o [W]	L _{wa} [dB]	P _o [W]	L _{wa} [dB]	
50	110	42	90	39	4
100	180	44	145	41	
200*	290	47	240	44	
400	520	53	430	50	
500	610	54	510	51	
630	730	55	600	52	6
630	680	55	560	52	
800	800	56	650	53	
1000	940	58	770	55	
1250	1150	59	950	56	
1600	1450	61	1200	58	
2000	1800	63	1450	60	
2500	2150	66	1750	63	

*Determined by Interpolation.

3.11.3 Tenders submitted shall be based on the capitalisation factors for no-load loss and load loss stated in the invitation to tender⁴.

If the capitalised value of the total losses exceeds the value calculated on the basis of tenders, the purchase price shall be correspondingly reduced. The calculated reduction shall be based on the above-mentioned capitalisation factors. No compensation is made for load and no-load losses lower than those stated.

If a load or no-load loss differs by more than +15%, or the total loss by more than +10% from the loss specified in the tender, the purchaser reserves the right to reject the transformer.

If the purchase covers a batch of transformers, the losses for the individual transformers shall apply.

4. CONSTRUCTIONAL DETAILS

4.1 Tap-changers

The transformer shall be provided with a tap-changer for no-voltage switching between the tappings mentioned in para. 3.6. The tap-changer shall be integrated into the transformer tank. Clockwise turning of the tap-changer shall increase the voltage on the low voltage side.

The tap-changer shall be readily accessible for operation and reading of the step setting, also if the transformer is fitted with high- and low voltage cables. The steps shall be clearly marked with the figures 1, 2, 3, 4 and 5, where 1 indicates connection of the maximum number of primary windings. The tap-changer must not limit the transformer's overload capacity.

4.2 Cooling equipment

The transformer cooling system shall be designed for natural oil and air circulation (ONAN).

⁴See DEFU report RA 532 "Transformere udsat for harmoniske strømme" in Danish.

4.3 Bushings

Bushings may be designed either as insulators or as plug-in systems, but unless otherwise specified in the invitation to tender the insulator type shall be used. Bushings must not limit the overload capacity of the transformer.

Bushings shall be mounted on the transformer cover and shall be designed and positioned according to the following guide lines.

4.3.1. Isolators shall be made of brown porcelain and be suitable for use in a heavily polluted environment. (heavy pollution cf. CENELEC EN 60071-2). Creepage distance to earth shall at least be:

Nominal voltage, U_r [kV]	Creepage distance [mm]
10	280
15	400
20	580

The low voltage insulators shall be designed in accordance with CENELEC EN 50386.

The high voltage insulators shall be designed in accordance with CENELEC EN 50180.

4.3.2. Plug-in systems shall be designed in accordance with CENELEC HD 428.2.2 S1.

4.3.3. Connecting bolts and nuts etc. on the insulators on the high voltage side of the transformer shall be designed according to CENELEC EN 50180.

4.3.4. Connecting bolts and nuts etc. on the insulators on the low voltage side shall be designed according to CENELEC EN 50386. Connecting flanges shall be provided for transformers with a power rating equal to or greater than 500 kVA.

4.3.5. Bushings shall be placed and marked as stated in Appendix B2. Markings shall be weather and oil proof.

The centre distance between the bushings shall at least be:

Nominal voltage, U_r [kV]	Rated power [kVA]	Centre distance [mm]
0.4	≤ 200	70
0.4	$> 200, < 1600$	150
0.4	≥ 1600	165
0.69	≤ 200	70
0.69	$> 200, < 1600$	150
0.69	≥ 1600	165
10	50...2500	265
15	50...2500	265
20	50...2500	265

4.4 Transformer tank etc.

Transformer tank, gaskets, etc. shall be dimensioned so as to ensure that they will remain oil proof and free from permanent deformation at loads within the limits specified in CENELEC EN 60076 - 7.

Corrugated plate cooling radiators with fins more than 100 mm deep shall be supported at the top and bottom.

The transformer shall have two connection points for earth conductors, one on the cover beside the neutral connection on the low-voltage side, the other at the base of the transformer tank. Earthing terminals shall be dimensioned in accordance with CENELEC EN 50216-4. Both points may be made as 35 mm long, M12 earthing screw provided with two nuts, or as a terminal connection for 240 mm² Cu-cable. Screws etc. shall be stainless steel or cuprodur.

4.5 Surface treatment

The design and surface treatment of the transformer shall meet the requirements specified in Appendix B1.

4.6 Dimensions

Unless otherwise specified in the invitation to tender, transformers with bushings designed in accordance with 4.3 shall be dimensioned within the following limits, (see also Appendix B2)

Rated power [kVA]	Length		Width b [mm]	Height			
	a ₁ [mm]	a ₂ [mm]		h ₁ [mm]	h ₂ [mm]	h ₃ [mm]	
			U _r = 10 kV			U _r = 15 And 20 kV	
50	950	-	750	1500	1000	1400	1500
100	1050	-	800	1650	1100	1500	1600
200	1300	-	850	1700	1150	1550	1650
400	1650	1000	900	1900	1350	1750	1850
500	1700	1000	900	1900	1400	1800	1900
630	1800	1050	930	1940	1450	1850	1950
800	1900	1050	1000	2150	1550	1950	2050
1000	2050	1100	1100	2400	1700	2100	2200

(Note! Not all conventional prefabricated substations fit the above dimensions.)

5. ACCESSORIES

The transformer shall be equipped with the accessories described below. If the transformer's oil system is hermetically sealed, items 5.1, 5.2 and 5.3. do not apply.

Accessories shall be in accordance with the relevant part of CENELEC EN 50216.

5.1 Oil conservator

The oil conservator shall be positioned as shown in Appendix B2. Its capacity shall correspond to at least 10% of the oil volume to which it is connected. The capacity of the sump shall be 5...10% of the oil conservator volume. The sump shall be provided with a top cover and drainage system.

In transformers of 50...200 kVA rated power the oil conservator shall be installed along the low-voltage side, at a level above the connecting bolts of the LV bushings. Alternatively, it can be placed at the end of the transformer, cf. Appendix B2. In case of transformers with power ratings equal to or higher than 800 kVA, the oil conservator must be able to be positioned at either end of the transformer. When the oil conservator is removed, the bushings shall be the highest points on the transformer.

The oil conservator shall be equipped with an oil level glass/indicator showing normal oil levels at oil temperatures of -20, 0 and +20 °C. The oil level glass shall be made of a non-flammable material and enable reading both parallel to the oil conservator and at a right angle to the end of the oil conservator. Transformers with a power rating equal to or higher than 500 kVA shall be fitted with an oil level glass/indicator at both ends of the oil conservator, unless the oil conservator can be reversed or the glass/indicator can be transferred from one end to the other.

5.2 Moisture-removing breather

Transformers with a power rating equal to or higher than 1000 kVA shall be able to accommodate a moisture-removing breather. The moisture-removing breather shall be in accordance with CENELEC EN 50216-5.

5.3 Valves

The transformer tank shall be provided with an oil drain outlet designed in accordance with CENELEC EN 50216-4 and placed as low down on the side of the tank as possible. The drainage of transformers rated below 1000 kVA shall be executed through a valve with a 22 mm diameter opening. In the case of transformers with a power rating equal to or higher than 1000 kVA, two valves with 31 mm diameter openings must be positioned at diagonally opposite corners.

5.4 Thermometers and thermometer pockets

The transformer cover shall incorporate a thermometer pocket in accordance with CENELEC EN 50216-4. Transformers with a power rating equal to or higher than 500 kVA must have two thermometer pockets. In transformers provided with a gas cushion the pocket must be long enough to ensure oil immersion. The pocket shall be filled with oil and closed by a pipe stop.

Thermometers shall be fitted with maximum pointers if they are included in the delivery.

5.5 Transport arrangements etc. Transformers shall be provided with rollers for lengthwise transport. Transformers with a power rating equal or higher than 500 kVA shall have hinged rollers that also allow transverse movement.

The rollers shall be in accordance with CENELEC EN 50216-4 and be selected from the table below:

Diameter of roller [mm]	Thickness of roller [mm]	Max. carrying capacity for each roller [t.]
125	40 or 50	2.5
160	50	3.6
200	70	6.3

The distance between the rollers shall be in accordance with CENELEC EN 50216-4 and determined from the table below:

Rated power [kVA]	Distance between rollers (see drawing in Appendix B2) [mm]
$S \leq 250$	520
$250 \leq S \leq 1250$	670
$1250 \leq S \leq 1600$	820
$1600 \leq S \leq 2500$	820 or 1070

Transformers with power ratings equal or higher than 1000 kVA shall be equipped on the base frame with the necessary pulling lugs for transport.

The transformer shall be fitted with lugs or hooks for lifting both the complete, oil-filled transformer as well as the core with cover.

5.7 Oil Unless otherwise specified in the invitation to tender, mineral oil shall be applied.

The oil shall comply with current environmental legislation.

5.8 Marking A climate and oil resistant rating plate shall be placed on the low voltage side. The plates shall show the minimum information specified in CENELEC EN 60076-1, the transformation ratios under no-load conditions and the oil type. In the case of transformers with power ratings equal to or higher than 400 kVA the rating plate must be able to be transferred to any of the transformer's sides.

The following information shall be contained in the rating plate:

- Transformer type
- Reference to standard
- Product name
- Product serial number
- Year of manufacture
- Number of phases
- Rated power
- Rated frequency
- Rated voltages and tapping voltage for the individual tappings.
- Rated current
- Connections
- Short-circuit impedance
- Cooling.
- Total weight
- Weight of insulation oil
- Insulation level

Special requirements:

- Type of insulating oil if different from mineral oil

6. TESTS

The purchaser's approval of a supply is subject to a satisfactory result of the routine tests specified in CENELEC EN 60076-1. Furthermore type tests according to CENELEC 60076-1

for a transformer representative of the transformer type shall be carried out with a satisfactory result.

Special mechanical tests shall be performed for transformers that are completely oil filled with corrugated hermetically sealed transformer tanks. The tests shall be in accordance with CENELEC HD 428.6 and shall be carried out on a transformer representative of the transformer type and to a satisfactory result.

Special tests for documentation of the short-circuit withstand of the transformer cf. CENELEC EN 60076-5 and of the sound power level cf. CENELEC EN 60076-10 shall be performed.

7. DATA TO BE PROVIDED IN INVITATION TO TENDER

Invitations to tender shall contain the following data and particulars:

- Cooling, cf. 4.2
- Rated power, cf. 3.2
- Rated frequency, cf. 3.1
- Rated voltage (primary and secondary), cf. 3.5
- Max. load losses, cf. 3.11.1
- Max. no-load losses, cf. 3.11.2
- Capitalisation factors for load and no-load losses, cf. 3.11.3
- Max. sound power level, cf. 3.11.2
- Highest voltage for windings (primary and secondary). Cf. 3.10
- Insulation level, cf. 3.10
- Tappings, cf. 3.6
- Tap-changer for no-voltage switching, cf. 4.1
- Connections, cf. 3.7
- Method of system earthing for windings (primary and secondary), cf. 1
- Any peculiarities of installation, assembly, transport and handling.
- Special restrictions to dimensions and weight, if any.
- Indications as to where various accessories shall be placed.

Special requirements:

- Short-circuit impedance, cf. 3.8
- Short-circuit power of the system, cf. 3.9.
- Special ambient temperature conditions or restrictions in connection with cooling, if any.
- Contents, if any, of over harmonic components in the load current, cf. 3.2.1
- Whether the transformer shall have a constant reduction ratio or whether there are non-conforming requirements concerning tappings cf. 3.6
- Whether bushings shall be plug-in bushings cf. 4.3
- In case of requirements to surface treatment cf. B1, e.g. whether hot dip galvanising is preferred.
- Requirements to dimensions etc., if any cf. 4.6
- Whether transformer shall be supplied with a lower sound power level cf. 4.7
- Special requirements to the type of oil cf. 5.6
- Whether the transformer shall be supplied with an oil conservator cf. 5.1
- Shall the Moisture-removing breather be included in the supply cf. 5.2
- Shall the transformer be equipped with valves cf. 5.3
- Are thermometer pocket(s) cf. 5.4 dispensable, or shall thermometer(s) be included in the supply.
- Special requirements with regards to transportation rollers.

Commercial information:

- Time of delivery and circumstances of unloading
- Delivery address
- Earliest and latest time of delivery
- Possible term of delivery; unless otherwise specified Carriage Paid to place of delivery (Inco terms 2000)
- Deadline for submission of tender, binding dimensional drawings etc.
- Any requirements in respect of insurance, warranty period, deposits, period for which the tender is open for acceptance, etc.

The commercial terms and conditions should also be expanded further.

8. DATA TO BE PROVIDED IN TENDERS SUBMITTED

Tenders shall contain the following information:

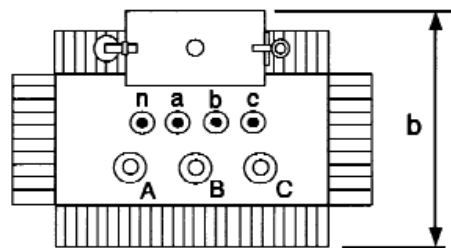
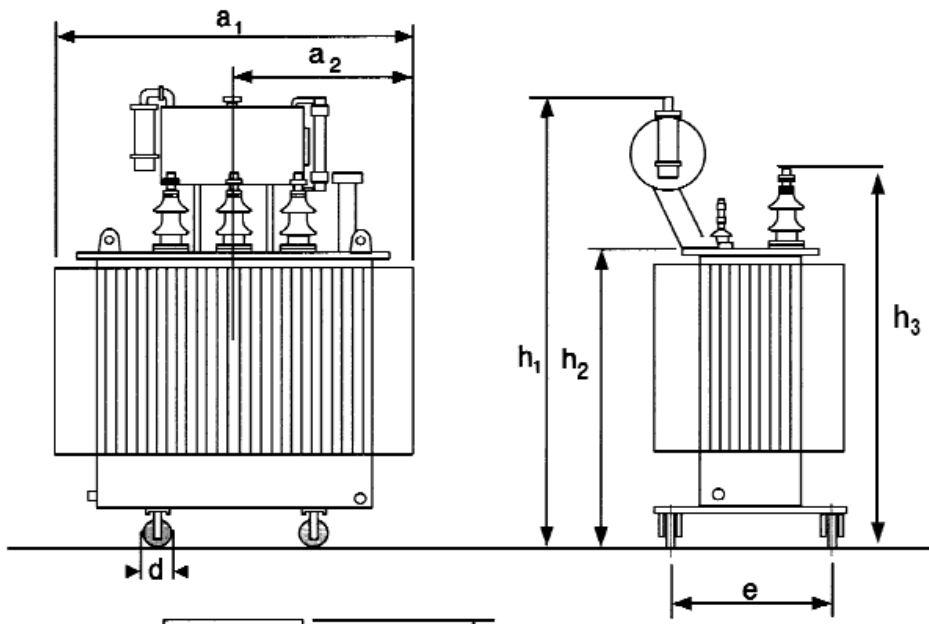
- Price of complete supply.
- Any price adjustments.
- Information in respect of customs duties, VAT and exchange adjustments.
- Terms of payment.
- Guaranteed values for no-load losses and no-load current at rated voltage.
- Guaranteed values for load losses and short circuit impedance at rated transformation ratio and 75 °C reference temperature.
- Guaranteed sound power level.
- Data for bushings, creepage distance and rated current.
- Oil type and inhibitor, if any. If an inhibitor is used, provision of data for the base oil.
- Oil content (kg) and volume.
- Total weight of the transformer.
- For hermetically sealed transformers: whether or not a gas cushion is included.
- For hermetically sealed transformers without a gas cushion: the amount by which the volume of the transformer tank may vary (minimum 10%) without permanent tank deformation. If necessary, the maximum oil temperature should be specified.
- Surface treatment.
- Binding dimensional drawings. Delivery time.
- Warranty period.

In addition, the supplier shall confirm that the requirements specified in the invitation to tender are met. Any deviations shall be detailed.

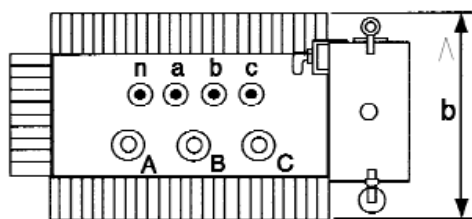
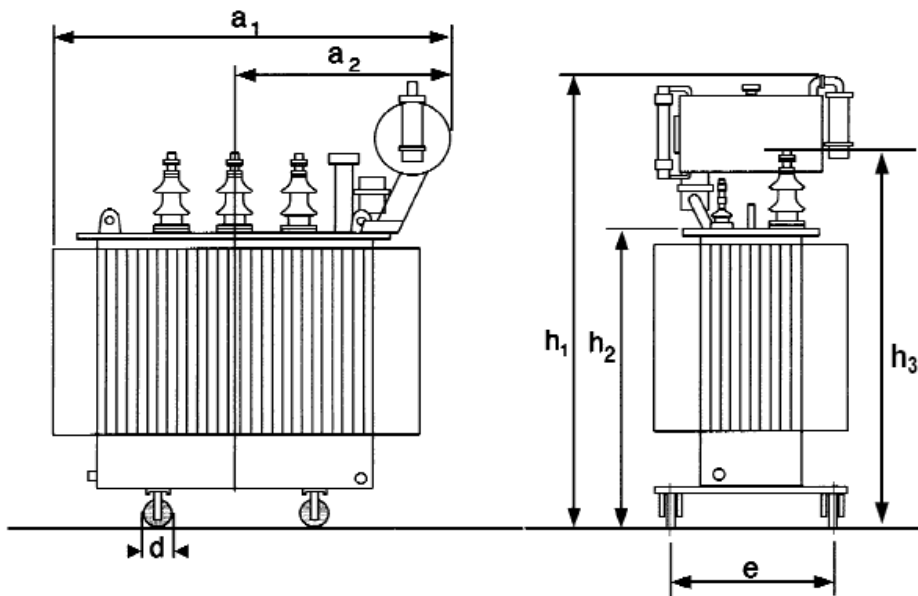
B1. CORROSION PROTECTION

- B1.1** The target service life should be 20 years or more.
- B1.2** An environmental impact corresponding to heavy pollution (heavy pollution cf. CENELEC EN 60071-2).
- B1.3** All structural parts shall be well-drained. Profile and plate edges shall be rounded, $r \geq 2$ mm or half the metal thickness. Welding deposits and protruding surface flaws shall be completely removed.
- All welds shall be fully welded and all welding slag removed before the surface treatment. After welding with coated electrodes, the surface shall be carefully washed with water where subsequent blast-cleaning is to be employed.
- B1.4 Treatment of outer surfaces** The supplier may choose between the following protective systems:
- B2.4.1. Painting
Surface preparation by blast-cleaning corresponding to min. Sa 2 1/2 according to DS/EN ISO 8501-1.
- The surface treatment shall be carried out as follows:
- | | |
|---|--|
| Application of base coat: two-component high-zinc epoxy paint or zinc coating: | min. 50 μm |
| Application intermediate coat: two-component epoxy paint or vinyl or chlorinated-rubber paint | min. 140 μm
min. 160 μm |
| Application of finish coat, on epoxy: two-component polyurethane or vinyl/acrylic enamel | min. 30 μm |
- Finish coat, on thermoplastic intermediate coat: thermoplastic finish coat.
- Alternative paint treatments may be proposed to the purchaser for evaluation and approval.
- Cross-cut test according to DS/EN ISO 2409 shall produce the values Gt 0, Gt 1 or Gt 2. Test requirements shall be met both at the time of delivery and at the end of the warranty period.
- The pinhole rating shall be tested with a low-voltage pinhole detector (9V, wet sponge, see for example DS/R 454). Max. acceptable number of pinholes:
- length of edge 3 pinholes/m length of edge
 - surface 3 pinholes/m² surface
- B2.4.2 Hot dip galvanising according to DS/EN 1461, class B.
- B2.4.3 Where the metal thickness or the design prevents the use of either hot dip galvanising class B or painting according to 4.1, hot dip galvanising according to DS/EN ISO 1461, class C, is preferable to paint treatment. The reasons for any such deviation shall be stated and explained in the tender.
- B1.5** Screws, nuts, washers, etc. shall be made of acid proof stainless steel (AISI 1316). Screw threads shall be rolled. Threads etc. to be greased.
- B1.6** If the supplier offers alternative treatments, the treatments suggested above shall serve as quality references. In general, higher coating thicknesses should be asked for in the case of these alternatives, especially if they do not include a high-zinc base coat. The requirements in respect of pinhole rating and adhesion are the same.
- B1.7 Treatment of inner surfaces** The transformer tank and – if provided – the oil conservator shall be painted on the inside with an oil-proof paint. This also applies to the transformer tank.
- The inside of cooling elements shall be cleaned of rust and welding slag, etc.

Appendix B2. Dimension drawings



a. 50...200 kVA



b. 400 kVA ... 2500 kVA

Note: If the transformer's oil system is hermetically seal h_1 will be equal to h_3 .