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Determination of transformer and reactor sound levels

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British Standard

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Committees responsible for this British Standard

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- Association of Consulting Engineers
- British Cable Makers' Confederation
- British Railways Board
- Electricity Industry in United Kingdom
- Institution of Plant Engineers
- Transmission and Distribution Association (BEAMA)

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Summary of pages

The following table identifies the current issue of each page. Issue 1 indicates that a page has been introduced for the first time by amendment. Subsequent issue numbers indicate an updated page. Vertical sidelining on replacement pages indicates the most recent changes (amendment, addition, deletion).

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Change of identifier

Wherever BS 6056 : 1991 appears in this standard, it should be read as BS EN 60551 : 1993.

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National foreword

This British Standard has been prepared under the direction of the Power Electrical Standards Policy Committee.

It is based on IEC Publication 60551 : 1987 'Determination of transformer and reactor sound levels' published by the International Electrotechnical Commission (IEC) and implements HD 399 S2 of the European Committee for Electrotechnical Standardization (CENELEC). This standard supersedes BS 6056 : 1981, which is withdrawn.

In 1992 the European Committee for Electrotechnical Standardization (CENELEC) accepted IEC 551 : 1987 (modified) as European Standard EN 60551 : 1992. As a consequence of implementing the European Standard this British Standard is renumbered as BS EN 60551 and any reference to BS 6056 should be read as a reference to BS EN 60551.

Amendment 1 to IEC 60551, incorporating further common modifications, was adopted by CENELEC as amendment A1 to EN 60551 in 1997 and was incorporated into this British Standard in 1998.

For ease of reproduction, use has been made of the IEC text where appropriate; consequently some terminology and certain conventions are not identical with those used in British Standards. For the purposes of this British Standard, any references to IEC page numbers in the text should be ignored.

The common modifications to the IEC text contained in EN 60551 have been inserted into the text where applicable and are identified by a line in the left-hand margin.

Cross-references

Details of international standards quoted in this British Standard for which there is an identical or technically equivalent British Standard are given below.

International standard	Corresponding British Standard
IEC 651 : 1979	BS 5969 : 1981 Specification for sound level meters (Identical)
ISO 3746 : 1979	BS 4196 Sound power levels of noise sources Part 6 : 1981 Survey method for determination of sound power levels of noise sources (Identical)

The Technical Committee has reviewed the provisions of IEC Publication 726, to which reference is made in the text, and has decided that they are acceptable for use in conjunction with this standard. A related British Standard to IEC 76-1 : 1976 is BS 171 'Power transformers : Part 1 : 1978 General'. A related British Standard to IEC 289 : 1968 is BS 4944 : 1973 'Specification for reactors, arc-suppression coils and earthing transformers for electric power systems'.

A British Standard does not purport to include all the necessary provisions of a contract. Users of British Standards are responsible for their correct application.

Compliance with a British Standard does not of itself confer immunity from legal obligations.

Descriptors: Power transformers, electric reactors, sound, acoustic measurement

English version

Determination of transformer and reactor sound levels (includes amendment A1 : 1997)

(IEC 551 : 1987 +A1 : 1995, modified)

Détermination des niveaux de bruits des
transformateurs et des bobines d'inductance
(inclut l'amendement A1 : 1997)
(CEI 551 : 1987 +A1 : 1995, modifiée)

Bestimmung der Geräuschpegel von
Transformatoren und Drosselspulen
(enthält Änderung A1 : 1997)
(IEC 551 : 1987 +A1 : 1995, modifiziert)

This European Standard was approved by CENELEC on 15 September 1992. CENELEC members are bound to comply with the CEN/CENELEC Internal Regulations which stipulate the conditions for giving this European Standard the status of a national standard without any alteration.

Up-to-date lists and bibliographical references concerning such national standards may be obtained on application to the Central Secretariat or to any CENELEC member.

This European Standard exists in three official versions (English, French, German). A version in any other language made by translation under the responsibility of a CENELEC member into its own language and notified to the Central Secretariat has the same status as the official versions.

CENELEC members are the national electrotechnical committees of Austria, Belgium, Denmark, Finland, France, Germany, Greece, Iceland, Ireland, Italy, Luxembourg, Netherlands, Norway, Portugal, Spain, Sweden, Switzerland and United Kingdom.

CENELEC

European Committee for Electrotechnical Standardization
Comité Européen de Normalisation Electrotechnique
Europäisches Komitee für Elektrotechnische Normung

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Foreword

At the request of CENELEC Technical Committee TC 14, Power transformers, HD 399 S2 : 1991 (IEC 551 : 1987, modified) was submitted to the CENELEC voting procedure for conversion into a European Standard.

The text of the International Standard together with the common modifications accepted for HD 399 S2 : 1992 was approved by CENELEC as EN 60551 on 15 September 1992.

The following dates were fixed:

- latest date of publication of an identical national standard (dop) 1993-09-01
- latest date of withdrawal of conflicting national standards (dow) 1993-09-01

Annexes designated 'normative' are part of the body of the standard. In this standard, annex ZA is normative.

Foreword to amendment A1

The text of amendment 1 1995 to the International Standard IEC 60551 : 1987, prepared by IEC TC 14 'Power transformers', together with the common modifications prepared by the Technical Committee CENELEC TC 14 'Power transformers', was submitted to the formal vote and was approved by CENELEC as amendment A1 to EN 60551 : 1992, on 1997-03-11.

In this amendment to EN 60551 the common modifications to the amendment to the International Standard are indicated by a vertical line in the left margin of the text.

The following dates were fixed:

- latest date by which the amendment has to be implemented at national level by publication of an identical national standard or by endorsement (dop) 1997-12-01
- latest date by which the national standards conflicting with the amendment have to be withdrawn (dow) 1997-12-01

Annexes designated "normative" are part of the body of the standard.

In this standard, annexes A, B, C and ZA are normative.

Annex ZA has been added by CENELEC.

DETERMINATION OF TRANSFORMER AND REACTOR SOUND LEVELS

1. Scope

This standard defines the methods by which the sound levels of transformers, reactors and their associated cooling equipment shall be determined so that compliance with any specification requirements may be confirmed and the characteristics of the noise emitted in service determined.

This standard is intended to apply to measurements made in the manufacturer's works since conditions may be very different when measurements are made on site because of the proximity of other objects, background extraneous noises, etc. Nevertheless, the same general rules as are given herein may be followed when on-site measurements are made.

Standard measurements use the A-weighted sound pressure level as a measured variable. In case of difficult measuring conditions, sound intensity measurements are advantageous

Because of some deviations in the determination of the sound power level value, depending on the type of measurement (sound pressure or sound intensity), the procedure should be agreed upon between manufacturer and purchaser at the time of placing the order. The application of sound intensity measurement is described in annex B.

According to this standard, measurements on transformers are made under no-load. If a transformer has a very low no-load noise, for example in the case of extremely low induction designs, the noise due to load current can also influence the sound level. Annex C specifies the measurement conditions for the determination of the noise due to load current.

In those cases where sufficient power is available in the factory to permit full energization of reactors, the methods to be followed are the same as for transformers. Such measurements shall be made by agreement between the manufacturer and the purchaser. Alternatively, measurements may be made on site where conditions are suitable.

The methods are applicable to transformers and reactors covered by IEC Publications 76, 726 and 289, without further limitation as regards size or voltage and when fitted with their normal auxiliary equipment, inasmuch as it may influence the measurement result.

Although the following text refers only to transformers, it is equally applicable to reactors provided that it is recognized that the current taken by a reactor is dependent on the voltage applied and, consequently, that a reactor cannot be tested at no-load.

This standard provides a basis for calculation of sound power levels.

The methods of measurement and the environmental qualification procedure given in Appendix A are in accordance with ISO Standard 3746. Measurements made in conformity with this IEC standard tend to result in standard deviations which are equal to or less than 3 dB.

2. Definitions

For the purpose of this standard, the following definitions apply.

2.1 Sound pressure level, L_p

The value in decibels equal to twenty times the logarithm to the base of 10 of the ratio of the sound pressure to the reference sound pressure.

Note. — For the purposes of this standard, A-weighted values of L_p are used, i.e., L_{pA} = A-weighted sound pressure level, and the reference sound pressure is 20 μ Pa.

2.2 A-weighted surface sound pressure level, $\overline{L_{pA}}$

The A-weighted sound pressure level in decibels averaged over the measurement surface as required in Clause 6.

2.3 Sound power level, L_W

The value in decibels equal to ten times the logarithm to the base 10 of the ratio of a given sound power to the reference sound power.

Note 1. — For the purposes of this standard, A-weighted values of L_W are used, i.e. L_{WA} = A-weighted sound power level, and the reference sound power is 1 pW (10^{-12} W).

Note 2. — If the A-weighted sound power level is determined by sound intensity measurements, it is designated L_{WA1} . See annex B.

2.4 Sound spectrum

The distribution of sound levels within the frequency range of interest. It is usually obtained as measurements of sound pressure levels in sequential frequency bands, e.g. in octave, third octave or narrow bandwidths.

Note — A method for determining the sound spectra is given in note 4 to subclause 5.2.

2.5 Principal radiating surface

A hypothetical surface surrounding the transformer or cooling equipment which is assumed to be the surface from which sound is radiated.

Note. — The method of determining the principal radiating surface for particular equipment is given in Sub-clause 5.2.

2.6 Prescribed contour

A horizontal line, spaced at a definite distance from the principal radiating surface, along which the measuring positions are located.

Note. — The method for determining the prescribed contour for particular equipment is given in Sub-clause 5.2.

2.7 Measurement surface

A hypothetical surface of area S which envelops the source and on which the measuring positions are located.

Note. — The methods for the determination of this area are given in Sub-clause 6.2.

2.8 Measurement distance

The distance between the principal radiating surface and the measurement surface.

2.9 Background noise

The A-weighted sound pressure level at each measuring position with conditions as given in Sub-clause 5.1, the test object being inoperative.

3. Instruments

Measurements shall be made using a Type 1 sound level meter complying with IEC Publication 651.

An acoustic check of the measuring equipment using a calibrated noise source shall be made immediately before and after the measurement sequence.

The instruments shall be calibrated in accordance with ISO Standard 3746.

4. Conditions for measurement

4.1 *Criteria for adequacy of the test environment*

Ideally, the test environment should be free from reflecting objects other than a reflecting floor so that the equipment under test radiates into a free field over a reflecting plane. Test environments that are suitable for measurements according to this standard are those which meet the qualification procedures of Appendix A.

4.2 *Operating conditions of equipment during measurement*

For measurements made on the transformer with or without its auxiliary cooling plant, the transformer shall be on no-load and excited at rated voltage of sinusoidal or practically sinusoidal waveform and rated frequency with the tap-changer (if any) on the principal tapping. The voltage shall be measured in accordance with Sub-clause 8.5 of IEC Publication 76-1.

If the transformer is fitted with reactor-type on-load tap-changer equipment and the reactor may, on certain tap-change positions, be permanently energized, the measurements shall be made with the transformer on a tapping which involves this condition and as near as possible to the principal tapping. The excitation voltage shall be appropriate to the tapping in use.

Notes 1. – Under special conditions of intended application of the transformer (particularly under variable flux voltage variation) it may be agreed to measure the sound levels on a tapping other than the principal tapping (or with a voltage other than the rated voltage on an untapped winding). This should then be clearly indicated in the report of sound level measurement.

2. – If the supply is suddenly applied to the unit under test, it is advisable to delay noise measurements on large transformers for some minutes after the instant of switching.

4.3 *Quantities to be measured*

The A-weighted sound pressure levels shall be measured for the transformer and the background noise sources. To avoid measurement errors due to disturbing influences, the fast response indication of the meter shall be used.

5. Measurement of sound pressure levels

5.1 *Background noise measurement*

The A-weighted sound pressure level of the background noise shall be measured immediately before and after the measurement on the transformer.

If the background sound pressure level is clearly much lower than the combined level of the background and transformer (difference not less than 10 dB), measurements of background noise may be made at only one of the measuring positions and no correction of the measured sound level of the equipment is necessary.

If the background sound pressure level is such that the difference in dB, between the combined sound pressure level of the transformer plus the background and the background sound pressure level alone, is less than 10 dB but not less than 3 dB, the corrections shown in Sub-clause 5.3, Table I shall be applied. In such cases, the background level shall be determined at every measuring position.

Note 1. – When the total number of measuring positions exceeds 10, it is permissible to measure the background sound pressure level at only 10 positions equally distributed around the transformer.

If the difference is less than 3 dB, the test will not be valid unless the combined level of the background and transformer noise is less than the guaranteed value. In such a case, the lower value for this difference will be taken and the combined level minus 3 dB may be regarded as the upper value of the sound pressure level of this position. This condition shall be recorded in the test report.

Note 2. — While the present standard permits a small difference between the background noise level and that resulting from the combination of the equipment and background noise, every effort should be made to obtain a difference of at least 6 dB.

The height(s) of the microphone(s) during the background noise measurements shall be the same as for the measurements of the noise of the transformer and the background measurements shall be taken at points on the prescribed contour(s).

5.2 Sound pressure level measurements for the transformer

The following measurement methods cover the different types of cooling employed, depending on whether the coolers are less than or more than 3 m away from the principal radiating surface of the main tank. They also permit the sound power level of the complete equipment to be calculated.

While the text of Sub-clauses 5.2.2 and 5.2.3 refers only to air cooling, the same principles as set out therein apply to measurements on transformers equipped with water coolers.

Notes 1. — In the case of certain equipment, it may be necessary to apply test specifications (height of the prescribed contour and its distance to the object to be tested) different from those indicated hereafter.

These test specifications should be according to the relevant standards if any, or be subject to agreement between manufacturer and purchaser.

In the case of transformers with horizontal high-voltage bushings, the contour used has to be determined by safety considerations. This may be achieved by confining the contour to the safe zone. (See Sub-clause 6.2, *e*.)

2. — With the use of storage type measuring equipment with an averaging device and thereby shorter measuring and recording times, the microphone can be moved with constant speed on the prescribed contour around the transformer and/or cooling equipment for determining an averaging record of the measurements for the determination of the sound pressure level. The number of recorded readings shall be not less than the number of measuring positions specified herein.

3. — In the figures showing typical microphone positions the spacing between measuring positions is indicated by *D*.

4. — When required, the sound pressure level spectrum may also be obtained from measurements made in accordance with subclauses 5.2.1 to 5.2.4 as appropriate in octave, third octave or narrow band band widths. The sound pressure level spectra obtained at each measuring position may then be evaluated as sound power level spectra by using the procedure in clause 6.

The measurement bandwidth, i.e. octave, third octave or narrow band, is subject to agreement between the manufacturer and the purchaser. Sound spectra having small band widths, e.g. ≤ 5 Hz, are particularly advantageous if the sound pressure level of the transformer is not very much higher than the background level.

From narrow band measurements at frequencies of twice the network frequency and its multiples, spectrum sound power levels L_{WAj} may be calculated. The A-weighted sound power level L_{WA} of the transformer in decibels is then determined by using the following equation:

$$L_{WA} = 10 \log_{10} \left[\sum_{j=1}^{j=Nf} 10^{0,1 L_{WAj}} \right]$$

where:

L_{WA} = A-weighted sound power level, in decibels – Reference 10^{-12} W

L_{WAj} = A-weighted sound power level at the j^{th} measuring frequency

N_f = Total number of measuring frequencies

This same equation applies to the calculation of L_{WA} from measurements taken at the centre frequencies of octave or third octave band widths.

5.2.1 *Transformers having no forced air cooling auxiliaries or with forced air cooling auxiliaries mounted on a separate structure spaced not less than 3 m away from the principal radiating surface of the main tank. Dry-type transformers in enclosures and dry-type transformers with forced air coolers inside the enclosure*

Measurements on the transformer only are to be made in accordance with this Sub-clause 5.2.1; those on any forced air cooling auxiliaries are to be made in accordance with Sub-clause 5.2.3 below.

The principal radiating surface is the surface obtained by the vertical projection, from the top of the transformer tank cover (excluding bushings, turrets and other accessories situated above the tank cover) to the base of the tank, of a string contour encircling the transformer. (See Figure 1, page 28.) The principal radiating surface shall include cooling equipment attached to the tank, tank stiffeners and such auxiliary equipment as cable boxes, tap-changer, etc., and exclude any forced air cooling auxiliaries. Projections such as bushings, oil pipework, oil conservators, tank underbase, valves and other secondary elements shall also be excluded.

The prescribed contour shall be spaced 0.3 m away from the principal radiating surface as defined above.

For transformers with a tank height less than 2.5 m, the prescribed contour shall be on a horizontal plane at half the tank height.

For transformers with a tank height equal to or greater than 2.5 m, two prescribed contours shall be used which are on horizontal planes at one-third and two-thirds of the tank height.

Because of the distance between the prescribed contour and the forced air cooling auxiliaries, no account need be taken of the proximity of such auxiliaries when arranging the measuring positions. Any oil circulating pumps and forced air cooling equipment shall be out of service during the measurements on the transformer.

The measuring positions shall be approximately equally spaced and not more than 1 m apart with a minimum number of six (see Figure 1, page 28).

5.2.2 *Transformers having forced air cooling auxiliaries or water cooling equipment mounted either directly on the tank or on a separate structure spaced less than 3 m away from the principal radiating surface of the main tank (see note below)*

Two sets of measurements shall be made, both with the transformer energized:

- 1) with the forced air cooling equipment and any oil circulating pumps out of service; and
- 2) with the forced air cooling equipment and any oil circulating pumps in service.

The principal radiating surface is the surface obtained by the vertical projection from the top of the transformer tank cover (excluding bushings, turrets and other accessories situated above the tank cover, see Figure 1) to the base of the tank, of a string contour encircling the apparatus. The principal radiating surface shall include the forced air cooling auxiliaries, tank stiffeners and such auxiliary equipment as cable boxes, tap-changer, etc.

Projections such as bushings, oil pipework, oil conservators, tank or cooler underbases, valves, control cubicles and other secondary elements shall be excluded.

For the purpose of measurements 1), the prescribed contour shall be spaced 0.3 m away from the principal radiating surface. For the purpose of measurements 2), the prescribed contour shall be spaced 2 m away from the principal radiating surface. (See distance *X* in Figures 2 and 3, pages 29 and 30).

For transformers with a tank height less than 2.5 m the prescribed contour shall be on a horizontal plane at half the tank height.

For transformers with a tank height equal to or greater than 2.5 m, two prescribed contours shall be used which are on horizontal planes at one-third and two-thirds of the tank height.

The measuring positions shall be approximately equally spaced and not more than 1 m apart, with a minimum number of 10 (see Figure 2, for transformers having forced air cooling auxiliaries mounted on the tank and Figure 3 for transformers having these auxiliaries mounted on a separate structure. Figures 7 and 8 apply to large power transformers constructed for Schnabel-car transportation — self supporting tank — with integrated forced air cooling, equipped with large sound absorbers. Said figures 7 and 8 show the typical microphone positions for noise measurement).

Notes 1. — Where the transformer is designed and intended for enclosure and the cooler, external to the enclosure, is spaced less than 3 m away from the transformer, then the procedure given in Sub-clauses 5.2.1 and 5.2.3 should be followed.

2. — If, in large power transformers constructed for Schnabel-car transportation, very long (up to ca. 1.5 m) sound absorbers are installed to reduce fan noise, the clearances between measuring positions and absorber openings are so small that the sound pressure level measured in this region, when fans are operating, will be too high.

It is therefore necessary for sound measurements made at 2 m from the principal radiating surface and fans in operation, to consider the sound absorbers as an integral part of the cooling equipment and correspondingly choose the principal radiating surface according to figure 8.

5.2.3 *Forced air cooling auxiliaries or water cooling equipment mounted on a separate structure spaced not less than 3 m away from the principal radiating surface of the transformer*

These measurements are in addition to those made on the main equipment. They shall be made with the transformer unenergized and with all forced air cooling equipment and oil circulating pumps in operation. These measurements shall be regarded as additional requirements, unless otherwise specified, since it is often not the practice to erect separate cooling equipment at the manufacturer's works except when temperature-rise tests are being made on the main equipment.

The principal radiating surface is the surface obtained by the vertical projection from the top of the cooler structure to the base of the active parts (see Figure 4, page 31) of a string contour encircling the apparatus but excluding oil conservators, framework, pipework, valves and other secondary elements.

The prescribed contour shall be spaced 2 m away from the principal radiating surface as defined above.

For cooler structures with an overall height less than 4 m (excluding oil conservators, pipework, etc.), the prescribed contour shall be on a horizontal plane at half the height. For cooler structures with an overall height (excluding oil conservators, pipework, etc.) equal to or greater than 4 m, two prescribed contours shall be used which are on horizontal planes at one-third and two-thirds of the height.

The measuring positions shall be approximately equally spaced and not more than 1 m apart, with a minimum number of 10 (see Figure 5, page 32).

5.2.4 *Dry-type transformers without enclosures*

The principal radiating surface is the surface obtained by the vertical projection from the top of the transformer structure to the base of the active parts (see Figure 6, page 33) of a string contour encircling the dry-type transformer excluding framework, external wiring and connections and attached apparatus not affecting the sound radiation.