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Détermination des niveaux de bruit des transformateurs
et des bobines d'inductance

Determination of transformer and reactor sound levels

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INTERNATIONAL ELECTROTECHNICAL COMMISSION

**DETERMINATION OF TRANSFORMER
AND REACTOR SOUND LEVELS**

FOREWORD

- 1) The formal decisions or agreements of the IEC on technical matters, prepared by Technical Committees on which all the National Committees having a special interest therein are represented, express, as nearly as possible, an international consensus of opinion on the subjects dealt with.
- 2) They have the form of recommendations for international use and they are accepted by the National Committees in that sense.
- 3) In order to promote international unification, the IEC expresses the wish that all National Committees should adopt the text of the IEC recommendation for their national rules in so far as national conditions will permit. Any divergence between the IEC recommendation and the corresponding national rules should, as far as possible, be clearly indicated in the latter.

PREFACE

This standard has been prepared by IEC Technical Committee No. 14: Power transformers.

The text of this standard is based on the following documents:

Six Months' Rule	Report on Voting	Two Months' Procedure	Reports on Voting
14(CO)58	14(CO)66	14(CO)67 14(CO)68	14(CO)69 14(CO)70

Full information on the voting for the approval of this standard can be found in the Voting Reports indicated in the above table.

The following IEC publications are quoted in this standard:

Publications Nos. 76: Power transformers.
76-1 (1976): Part 1: General.
289 (1968): Reactors.
651 (1979): Sound level meters.
726 (1982): Dry-type power transformers.

Other publication quoted:

ISO Standard 3746 (1979): Acoustics – Determination of sound power levels of noise sources – Survey method.

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.

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. — 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).

2.4 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.

2.5 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.

2.6 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.

2.7 Measurement distance

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

2.8 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 test report.

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 the energy average 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*.

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).

Note. — 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.

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.

The prescribed contour shall be spaced 0.3 m away from the principal radiating surface as defined above unless for safety reasons 1 m is chosen. The measuring positions shall be approximately equally spaced and not more than 1 m apart with a minimum number of six (see Figure 6).

5.3 *Corrections for background noise*

The sound pressure levels recorded at each of the measuring positions according to Sub-clause 5.2 shall be corrected for the influence of background noise according to Table I.

The background noise is measured according to Sub-clause 5.1.

TABLE I
Correction for influence of background noise

Difference between sound pressure level measured with the equipment operating and background sound pressure level alone	Correction to be subtracted from sound pressure level measured with the equipment operating to obtain sound pressure level due to the equipment
dB	dB
3	3
4-5	2
6-8	1
9-10	0.5

6. Calculation of surface sound pressure level and sound power level

6.1 Calculation of surface sound pressure level

An A-weighted surface sound pressure level, $\overline{L_{pA}}$, shall be calculated from the measured values of the A-weighted sound pressure level, L_{pAi} (after corrections are applied according to Sub-clause 5.3, Table I, if necessary) by using the equation:

$$\overline{L_{pA}} = 10 \log_{10} \left[\frac{1}{N} \sum_{i=1}^N 10^{0.1 L_{pAi}} \right] - K \quad (1)$$

where:

$\overline{L_{pA}}$ = A-weighted surface sound pressure level, in decibels—Reference: 20 μ Pa

L_{pAi} = A-weighted sound pressure level at the i^{th} measuring position corrected for the background noise according to Table I, in decibels—Reference: 20 μ Pa

N = Total number of measuring positions

K = Environmental correction to account for the influence of reflected sound, in decibels. The procedure for the calculation is given in Appendix A

The environmental correction K typically ranges from 0 dB (for measurements outdoors) to more than 10 dB for measurements indoors in highly reverberant rooms.

For the purposes of this standard, the maximum allowable value of the environmental correction K is 7 dB.

Notes 1. — To get the A-weighted surface sound pressure level $\overline{L_{pA}}$ it is also possible to correct the energy average of the measured values according to Sub-clause 5.2 with respect to the energy average of the background noise level according to Sub-clause 5.1. The correction for the environmental influence is made as shown in equation (1).

2. — When the range of values of L_{pAi} does not exceed 5 dB, a simple arithmetical average may be used. This average will not differ by more than 0.7 dB from the value calculated using equation (1).
3. — Due to the specific harmonic tone-content of transformer noise it is possible that standing waves may be an additional influence of the environment on measured sound pressure levels (L_{pAi}). In this case the application of a single correction factor does not suffice. Therefore the measurements should be performed, whenever possible, in surroundings where "environmental-influence" correction is not necessary.

6.2 Calculation of the area of the measurement surface

- a) Measurements on transformers energized and forced air cooling auxiliaries unenergized, as indicated in Sub-clauses 5.2.1, 5.2.2 1) and 5.2.4 made at 0.3 m from the principal radiating surface.

The area S of the measurement surface, expressed in square metres, is calculated by the formula:

$$S = 1.25 h l_m \quad (2)$$

where:

h = height in metres of the transformer tank, or alternatively the height of the core and its framework in the case of dry-type transformers without enclosures

l_m = length of the prescribed contour in metres

1.25 = empirical factor intended to take account of the sound energy radiated by the upper part of the transformer or coolers

- b) Measurements on transformers energized with forced air cooling auxiliaries also energized, as indicated in Sub-clause 5.2.2 2), made at 2 m from the principal radiating surface.

The area S of the measurement surface, expressed in square metres, is calculated by the formula:

$$S = (h + 2) l_m \quad (3)$$

where:

h = height of the transformer tank, in metres

l_m = length of the prescribed contour, in metres

2 = measurement distance, in metres

- c) Measurements on forced air cooling auxiliaries mounted separately from the transformer, as indicated in Sub-clause 5.2.3, made at 2 m from the principal radiating surface.

The area S of the measurement surface, expressed in square metres, is calculated by the formula:

$$S = (H + 2) l_m \quad (4)$$

where:

H = height of the cooling equipment, including fans, in metres (see Fig. 4, page 31)

l_m = length of the prescribed contour, in metres

2 = measurement distance, in metres

- d) Measurements on dry-type transformers energized as indicated in Sub-clause 5.2.4, made at 1 m from the principal radiating surface.

The area S of the measurement surface, expressed in square metres, is calculated by the formula:

$$S = (h + 1) l_m \quad (5)$$

where:

h = height of core with framework, in metres

l_m = length of the prescribed contour, in metres

1 = measurement distance, in metres

- e) Measurements on transformers where safety clearance considerations require a measurement distance which for all or part of the prescribed contour exceeds the provisions of Items a) to d) above.

The area S of the measurement surface, expressed in square metres, is calculated by the formula:

$$S = \frac{3}{4\pi} l_m^2 \quad (6)$$

where:

l_m = length of the prescribed contour, in metres, as dictated by safety clearances

6.3 Calculation of sound power level

The A-weighted sound power level of the equipment L_{WA} shall be calculated from the equation:

$$L_{WA} = \overline{L_{pA}} + 10 \log_{10} \frac{S}{S_0} \quad (7)$$

where:

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

S = area of the measurement surface, in square metres—Reference: $S_0 = 1 \text{ m}^2$

For transformers with forced air cooling equipment mounted directly on the tank (see Sub-clause 5.2.2), the sound power level of the cooling equipment L_{WA0} in decibels is:

$$L_{WA0} = 10 \log_{10} (10^{0.1 L_{WA1}} - 10^{0.1 L_{WA2}}) \quad (8)$$

where:

L_{WA1} = sound power level of the transformer + cooling equipment in decibels (see Sub-clause 5.2.2)

L_{WA2} = sound power level of the transformer in decibels (see Sub-clause 5.2.1)

Note. — If the sound power levels of the individual fans and pumps of a cooling equipment according to Sub-clause 5.2.3 are known, the total sound power of the cooling equipment can be obtained by adding together the individual values on an energy basis (analogous to equation (1)). This method of determining the sound power level of cooling equipment is subject to agreement between manufacturer and purchaser.