

COOLING TECHNOLOGY INSTITUTE

TEST CODE FOR MEASUREMENT OF SOUND FROM WATER-COOLING TOWERS



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This guideline document summarizes the best current state of knowledge regarding the specific subject. This document represents a consensus of those individual members who have reviewed this document, its scope and provisions. It is intended to aid all users or potential users of cooling towers.

Approved by the CTI Executive Board.



This document has been revised and approved as part of CTI's Five Year Review Cycle. This document is again subject to review in 2019.

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CTI Executive Board

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Test Code for Measurement of Sound From Water-Cooling Towers

Section 0. Preamble

There are two fundamental reasons to measure sound emissions from a cooling tower.

- (1) To determine compliance with occupational safety regulations. This requires the measurement of maximum sound pressure levels at near-field locations typically accessed by plant personnel
- (2) To predict the contribution of cooling tower sound to the overall sound level from a facility at distant locations in the far-field. Such locations are typically plant boundaries, residential area boundaries, dwellings, etc.

Since measurements in the far-field typically pose difficulties in resolving differences between the sound contributions from various sources and determination of background levels, resolution of contractual guarantees may be impossible based on far field measurements. The interest of the end user is best served by specifying sound levels near the tower and testing in that manner, such that outside influences are substantially reduced or avoided.

The determination of large cooling tower contributions to far field sound pressure levels should be accomplished by carrying out near field sound pressure level measurements followed by the computation of major source (fan outlet, air inlet, etc.) sound power levels. Therefore the cooling tower sound level guarantee should be the near-field sound pressure levels.

Section 1. Purpose of the Test Code

The purpose of this code is to provide standard test procedures for measuring the near-field air borne sound from water-cooling towers with reproducible and consistent results. The results obtained can be used to demonstrate compliance with the guarantees offered by the manufacturer, compliance with noise safety ordinances, and as a basis to compare vendor offerings.

Different protocols are provided for both small and large towers. Section 8.0 Sound Measurements on Small Towers provides a methodology to determine free-field sound pressure levels and sound power calculations following a relatively simple protocol. Section 9.0 Sound Measurements for Large Towers provides two procedures, one for the determination of sound pressure levels affecting worker exposure and a second for determining partial sound powers and calculation of total sound power for large towers.

The choice of which measurement procedure is to be used shall be made by mutual agreement of the parties prior to the test.

Section 2. Scope

This code applies to wet and wet/dry (parallel path), open and closed circuit cooling towers, mechanical or natural draft. The equipment being tested is the cooling tower consisting of the structure (individual cell or tower) with the heat exchange surface, water distribution and collection system, and mechanical equipment in the case of a mechanical draft tower. If other sound producing equipment must be included in or excluded from the equipment being tested, particular reference shall be made to this effect in the test protocol and in the test report.

Section 3. Test Requirement

The test shall be conducted by a CTI Licensed Test Agency or other independent agency mutually acceptable to the parties to the test. For compliance testing, the authorized representatives of the manufacturer shall be invited to witness the test. For compliance tests, the manufacturer shall be given

permission to inspect the tower in advance and prepare it for the test. In no case shall any directly involved party be barred from the test site. Compliance test(s) shall be conducted within 18 months after structural completion of the tower, unless otherwise stipulated by contractual agreement of owner and manufacturer.

3.1 Flexibility. It is recognized that the data limitations specified throughout this test procedure represent desired conditions that may not exist at the time the test is performed. In such cases, existing conditions may be used if mutually agreed upon by authorized representatives of the manufacturer, the purchaser, and the test agency, prior to the test.

3.2 Impartial Testing Service It is the intention of the Cooling Technology Institute that independent third-party compliance tests are provided, whether by CTI Licensed or other independent testers. This means that any situation in which the testing agency has a material or any other interest in the outcome of the test must be avoided. The test agency referred to in this Code shall have no connection with the manufacturer, the purchaser or the Cooling Technology Institute, other than a contractual agreement with the latter, unless mutually agreed by the parties to the test.

3.2.1 Certain categories of business interests or activities may compromise the objectivity of an agency and are considered by CTI as inappropriate for an organization providing impartial testing services. When any portion of the revenues of a testing agency or any of its corporate parents or subsidiaries is derived from these interests or activities, this will preclude that organization from consideration. The following is a non-exclusive listing of examples of these categories of business interest or activities:

- a) The manufacture, repair, replacement or upgrade of cooling towers or cooling tower components.
- b) Operation or ownership of cooling towers related to primary income generating processes.

3.2.2 Further, any specific situation in which the testing agency can be said to have an interest in the outcome of a particular test is considered a conflict of interest and is to be avoided. The following is a non-exclusive listing of examples of such situations:

- a) Performing cooling tower design, engineering, construction or related consultation services, such as bid evaluation, for a party to a particular test (for the purpose of this paragraph, operation and maintenance recommendations do not constitute "related consultation services").
- b) Engaging in a contractual or business relationship with the cooling tower manufacturer, constructor or supplier of components or equipment on a particular tower to be tested. A conflict of interest shall not exist if the testing agency has conducted independent testing of other cooling towers for cooling tower owners, manufacturers, constructors or suppliers of components and equipment.

Section 4. Relevant Standards

4.1 Normative Standards Listed here are the standards, handbooks, and other publications essential to the implementation of this standard. All references listed here are part of this standard.

- ANSI S1.4-1983, (R2006) with Amd.S1.4A-1985 Specification for Sound Level Meters
- ANSI S1.11-2004 (R2009) Specification for Octave-Band and Fractional-Octave-Band Analog and Digital Filters.
- ANSI S1.40-2006, Specification for Acoustical Calibrators.
- ANSI S1.43-1997 (R2007) Specification for Integrating-Averaging Sound Level Meters
- ANSI S12.54-2011 / ISO 3744:2010, Determination of Sound Power Levels of Noise Sources for Essentially Free-Field Conditions over a Reflecting Plane.
- CTI ATC-105, Acceptance Test Code for Water Cooling Towers, February 2000

- CTI BUL-109 Nomenclature, 1997
- IEC 61672-1 Ed. 1.0 b:2002 Electroacoustics – Sound Level Meters – Part 1: Specifications
- IEC 61672-2 Ed. 1.0 b:2003 Electroacoustics – Sound Level Meters –Part 2: Pattern Evaluation Tests
- IEC 60942 (2003-01), Sound Calibrators.

4.2 Informative Standards Listed here are the standards, handbooks, and other publications which may provide useful information and background but are not considered essential or part of this standard.

General Reference

- ANSI S1.6-1984 (R2011), Preferred Frequencies, Frequency Levels, and Band Numbers for Acoustical Measurements.
- ANSI S1.13-2005 (R2010) Measurement of Sound Pressure Levels in Air. (Note: for SPL only, not for measuring PWL)
- IEC 61260 (1995-08), Electroacoustics - Octave-band and fractional-octave-band filters.
- ISO 266:1997, Acoustics -- Preferred Frequencies.
- ISO 1683:2008, Acoustics--Preferred Reference Quantities for Acoustic Levels.
- ISO 3740-2000, Determination of Sound Power Level of Noise Sources - Guidelines for the Use of Basic Standards
- ISO 3746:2010: Acoustics – Determination Of Sound Power Levels And Sound Energy Levels Of Noise Sources Using Sound Pressure - Survey Method Using An Enveloping Measurement Surface Over A Reflecting Plane
- DIN 45635-46:1985, Measurement of noise emitted by machines; airborne noise emission; enveloping surface method; cooling towers

Propagation Standards

- ANSI S1.26-1995 (R2009) Method for Calculation of Absorption of Sound by the Atmosphere
- ANSI S12.8-1988 (R2008) Methods for Determining the Insertion Loss of Outdoor Noise Barriers
- CONCAWE Report 4/81 – The propagation of Noise from Petroleum and Petrochemical Complexes to Neighboring Communities
- EEMUA Publication No. 140 – Noise Procedure Specification
- VDI 2714 – Outdoor Sound Propagation
- ANSI/AHRI 275-2010 – Application of Outdoor Unitary Equipment A-Weighted Sound Power Ratings
- ISO 9613-1:1993 Acoustics – Attenuation of sound during propagation outdoors – Part 1: Calculation of the absorption of sound by the atmosphere
- ISO 9613-2:1996 Acoustics – Attenuation of sound during propagation outdoors – Part 2: General Method of Calculation

Section 5. Definitions

5.1 Terms in this document follow the standard industry definitions in the current edition of *CTI BUL-109, Nomenclature* unless otherwise provided in this section.

Air Inlet Surface is a plane, located at the outermost edge of the tower, through which air enters the tower. For example, the outer edge of the air inlet face is at the perimeter columns when louvers are not present, or the outer tip of the louvers when they are present, or the outer edge of attenuators, if so equipped.

Base Level is the underside of towers located at or above grade, and is the bottom of the air inlet for towers with cold water basin floor below grade.

Background Noise is any noise not generated by the tower under test or that is directly emitted by attached components that do not belong to the object under test.

Characteristic Dimension, D_o , is a geometric dimension specific to the equipment to be tested. It is used to differentiate between large towers and small towers and between near-field and far-field. D_o is the square root of the sum of the squares of half the tower short axis dimension, w_T , half the tower long axis dimension, l_T and the tower height, h_T :

$$D_o = [(w_T/2)^2 + (l_T/2)^2 + h_T^2]^{0.5} \quad (1)$$

Decibel is defined as 10 times the base 10 logarithm of a ratio of two quantities, one of which is usually a reference quantity. Decibel is denoted as **dB** and sound in decibels is often referred to as a **level**. A sound level in dB is calculated as follows:

$$\text{level} = 10 \log_{10} (\text{quantity} / \text{reference quantity}) \quad (2)$$

Directivity is a quality of the noise source relating to the amount to which it does not emit noise uniformly in all directions. A perfect source that emits the same noise in all directions would have no directivity. Most real sources have some degree of directivity.

Far Field is where the sound pressure levels start to attenuate in accordance with the inverse square law. The far field begins approximately at a distance of one to two times the characteristic dimension, D_o from the source.

Free Field is a sound field in a homogeneous, isotropic medium, free from boundaries other than the ground. In practice, it is a field in which the reflection effects of the boundaries other than the ground are negligible over the region of interest.

Inverse Square Law is an idealized method of extrapolating sound levels from one distance to another. It is based on the theory that a homogeneous sound source (a source which produces spherical waves of constant sound power with no directivity) will show a decrease in outward-directed sound intensity that is proportional to the square of the distance from the source. For that sound source the sound pressure level will drop off 6 dB for each doubling of distance or:

$$L_{p2} = L_{p1} - 20 \log_{10} (\text{distance}_2 / \text{distance}_1) \quad (3)$$

Large Tower has a characteristic dimension D_o greater than 7.5m (25 ft). This definition typically applies to custom built field-erected cooling towers, unless otherwise specified.

Leq is the equivalent sound level recorded by an integrating-averaging sound level meter over the prescribed measurement time interval.

Near Field is the region within one to two characteristic dimensions of a sound source. In the near field, the sound pressure decreases by less than the "inverse square" rule.

Partial Sound Power is the portion of the total sound power that can be computed for a separately identifiable part of the tower.

Reflecting Plane is, for the purpose of this code, a hard, flat ground surface, such as asphalt or concrete, that extends a distance of $\lambda/2$ (for the lowest frequency of interest, where λ is the wavelength of a sound frequency in air) beyond the projection of the measurement surface on the reflecting plane. Note that for 63 Hz, the distance $\lambda/2$ is about 2.75 meters (9 ft.); for 31.5 Hz it is about 5.5 meters (18 ft.).

Small Tower has a characteristic dimension D_o less than or equal to 7.5m (25 ft). This definition typically applies to factory-assembled towers on a per-cell basis, unless otherwise specified.

Sound Power Level (L_w or PWL) is the sound quantity in decibels of the emitted sound power, W , of the source. The reference sound quantity for power used in this standard is the picowatt equal to 1×10^{-12} Watt, denoted as W_o . A sound power level is calculated as follows:

$$L_w \text{ (dB)} = 10 \log_{10} (W/W_o) \quad (4)$$

L_w or PWL cannot be measured directly, it can only be computed from the L_p or SPL according to the general equation:

$$L_w = L_p + 10 \log_{10} S$$

Where S is the emission surface in m^2

Sound Pressure Level (L_p or SPL) is the sound quantity in decibels of the square of the root mean squared (rms) sound pressure time variation of the atmospheric pressure, ΔP^2 . The reference sound quantity for pressure used in this standard is the square of a pressure equal to 2×10^{-5} Pascal, denoted as P_o . A sound pressure level is calculated as follows:

$$L_p \text{ (dB)} = 10 \log_{10} (\Delta P^2/P_o^2) \quad (5)$$

or

$$L_p \text{ (dB)} = 20 \log_{10} (\Delta P/P_o) \quad (6)$$

Section 6. Instrumentation

As proper usage of all test instrumentation is essential to obtain valid measurements, all instrumentation shall be operated in accordance with the procedures and precautions set forth in the operation manuals furnished by the instrument manufacturer.

6.1 Sound Level Meter and Microphone System The sound level meter and microphone system shall meet the requirements of ANSI S1.4/S1.4a Type 1 (Precision) or IEC 61672 Type 1. Instrument manufacturer's specifications for orienting the microphone with respect to the source of sound and the location of the observer relative to the meter shall be followed. Frequency response shall be within the tolerances given in ANSI S1.4 or IEC 61672 for a Type I instrument system. A real-time analyzer with separate microphone(s) meeting the above specifications may be substituted for the sound level meter.

6.2 Windscreen. In all tests, a porous ball shall be used on the microphone as a wind screen. The effect of the windscreen on the microphone response shall be no more than ± 1 dB for frequencies of 20 to 4000 Hz or ± 1.5 dB for frequencies of 4000 to 10000 Hz.

6.3 Filter (Frequency) Band Analyzer The analyzer shall meet requirements of ANSI S1.11 (Class II) or IEC 61260.

6.4 System Calibration. The instrumentation system, including the microphone and cable, shall be field calibrated immediately before and after testing. The calibration shall be performed with an acoustical calibrator meeting the requirements of ANSI S1.40 and IEC 60942 Class 1.

The calibrator shall be checked annually to verify compliance with the requirements of ANSI S1.40 and IEC 60942.

6.5 Recorders If a tape recorder or graphic level recorder is used, its stability and frequency response shall be at least equal to those of the sound level meter and microphone system, over the frequency range of interest.

6.6 Fan Speed Measurement Device A device with minimum accuracy of $\pm 2.0\%$ of fan speed shall be used.

6.7 Electrical Power Measurements Electrical power measurements shall be made with instruments that yield a true rms power, based on measured current, voltage, and power factor. The accuracy of the instrument and associated read-out devices shall be equal to or better than 2% of the actual value.

6.8 Air Velocity Measurement Device A device with minimum accuracy of $\pm 5.0\%$ of air velocity shall be used.

6.9 Recording Precision Survey data reporting and calculation of octave band sound levels, sound power levels and corrections shall be performed in terms of tenths of a dB, but shall be consistent throughout. Final A-weighted sound levels or sound power levels shall be reported to the nearest whole decibel.

Section 7.0 Conditions and Environment of the Test

7.1 Operating Conditions of the Cooling Tower

7.1.1 Mechanical Draft Towers The sound measurements shall be taken with all fans operating at full speed with the motor power at or near design, and with the water flow distributed to all cells as recommended by the manufacturer, unless agreed otherwise. Heat load is not mandatory during mechanical draft cooling tower sound measurements. Water flow rates are usually measured with a pitot tube equipped with an air-over-water manometer but any other method of measurement in accordance with STD-146 "Standard for Liquid Flow Measurement" or mutually agreed upon by the parties to the test shall also be acceptable.

For mechanical draft towers, the following deviations from design conditions shall not be exceeded:

Circulating water flow.. $\pm 15\%$
Fan driver power..... $\pm 10\%$
Fan speed..... $\pm 5\%$

7.1.2 Natural Draft Towers For natural draft towers, the following deviations from design conditions shall not be exceeded:

Circulating water flow.. $\pm 10\%$
Cooling range..... $\pm 20\%$
Wet bulb temperature . $\pm 8.5^\circ\text{C}$ (15°F)
Dry bulb temperature.. $\pm 14^\circ\text{C}$ (25°F)

The absence of heat load on natural draft towers will influence water pull back in the air inlet which may affect measurement results.

7.1.3 Exceptions If the specified operating conditions cannot be obtained, the sound test may be conducted at other conditions or with adjustments to design mutually agreed upon by all the parties concerned, and the actual test conditions shall be clearly described in the test report. The method to determine compliance with the requirements on operating conditions shall be agreed upon in advance by the parties to the test.

7.2 Weather During the test the ambient weather conditions (for example: temperature, humidity, wind or cooling air speed and barometric pressure) shall be noted. Limitations to operation specified by the instrument manufacturer shall be followed.