

COOLING TECHNOLOGY INSTITUTE

Isokinetic Drift Test Code



July 2011

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

Approved by the CTI Executive Board.



This document has been reviewed and approved as part of CTI's Five Year Review Cycle. This document is again subject to review in 2016.

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Part I – Test Procedure

Section 1. Introduction

1.1 Scope. This code describes the measurement of drift emissions and/or determination of particulate matter from water-cooling towers using isokinetic methods.

1.2 Purpose. The purpose of the Code is to describe instrumentation and procedures for the testing and evaluation of drift from water-cooling towers.

1.2.1 Overview. In the operation of an evaporative cooling tower, moving air contacts water for heat transfer. The circulating water is distributed as droplets and films to maximize the surface area exposed to the air. In these processes, small water droplets are entrained in the air moving through the tower. Droplets that are not removed from the air stream are exhausted from the cooling tower into the environment. These droplets, which possess the same minerals (but not necessarily in the same concentrations) as the circulating water, are known as drift.

Cooling tower exit air contains water vapor, drift droplets, condensate droplets and particulate which originates in the ambient air but is unscrubbed by the cooling tower. The proportion of these constituents in the exit air are regulated by a number of factors including, but not limited to, drift eliminator design and installation, water distribution and fill system design, ambient psychrometric and wind conditions, circulating water chemistry, etc.

Cooling tower drift measurements are required for laboratory research and field measurement of drift emission rates. The impetus behind such measurements usually falls into one of four categories.

- a) Drift contractual acceptance testing
- b) Determination of compliance with regulatory requirements for drift or particulate matter.
- c) Environmental impact assessment and modeling
- d) Status testing on existing cooling towers.

If drift measurements are conducted to verify performance for contractual drift guarantees, it is emphasized that the guarantee basis is for drift only, and the guarantee is independent of the influence of ambient air constituents. Ambient air constituents that are drawn into the tower and then escape via the exit air stream may bias drift measurements. This requires that the drift measurement and calculation analysis method remain independent of significant influence of elements found in the inlet air stream. Background constituent levels cannot be subtracted from outlet levels since the scrubbing effect of the cooling tower is unknown. This is of particular importance when low levels of drift are measured.

1.2.2. There are two basic methods of drift measurement:

1. Isokinetic (IK) for drift rate measurement and
2. Sensitive Surface (SS) for drift droplet size characterization.

Each method yields specific information regarding the drift characteristics of the tower.

Highlights of the two methods are provided below:

ISOKINETIC METHODS (IK)

POSITIVE ATTRIBUTES

1. High collection efficiency on all droplet sizes.
2. Analysis for specific elements possible.
3. Provides integrated sample over exit area.

NEGATIVE ATTRIBUTES

1. Airborne elements may bias results.
2. Long sample times required for high efficiency drift eliminators or low mineral concentrations.

SENSITIZED SURFACE METHODS (SS)

POSITIVE ATTRIBUTES

1. Provides droplet size characteristics above 30 μm .
2. Not effected by airborne elements.
3. Provides relative indication of drift eliminator effectiveness.

NEGATIVE ATTRIBUTES

1. Poor collection efficiency on small droplets less than 30 μm .
2. Cannot distinguish between condensation and drift.
3. No droplet analysis for specific constituents.

1.2.3 This code describes a Heated Bead Isokinetic (HBIK) Drift Test Procedure. However, an alter-native Isokinetic Procedure with demonstrated performance may be utilized, if mutually agreed to by all parties.

The HBIK method is an isokinetic sampling method derived from applicable stack sampling procedures that have been modified to address the unique operating and environmental challenges associated with testing a cooling tower. These challenges include sampling a dilute pollutant in a saturated exhaust above a very large diameter fan stack. A composite sample of the exhausted metallic salts is collected from multiple sampling stations. The drift rate is a function of the ratio of the tracer element mass (tracer elements) to concentration of the tracer element in the circulating water.

1.2.4 The Sensitive Surface system most often used relies on droplet collection by inertial impaction on water sensitive paper. The paper is chemically treated so that a droplet impinging on it will generate a well-defined dark

blue stain on the pale yellow background of the paper. The size and shape of the stain are functions of the impingement dynamics (i.e., speed and angle, and the original droplet diameter). If the technique is employed correctly, the stain will be circular, or nearly circular, in shape. The relationship between the stain and the droplet size is obtained by calibrating the SP system by means of a monodisperse water droplet generator over a range of droplet sizes and impaction velocities.

The processing of the exposed sensitive paper consists of evaluating the stain diameters, and grouping the counts of all stains by stain-size ranges. Once the stain sizes are counted and grouped according to size, calibration curves for specific droplet sizes and impaction velocities are employed via computer programs to generate the original droplet sizes from which the stains were formed. In addition, a correction factor is applied to compensate for the collection efficiency of each droplet size range. This factor, which is important only for droplets of less than approximately 30 microns, is computed by the procedures of Ranz and Wong.

1.3 Flexibility. It is recognized that the data limitations specified throughout this test procedure represent desired

conditions which may not exist at the time the test is performed. In such cases, existing conditions may be used if mutually agreed upon prior to the test by authorized representatives of the manufacturer, the tower owner, and the CTI.

1.4 Other Uses. Although intended primarily for drift acceptance testing, all or parts of this Code may be used for other purposes, such as the determination of mineral mass emission.

1.5 Impartial Testing Service. The CTI Representative referred to in this Code shall be an impartial party to the test and shall have no connection with the manufacturer, the purchaser, or the Cooling Technology Institute, other than a contractual agreement with the latter. This Representative shall be sufficiently qualified to ensure that measurements and evaluations are made in accordance with the Code. The CTI Representative is hereinafter referred to as the CTI.

1.6 Nomenclature.

The symbols used in this Code are identified in Table 2.

Table 1
Nomenclature

Symbol	Definition	[SI]	[IP]	Section	Eq. #
A_N	Area of intake nozzle on isokinetic device	m ²	ft ²	4.1.3, 4.3, C-1,	6, 7, 12, 13
A_{SP}	Area of sampling plane	m ²	ft ²	4.3, C-1	12, 13
C_{Pitot}	Calibration coefficient of air velocity pressure Pitot tube	-	-	4.1.1	4
C_{STD}	Concentration of mineral emission	mg/L	g/ft ³	C-1	15
C_{TC}	Concentration of tracer element in circulating water	mg/L	ppm	4.3, C-1	12, 13
D_h	Hub diameter	m	ft	3.9.2	3
D_s	Stack diameter	m	ft	3.9.2	3
E_R	Emission rate	g/s	lb/hr	C-1	14, 15
hp_D	Design brake horsepower	kW	HP	2.3.5, C-2	1, 16, 17
hp_T	Tested brake horsepower	kW	HP	2.3.5, C-2	1, 16, 17
K	Coefficient = $\sqrt{2}$ [SI] or 1097 [IP]	-	-	4.1.1	4
K_0	Coefficient = 16.67 [SI] or 1 [IP]	-	-	4.1.3	6, 7
K_1	Coefficient = 10 [SI] or 37.854 [IP]	-	-	4.3, C-1	12, 13
K_7	Coefficient = 10^5 [SI] or 1.997×10^5 [IP]	-	-	C-1	14
K_8	Coefficient = 10^{-3} [SI] or 7.9366 [IP]	-	-	C-1	15
M	Number of sampling points on a single radius	-	-	3.9.2	3
m	Sampling point number	-	-	3.9.2	3
$M_{F,i}$	Mole fraction of dry gas	-	-	4.1.3	7, 8, 9
np	Number of sampling points	-	-	4.1.5, C-3	11, 18
$Q_{M,i}$	Measured sample volumetric flow rate	L/min	ft ³ /min	4.1.3	7
$Q_{N,i}$	Sample volumetric flow rate	L/min	ft ³ /min	4.1.3	6
Q_{STD}	Sample plane flow rate, dry standard conditions	L/s	ft ³ /s	C-1	15
Q_{WT}	Water flow rate during test	L/s	gpm	4.3, C-1	12, 13, 14
$t_{1,i}$	Nominal sampling time	min	min	4.1.2	5
$t_{2,i}$	Actual sampling time adjusted for angularity of the flow	min	min	4.1.2, 4.1.5, C-3	5, 11, 18
TDS	Total dissolved solids	mg/L	mg/L	C-1	14
t_E	Total equivalent sample time	s	min	4.3, C-1	12, 13
$U_{N,i}$	Sample velocity at nozzle inlet	m/min	ft/min	4.1.3, 4.1.4, 4.1.5, C-3	6, 7, 10, 11, 18
$U_{S,i}$	Air velocity	m/min	ft/min	4.1.1, 4.1.4, 4.1.5, C-3	4, 10, 11, 18
V_{Cth}	Threshold velocity	m/s	ft/min	2.3.5, C-2	1, 2, 16, 17
$V_{D(avg)}$	Design average velocity	m/s	ft/min	2.3.5 C-2	1, 17
$V_{U(avg)}$	Measured average exit velocity	m/s	ft/min	2.3.5, C-2	2, 16
$\omega_{M,i}$	Specific humidity metering device	-	-	4.1.3	9
$\omega_{N,i}$	Specific humidity at the sampling plane	-	-	4.1.3	8, 9
W_T	Net weight of tracer	μg	μg	4.3, C-1	12, 13
X_m	Sample location, distance from wall	m	ft	3.9.2	3
$\Delta P_{s,i}$	Differential pressure (velocity pressure) at each sampling point	Pa	inH ₂ O	4.1.1	4
θ_i	Angle between flow direction and the normal to the sample plane	deg.	deg.	4.1.2	5
ρ	Air density	kg/m ³	lb/ft ³	4.1.1	4
ρ_{CW}	Density of the circulating water	kg/m ³	lb/ft ³	C-1	14
$\rho_{M,i}$	Density at measuring device	kg/m ³	lb/ft ³	4.1.3	7
$\rho_{N,i}$	Density at sample plane	kg/m ³	lb/ft ³	4.1.3	7

2.0 CONDITIONS OF TEST

2.1 Conduct of Test. Drift acceptance testing shall be conducted by the CTI in the presence of authorized representatives of the tower manufacturer and the tower purchaser, if they elect to attend. For acceptance testing, these representatives shall be given adequate notice to inspect the tower in advance, prepare it for the test and to attend the testing. In no case shall any directly involved party be barred from the test site.

2.2 Condition of Equipment. At the time of the test, the tower shall be in good operating condition. The Test shall be conducted under the following guidelines:

- Acceptance test(s) shall be conducted within 24 months after structural completion of the tower or 18 months of operation, unless otherwise stipulated by mutual agreement of purchaser and manufacturer.
- The cooling tower shall have been operated a minimum of 700 hours with a heat load, unless otherwise stipulated by mutual agreement of purchaser and manufacturer.
- The water distribution system shall be in good repair and essentially clear and free of foreign materials which may impede the normal water flow.
- Mechanical equipment, if involved, shall be in good working order. Fans shall be rotating in the correct direction, with proper orientation of leading and trailing edges. Axial fan blades shall be at a uniform angle. Centrifugal fans shall be free of foreign material and properly secured to the shafts.
- Drift eliminators shall be essentially clear and free of algae and other deposits which may impede normal air flow.
- Fill shall be essentially free of foreign materials such as oil, tar, scale, or algae which may impede or disrupt normal air or water flow.
- Cross-flow towers shall be operated such that the level of water in the cold water basin level is at the recommended height to prevent air bypass beneath the fill.
- Plume abated cooling towers shall have dry section inlet dampers in the closed position if present. If dampers are not present, by mutual consent of the test parties, the air inlets may be temporarily blocked to prevent ambient concentrations of tracer elements from entering the cooling tower.

2.3 Operating Conditions. The drift test of any cooling tower shall be conducted within the following limitations:

2.3.1 Requirements for drift testing of any tower shall include:

- The temperature of the inlet air stream should remain above the freezing point of water.

- The sampling area should be free from visible collection of condensation on surfaces.
- The tower should be free of airborne foam at the sampling elevation.
- The test period shall be free from any natural precipitation.

2.3.2 The circulating water flow rate shall be within $\pm 10\%$ of the design value.

2.3.3 The operating fan horsepower of mechanical draft towers, when corrected for air density, shall be within $\pm 10\%$ of the design value.

2.3.4 For contractual acceptance tests, the water surface tension shall not fall below the specified design basis surface tension value. If not specified contractually, for contractual acceptance tests, the surface tension of the circulation water shall not fall below 63 dynes/cm.

2.3.5 When the drift sampling is conducted at the exit plane of the fan stack, the average wind velocity shall be measured at the fan stack discharge elevation upwind of the test cell per paragraph 3.6.

The average allowable wind velocity shall not exceed 75% of the average exit velocity, based on the gross diameter of the fan stack being tested.

The average exit velocity can be determined using the manufacturer's data sheets, if available.

Alternately, the design average exit velocity can be calculated from the design fan air flow rate divided by the gross stack exit area or the stated average exit velocity.

If the manufacturer's nominal air velocity data is used, it must be corrected for the difference between the design airflow rate and the test airflow rate. The following equation can be used to determine the threshold velocity:

$$V_{Cth} = .75 * V_{D(avg)} * \sqrt[3]{\frac{hp_T}{hp_D}} \quad (1)$$

Where:

V_{Cth} = Threshold velocity, m/s (ft/min)

$V_{D(avg)}$ = Design average air velocity, m/s (ft/min)

hp_T = Tested brake horsepower, kW (HP)

hp_D = Design brake horsepower, kW (HP)

If the manufacturer's data is not available, the average exit velocity can be determined by measuring the air exit velocity at each of the local sampling stations during the first drift test traverse and calculating the average exit velocity.

$$V_{Cth} = .75 * V_{U(avg)} \quad (2)$$

Where:

$V_{U(avg)}$ = Average measured air velocity, m/s (ft/min)



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