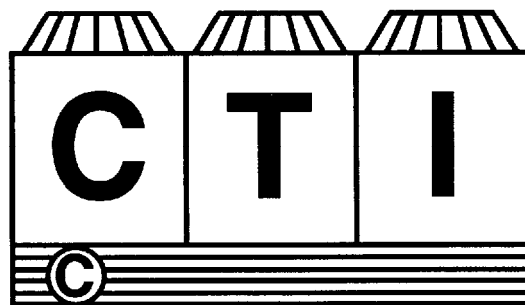


COOLING TOWER INSTITUTE

CTI CODE TOWER Standard Specifications

Standard for Water Flow Measurement

Part I: Test Procedure Part II: Appendix



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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.

WATER FLOW MEASUREMENT STANDARD

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PART I

Flow Measurements

1.0 SCOPE AND PURPOSE

- 1.1 Scope - This standard covers methods for cooling tower water flow measurement.
- 1.2 Purpose - The basic intent of this standard is to provide a flow measurement procedure that is accurate and meets the requirements of the Cooling Tower Acceptance Test Code.
- 1.3 Water Flow to be Measured - The following water quantities should be measured.
- 1.3.1 Circulating water flow.
- 1.3.2 Make-up water flow.*
- 1.3.3 Blowdown flow.*
- * if not stopped during test.
- 1.4 Reference Codes and Standards - By reference in the body of this Standard, CTI automatically adopts and makes a part of this Standard any existing Standard or code by other technical organizations that is referred to herein. In the event of conflict between sections of this Standard and other codes or Standards adopted by reference, this Standard will apply.
- 1.5 Nomenclature - The symbols used in this code are identified in the following tabulations.

Symbol	Description	English Units	Metric Units
A	Cross sectional area of the pipe at the Pitot traverse point (See 5.1.7 for Pitot projected area effect).	ft ²	m ²
C	Calibration coefficient for pitot tube	dimensionless	
cm	Length	-	centimeter
ter	d	Manometer reading	in
cm			
DP	Differential pressure	PSI	Pa
ft	Length	foot	-
g	Acceleration due to gravity	ft/s ²	m/s ²
gal	Volume	gallon	-
H	Velocity pressure of flowing fluid	in of flowing fluid	cm of flowing
fluid			
hr	Time	hour	hour
in	Length	inches	-
kg	Mass	-	kilogram
l	Volume	-	liter
lb _f	Force	Pound	-
lb _m	Mass	Pound	-
m	Length	-	meter
mm	Length	-	millimeter
ters			
min	Time	minute	minute
N	Force	-	Newton
Pa	Pressure	-	N/m ²
P _L	Low Pressure	psi	Pa
P _s	Static Pressure	psi	Pa
P _t	Total Pressure	psi	Pa
P _v	Velocity Pressure	psi	Pa
psi	Pressure	lb _f /in ²	-
Q	Water Flow Rate	gal/min	l/s
s	Time	second	second
S.G.	Specific gravity	dimensionless	
t ₁	Time for signal to travel upstream	second	second
t ₂	Time for signal to travel downstream	second	second
v	Fluid velocity	ft/s	m/s
V	Velocity, weighted average	ft/s	m/s
v ₁	On-off valve	-	-
v ₂	On-off valve	-	-

v_3	3-way valve	-	-
v_4	3-way valve	-	-
v_s	Speed of sound in fluid	ft/s	m/s
x_1	Signal travel distance upstream	ft	m
x_2	Signal travel distance downstream	ft	m

Greek Letter	Greek Symbol	Description	English Units	Metric Units
Rho	ρ	Actual fluid density	lb _m /ft ³	kg/m ³
Rho	ρ_{ff}	Density of flowing fluid	lb _m /ft ³	kg/m ³
Rho	ρ_{mf}	Density of manometer fluid	lb _m /ft ³	kg/m ³

2.0 PIPING REQUIREMENTS

The meter orientation in the pipe is critical to the accuracy of the flow measurement. The contracting parties shall investigate the individual flow meter and evaluate the existing piping configuration to predetermine the flow meter limitations.

- 2.1 **Meter Tube or Metering Section** - The "metering section" shall mean the straight upstream and downstream pipe of the same size between the flow measurement primary and the nearest pipe fitting. There shall be no pipe connections (in flow or out flow) within these pipe dimensions other than the static pressure taps or pitot taps. The pressure taps should be installed in accordance with Appendix II-C of this Standard.

- 2.2 **Pipe Length** - The length of the metering section recommended by the flow meter manufacturer should be used when practical. A minimum of (and preferably more than) 20 pipe diameters of straight pipe upstream and 5 pipe diameters of straight pipe downstream is recommended (See Typical Meter Run Piping Configurations, Appendix II-C).

Where the available straight pipe for flow measurement is MORE or LESS than the manufacturer's recommended minimums, THEN the following "rule of thumb" is recommended for the optimum location of the flow measurement primary in the available straight pipe section for best flow measurement results:

"Use 20% of the straight pipe, OR a maximum of 5 pipe diameters, DOWNSTREAM of the flow measurement primary, AND use the remaining 80% (or more) straight pipe UPSTREAM of the flow measurement primary".

- 2.3 **Circular Pipe** - The average measured pipe internal diameter should be used in the flow calculations. The pipe internal diameter should be precisely measured on at least two (2) diameters 90 degrees opposed at the plane of the flow measurement. It is the intent to establish the true cross sectional area of the pipe by the best means available.
- 2.4 **Pipe Internal Surface Roughness** - The internal surface of the pipe should be straight, free from mill scale, pits, holes, scoring, reamer scores, rifling striations, grooves or ridges resulting from

seams, distortion caused by welding, offsets, bumps or other irregularities which may affect the flow measurement accuracy.

- 2.5 **Straightening Vanes** - Straightening vanes in the flow metering section may be used to improve velocity profile. If installed, straightening vanes shall be located at a minimum two (2) diameters upstream of the flow measurement plane. The straightening vanes must be preceded by at least two or more diameters of straight pipe in every case.

- 2.5.1 **Tubular Type** - The tubular type consisting of many small tubes tacked within the pipe shall have the minimum distance between the tube centers not to exceed 1/4 of the pipe diameter and the overall tube length shall be at least eight times the tube diameter.

- 2.5.2 **Perforated Plate Type** - The perforated plate type consists of at least three internal perforated plates; each plate to be held one pipe diameter apart by spacers. The perforated plate must be secured firmly within the pipe. The perforated plate installation will cause some permanent pressure loss.

3.0 CONTAMINANTS OR DISTURBANCES IN WATER FLOW

The presence of contaminants in the flow stream can cause loss of flow measurement accuracy.

- 3.1 **Particulates and/or Solids** - Particulate and solid may cause partial or total plugging of pressure taps.
- 3.2 **Air Bubbles** - Any source of free air (or gas) bubbles should be eliminated during the test. Bleed valves should be installed at all high points in the instruments and on the instrument lines where air (or gas) may collect. These high points should be blown down to eliminate all air (or gas) from the system at a frequency appropriate for the application.

Sonic-type flow meters require some air bubbles in the flow stream for proper operation. It is recommended that the instrument manufacturer should be consulted for a recommendation.

- 3.3 **Pulsating or Surging Flow** - Pulsating or surging adversely affects measuring accuracy.

Flow measuring device shall be located as far as practical from the source of the pulsation. In the event this cannot be achieved, a properly sized pulsation dampener may be required. Any noticeable pulsation effects should be documented in the test report.

- 3.4 **Swirl Flow in Pipe** - Swirl is spiraling flow which strikes the flow meter at an oblique angle. Once introduced into the flow stream, it can persist for up to 200 pipe diameters before normal straight pipe will remove it. The severity of the swirl component is directly related to the piping or valving configuration which generates the swirl flow.

If the source of swirl can not be eliminated, it is recommended that flow straighteners or straightening vanes be installed per section 2.5. If necessary the yaw angle (deviation of the fluid flow path from parallel to the pipe axis) may be determined by measuring the rotation angle of a standard pitot tube at a point of maximum manometer deflection.

4.0 ACCURACY FOR WATER FLOW MEASUREMENT

The accuracy of the measurement depends on the location and type of instrument used and the stability of the test conditions.

5.0 TYPE OF PRIMARY FLOW MEASUREMENT DEVICES AND METHODS

- 5.1 **Pitot Tube** - The CTI's basic reference standard flow measurement instrument is the pitot tube (See Appendix II-F). The pitot traverse provides acceptable levels of accuracy because it is sensitive to the actual local velocity of profile in the pipe.

- 5.2 **Other Flow Measurement Devices** - The following listed flow measurement devices are acceptable to CTI for cooling tower testing when the selected device is mutually agreed upon by the contracting parties.

A brief synopsis of these flow meters is presented in the Appendix II-G of this Standard. Specific and full details for flow meter selected should be obtained from the instrument manufacturer.

- 5.2.1 Orifice Meter (See Appendix II-G (a)).
- 5.2.2 Flow Nozzle (See Appendix II-G (b)).
- 5.2.3 Venturi (See Appendix II-G (c)).
- 5.2.4 Multiport Averaging Pitot Flow Meter (See Appendix II-G (d)).
- 5.2.5 Vortex Shedding Meter (See Appendix II-G (e)).
- 5.2.6 Turbine Meter (See Appendix II-G (f)).
- 5.2.7 Variable Area Meter (See Appendix II-G (g)).
- 5.2.8 Magnetic Flow Meter (See Appendix II-G (h)).

- 5.2.9 Sonic and Ultrasonic Flow Meter (See Appendix II-G (i)).

- 5.2.10 Positive Displacement Flow Meter (See Appendix II-G (j)).

- 5.2.11 Open Channel Flow Measurement (See Appendix II-G (k)).

- 5.2.12 Tracer Injection Measurement Method (See Appendix II-G (l)).

6.0 PRIMARY DEVICE CALIBRATION

An independent flow laboratory, which has previously performed flow calibrations of similar size flow measurement devices, shall be employed. An updated list of hydraulic laboratories may be obtained from CTI. The test laboratory chosen shall be acceptable to all parties to the test.

7.0 FLOW SIGNAL CONDITIONING AND READOUT

Regardless of the type of flow measurement device, all signal conditioning and readout components need to be consistent with the specified accuracy and operating principles of the flow measurement device. The operator must be aware of the condition of the flow measurement readout device, its calibration and its use.

- 7.1 **Manometer** - Manometers of various types are a simple device for differential pressure (DP) measurements. The type of manometer selected must be suitable for both the differential and system pressures expected in a particular application.

- 7.1.1 **Air over Water Manometer** - The inverted U-tube manometer with air over water is the CTI's standard instrument for DP measurements. The total deflection between the two menisci then indicates the DP due to fluid flow for head type flow measurement devices. (See example of air-over-water manometer in Appendix Section II-E).

- 7.1.2 **Liquid-Liquid "U"-Tube Manometer** - The upright U-tube manometer uses an indicating fluid other than air as the secondary fluid. The secondary fluid must be totally immiscible with water, must have a readily discernable interface, and its density must be accurately determined. Refer to the manometer manufacturer for specific information regarding different manometer fluids and proper manometer operating procedures.

- 7.1.3 **Inclined Manometers** - Inclined manometers are used to magnify or expand the readable scale of the differential pressure reading for very low DP readout applications. Secondary fluid requirements must be same as that for u-tube manometer in article 7.1.2.

- 7.1.4 **Manometer Readings**