COOLING TECHNOLOGY INSTITUTE

MULTI-AGENCY TESTING PROGRAM

2014 ANNUAL REPORT

Prepared by:

THE MULTI-AGENCY TESTING COMMITTEE
Frank Michell, Chair
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For:

The Cooling Technology Institute
P.O. Box 681807
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February 9, 2015
1.0 Introduction

1.1 Background
For over 60 years, the Cooling Technology Institute (CTI) has provided cooling tower performance testing services to members and non-members alike. Starting in January 1993, the CTI has provided these testing services through several testing agencies, each examined, qualified, and licensed by the CTI to conduct such tests. The documents establishing the program, and under which it currently operates, were developed by a task force under the auspices of the CTI Performance & Technology Committee. Currently, four agencies are licensed to conduct thermal performance tests -- CleanAir Engineering, Inc.; Cooling Tower Testing Associates, Inc.; Cooling Tower Technologies Pty. Ltd.; and McHale & Associates, Inc. Two agencies are licensed to conduct drift testing -- CleanAir Engineering, Inc.; and McHale & Associates, Inc. A new program to license multiple agencies to conduct sound testing in accordance with CTI ATC-128 is starting January 1, 2015.

For additional information on the licensed test agencies (as of December 31, 2014), addresses, and whom to contact, please see Appendix A.

1.2 Organization
The program is administered by the CTI Multi-Agency Testing Committee, which works closely with the licensed agencies to ensure tests bearing the CTI name are conducted by qualified, impartial personnel; using good, calibrated instrumentation; in full compliance with the intent of the applicable CTI codes and standards.

The licensed agencies operate in accordance with a License Agreement, which includes a Testing Manual prepared specifically for this program. The first level of oversight for the general operation of the program is the Thermal Testing Program Committee, which is comprised of the licensed thermal testing agencies and includes the chair of the Multi-Agency Testing Committee and the chair of the Performance and Technology Committee as non-voting members. This committee also provides a forum where the licensed agencies can discuss, and hopefully resolve among themselves, any technical or administrative problems that may arise.

The resolution of questions regarding the activities of the licensed testing agencies falls to either of two CTI committees:

a) Technical issues regarding the interpretation of test codes and the Testing Manual are the province of the Performance and Technology Committee and the Multi-Agency Testing Committee.
b) The Multi-Agency Testing Committee is responsible for the administration of the license agreements.

The Multi-Agency Testing Committee, supported as necessary by the Performance and Technology Committee, maintains the License Agreement Testing Manual, screens potential new agencies, and conducts technical audits of agencies as required. The Multi-Agency Testing Committee has responsibility for business related audits of new and current agencies, and coordinates the activities of the Thermal and Drift Testing Program Committees. It should be emphasized that these review and oversight activities are in no way permitted to compromise the confidential aspects of individual tests.

Although the Multi-Agency Testing Committee and the P & T Committee are available to assist in the resolution of any questions concerning interpretation and implementation of CTI Codes and Standards as they may pertain to a specific test, such involvement is provided only at the request of all the official parties to the test.

CTI endeavors to meet the testing needs of the worldwide cooling tower industry, including tower users, manufacturers, contractors, and suppliers. The Thermal and Drift Testing Program Committees, chaired by the chair of the Multi-Agency Testing Committee, work to ensure the needs of the users of the CTI testing services are being met.

The Multi-Agency Testing Committee is structured with a Chair and two Vice Chairs. The User, Supplier and Manufacturer categories of the CTI membership are each represented, assuring that at least one of the three is likely to be free of a conflict of interest in any specific situation.

2.0 Testing Services

2.1 General

The CTI currently offers the following tower testing services as part of the Multi-Agency Testing Program:

- Thermal Performance Acceptance Testing.
- Thermal Performance Status Testing.
- Special Tests.
- Drift Testing.
- Sound Testing (Beginning in 2015).
Agencies licensed under the Thermal Testing Program may conduct acceptance, performance status, and special thermal testing. Acceptance and performance status tests are generally conducted in accordance with CTI ATC-105, although tests may be conducted using another thermal testing code with the consent of all the parties to the test. Special testing includes any sub-part of testing according to CTI ATC-105. A parallel licensing program for Drift Testing is in place, with testing conducted in accordance with CTI ATC-140.

Thermal testing agencies are licensed to conduct Type A, Type B, or both types of testing. Type A testing utilizes mercury-in-glass thermometry with manual readings. It is generally used when the expense of Type B testing is inconsistent with the cost of the tower being tested. Type B testing employs remote data acquisition equipment for temperature measurement and some other measurements. Agencies with a Type A license are required to have the minimum amount of equipment to conduct a mercury-in-glass test on a small cooling tower such as a factory assembled tower. Agencies with a Type B license are required to have the minimum amount of equipment required to test a single, large tower in full accordance with ATC-105 and the Testing Manual. The existing agencies are all licensed to conduct Type B testing. The Multi-Agency Testing Committee plans to either alter Type A testing or obsolete it.

Information on testing services can be obtained from the CTI offices in Houston or from any of the licensed CTI testing agencies. When an inquiry for a specific test is received at the CTI office, a list of the licensed agencies, including a brief summary of their capabilities, is provided. A copy of the agency information summary, current as of the date of this report, is included in Appendix A. Potential clients contact the agency of their choice to obtain pricing and scheduling information. When requested, the agency sends a copy of CTI FSP-156, *Preparation for an Official CTI Thermal Performance, Plume Abatement, or Drift Emission Test*. After the test has been conducted by the CTI agency selected by the customer, a report number is issued by the CTI office and a final report is sent to the parties to the test.
2.2 Thermal Performance Acceptance Testing and Performance Status Testing
Thermal performance acceptance and performance status tests of natural draft and mechanical
draft, evaporative and wet/dry cooling towers, and closed circuit cooling towers are conducted
under the provisions of CTI ATC-105, *Acceptance Test Code for Water-Cooling Towers* or
Supplement to ATC-105, *Acceptance Test Code for Closed Circuit Cooling Towers*, unless
otherwise specified by the parties to the test. An acceptance test is conducted on a new or
refurbished tower to determine if the performance meets the manufacturer’s contractual guarantee.
The CTI Licensed Testing Agency is required to assure that the tower manufacturer and tower
purchaser are given sufficient notice to witness the acceptance test and the collected test
information is distributed to both parties. If a thermal performance test is not being conducted to
determine compliance with a contractual guarantee, it is considered a performance status test.

2.3 Drift Testing
Drift testing is conducted in accordance with ATC-140, *Isokinetic Drift Measurement Test Code
for Water Cooling Towers*, unless otherwise specified by the parties to the test. As with thermal
tests, drift tests may be either acceptance or status tests.

2.4 Special Tests
Special tests include any tests which can be conducted using a portion of ATC-105 without
determining tower capacity. An example is measurement of water flow rate by Pitot traverse.

2.5 Other, Non-licensed Testing
CTI test codes exist for other types of testing, including Sound (ATC-128) and Plume Abatement
(ATC-150). Through 2014 a thermal testing license program and a drift testing license program
were available. Testing according to other CTI test codes are not subject to the license and are
available outside the CTI Licensing Program. The CTI Sound testing program per ATC-128 starts
in 2015.

3.0 CTI Testing Activities for 2014
In calendar year 2014, a total of sixty three (63) thermal tests were conducted. A distribution of the
tests by type is shown in Table 1 below.
Table 1. Distribution of Tests by Type

<table>
<thead>
<tr>
<th>Type of Test</th>
<th>2014</th>
<th>2013</th>
<th>2012</th>
<th>2011</th>
<th>2010</th>
</tr>
</thead>
<tbody>
<tr>
<td>Acceptance – New</td>
<td>25</td>
<td>33</td>
<td>39</td>
<td>47</td>
<td>36</td>
</tr>
<tr>
<td>Acceptance -- Rebuilt</td>
<td>10</td>
<td>14</td>
<td>13</td>
<td>6</td>
<td>14</td>
</tr>
<tr>
<td>Acceptance – Total</td>
<td>35</td>
<td>47</td>
<td>52</td>
<td>53</td>
<td>50</td>
</tr>
<tr>
<td>Performance – New</td>
<td>0</td>
<td>2</td>
<td>6</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>Performance – Rebuilt</td>
<td>3</td>
<td>8</td>
<td>6</td>
<td>10</td>
<td>8</td>
</tr>
<tr>
<td>Performance – Old</td>
<td>21</td>
<td>24</td>
<td>24</td>
<td>27</td>
<td>13</td>
</tr>
<tr>
<td>Performance – Total</td>
<td>24</td>
<td>35</td>
<td>32</td>
<td>43</td>
<td>22</td>
</tr>
<tr>
<td>Special</td>
<td>4</td>
<td>0</td>
<td>0</td>
<td>13</td>
<td>9</td>
</tr>
<tr>
<td>Grand Total (Thermal Tests)</td>
<td>63</td>
<td>82</td>
<td>84</td>
<td>109</td>
<td>81</td>
</tr>
</tbody>
</table>

The overall average of the Tower Capabilities, the maximum and minimum capabilities, and the number of tests with one or more parameters out of code are shown for each type of test in Table 2 below. Approximately 66% were conducted with no more than one parameter out of code. The acceptance tests had about 60% falling into this category.

Table 2. Summary of 2014 Thermal Test Results

<table>
<thead>
<tr>
<th>Type of Test</th>
<th># Tests</th>
<th>% Tower Capability</th>
<th>Parameters out of Code</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Max</td>
<td>Avg.</td>
</tr>
<tr>
<td>Acceptance – New</td>
<td>25</td>
<td>145.9</td>
<td>103.3</td>
</tr>
<tr>
<td>Acceptance -- Rebuilt</td>
<td>10</td>
<td>107.2</td>
<td>101.0</td>
</tr>
<tr>
<td>Acceptance – All</td>
<td>35</td>
<td>145.9</td>
<td>102.7</td>
</tr>
<tr>
<td>Performance – New</td>
<td>0</td>
<td>0.0</td>
<td>0.0</td>
</tr>
<tr>
<td>Performance – Rebuilt</td>
<td>3</td>
<td>106.9</td>
<td>102.1</td>
</tr>
<tr>
<td>Performance – Old</td>
<td>21</td>
<td>124.0</td>
<td>91.3</td>
</tr>
<tr>
<td>Performance – All</td>
<td>24</td>
<td>124.0</td>
<td>92.5</td>
</tr>
<tr>
<td>Overall</td>
<td>59</td>
<td>145.9</td>
<td>99.2</td>
</tr>
</tbody>
</table>

The number of tests (expressed as a percentage) with any particular parameter out of code are shown in Table 3 below for each type of test and overall. The parameter most often out of code was the cooling range, which occurred on 30% of all tests, followed by flow and fan horsepower each approximately 27% of all tests. On acceptance tests on new cooling towers, fan horsepower and flow were out of code on 36% of the tests and cooling range was out of code on 32% of the tests.
Table 3. Test Parameters Out of Code – Percentage of Tests

<table>
<thead>
<tr>
<th>Type of Test</th>
<th>Wet Bulb</th>
<th>Range</th>
<th>Flow</th>
<th>Fan HP</th>
<th>Wind</th>
<th>Dry Bulb</th>
</tr>
</thead>
<tbody>
<tr>
<td>Acceptance – New % of Tests</td>
<td>8%</td>
<td>32%</td>
<td>36%</td>
<td>36%</td>
<td>4%</td>
<td>0%</td>
</tr>
<tr>
<td>Max. Dev.</td>
<td>-11%</td>
<td>-79%</td>
<td>-36%</td>
<td>-36%</td>
<td>1.7%</td>
<td>--</td>
</tr>
<tr>
<td>20</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>3.7</td>
<td></td>
</tr>
<tr>
<td>Acceptance – Rebuilt % of Tests</td>
<td>30%</td>
<td>20%</td>
<td>20%</td>
<td>10%</td>
<td>0%</td>
<td>0%</td>
</tr>
<tr>
<td>Max. Dev.</td>
<td>-25</td>
<td>29%</td>
<td>-39%</td>
<td>-20%</td>
<td>--</td>
<td>--</td>
</tr>
<tr>
<td>45</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Performance – New % of Tests</td>
<td>--</td>
<td>--</td>
<td>--</td>
<td>--</td>
<td>--</td>
<td>--</td>
</tr>
<tr>
<td>Max. Dev.</td>
<td>--</td>
<td>--</td>
<td>--</td>
<td>--</td>
<td>--</td>
<td>--</td>
</tr>
<tr>
<td>Performance – Rebuilt % of Tests</td>
<td>0%</td>
<td>33%</td>
<td>0%</td>
<td>67%</td>
<td>33%</td>
<td>0%</td>
</tr>
<tr>
<td>Max. Dev.</td>
<td>--</td>
<td>-18%</td>
<td>--</td>
<td>--</td>
<td>0.9</td>
<td>--</td>
</tr>
<tr>
<td>20</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>2.0</td>
<td></td>
</tr>
<tr>
<td>Performance – Old % of Tests</td>
<td>18%</td>
<td>32%</td>
<td>23%</td>
<td>18%</td>
<td>18%</td>
<td>0%</td>
</tr>
<tr>
<td>Max. Dev.</td>
<td>11</td>
<td>59%</td>
<td>-16%</td>
<td>-43%</td>
<td>2.4</td>
<td>--</td>
</tr>
<tr>
<td>19</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>5.36</td>
<td></td>
</tr>
<tr>
<td>All Tests % of Tests</td>
<td>15%</td>
<td>30%</td>
<td>27%</td>
<td>27%</td>
<td>10%</td>
<td>0%</td>
</tr>
<tr>
<td>Max. Dev.</td>
<td>-25</td>
<td>-79%</td>
<td>39%</td>
<td>--</td>
<td>2.4</td>
<td>--</td>
</tr>
<tr>
<td>45</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>5.4</td>
<td></td>
</tr>
</tbody>
</table>

The thermal test results are shown graphically in several figures. The thermal acceptance test results for new cooling towers are shown on Figure 1 as a function of the design circulating water flow rate. The average capability of new acceptance tests that were less than 100% was 94.5%. The thermal acceptance test results for rebuilt cooling towers are shown on Figure 2. The performance test (tests performed without contractual guarantee compliance determination) results are shown on Figure 3. The combined thermal test results for all thermal tests are shown on Figure 4. A historical overview of the thermal performance testing is shown on Figure 5.

The thermal test results were analyzed to determine if there were any obvious trends or insights. The test results were grouped into the design flow bands shown on Figure 6, to determine if a particular cooling tower size range was problematic with regard to thermal performance on new cooling tower acceptance tests. Also shown on Figure 6 is the thermal capability without the horsepower correction for the same tests, the test results for each design flow range segregated between initial tests and retests, and the average as-tested capability of tests with a capability less than 100%.

The test results were analyzed to show the affect of the number of parameters out of code, as shown on Figure 7, on new cooling tower acceptance tests.
The test results for thermal acceptance tests were sorted, as shown on Figure 8, to show a breakdown of the thermal performance test results for crossflow and counter flow cooling towers for both new and rebuilt towers.

The percent of thermal acceptance tests with 100% or greater as-tested capability for new and refurbished towers is shown on Figure 9 for the last five years. The data shows that approximately 50% of new tower acceptance tests and 60% of refurbished tower acceptance tests have a capability of 100% or greater over the last 6 years.

The CTI Office requested feedback from each test representative party to each test performed by the licensed test agencies. Completed surveys received by the CTI Office were positive.
Figure 1

2014 COOLING TOWER THERMAL TESTS
ACCEPTANCE TESTS -- NEW COOLING TOWERS
Figure 2

2014 COOLING TOWER THERMAL TESTS
ACCEPTANCE TESTS -- REBUILT COOLING TOWERS

Test Capability -- % Design Flow vs. Water Flow Rate (l/s)
Figure 3

2014 COOLING TOWER THERMAL TESTS
PERFORMANCE TESTS

Water Flow Rate (l/s)

Test Capability – % Design Flow

△ PERF - REBUILD □ PERF - OLD ● PERF - NEW
Figure 4

2014 COOLING TOWER THERMAL TESTS
ALL TESTS

Test Capability – % Design Flow

Water Flow Rate (l/s)

- ACCEPT-NEW
- ACCEPT-REFURB
- PERFORMANCE
Figure 5

THERMAL PERFORMANCE -- HISTORIC OVERVIEW

Test Capability % Design Flow

YEAR

Note: From 1988 to 1994, acceptance test data did not distinguish between new and refurbished towers
Figure 6

2014 Thermal Acceptance Tests
New Cooling Towers

Design Flow Band, l/s (gpm)

- As Reported
- w/o HP Correction
- 1st Test
- Retest
- <100%
Figure 7

Capability versus Parameters Out-of-Code for Acceptance Tests on New Towers
Figure 8

2014 Thermal Acceptance Tests

Average Capability, %

New Crossflow | Rebuilt Crossflow | New Counterflow | Rebuilt Counterflow

Cooling Tower Type
Figure 9

Acceptance Tests with 100% or Greater Capability

Year

Percent of Tests with 100% or Greater Capability


New Towers
Refurbished Towers
APPENDIX A
CTI Licensed Thermal Testing Agencies

Effective 1/1/2015

<table>
<thead>
<tr>
<th>License Type*</th>
<th>Agency Name</th>
<th>Address</th>
<th>Contact Person / E-mail / Web site</th>
<th>Telephone Number</th>
<th>FAX Number</th>
</tr>
</thead>
<tbody>
<tr>
<td>A, B</td>
<td>Clean Air Engineering, Inc.</td>
<td>7936 Conner Rd Powell, TN 37849 U.S.A.</td>
<td>Kenneth Hennon <a href="mailto:khennon@cleanair.com">khennon@cleanair.com</a> <a href="http://www.cleanair.com">www.cleanair.com</a></td>
<td>(800) 208-6162</td>
<td>Or (865) 938-7555</td>
</tr>
<tr>
<td>A, B</td>
<td>Cooling Tower Technologies Pty. Ltd.</td>
<td>PO Box 4157 Bexley North, NSW 2207 AUSTRALIA</td>
<td>Ronald Rayner <a href="mailto:coolingtwrtech@bigpond.com">coolingtwrtech@bigpond.com</a> <a href="http://www.cti.org">www.cti.org</a></td>
<td>61 2 9789 5900</td>
<td>61 2 9789 5922</td>
</tr>
<tr>
<td>A, B</td>
<td>Cooling Tower Test Associates, Inc.</td>
<td>15325 Melrose Drive Stanley, KS 66221 U.S.A.</td>
<td>Thomas E. Weast <a href="mailto:cttakc@aol.com">cttakc@aol.com</a> <a href="http://www.cttai.com">www.cttai.com</a></td>
<td>(913) 681-0027</td>
<td>(913) 681-0039</td>
</tr>
<tr>
<td>A, B</td>
<td>McHale &amp; Associates, Inc.</td>
<td>4700 Coster Road Knoxville, TN 37912 U.S.A.</td>
<td>Bernard J. Pastorik, P.E. <a href="mailto:bernie.pastorik@mchale.org">bernie.pastorik@mchale.org</a> <a href="http://www.mchale.org">www.mchale.org</a></td>
<td>(865) 588-2654</td>
<td>(865) 934-4779</td>
</tr>
</tbody>
</table>

* Type A license is for the use of mercury-in-glass thermometers; typically used for smaller towers.

Type B license is for the use of remote data acquisition devices, which can accommodate multiple measurement locations required by larger towers.
CTI Licensed Drift Testing Agency
Effective 1/1/2015

<table>
<thead>
<tr>
<th>Agency Name</th>
<th>Address</th>
<th>Contact Person / E-mail / Website</th>
<th>Telephone Number</th>
<th>FAX Number</th>
</tr>
</thead>
</table>
| Clean Air Engineering, Inc.  | 7936 Conner Rd Powell, TN 37849 U.S.A. | Kenneth Hennon
  khennon@cleanair.com
  www.cleanair.com | (800) 208-6162
  Or (865) 938-7555 | (865) 938-7569 |
  bernie.pastorik@mchale.org
  www.mchale.com | (865) 588-2654 | (865) 934-4779 |
## Data on CTI Licensed Thermal Testing Agencies

**Effective 1/1/2015**

<table>
<thead>
<tr>
<th>Agency Name</th>
<th>License Type*</th>
<th>Licensed Testing Agency Since</th>
<th>Number of Lead Testers**</th>
<th>Number of Data Loggers**</th>
<th>Pipe Diameters covered by Pitot Tubes</th>
<th>Total Number Wet Bulb Instruments</th>
<th>Geographic Preference</th>
</tr>
</thead>
<tbody>
<tr>
<td>CleanAir Engineering, Inc.</td>
<td>A&amp;B</td>
<td>2006</td>
<td>9</td>
<td>30</td>
<td>150 – 5260 mm (6” – 207”)</td>
<td>&gt;150</td>
<td>Worldwide</td>
</tr>
<tr>
<td>Cooling Tower Technologies Pty. Ltd.</td>
<td>A&amp;B</td>
<td>2004</td>
<td>1</td>
<td>4</td>
<td>150 - 3600 mm (6” - 142”)</td>
<td>40</td>
<td>Worldwide</td>
</tr>
<tr>
<td>Cooling Tower Test Associates, Inc.</td>
<td>A&amp;B</td>
<td>1997</td>
<td>2</td>
<td>9</td>
<td>50 - 4265 mm (2” - 168”)</td>
<td>60</td>
<td>Worldwide</td>
</tr>
<tr>
<td>McHale &amp; Associates, Inc.</td>
<td>A&amp;B</td>
<td>2006</td>
<td>8</td>
<td>50</td>
<td>150 - 5500 mm (6” - 216”)</td>
<td>&gt;150</td>
<td>Worldwide</td>
</tr>
</tbody>
</table>

* Type A license is for the use of mercury-in-glass thermometers, typically used for smaller towers.
  
  Type B license is for the use of remote data acquisition devices, which can accommodate multiple measurement locations required by larger towers.

** Maximum number of concurrent tests will be limited by the number of lead testers and/or the number of data loggers.
## Data on CTI Licensed Drift Testing Agencies

**Effective 1/1/2015**

<table>
<thead>
<tr>
<th>Agency Name</th>
<th>Licensed Testing Agency Since</th>
<th>Number of Lead Testers*</th>
<th>Number of Drift Sampling Trains*</th>
<th>Geographic Preference</th>
</tr>
</thead>
<tbody>
<tr>
<td>CleanAir Engineering, Inc.</td>
<td>2006</td>
<td>8</td>
<td>5</td>
<td>Worldwide</td>
</tr>
<tr>
<td>McHale &amp; Associates, Inc.</td>
<td>2006</td>
<td>9</td>
<td>5</td>
<td>Worldwide</td>
</tr>
</tbody>
</table>

*Maximum number of concurrent tests will be limited by the number of lead testers and/or the number of drift sampling trains.*