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DESIGN AND OPERATION OF A COUNTERFLOW FILL AND NOZZLE TEST CELL: CHALLENGES AND SOLUTIONS

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1. INTRODUCTION

Factory-assembled cooling towers are generally compact enough to be tested and certified in environmental test chambers of reasonable proportions. Field-erected towers however can only be tested on-site after their construction has been completed. In order to rate them beforehand, to comply with the design conditions specified by the end-user, their components must be tested individually in test cells specially designed to that effect. Finding the solutions to problems like the size of the test cells, their configuration and operation, the type of instrumentation used to capture the fundamental thermodynamic data, etc., requires good engineering skills, time and money to be able to acquire meaningful and useful data.

Only a handful of cooling tower manufacturers and equipment suppliers worldwide own and operate fill test cells. Until a few years ago a test cell was available for third party testing on the west coast but it has since been shut down.

In the mid-eighties the Electric Power Research Institute (EPRI), funded by some of the largest US power producers, built a fill test cell near Houston, Texas. EPRI pursued an ambitious test program of many different counterflow fills commercially available at that time. The results were published and made available to EPRI members.

In the past ten years several industry consultants have presented the results of their research on cooling tower fills to the Cooling Technology Institute (CTI) membership. While their work was technically excellent and informative, the raw data and the methodology of data analysis were not divulged to the public, leaving the use of the final data subject to interpretation.

It is therefore an important technological step for a manufacturer to generate reliable data for proprietary fill and spray nozzle performance. This paper will present some of the most relevant aspects of the design, construction, instrumentation and operation of a state-of-the-art fill and nozzle test cell.

2. CHALLENGES

A vast majority of the new cooling towers erected in the field today are specified to be counterflow so the primary focus of R&D is on counterflow applications. A test cell is a scaled-down version of the manufacturer's proprietary design. It is designed to work in a controlled environment susceptible

to produce constant conditions of operation on both the water side and the air side.

At the onset of the design phase the engineer faces several challenges.

- Sufficient water side heat load must be available so that the maximum temperature range – commensurate with the most severe applications - can be obtained easily and kept steady for a reasonable period of time.
- The water flow must be distributed uniformly over the fill. Properly selecting the spray nozzles is critical. Knowing the spray pattern, in other words the relationship between flow rate, pressure and area of coverage, is essential to get meaningful results.
- While in large field-erected towers, the quantity of hot water which bypasses the fill section is relatively small and controllable, this is not true in a small-scale test facility. Quantifying the amount of “wall water bypass” is another critical factor to obtaining reliable results.
- Uniformity of air flow is obtained by selecting the right fan(s) and including aerodynamic features such as guide vanes and settling screens where necessary.
- The instrumentation must be properly chosen and adequately located throughout the test cell. Accuracy and redundancy are important to make sure the measurements are representative of the conditions of operation and the results can be trusted.
- In this configuration, the test section has been designed to minimize thermal transfer in the rain zone below the fill so as to focus on the thermodynamic properties of the fill and spray zone only. Accordingly the water collection system below the fill has been designed to minimize the rain zone while its effect on the airflow profile when the air enters the fill is minimal. (If the rain zone is not minimized, its thermal and aerodynamic contributions must be taken into account in the test interpretation).

3. DESCRIPTION

The counterflow test cell described in this paper is a forced draft configuration with two main parts: a horizontal section where the airflow is produced and quantified followed by a vertical section with the fill and spray nozzles. The cell cross section is rectangular measuring 2.4 m (8 ft) long by 1.8 m (6 ft) wide. The test cell can be broken down into seven segments:

1. Two horizontal tubular inline fans in parallel driven by two 40 horsepower TEFC 3-phase electric motors and a variable-frequency drive produce the cooling airflow.
2. The air flow measurement chamber follows the guidelines of ANSI/AMCA Standard 210. It includes several layers of settling screens upstream and downstream of a bank of elliptically-shaped flow nozzles with piezometer rings to measure the local static and differential pressures. Multiple wet bulb and dry bulb instruments measure the entering air temperatures.
3. Joining the horizontal and the vertical sections is a 90° bend with guiding vanes to distribute the air evenly upward into the fill test section.

4. A cold water collection system with several tiers of sloped troughs catches the cold water falling below the fill; the cold water from the troughs is discharged into a box intended to mix the cold water and to direct it to a tank outside the cell; redundant temperature sensors measure the cold water temperature downstream of the box.
5. The fill section is 2.4 m (8 ft) long by 1.83 m (6 ft) wide by 2.4 m (8 ft) high. Fill supports can be adjusted up or down to accommodate various fill depths and keep a constant spray height. Watertight doors in the side walls provide access to install or remove fill packs.
6. The water spray section includes PVC pipes fitted with spray nozzle adaptors, redundant hot water temperature sensors and a spray pressure fitting. This section has changeable pipe supports so the spray height can be adjusted too. This section also contains a system which catches and re-directs the wall water to an outside tank where its flow rate and temperature are measured.
7. A layer of drift eliminators is installed above the spray section. This section also includes multiple leaving wet bulb and dry bulb temperature sensors.
8. The test cell is installed in an environmental test chamber where a system of exhaust and intake fans and dampers are used to control the conditions of the entering air and maintain steady conditions during the test runs.

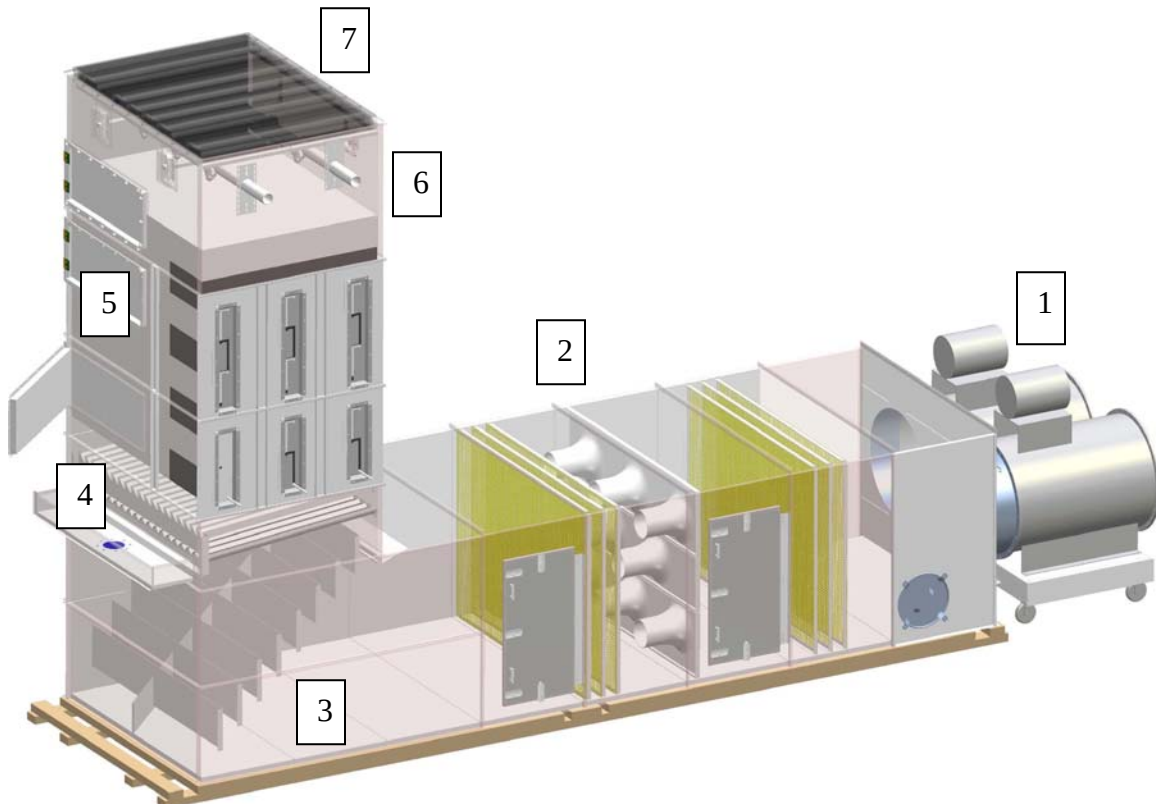


Figure 1: Counter-Flow Test Cell