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AN EVALUATION OF THE X-GRID FILL PACK FOR COOLING TOWERS

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Abstract

Due to fouling of the conventional corrugated asbestos fill pack for cooling towers, Umzimkulu repacked three cells with the innovative "X-Grid" expanded metal splash pack made from 3CR12. The characteristics, installation and efficiencies of the "X-Grid" are evaluated and these parameters together with the costs and advantages are compared to other fill pack types in use at Umzimkulu.

Introduction

Historically at Umzimkulu the asbestos fill packs became badly fouled towards the latter part of the crush season, resulting in reduced cooling efficiency with an adverse effect on process. This often necessitated manual cleaning, which was time consuming and costly from the chemical wastage point of view as the basin also had to be drained.

Prior to 1987 the seven cells of the cooling tower at Umzimkulu were packed with corrugated asbestos film. In 1987, No. 7 cell was refurbished with the plastic splash pack because of its cost and construction advantages. A year later, No. 6 cell was repacked with 3CR12 expanded metal "X-Grid".

Although X-Grid is a new concept in cooling tower fill pack the many advantages make it attractive. While no adverse effect in performance was noted in the No. 6 cell the cleanliness of the fill pack throughout the year led to the decision to replace future cell packs with "X-Grid". Two extra cells, No. 1 and No. 5, were packed with "X-Grid" at the beginning of the 1989 season.

This paper serves to evaluate the performance and advantages of "X-Grid" relative to other fill packs at Umzimkulu.

Characteristics

At the outset certain characteristics of "X-Grid" attracted Umzimkulu to this type of fill.

Cost effectiveness

The "X-Grid" was lower in cost than corrugated asbestos fill pack but more expensive than the Hamon "Losange" plastic fill pack (refer to Table 1).

Table 1

Cost comparison of various fill packs

Cell Pack Type	Hamon "Losange" Film Pack	"X-Grid" 3CR12	Corrugated Asbestos
Cost Factor units	100	125	300

Thermodynamic efficiency

The manufacturers claim good heat transfer characteristics (Anon[2]). As the concept is still relatively new, a complete prototype pack has been installed and performance tests experimenting with opening sizes and bar widths are being conducted by the manufacturers.

Installation

The grid is easy to install with a very robust and effective suspension system. Due to the open area design, fouling of the splash pack is highly unlikely.

Design and Installation

A technical description for an induced draught cooling tower repack made from 3CR12 expanded metal "X-Grid" is given by Hamon Sobelco (personal communications).

Splash pack

The "X-Grid" is constructed from 1,2 mm thick 3CR12 expanded metal with the opening sizes designed to specification. The grid is suspended from stainless steel wire 2,6 mm (min) in diameter supported from twelve 50 mm diameter pipes resting between 3CR12 channel beams end to end in the cell. Walkways are also constructed in the top of the cell to facilitate cleaning of the sprays. The splash pack is constructed in a light tray format (600 mm modules), the grids being clipped together by retaining spigots. These make up a horizontal plane. Between each plane is a spacer tube 200 mm in length through which the suspension wires are positioned. The pack is made up to 15 tiers. Loads are thus taken up by the plastic spacer tubes in compression and the stainless steel wires in tension. Because of this unique suspension system the chain collapse so often associated with other types of splash grid packings is extremely unlikely.

Water distribution

The hot water is fed into the main 315 mm dia P.V.C. header which is overwrapped with fibreglass. The hot water is distributed over the fill by a network of P.V.C. lateral pipes (125 mm dia.) connected to the header with Z joints, which are welded and fibreglassed to the header. The lateral pipes are equipped with suitably spaced and sized plastic Hamon sprays to ensure efficient distribution of the hot water.

Drift eliminators

A layer of P.V.C. wave type drift eliminators is located on the existing concrete beams above the water distribution system. This reduces the drift loss to 0,02%. The drift eliminator waves are kept apart by plastic spacers and locked into panels by threaded stainless steel tie rods and nuts. Reduction of water loss is achieved by the removal of droplets.

The internal support system

The P.V.C. header and lateral pipes are supported by 3CR12 pipe hangers suspended from the concrete beams on which the drift eliminators are positioned. 3CR12 angle brackets are anchored to the walls as end supports to 3CR12 channel beams. The fill is suspended from the 50 mm stainless steel pipes positioned on the 3CR12 channel beams.

Future use of "X-Grid"

The future uses of "X-Grid" are set out by Industrial Water Consultants (Anon[2]) in which certain advantages are shown.

Deterioration

According to the manufacturers a packing system in any cooling tower should have a life expectancy equal to that of the cooling tower structure. "X-Grid" satisfies this criterion far better than the existing packing materials such as plastic and asbestos which are prone to deterioration with age.

Water Quality

Due to the non-clogging nature of "X-Grid", water quality is improved as a result of less slime formation and sulphate reducing bacteria manifestation. This aspect will reduce pipe corrosion which can result in lower chemical costs for water treatment. With 3CR12 steel, chloride based chemical water control is not recommended, although a small amount of chloride concentration can be tolerated.

Fire

Both timber and plastic packs present a fire hazard during times of tower shut-down.

Maintenance

Other packs have shown structural weakness causing localized packing collapse, which is costly to repair. Clogging of small openings of other type packs reduces the tower performance and results in higher operating costs. Slime build up on "X-Grid" has not occurred, eliminating on-the-run cleaning entirely.

Performance Evaluation

The evaluation of cooling tower performance is a very detailed and exact science which should be carried out according to strict test conditions, specified by the Cooling Tower Institute (CTI)(Anon[1]).

If a meaningful comparison be required from test data, the myriad of conditions that affect tower performance must be taken into account so that results obtained will have the same common base.

In this exercise every care was taken to ensure consistent and accurate data collection within the boundaries prescribed by CTI (Anon[1]). However, certain design specifications from the manufacturers are not obtainable, which necessitates the making of strategic assumptions. Due to these assumptions it is unfortunate that the data shown cannot be used for other tower comparisons according to CTI values, but the results are nevertheless a useful indication of the comparison of different fill packs in operation at Umzimkulu.

Test parameters

At present the Umzimkulu cooling tower has a variety of fill packs which make a comparison of the different cells ideal. These are shown in Table 2.

Table 2

Fill types

Cell No.	Fill Type
1	"X-Grid" by Hamon Sobelco
2	Corrugated asbestos
3	Corrugated asbestos
4	Corrugated asbestes
5	"X-Grid" by Hamon Sobelco
6	"X-Grid" by I. W. C.
7	Plastic Splash Pack by Hamon Sobelco

Test data

The test data shown are averaged over a period of 19 days in which samples were taken. The following field test data collected and used for calculation purposes are shown in Table 3.

As design characteristics for the various fill packs in use at Umzimkulu are not available, the above design parameters are assumed. However, this does not detract from the final result, as any reasonable values can be used to produce the same net end results when comparisons between the cells are made.

Water Circulation Rate

Actual water flow rates for this exercise are not essential because no attempt is being made to predict the amount of water the tower can cool or to predict cooling water temperatures. What is significant, however, are the relative flow rates to each cell, which were predicted by using a chloride tracer test in which the chloride concentration versus time is plotted on a graph for each cell. The area described under the curve of each cell is the measure of total mass of chloride passing through each cell which in turn is a measure of the flow of water through each cell. Figures 1 and 2 show the profile of each chloride tracer test for each cell.

As the water flow rate capacity of a cooling tower is directly proportional to the air flow, and the air flow is proportional to the cube root of the power delivered by the fans, the test L/G ratio can be computed and this in turn can be used with the test data to calculate a performance characteristic for each cell (KaV/L). The cold water temperature in each case has a significant effect on the end result.

Table 3

Test data

	Cell							Design Parameters
	1	2	3	4	5	6	7	
Water circulation Flow ratio	0,1897	0,1653	0,1647	0,1665	0,2009	0,1871	0,1938	0,1811
T_1 °C — HWT	50,6	50,6	50,6	50,6	50,6	50,6	50,6	50
T_2 °C CWT	37,1	36,8	36,1	34,9	36,6	37,0	34,8	30
Range (T_1-T_2) °C	13,5	13,8	14,5	15,7	14,0	13,6	15,8	20
WBT °C	19,4	19,4	19,4	19,4	19,4	19,4	19,4	23,3
Approach °C	17,7	17,4	16,7	15,5	17,2	17,6	15,4	6,7
Test fan motor amps	38	40	50	52	52	44	50	varied
Design fan motor amps	54,0	55,6	54,0	59,7	59,7	58,0	58,0	-
Test L/G	1,30	1,12	—	1,06	1,28	—	1,24	1,1

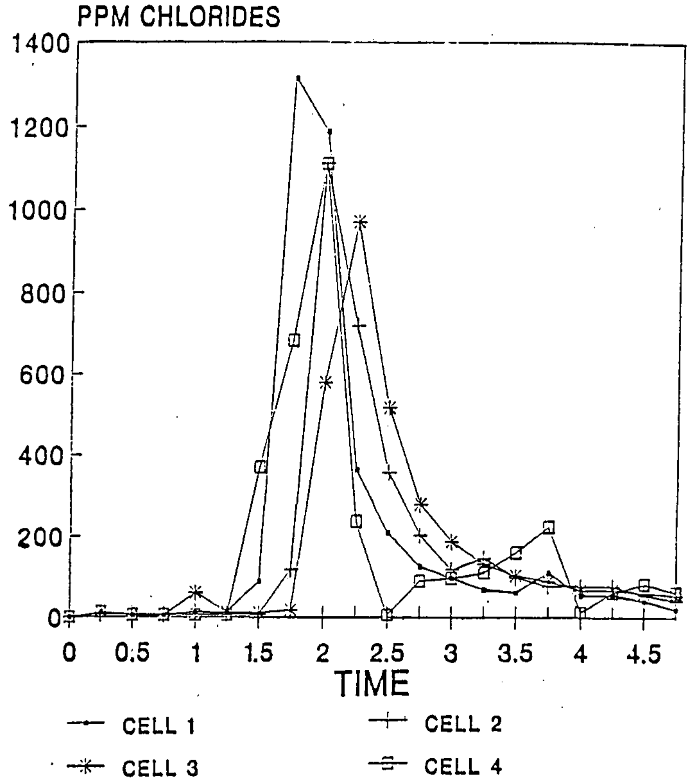

FIGURE 1 Chloride tracer test — cells one to four

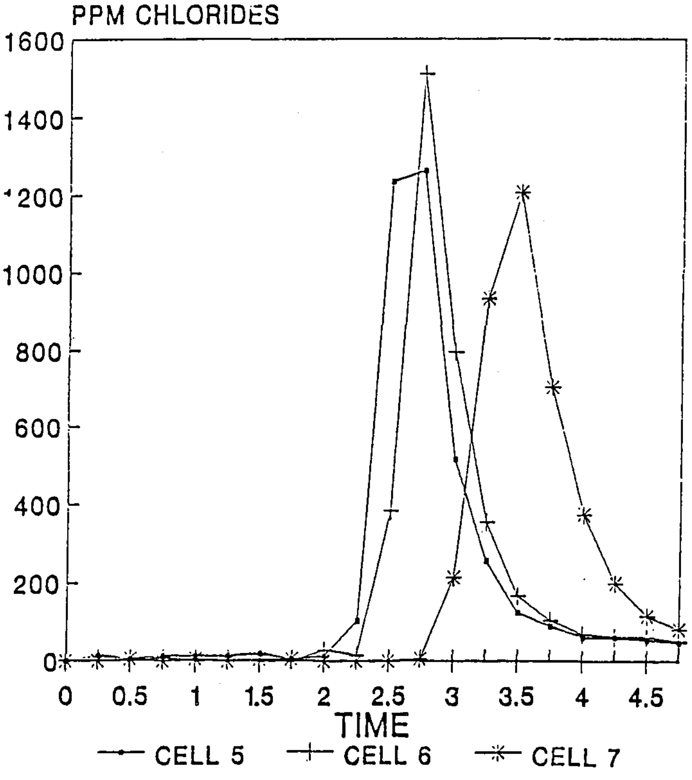

FIGURE 2 Chloride tracer test — cells five to seven

Calculations

The test L/G value (Anon[1]), using a "design L/G" from Figure 3, is used in the following equations:

Test L/G = (design L/G)

$$\frac{(\text{test m}^3/\text{hr})}{(\text{design m}^3/\text{hr})} \times \frac{(\text{Fan design power}) \ 1/3}{(\text{Fan test power})}$$

which can be modified to:

Test L/G = (design L/G)

$$\frac{(\text{test water flow ratio})}{(\text{design water flow ratio})} \times \frac{(\text{design fan motor amps}) \ 1/3}{(\text{test fan motor amps})} \quad \ldots (1)$$

Test L/G ratios so calculated are then used with the test data to calculate test KaV/L values (Anon[1]).

$$\text{where: } \quad \text{KaV/L} = \int_{T_2}^{T_1} \frac{dT}{h_w - h_a} \quad \ldots\ldots (2)$$

An example of this calculation is shown in Appendix 1 and the results of all KaV/L calculations are shown in Table 5.

Design requirements curve

The design requirements curve (Anon[1]) is used in conjunction with a described KaV/L versus L/G relationship to determine performance. This curve is termed the "design requirements" curve, which is a measure of the degree of difficulty of the design requirements and has nothing to do with the physical characteristics of the tower (cell).

It is constructed by assuming values of L/G and design parameters from Table 3 to calculate design KaV/L values. Design KaV/L values were thus obtained for assumed L/G values as shown below in Table 4. Appendix 2 shows the full calculation for an assumed 0,8 L/G ratio. The above points are plotted on logarithmic graph paper as shown in Figure 3 and Figure 4.

Table 4
Design requirement values

L/G value (assumed)	0,2	0,4	0,8	1,0	1,2	1,5	2,0
KaV/L value (calculated)	0,826	0,875	0,998	1,078	1,176	1,377	2,090

Characteristic curve

An arbitrary characteristic curve (Anon[1]) is also plotted in Figure 3 and Figure 4. It should be noted that the slope

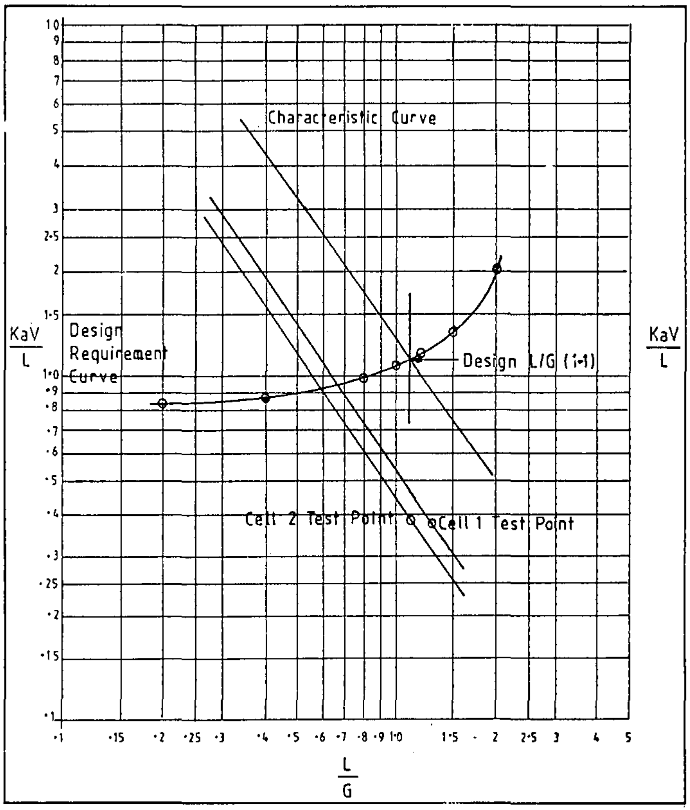

FIGURE 3 Test cells one and two

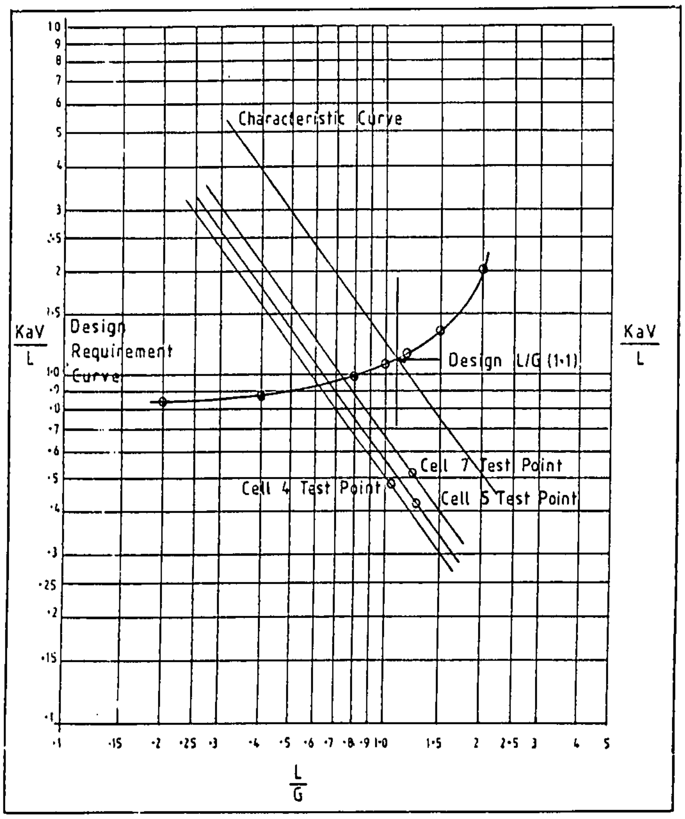

FIGURE 4 Test cells four, five and seven

or position is not critical to the test outcome as the end result only reflects the comparison between two cells and not absolute values.

The "design L/G" is the L/G value at the intersection of the characteristic and design requirements curve, which in this case is 1,1, (see Figure 3 and Figure 4). The design L/G value is used in equation 1.

Results

An example for cell 1 is given below:

$$\text{from eqn (1) test L/G} = (1{,}1) \times \frac{(0{,}1897)}{(0{,}1811)} \times \frac{(54{,}0)}{(38{,}0)}\ 1/3$$

$$= 1{,}295$$

from eqn (2) KaV/L = 0,38 (see Appendix 1 for full calculations)

This point is plotted in Figure 3 and a curve parallel to the characteristic curve is drawn through it. This curve intersects the design requirements curve at an L/G of 0,63. This value is termed the actual L/G capability (Anon[1]). The cell performance is given by the equation:

$$\%\ \text{Capability} = \frac{\text{actual L/G capability}}{\text{Design L/G}} \times 100$$

$$= \frac{0{,}63}{1{,}1} \times \frac{100}{1} = 57{,}2\%$$

Similarly, results of the other test cells are shown in Table 5.

Discussion

While the water flow rate, L, is predicted with some degree of certainty, an assumption for air flow rate, G, must be made. As G cannot be calculated, and since it was not measured, it must of necessity be assumed a constant between two cells for a comparison to be made.

Fan blade angles and power consumptions of fan motors have a direct effect on G and both these factors must be relatively close if a constant G between two cells can be assumed. Table 6 gives these figures.

From Table 6 it can be seen that for cells 1 and 2 the power consumption in amps and the blade angles are relatively close, and therefore a constant G between these two cells can be assumed. A comparison between these two cells can now be made. Similarly cells 4 and 5, and 5 and 7, can also be compared.

From Table 5 it can be seen that "X-Grid" in cell 1 shows a better performance than corrugated asbestos in cell 2 by 5,4%. Similarly cell 5, "X-Grid", shows a better performance than cell 4, corrugated asbestos by 6,3%. The plastic grid in cell 7 shows a better performance than "X-Grid" in cell 5 by 3,7%.

Conclusions

"X-Grid" in 3CR12 expanded metal has some major advantages over its competitors in terms of its durability, corrosion resistant nature, longevity, and sturdy robust structure. Its open design makes it virtually clog free and maintenance free. In terms of its longevity it has important cost advantages.

It appears that "X-Grid" thermodynamic properties are better than those of the existing corrugated asbestos film packs presently in use at Umzimkulu but worse than those of the plastic splash pack.

REFERENCES

1. Anon (1961; 1967). Cooling Tower Institute. *CTI bulletin* ATP 105 (May 1967) and *CTI bulletin* TPR 121 (Dec 1961).
2. Anon (1988). Industrial Water Consultants (1988). Draft release. *A new concept in cooling tower packing.*

Table 5

Results

Cell No.	Test L/G	Test KaV/L	L/G Capability	% Capability
1	1,30	0,381	0,63	57,2
2	1,12	0,385	0,57	51,8
4	1,06	0,485	0,60	54,6
5	1,28	0,410	0,67	60,9
7	1,24	0,509	0,71	64,6

Table 6

Individual cell power consumption

Cell	1	2	3	4	5	6	7
Average blade angle	9,3	8,5	11,75	9,75	14,25	7,50	11,5
Power consumption in amps	38	40	50	52	52	44	50

APPENDIX 1

Example: cell number 1

KaV/L Calculation

GIVEN:
HWT $T_1 = 50.6$
CWT $T_2 = 37.1$
$WBT = 19.4 = h_1$
TEST $L/G = 1.3$

FROM THE ENTHALPY TABLE @ WBT
$h_1 =$ 2538
$h_2 = h_1 + L/G \; (T_1 - T_2)$
$=$ 2556

KaV/L = 0.381

T DEG C	h_u	h_a	$(h_u - h_a)$	$\frac{1}{(h_u) - h_a)}$
$T_2 = 37.0$	2570	$h_1 = 2538.00$		
$T_2 + 0.1\,(T_1 - T_2) = 38.5$	2573	$h_1 + 0.1L/G\,(T_1 - T_2) = 2539.76$	33.24	0.0301
$T_2 + 0.4\,(T_1 - T_2) = 42.5$	2580	$h_1 + 0.4L/G\,(T_1 - T_2) = 2545.02$	34.98	0.0286
$T_1 + 0.4\,(T_1 - T_2) = 45.2$	2585	$h_2 + 0.4L/G\,(T_1 - T_2) = 2548.53$	36.47	0.0274
$T_1 + 0.1\,(T_1 - T_2) = 49.3$	2591	$h_2 + 0.1L/G\,(T_1 - T_2) = 2553.80$	37.20	0.0269
$T_1 = 50.6$	2593	$h_2 = 2556.00$		

where: $$KaV/L = \int_{T_2}^{T_1} \frac{.dT}{h_u - h_a} = \left(\frac{T_1 - T_2}{4}\right) \times \left(\frac{1}{h_u - h_a}\right)$$

$$= \left(\frac{50.6 - 37.1}{4}\right) \times (0.11297)$$

$$= 0.381$$

APPENDIX 2

Example: Designer L/G vs KaV/L

KaV/L Calculation

GIVEN:
HWT $T_1 = 50$
CWT $T_2 = 30$
$WBT = 23.3 = h_1$
ASSUME $L/G = 0.8$

FROM THE ENTHALPY TABLE @ WBT
$h_1 =$ 2545
$h_2 = h_1 + L/G \; (T_1 - T_2)$
$=$ 2561.00

KaV/L = 0.998

T DEG C	h_u	h_a	$(h_u - h_a)$	$\frac{1}{(h_u) - h_a)}$
$T_2 = 30.0$	2556	$h_1 = 2545.00$		
$T_2 + 0.1\,(T_1 - T_2) = 32.0$	2560	$h_1 + 0.1L/G\,(T_1 - T_2) = 2546.60$	13.40	0.0746
$T_2 + 0.4\,(T_1 - T_2) = 38.0$	2572	$h_1 + 0.4L/G\,(T_1 - T_2) = 2551.40$	20.60	0.0485
$T_1 + 0.4\,(T_1 - T_2) = 42.0$	2578	$h_2 + 0.4L/G\,(T_1 - T_2) = 2554.60$	23.60	0.0427
$T_1 + 0.1\,(T_1 - T_2) = 48.0$	2589	$h_2 + 0.1L/G\,(T_1 - T_2) = 2559.40$	29.60	0.0338
$T_1 = 50.0$	2592	$h_2 = 2561.00$		

where: $$KaV/L = \int_{T_2}^{T_1} \frac{.dT}{h_u - h_a} = \left(\frac{T_1 - T_2}{4}\right) \times \left(\frac{1}{h_u - h_a}\right)$$

$$= \left(\frac{50 - 30}{4}\right) \times (0.19969)$$

$$= 0.998$$

APPENDIX 3

Nomenclature

T = Bulk water temperture; °C
T_1 = Hot water temperature; °C
T_2 = Cold water temperature; °C
WBT = Wet bulb temperature; °C
L/G = Liquid to gas ratio; kg water per kg dry air
KaV/L = Tower characteristic
h = enthalpy of air - water vapour mix; kJ/kg
h_a = enthalpy at WBT; kJ/kg
h_u = enthalpy at bulk water temperature; kJ/kg
h_1 = enthalpy at inlet WBT; kJ/kg
h_2 = enthalpy at exhaust WBT; kJ/kg

Where T_1 is a common temperature to all cells taken after good mixing prior to entering the common inlet manifold.

T_2 is an average of six readings taken from different points in each cell, the samples being collected from the falling rain prior to entering the basin.

WBT readings were taken from six points around the perimeter of the tower while each test data run was in progress using a wet bulb hand instrument.