MinWaterCSP

Minimized water consumption
in CSP plants

Deluge test bundle construction
WP 7, Deliverable 7.3

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Authors:
Francois Louw (Kelvion Thermal Solutions)

El Ghali Benounna (Iresen)

Stephan Krafzik (ENEXIO Germany)

Albert Zapke (ENEXIO Management)

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30/06/2017	REV00	Francois Louw (Kelvion Thermal Solutions) El Ghali Benounna (Iresen) Albert Zapke (ENEXIO Management, Stephan Krafzik (ENEXIO Germany)	Demonstrable for installation of fouling test facility

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1 Introduction

1.1 Background

As part of the MinWaterCSP H2020 project, a deluge cooling system is being developed that can be run in parallel to ordinary dry-cooled heat exchangers. The concept consists of bear round tube bundles of which the outside can be flooded intermittently with water, allowing the process fluid or vapour on the inside to cool or condense. The system would typically be initiated during peak atmospheric temperatures or adverse operating conditions, providing additional evaporative cooling in addition to the convective heat transfer through air.

For such applications, the deluge water would ideally be of poor quality in order to reduce water consumption cost (i.e. extracted from other locations of the plant or of high cycles of concentration). This quality could potentially be conducive to fouling, requiring further investigations.

For this purpose a literature overview on fouling has been conducted and a fouling test facility as depicted in figure 1.1 has been designed as part of deliverables 7.1 and 7.2. Deliverable 7.3 (Tasks 7.3.1 to 7.3.3) entailed the procurement, manufacturing, shipping to the relevant site (Green Energy Park, Ben Guerir, Morocco), installation and commissioning. The personnel at Iresen has presently commenced with test work using this facility.

The present document provides descriptive pictures and some preliminary results from operation of the test facility.

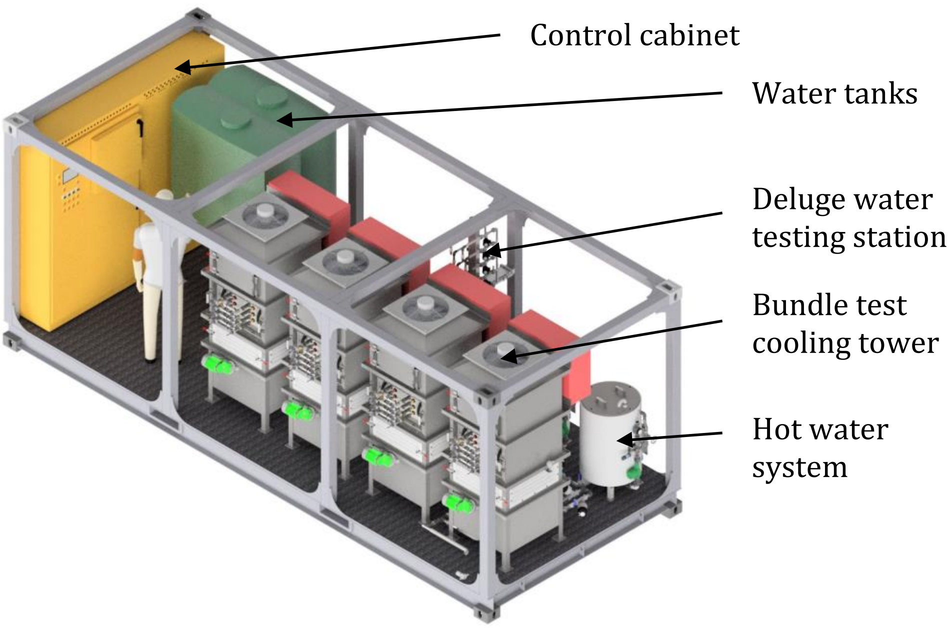

Figure 1.1: Bare tube bundle fouling test facility

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2 Fouling test facility installation

2.1 Test rig description

A detailed description of the functionality of the test facility is presented in Deliverable 7.2. However, a short summary with reference to figures 1.1 and 2.1 is merited in this document.

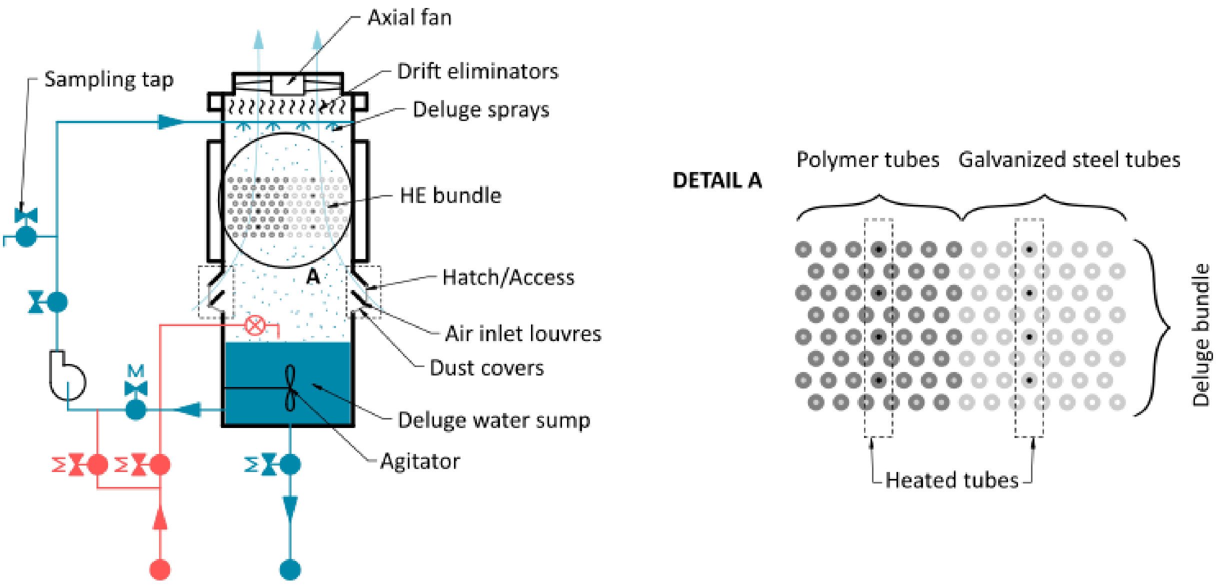

Figure 2.1: Process diagram of a single cooling tower

It can be observed that four cooling towers are mounted inside a transportable frame. Each cooling tower is connected to a hot water system providing warm water to the heated tubes of the bundle within each tower. A field panel an electrical interface between each tower and the main control cabinet.

In each cooling tower, a bare tube bundle is mounted, consisting of two different types of tube material. The first being galvanized steel and the second a polymer type tube. Before testing commences, different compositions of deluge water is mixed in the sump of each cooling tower according to a certain specification to investigate the fouling capability of the water as well as its effect on the heated tubes' performances over time. (Other variables are also investigated such as tube temperatures, water acidity, flooding rates, etc). A specific deluge program is then set on the human machine interface (HMI) (e.g. repetitive cycles of 5 minutes wet operation, 10 minutes dry operation), whereafter a deluge cycle is started. Deluge water is then circulated over the bundles, while air is induced counter-currently by fans at the top of each cooling tower. Any evaporated water is made up with demineralized water to have as little of an effect as possible on the deluge water composition. The deluge water is also regularly replaced to maintain a more or less constant composition over the period of testing. While testing, a range of measurements are logged on a local computer for analyses.

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2.2 Site layout

The test rig is installed as indicated in figure 2.2. Demineralized water is produced on site by a combination of solar PV and thermal heat. Reverse osmosed water is collected in a demineralized water tank, which is then fed to a buffer tank in the test facility. The demineralized water is used as described earlier. Similarly well water is also collected in a buffer tank for use in the hot water tanks as well as general cleaning. Water drained from the sumps of each cooling tower is released into two submerged tanks under gravity. The water in latter tanks are extracted as necessary.

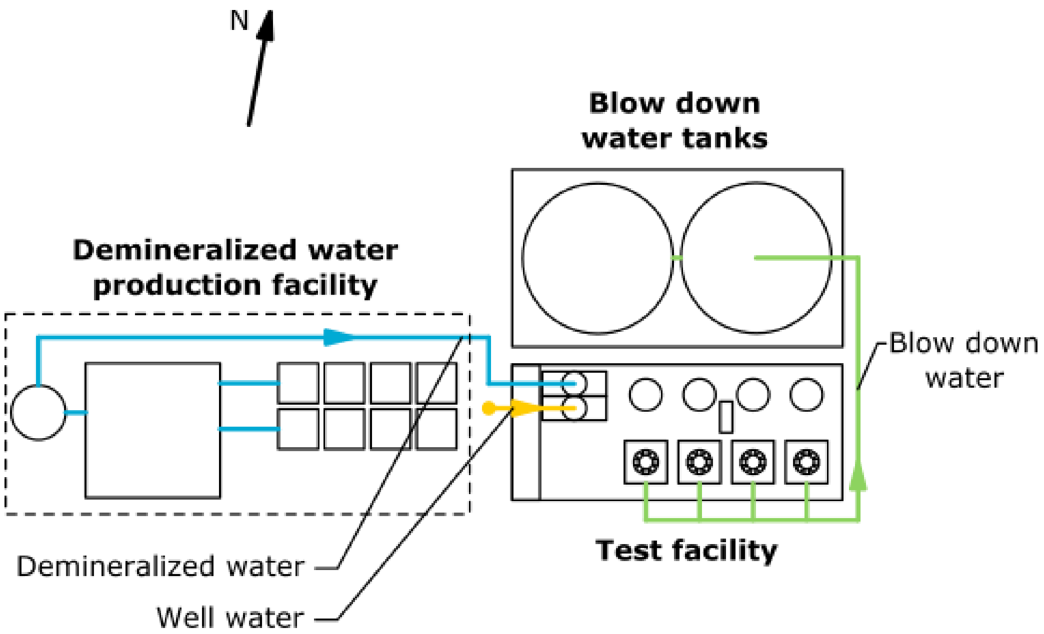

Figure 2.2: Plan view of site layout of installed test facility

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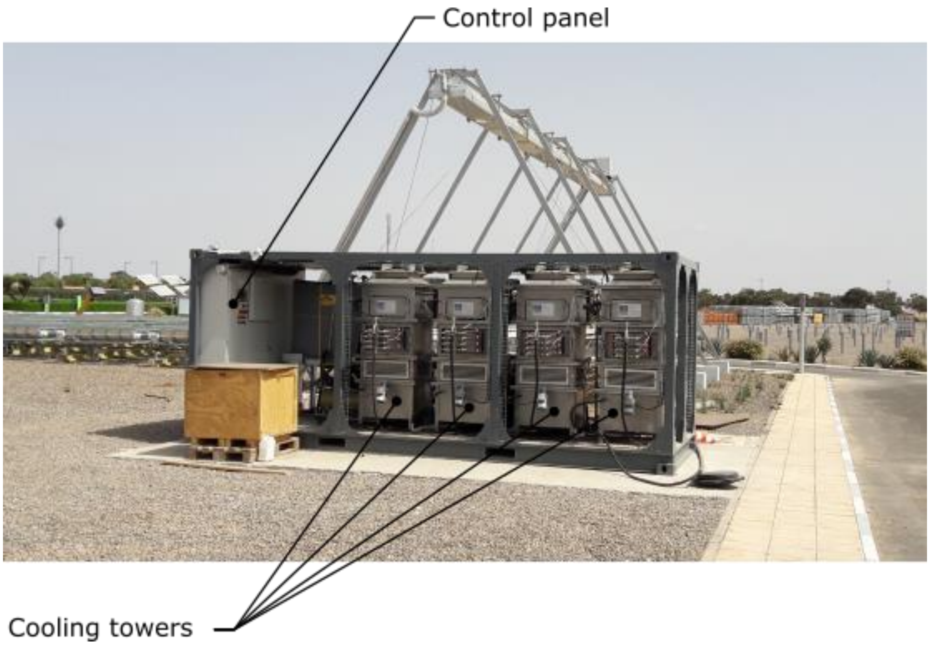
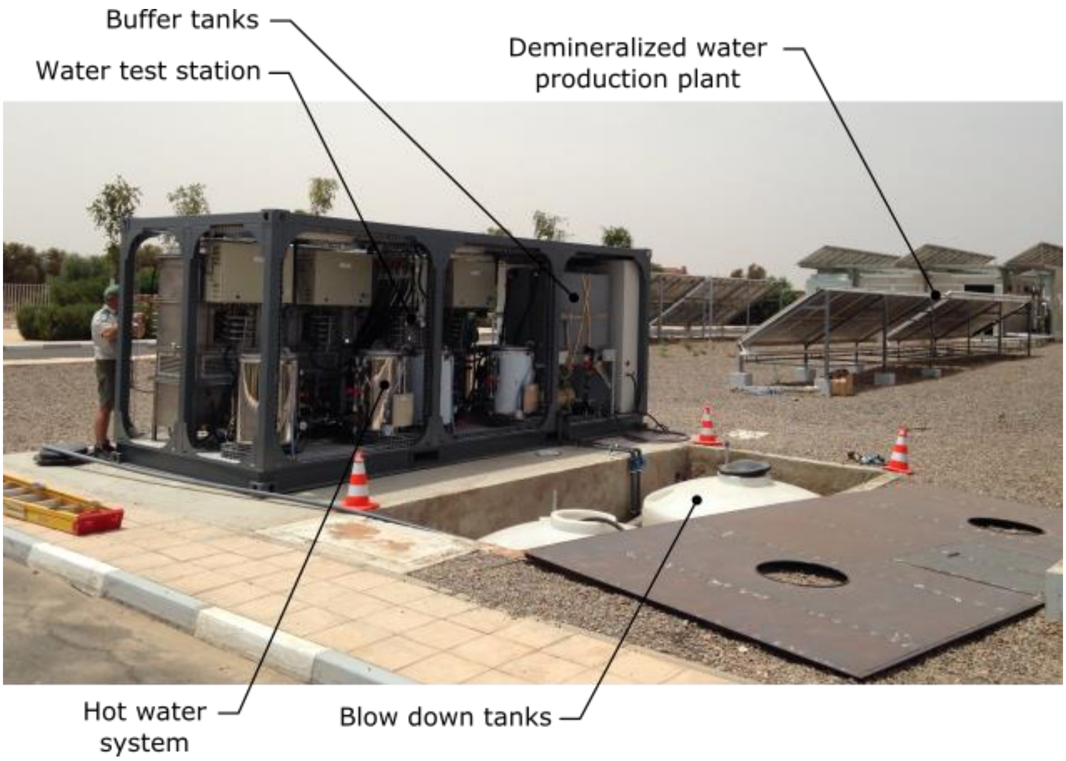
2.3 Installed facility

2.3.1 Overview



(a)



(b)

Figure 2.3: (a) South and (b) North-easterly views of the installed test facility

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Shipping of the test facility occurred on the 30th of March 2017 from Cape Town, South Africa and was unloaded at Green Energy Park, Ben Guerir, Morocco on the 8th of May 2017. The installed test facility is shown in figures 2.3 a and b. The relative positions of the demineralized water production plant and blow down tanks are also visible.

2.3.2 Operation

Sprayer operation can be observed through the top hatch in figure 2.4 together with a view of the sump through the hatch at the bottom in figure 2.5. Access at the top allows daily photography of the bundles to have a visual time lapse of how fouling accumulates. Access at the bottom gives the operator the ability to mix and control the specific composition of deluge water through additives.

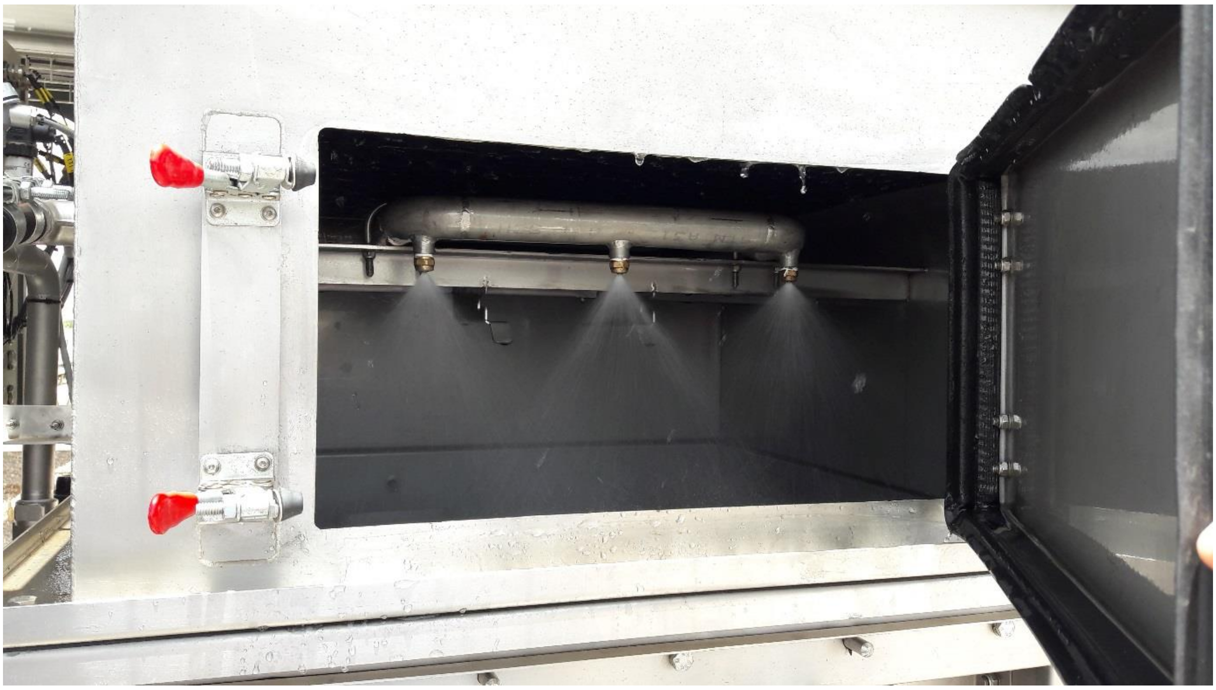

Figure 2.4: Sprayer operation viewed through the top hatch

Some preliminary analyses are being conducted on the test facility where the following are continuously monitored:

1. Deluge water:
    1.1. pH
    1.2. Turbidity
    1.3. Conductivity
    1.4. Temperatures at various locations
    1.5. Flow rates
2. Fan power
3. Make-up water flow rate

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Figure 2.5: View of the sump during operation through the bottom hatch

As an example the following results are shown for a 7 hour period, where the deluge water composition comprises Sodium Chloride (NaCl) – 1000 mg/l and is further subject to:

- Heated tube temperatures of approximately 70 °C
- Deluge water cycle times of 5 minutes wetting and 10 minutes drying, whereafter the cycle is repeated.

Figures 2.6, 2.7 and 2.8 presents a comparison between a single galvanized and polymer tube within one cooling tower for:

1. Logarithmic mean temperature difference (LMTD)
2. Heat transferred (Q)
3. Overall heat transfer coefficient (UA)

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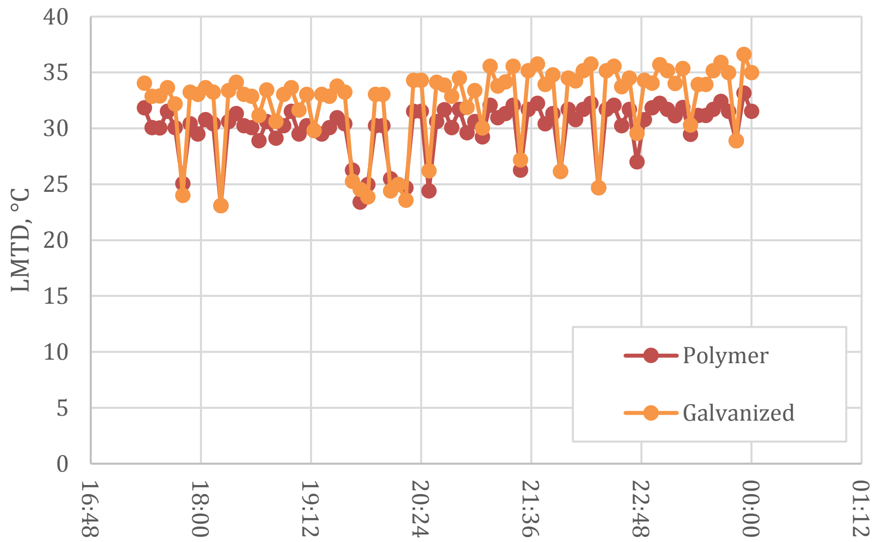

Figure 2.6: Tube logarithmic mean temperature difference comparison (at similar mass flows through the tubes) between polymer and galvanized tube

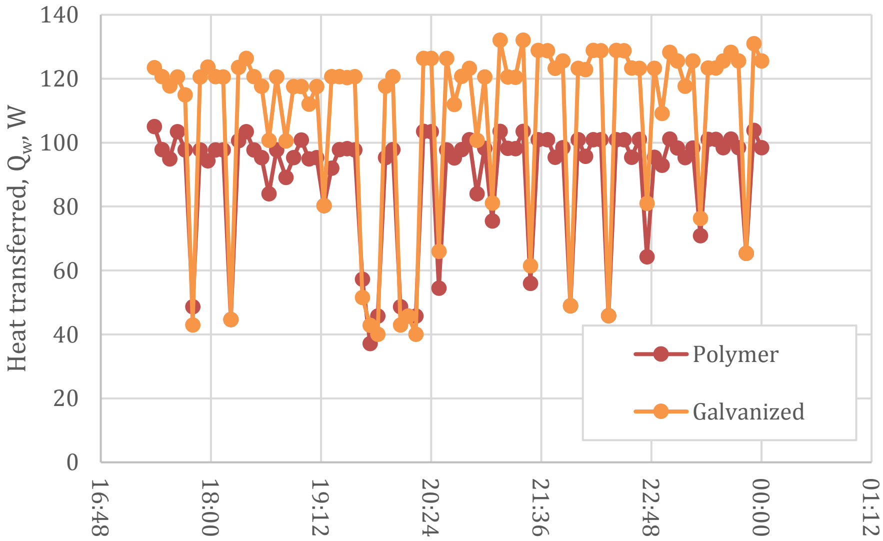

Figure 2.7: Heat transfer comparison between polymer and galvanized tube

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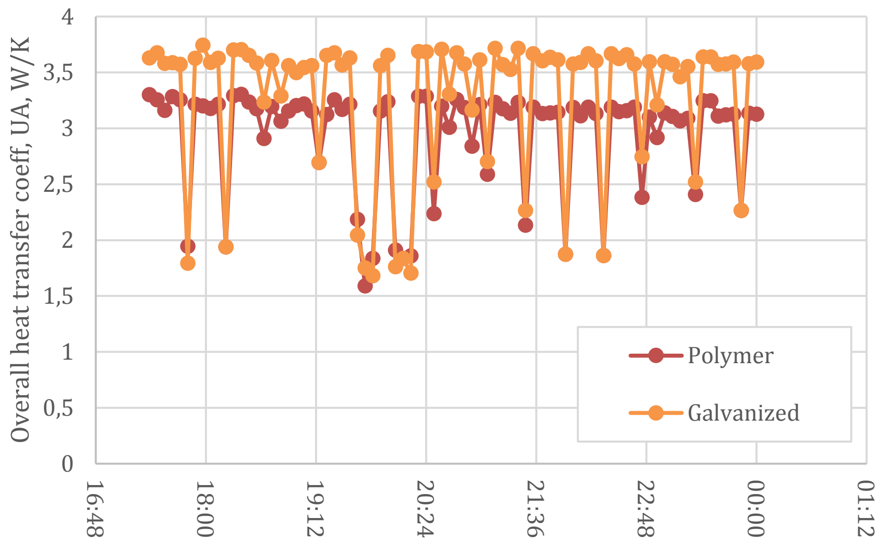

Figure 2.8: Overall heat transfer coefficient comparison between polymer and galvanized tube

3 Concluding remarks

Interpreting the graphs in figures 2.6 to 2.8, it can be observed that galvanised tube has superior heat transfer characteristics compared to the polymer tubes which is expected, since the conductivity of carbon steel is higher compared to the polymer type tube in the present case. The heat transferred between the wet and dry cycles differ by an order of 3 for the galvanized tube and approximately 2.5 for the polymer tube. It is yet to be determined how this will change over time as fouling commences.

The “spikes” in the data shows when data points were sampled during a dry cycle (some familiarization with the test facility is still presently under way to obtain correct sampling increments, measurements, flow rates, etc.).

The above photographs, descriptions and preliminary results indicates the completion of deliverable 7.3 on time as per the original time schedule. Testing will continue according to set testing programs until completed and analysed for the final deliverable (7.4) due at the end of December 2018 (M36).

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