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Test Report

EVALUATION OF THE EFFECTIVENESS OF OXYPOD IN REMOVING DISSOLVED OXYGEN FROM RECIRCULATED WATER

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Summary

On behalf of Goodwin Development Trust, NPL conducted work to evaluate the effectiveness of Oxypod in removing dissolved oxygen from circulated water. Tests were conducted at three flow rates, i.e., 5 L/min, 15 L/min and 25 L/min. Six tests were conducted at each flow rate (three tests with Oxypod and three tests bypassing the Oxypod). The tests were conducted at ambient temperature but the temperature of the recirculating water varied between 25 °C to 38 °C due to the heat generated by the friction between flowing water and the pipe. The results showed that the Oxypod can very effectively remove the dissolved oxygen in the flow rate range studied and the stable value of oxygen concentration achieved is less than 3 ppb. It is envisaged that corrosion of steel and copper pipes is unlikely at such low dissolved oxygen concentrations in water at a near neutral pH.

Reference: 2017050453

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Customer's artefacts

Date of receipt: 27th November 2017

Description of material: Original Oxypod and flow rate meter

Date of tests: Completed on 28th January 2018

1. INTRODUCTION

NPL was requested by Goodwin Development Trust to evaluate the effectiveness of Oxypod in removing dissolved oxygen from circulated water. The flow loop was manufactured by Goodwin and delivered to NPL for testing.

2. EXPERIMENTAL PROCEDURE

The flow loop with Oxypod, flow rate meter and oxygen meter are shown in Figure 1. The total volume of water contained in the flow loop was approximately 2.4 L.

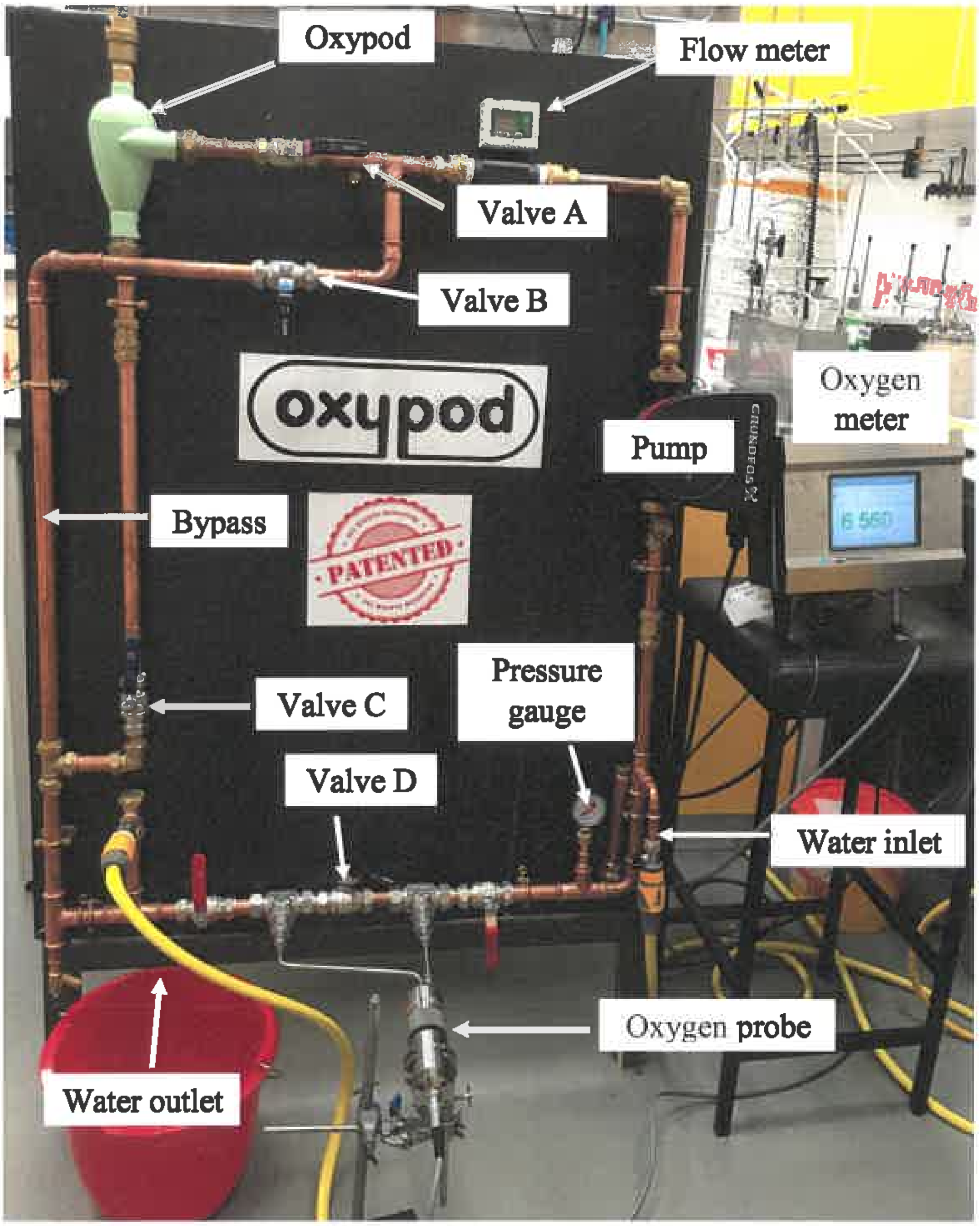

Figure 1. Flow loop for oxygen measurement

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The purpose of the project was to measure the dissolved oxygen concentration in the water as a function of time in the flow loop with an Oxypod installed. For comparison, the dissolved oxygen concentration was also measured in water bypassing the Oxypod. For reference tests (flowing water bypassing the Oxypod), Valves A and C were closed while Valve B was opened. For Oxypod tests, Valve B was closed but Valves A and C were opened. The flow rate was controlled by a combination of adjusting the pump setting and Valve D. The dissolved oxygen concentration (and water temperature) was measured by the oxygen probe placed in a bypass. The oxygen meter used was Hach Orbisphere 410 and the probe was 410K.

Prior to testing, the system was flushed with fresh tap water until the dissolved oxygen concentration reached a stable value of 10.5 ppm ± 0.5 ppm and the temperature of water reached about 14 °C. The loop pressure was set at 1.5 bar. The dissolved oxygen concentration and temperature were monitored and recorded every minute for 16.7 hours.

4. RESULTS

The variation of the dissolved oxygen concentration in water with time is shown in Figure 2. Good repeatability was observed between the tests. The oxygen concentration gradually decreased from about 10.5 ppm to less than 10 ppb in about 3 hours. The stable value of oxygen concentration after this period was between 1 and 2 ppb.

In the reference tests (flowing water bypassing the Oxypod), the dissolved oxygen concentration also decreased with time, albeit with much slower rate. This is because the dissolved oxygen was consumed by the corrosion process of copper and steel pipes (oxygen reduction is the coupled cathodic reaction for anodic dissolution of metals). Therefore, in a sealed system, the oxygen will eventually be depleted and corrosion will become negligible. However, if there are leaks in the system and hence a regular top-up of fresh water is required, corrosion will become an issue as there will be a continuing supply of oxygen.

It should be noted that the oxygen depletion rate due to the Oxypod is related to the stagnant water in the bypass section, which would take time to diffuse out. In service, the time for the

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dissolved oxygen concentration to reach a value below 10 ppb will depend on the volume of water in the recirculation system and whether there is stagnant water in the flow loop.

The variation of water temperature with time is shown in Figure 3. The temperature of water was increased gradually from an initial value of 14 °C to 31 °C for the Oxypod tests and 32 °C for the reference tests. Since the increase in water temperature is due to the heat generated by the friction between the flowing water and pipe, the extent of the increase in temperature reflects the degree of this frictional force. In this context, the difference in the final stable temperature would suggest that the friction between the flowing water and the pipe was less when the flow passed the Oxypod than through the bypass, possibly due to the removal of gas in the water and hence a decrease of vortex in the flow. However, this should not be overstated as the difference in the temperature was small.

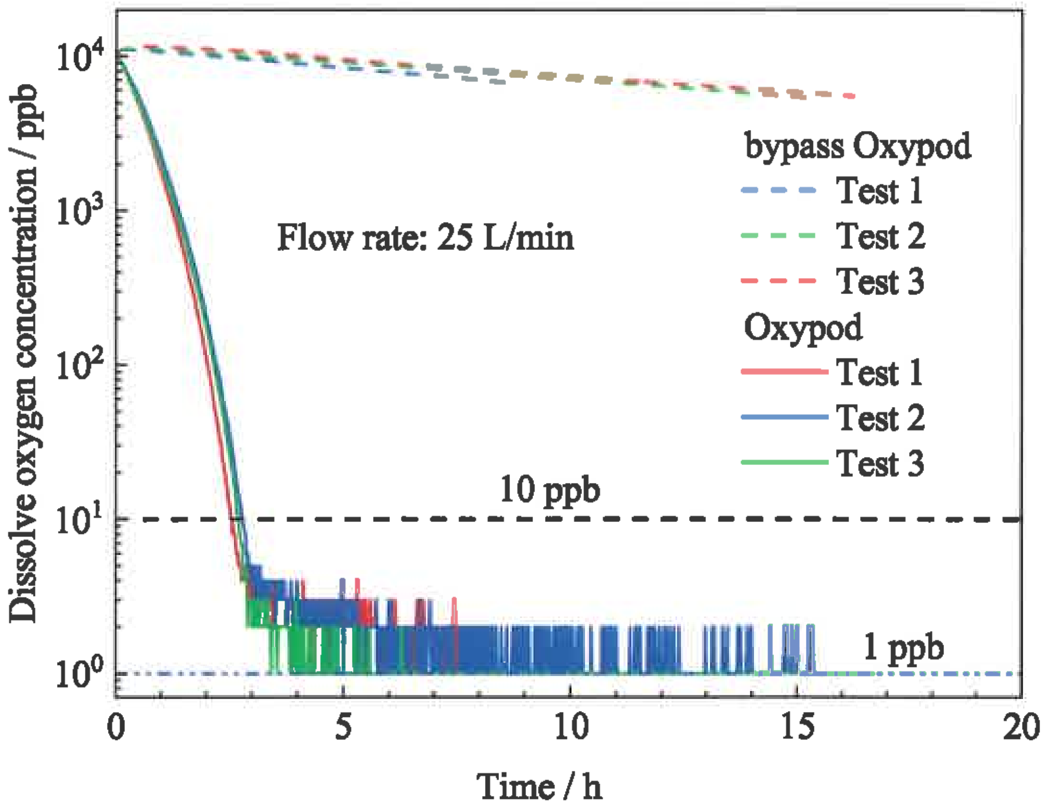

Figure 2. Variation of dissolved oxygen concentration in the water as a function of time at a flow rate of 25 L/min.

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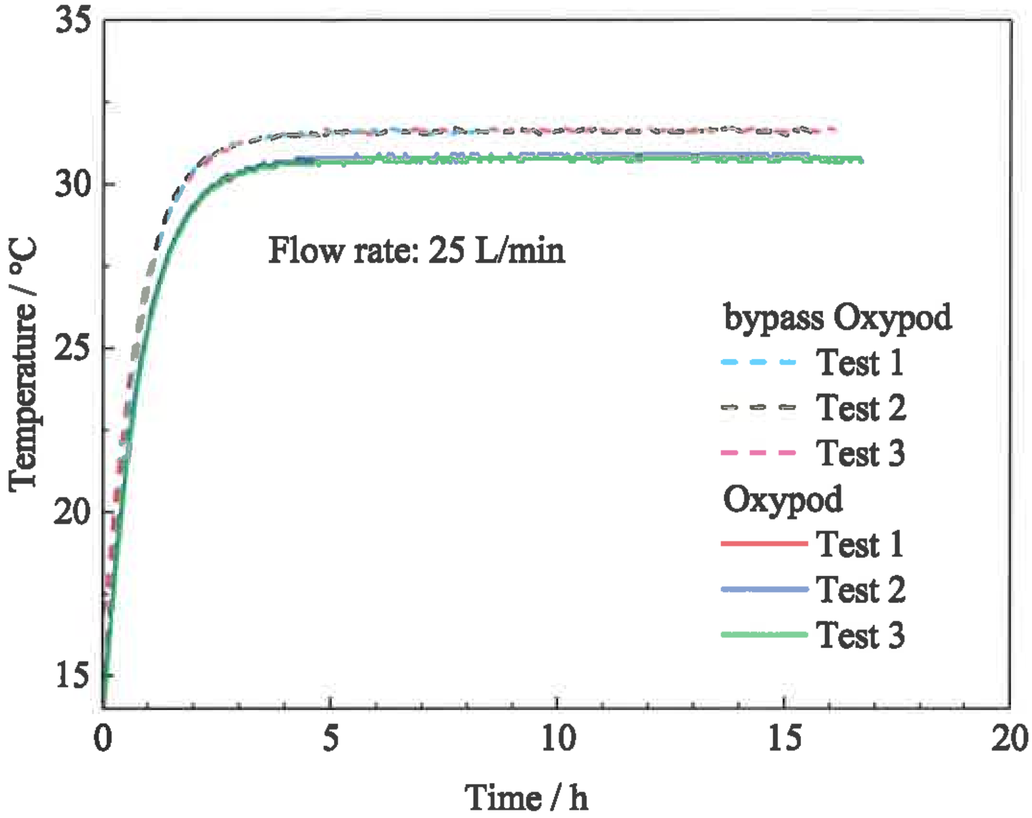

Figure 3. Variation of the water temperature as a function of time at a flow rate of 25 L/min.

The variation of the dissolved oxygen concentration with time at flow rates of 15 L/min and 5 L/min is shown in Figures 4 and 5. Similar to the data recorded at a flow rate of 25 L/min, the dissolved oxygen concentration gradually decreased with time. It took 4 hours and 5 hours for the oxygen concentration to reach a value below 10 ppb at flow rates of 15 L/min and 5 L/min respectively. The stable value of oxygen concentration after this time was about 1 ppb to 3 ppb.

The variation of the water temperature with time at flow rates of 15 L/min and 5 L/min is shown in Figures 6 and 7. The equilibrated temperature was found to decrease with flow rate, consistent with the temperature increase being related to friction. There was no apparent difference in the water temperature between the Oxypod tests and reference tests. This is not surprising as the frictional force at lower flow rates is smaller and hence the difference caused by the removal of gas is negligible under the conditions of these tests. However, it should be noted that the pipes are short and not insulated, therefore, these temperature variations may not be representative of conditions in service.

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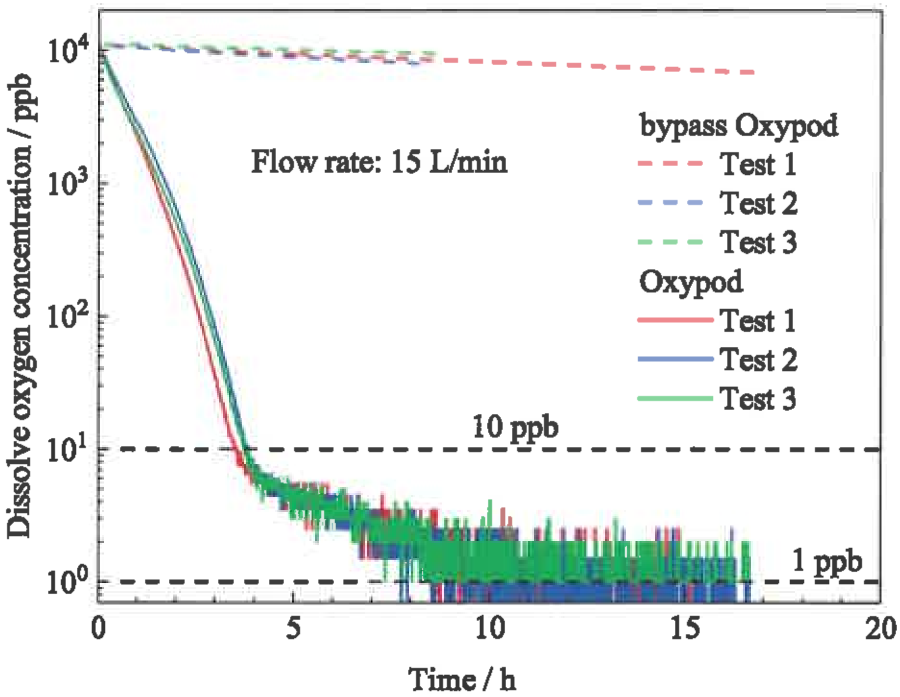

Figure 4. Variation of dissolved oxygen concentration in the water as a function of time at a flow rate of 15 L/min.

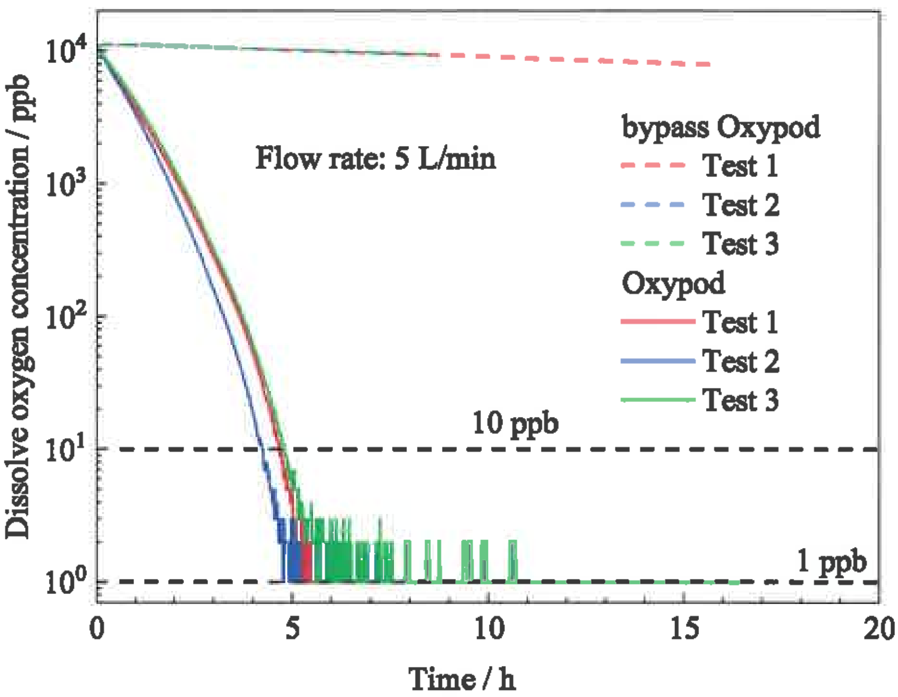

Figure 5. Variation of dissolved oxygen concentration in the water as a function of time at a flow rate of 5 L/min.

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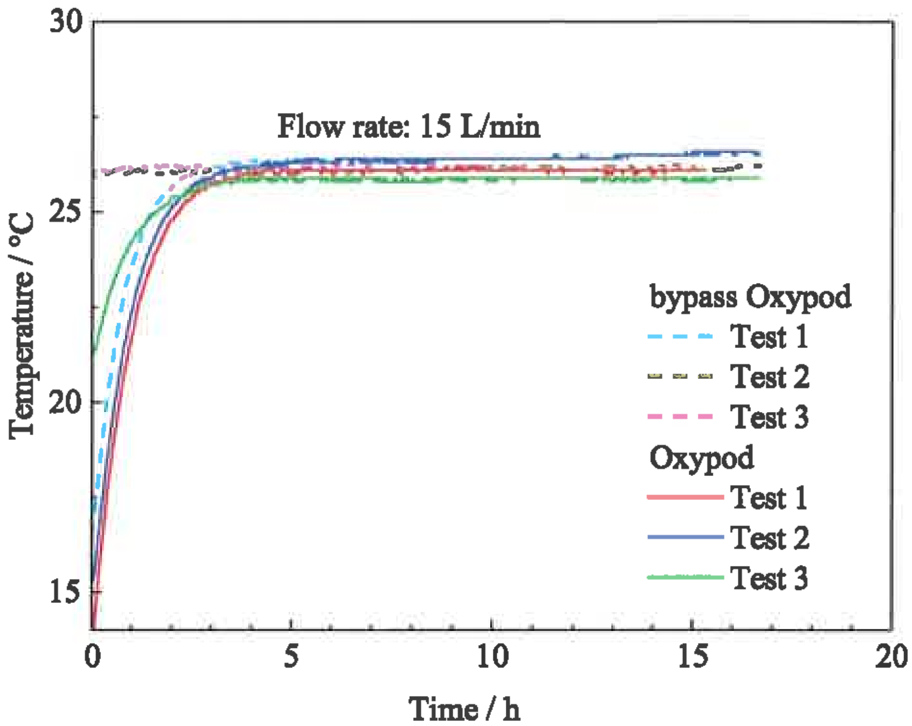

Figure 6. Variation of the water temperature as a function of time at a flow rate of 15 L/min.

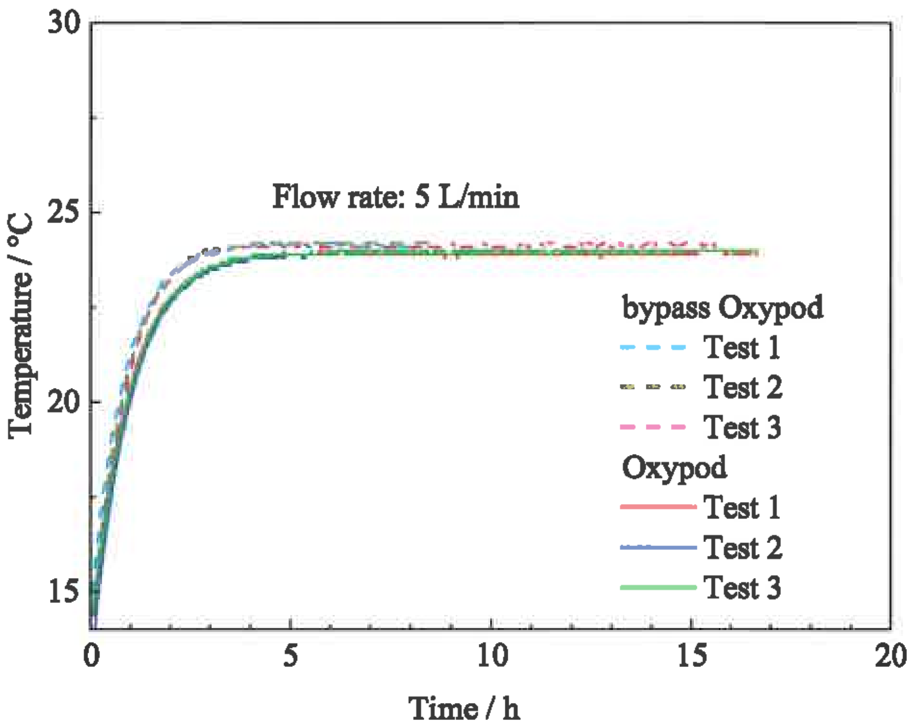

Figure 7. Variation of the water temperature as a function of time at a flow rate of 5 L/min.

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5. CONCLUSIONS

Eighteen tests were conducted to evaluated evaluate the effectiveness of Oxypod in removing dissolved oxygen from circulated water. The results showed that in the tested flow range (5 L/min to 25 L/min), the Oxypod can be used to remove the dissolved oxygen in the flowing water and the stable value of dissolved oxygen concentration achieved was between 1 ppb and 3 ppb. Corrosion of copper and steel pipes is considered unlikely at such low oxygen concentrations in water if there are no other oxidant species, as cathodic reaction due to oxygen reduction is negligible. The time taken for the oxygen concentration to reach a value of 10 ppb, which is generally considered as a requirement for corrosion tests under deaerated condition, varied from 3 hours to 5 hours, depending on the flow rate. However, it should be recognised that, in service, the time to effectively remove the dissolved oxygen would depend on the volume of water and whether there are stagnent water sections in the system.

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