

Optimisation chlorination strategy cooling water system Verve Energy's Cockburn and Kwinana power plants

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Presented at the API PowerChem 2008

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Abstract

In 2006, Verve Energy had, through the asset management department of Kwinana Power Station, contracted KEMA for advice on their antifouling methodology for its cooling water system. This has been done by optimizing its chlorination procedure by means of implementation of the Pulse-Chlorination® principle. Onset for the project was the commissioning of station Cockburn Stage 1 (CKB Stage 1). To implement Pulse-Chlorination, a series of tests needed to be conducted on site. The main purpose of these tests was to determine the most effective chlorine dosing intervals and concentration to mitigate mussel fouling.

The advised Pulse-Chlorination regime had been implemented by Verve Energy during spring 2006. During the first year of implementation, several inspections of the cooling water system have been carried out by divers. From the observations by the divers and the results of the inspection of the condensers in August 2007, it could be concluded that the advised Pulse-Chlorination regime was effective against macro fouling at Kwinana Stage C and CKB Stage 1. These results were confirmed by the results gained from the KEMA Biofouling Monitors which monitored the efficacy of the chlorination throughout this period.

During the inspections of the cooling water intake channels, some growth of mussels was noticed at the first part of the channels and the rest of the cooling system was clean. It was found that this was the result of inadequate mixing of hypochlorite with sea water that enters the cooling water intake channels. To improve the effectiveness of hypochlorite dosing, a new chlorine dosing

structure is being redesigned and optimised by applying Computational Fluid Dynamics (CFD) modelling of the injection interface to ensure optimal mixing.

It can be concluded that Pulse-Chlorination resulted in a reliable and very effective dosing strategy for both Kwinana and Cockburn power plants. This paper provides a concise overview of the main results and observations made during the project.

Key words: Cooling water, Fouling, Mussels, Antifouling substances, Optimisation, Pulse-Chlorination, Chlorination byproducts (CBPs), Environmental impact, IPPC, Best Available Technique

Introduction

Chlorination is still regarded world wide as a reliable and cost effective method in mitigating biofouling in cooling water systems. This is due to its proven efficacy, wide experience, moderate costs and opportunities to optimise the chlorination procedure, as well as the fact that low-level chlorination has not proven to have a major ecological impact [2] [3] [4]. The method we describe here is called Pulse-Chlorination[®], a chlorination procedure that has been declared as a Best Available Technique (BAT) under the terms of the EU Integrated Pollution Prevention and Control (IPPC) for macrofouling mitigation in once-through cooling water systems using chlorine [1].

Pulse-Chlorination is based on the principle that, in general, bivalves (mussels, oysters and clams) have a recovery period after exposure to a chlorination period before they open fully and restart filtration for oxygen and nutrition. The Pulse-Chlorination procedure takes advantage of this recovery time by applying short successive periods of chlorine dosing, i.e. alternating periods with and without chlorine (Figure 1).

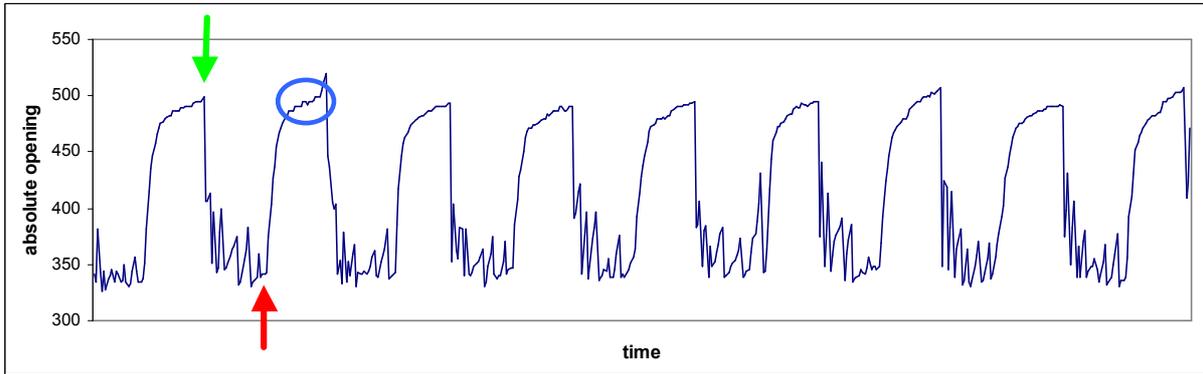


Figure 1. Valve movement behaviour of a mussel exposed to a Pulse-Chlorination hypochlorite dosing. Green arrow indicates the start ('on'), the red arrow the timing of stop ('off') of chlorination. The blue circle indicates the recovery period during which the mussel slowly opens.

Using continuous chlorination method, mussels will close and switch from aerobic to anaerobic metabolism when closed for longer periods. Using intermittent chlorination method, i.e. dosing chlorine for several hours during a day, mussels will close during the dosing period, but open to restart filtration during the period without chlorine. By applying Pulse-Chlorination, mussels will have to switch their metabolic mode continuously between aerobic and anaerobic. This leads to a rather quick physiological exhaustion. In principle, this dosing procedure does not apply chlorine as toxicant or oxidant to mitigate mussels, but rather as a trigger to force mussels to switch between their metabolic modes and the mussels are prevented from restarting filtration. This results in a more rapid effect, i.e. mortality of the mussels, compared to the conventional continuous chlorination method. Pulse-Chlorination method is applied starting from the 'spat-fall' period when the mussel-larvae enter the cooling water system and will settle on the available surfaces, which is prevented by the chlorination procedure. This approach thus prevents fouling from settling as larvae and it will keep the cooling water system clean.

KEMA has successfully implemented Pulse-Chlorination in many parts of the world. This includes Europe, the Middle East, East Asia and Australia [5, 6]. Based on our experience of these projects, we can make the following conclusions and findings:

- Pulse-Chlorination has been successfully applied in fresh, brackish and marine water
- At all locations, bivalves show similar behaviour to Pulse-Chlorination, but dosing regimes are never the same as these are location specific

- At all locations, Pulse-Chlorination is found to be effective against all other fouling species, e.g., barnacles
- Reduction of chlorine discharge to the environment is achieved by a decrease in dosing period and the amount of chlorine required
- The reduction of chlorine use automatically leads to a reduction of the discharge of chlorination by-products (CBPs)
- As less chlorine is needed, there is less wear and tear of the electro chlorination plant (ECP); hence, reducing maintenance and replacement costs of the plant
- Pulse-Chlorination is, in Europe, accepted by regulators as Best Available Technology (BAT), and is thus beneficial towards discharge allowance
- In general, the method leads to strong cost reductions, lower environmental impact, less maintenance, easy cleaning during maintenance stops, and improved ECP and CW operations in general.

Pulse-Chlorination at Verve Energy

Verve Energy Kwinana and Cockburn power stations are situated on Cockburn Sound, about 40 km south of Perth. Kwinana Power Station (KPS) is Verve Energy's second largest power station and consists of six units. Cockburn 1 Power Station (240 MW) is located immediately south of the existing Kwinana Power Station. The location of KPS and Cockburn Power Station (CKB) is of strategic importance to the state's power generation capacity due to access to the established transmission infrastructure. Both power stations draw their cooling water from the Cockburn Sound via two intake conduits which deliver cooling water to a screen bay. From the screen bay, the cooling water is diverted through several rotating drum screens towards the units of both power stations. In principle, the north intake provides cooling water for KPS Stage A&B of cooling water and the southern intake provides cooling water for KPS Stage C and Cockburn Stage 1. Both power stations have a separate outfall channel.

At Kwinana Stage A&B, thermal treatment is applied every 4 – 6 weeks to mitigate their fouling. The cooling water system of the newly built Cockburn power station is not designed to do so. Onset for the Pulse Chlorination implementation project in 2006 was the commissioning of station Cockburn Stage 1 (CKB-1) and to optimise its antifouling method based on Pulse-Chlorination principle. The hypochlorite generated

by the Electro-Chlorination Plants (ECP) is used for mussel mitigation and prevention against settlement of mussel larvae (spat) in the cooling water conduits.

Aim of the project

The aim of this project was to achieve an effective dosing regime for the CKB-1 and KPS Stage C power stations, as an alternative to heat treatment. Therefore, the technical possibilities hereto were investigated. In order to achieve this objective, two phases were carried out: an initial site survey and on-site research. An important provision for this study was to obtain an optimal dosing regime according to the Pulse-Chlorination principle for combining optimal fouling control with minimal chlorine discharge, while retaining safe plant operation.

Materials and methods

The initial site survey was carried out in February 2005. The sea water mussel *Mytilus galloprovincialis* (figure 2) was found to be the dominant fouling species. Other fouling species on site proved to be more sensitive to chlorine.



Figure 2. The three species of concern at Western Power. Left: *Mytilus edulis*; middle: *Mytilus galloprovincialis*; right: *Brachidontes erosus*.

One year later, the on site research study was carried out during a 5-week testing period. The reason for testing on-site is the fact that any Pulse-Chlorination regime, *Optimisation chlorination strategy cooling water system Verve Energy's Cockburn and Kwinana power plants. In Proceedings of API PowerChem 2008, 'Power Station Chemistry Solutions for the 21st Century, p 203 -209. Queensland Australia, 2008.*

in all details, is specific to the location and local conditions and circumstances where it is applied. Important aspects are the cooling seawater system lay out and operation, hydraulic conditions, geographical meteorology, local chemical conditions of the seawater and biology of fouling species throughout the year. All of these aspects and more have to be taken into account when developing and testing the Pulse-Chlorination regime for any specific location.

The tests to develop the optimal dosing regime are carried out in a mobile laboratory. The laboratory is a 20-ft sea container in which the behaviour of the local mussel is studied under different dosing time schedules and concentrations. This is achieved with the use of KEMA MusselMonitor [5]. Other environmental parameters such as pH, temperature, turbidity and oxygen are continuously monitored during the study period. Other tests conducted on site included a full scale Pulse Chlorination dosing test, chlorine demand tests and thermo-shock effectiveness.

Results

During the testing, an optimal dosing regime was established according to the Pulse-Chlorination principle. Also full scale dosing tests and chlorine demand measurements were carried out to determine the mixing and retention time of hypochlorite at each part of the system. The results have led to determination of the optimal chlorination regime and accompanying recommendations for operation of the chlorination procedure and monitoring the effectiveness throughout the year.

In March 2006, the recommended Pulse-Chlorination regime was implemented at Verve Energy's Kwinana and Cockburn power stations. Over the following 18 months, the intake channels were checked by divers on a regular basis and the effectiveness of the dosing was monitored by means of two KEMA Biofouling Monitors[®] (KBM).

The KBMs have been installed at strategic locations in the cooling water system. One is monitoring the condenser inlet on KPS-6, the other is monitoring the condenser inlet on CKB-1. The KBMs are inspected periodically that reveals almost always zero spat settlement on the KBM plates. In order to check the validity of the KBM results, spat settlement plates similar to the KBM plates are installed in the seawater intake screen bay area of KPS, which has non-chlorinated cooling water. These plates have shown heavy settlement of both mussel and barnacle spat. This contrast between the

two locations is a clear indication that the chlorination regime is effective in mitigation biofouling.



Figure 3. The KBM (left), with top right a view inside the monitor and right below the spat settlement plates with spat attached.

During the inspections of the cooling water intake channels, some growth of mussels was noticed in the first part of the channels and the rest of the cooling system was clean. Verve Energy and KEMA both concluded that this fouling was due to inadequate mixing of the dosed hypochlorite in the first part of the channel.

To optimise mitigation of mussel fouling in the first part of the CW intake channel, a new hypochlorite dosing ring is being redesigned and KEMA has carried out a validation study on the improved design by applying Computational Fluid Dynamics (CFD) modelling. This model enables prediction of the effectiveness of hypochlorite dosing and the (theoretic) chlorine concentrations directly after dosing, i.e. mixing. From the results of the CFD model, it was concluded that the improved design of the dosing ring will result an effective mixing of the hypochlorite in the first part of the cooling water system. This should result in effective mussel mitigation in the first part of the CW intake channels. This new dosing ring will be installed in May 2008.

During a planned maintenance overhaul in July 2007 of KPS-6, the condenser was opened for inspection and maintenance. It was observed that the condenser was very clean. There was no mussel or barnacle, only a small number of empty small mussel shells in the return water box.



Figure 4. Pictures taken during the July 2007 inspection of the KPS-6 condenser, showing a clean pipe plate and return water box.

Conclusions

Macrofouling mitigation was traditionally treated by means of heat treatment (hot water recirculation) about once every 4 – 6 weeks. Since Pulse Chlorination has been implemented, no hot water recirculations have been performed.

From all results gained during 18 months after implementation, it is concluded that Pulse-Chlorination provides both economical and ecological advantages and has showed to be a very effective alternative to heat treatment.

Acknowledgement

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