Predicted impact of power uprate on the water chemistry of Kuosheng boiling water reactor

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A theoretical model was adapted to evaluate the impact of power uprate on the water chemistry of a commercial boiling water reactor (BWR) in this work. In principle, the power density of a nuclear reactor upon a power uprate would change immediately, followed by water chemistry variations due to enhanced radiolysis of water in the core and near-core regions. It is currently a common practice for commercial BWRs to adopt hydrogen water chemistry (HWC) for corrosion mitigation. The optimal feedwater hydrogen concentration may be different after a power uprate is implemented in a BWR. A computer code DEMACE was used in the current study to investigate the impact of various power uprate levels on major radiolytic species concentrations and electrochemical corrosion potential (ECP) behavior of components in the primary coolant circuit of a domestic BWR-6 type reactor operating under either normal water chemistry or HWC. Our analyses indicated that under a constant core flow rate the chemical species concentrations and the ECP did not vary monotonously with increases in reactor power level at a fixed feedwater hydrogen concentration. In particular, the upper plenum and the upper downcomer regions exhibited uniquely higher ECPs at 108% and 115% power levels than at the other evaluated power levels.

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1. Introduction

Power uprates have become a common practice for the power utilities owning light water reactors (LWRs) to meet the increasing electricity demand under the restrictions of constructing new nuclear power plants. Since September of 1977, more than 100 power uprate applications in the United States alone have received approval from the regulatory body (Hettiarachchi, 2005). Among the three types of power uprate, measurement uncertainty (<2%), stretch power uprate (2–7%), and extended power uprate (7–20%, currently approved maximum percentage), there is no common selection for general nuclear power plants and a thorough evaluation is always required for every single LWR.

One practical way of increasing the reactor power is to deliberately adjust the fuel loading pattern and the control rod pattern and thus to avoid replacing the primary coolant pump with a new one of larger capacity. In this case, the power density of the reactor will increase with increasing power, and the mass flow rate in the primary coolant circuit (PCC) will only increase slightly (usually by less than 5%) or even remain unchanged. The higher power density in the reactor core due to a power uprate will lead to the production of more steam in the core fuel channels, and this will in turn result in higher linear liquid and steam velocities in the boiling core region and shorten the total residence time of the coolant in the core region. The combined effect of higher neutron and gamma photon dose rates and a shortened coolant residence time in the reactor core complicates the water chemistry in the PCC of an LWR due to enhanced radiolysis but a less irradiated time of the primary coolant.

In boiling water reactors (BWRs), intergranular stress corrosion cracking (IGSCC) on stainless steel and nickel-base alloy components has been a major issue of material degradation for decades. The IGSCC susceptibility of structural materials in a BWR is primarily dominated by the physical and chemical properties of the materials, tensile stresses, and the primary coolant chemistry. For mitigating IGSCC in an operating BWR, improvement on the primary coolant chemistry by hydrogen water chemistry (HWC) has been adopted worldwide (Hettiarachchi, 2005). The HWC technology is deemed effective when the electrochemical corrosion potential (ECP) in the PCC of a BWR at a specific feedwater hydrogen concentration ([H2]FW) is reduced to below −0.23 V SHE that signifies immunity of structural components to IGSCC. The U.S. Nuclear Regulatory Commission has recognized an ECP value of −0.23 V SHE to be the critical corrosion potential (E crit) of sensitized Type...
304 stainless steels (electrochemical potentiodynamic reactivation (EPR) = 15 C/cm²) in typical BWR environments (i.e., a coolant temperature >270 °C and coolant conductivity near 0.3 μS/cm).

The ECP in the PCC of a BWR is a mixed potential reflecting the amounts of major redox species (i.e., hydrogen, oxygen, and hydrogen peroxide) present in the reactor coolant. The concentrations of these redox species, however, are directly related to the degree of water radiolysis, which is dominated by the power density of the reactor and by the coolant residence time in the reactor core. When a reactor’s power is uprated, changes in power density (i.e., neutron and gamma photon dose rates) and coolant flow velocity in the reactor core would lead to concentration variations of the major redox species. Accordingly, the required [H₂]FW at different power levels for the HWC technology to take effect on IGSCC mitigation may thus be different. However, it has been demonstrated through theoretical analyses that the effectiveness of HWC actually varies from region to region (e.g., from core to downcomer or to recirculation system) in the PCC of a BWR due to various degrees of water radiolysis in these regions (Yeh et al., 1995; Yeh and Macdonald, 1996, 2006; Yeh and Chu, 2001; Yeh, 2002). Therefore, it is anticipated that the impact of power uprate on the effectiveness of HWC in the PCC of a BWR may also be different in different regions.

The concentrations of radiolysis products and the ECP values differ significantly in the PCC of a BWR. It is very difficult to actually measure the water chemistry data directly at various locations of an actual reactor. Accordingly, the impact of power uprate on the water chemistry of a BWR operating under HWC can only be evaluated theoretically through computer modeling. A deterministic model by the name of DEMACE was developed in the past for analyzing water chemistry variation and corrosion behavior of metallic materials in the PCC of a BWR (Yeh and Chu, 2001; Yeh, 2002; Yeh and Macdonald, 2006). In the current study, a local BWR, Kuosheng Unit 1 (Kuosheng-1), was selected for demonstrating the impact of various power uprates on the major redox species concentrations and on the ECP behavior of structural components in the PCC. Kuosheng-1 is a BWR-6 type reactor with a rated thermal power of 2894 MW, and its commercial operation started in December of 1981. It is currently operating under HWC with a 0.5 ppm (parts per million) [H₂]FW. Numerical simulations for Kuosheng-1 were carried out for [H₂]FW ranging from 0.0 to 2.0 ppm and for power levels ranging from 100% to 120%. Variations in oxygen (O₂), hydrogen (H₂), and hydrogen peroxide (H₂O₂) concentrations and in ECP at four selected locations in the PCC of Kuosheng Unit 1 (Kuosheng-1) were analyzed. The impact of power uprate on the corrosion mitigation effectiveness of HWC is discussed. Optimal HWC operating conditions for Kuosheng-1 at various power uprate levels are then proposed.

2. Modeling approaches

For simplicity in modeling, the entire PCC of a BWR was divided into 12 regions in the DEMACE computer model, as shown in Fig. 1. The DEMACE computer code consists of a radiolysis model for calculating chemical species concentrations, a mixed potential model for calculating ECP, and a coupled environment fracture model for calculating the crack growth rate. More detailed descriptions about these three models can be found in the literature (Yeh and Chu, 2001; Yeh, 2002; Yeh and Macdonald, 2006; Macdonald, 1992; Macdonald et al., 1996).

2.1. Power uprate simulation

When considering a power uprate in an NPP, the utilities generally have two options. One is to go for a higher mass flow rate with a new recirculation pump of higher capacity (Yeh and Wang, in press), and the other is to maintain the same mass flow rate but with new fuel loading and control rod patterns (Wang and Yeh, in press). The second option would reduce the cost for power uprate to a significant extent since a major component replacement is not required. Almost all uprated NPPs in the United States have adopted the second approach. Our earlier study focused on the change in coolant mass flow rate due to a change in power level on a specific loadline (Yeh and Wang, in press). We have also looked into the case of power uprates under a fixed core flow rate in a BWR-4 type reactor (Wang and Yeh, in press). In the current study, we again took into account the condition of a fixed core flow rate, but the evaluation target was switched to a BWR-6 type reactor (Kuosheng-1) to demonstrate that the impact of power uprate on the water chemistry of a BWR would actually vary from plant to plant.

The plant data used in the computer simulations are the same as those operating in the HWC ramping test conducted in 2006 except that the neutron and gamma photon dose rates and the mass flow rate of liquid coolant in the flow path between the core channel and the mixing plenum were recalculated based on a specifically selected operating power level. The dose rates of neutron and gamma photon were assumed to vary linearly as the reactor power level increased. The linear flow velocities of the liquid coolant in the upper plenum, stand pipe, and separator side regions were recalculated based on the steam quality produced in and the liquid left the reactor core at different power levels. The steam quality (X) is defined as the mass fraction of vapor in the mixture of liquid and vapor and can be expressed by

\[ X = \frac{H - H_f + H_i}{H_f}, \]  

(1)

where \( H \) is the enthalpy of the mixture at the core outlet, \( H_f \) is the enthalpy of the saturated liquid at the system pressure, and \( H_i \) is the...
enthalpy of the liquid at the core inlet, and \( H_{fg} \) is the enthalpy of vaporization at the system pressure. \( H \) is a function of total produced power and core flow rate and may be expressed as

\[
H = \frac{F_c Q_c}{m},
\]

where \( F_c \) is the hot channel factor in the core, \( Q_c \) is the total produced power in the core, and \( m \) is the core flow rate. As the reactor power level increases at a fixed pressure and a fixed core flow rate, \( H \) would accordingly increase and lead to an increase in \( X \).

The increases in steam quality as a function of reactor power level were calculated using the ZEBRA computer code (Bladeslee, 1974), and the results are shown in Fig. 2. For the core channel region, the variation in coolant flow velocity along the core channel was dominated by the steam quality (and hence the void fraction), and the liquid flow velocity became higher as the steam quality increased in this region at a fixed power level, as also shown in Fig. 2. The foregoing changes in radiation dose rates and in coolant flow velocity were expected to influence the steady-state water chemistry of the reactor since the degree of radiolysis and the time for the coolant to undergo radiolysis were altered at different power levels.

2.2. Modeling procedures

Before the actual modeling work on Kuosheng-1 under various power uprate conditions commenced, the DEMACE computer model was deliberately calibrated by fitting the predicted oxygen concentration at the recirculation system outlet of this reactor with measured data, obtained from the results of the HWC ramping test conducted in 2006. The operating conditions of Kuosheng-1 in 2006 were used in the model calculation during the calibration process. By adjusting the gas transfer coefficients in the core boiling channels of Kuosheng-1, a routinely taken technique (Yeh and Macdonald, 1996; Yeh and Chu, 2001; Yeh, 2002), and by applying the least square fitting algorithm, we were able to obtain predicted results that are in reasonably good agreement with the measured plant data as shown in Fig. 3.

The power uprate conditions considered in this study ranged from 0% to 20% with selected power levels of 100%, 102%, 104%, 107%, 108%, 109%, 114%, 115%, 116%, and 120%. At the beginning of this work, a 1% difference in power level was actually selected in the modeling work for comparison purpose. In order to simplify the resultant figures for discussion, only power levels leading to relatively more oxidizing coolant environments are discussed in this paper. At a specific power level, the coolant flow velocities in the core and other near-core regions were recalculated based upon the steam quality produced in the core fuel channels. The dose rates of neutron and gamma photon in Kuosheng-1 were calculated using an independent computer code by the name of DRONG (Yeh et al., 2000). In the meantime, the new power level at a fixed coolant flow rate would enable the calculation of steam quality and void fraction in the core region, and this part of the study was done using the ZEBRA computer code. Changes in void fraction in the core boiling region of a BWR are expected to have an important impact on the effectiveness of HWC since gas transfer rates of oxygen and hydrogen between the steam and liquid phases in this region are altered accordingly. After the foregoing parameters were derived, water chemistry and ECP modeling was then carried out for the entire PCC of Kuosheng-1 with [H2]FWs ranging from 0.0 to 2.0 ppm. To avoid lengthy discussion, only four particular locations of major IGSCC concerns in Kuosheng-1 were selected to demonstrate the impact of various power uprate levels on the effectiveness of HWC. The four specific locations of major IGSCC concerns selected were the outlet of the upper plenum region, the outlet of the upper downcomer region, the outlet of the recirculation system, and the outlet of the bottom lower plenum region which approximately represent the top guide, the belt area of the core shroud and jet pump risers, the recirculation piping, and the core shroud base and support, respectively. These locations have a long history of IGSCC incidents as reported in the literature (USNRC, 1994a,b, 1995).

3. Results and discussion

The simulation results are categorized into two portions showing variations in the concentrations of major redox species and in the ECP as a function of [H2]FW at the four selected locations.

3.1. Species concentrations

Although there are a total of 11 radiolysis species taken into account in the DEMACE model, only three major redox species with relatively significant concentrations are used in the calculation of ECP. Details on the full set of chemical reactions among these species and their respective rate constants can be found elsewhere (Yeh and Chu, 2001). Among the 11 radiolysis species \( (\cdot, H, H^+, OH, OH^-, \cdot \cdot, \cdot \cdot, \cdot \cdot \cdot, \cdot \cdot \cdot \cdot, \cdot \cdot \cdot \cdot \cdot, H_2) \), \( H_2 \) and \( H_2O_2 \) are directly produced during the course of water radiolysis, and \( O_2 \) is then produced through the decomposition of \( H_2O_2 \), not a direct radiolysis product. These three species actually dominate the magnitude of

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**Fig. 2.** Steam quality and liquid coolant flow velocity as a function of power level at the core exit of Kuosheng-1 operating at a fixed mass flow rate.

**Fig. 3.** Comparison of the calculated and the measured oxygen concentrations in the recirculation system of Kuosheng-1.
ECP because the concentrations of the other redox species (e.g., OH and HO2) are comparatively small and can thus be neglected. The concentration variations of the three major species as a function of \([H_2]_{FW}\) at the designated locations of Kuosheng-1 are of great importance.

### 3.1.1. Concentrations of \(H_2\)

The predicted \(H_2\) concentration \([H_2]\) in the reactor coolant at each selected location of Kuosheng-1 is shown in Fig. 4. It was observed that at a fixed power level the \([H_2]\) monotonously increased with increasing \([H_2]_{FW}\) up to 2.0 ppm at the outlets of the upper downcomer, the recirculation system, and the bottom lower plenum. However, the \([H_2]\) was relatively low at the upper plenum outlet, which resulted from the gas stripping process in the core boiling region, although it still increased with increasing \([H_2]_{FW}\) up to a maximum of 45 ppb (parts per billion) at 2.0 ppm \([H_2]_{FW}\), shown in Fig. 4(a). Under the power uprate condition, it seemed that a higher power uprate percentage would lead to a higher \([H_2]\) in the reactor coolant at all four locations, but the difference in \([H_2]\) among various uprate percentages at low \([H_2]_{FW}\)s was small.

### 3.1.2. Concentrations of \(O_2\)

Variations in \(O_2\) concentration \([O_2]\) at the selected locations are shown in Fig. 5. In general, a higher \([H_2]_{FW}\) led to predicted lower \([O_2]\)s at all four locations no matter what the power level was. Among these locations, the \([O_2]\) at the recirculation system outlet, shown in Fig. 5(c), was reduced most effectively under HWC, with a 0.5 ppm \([H_2]_{FW}\) being sufficient to scavenge all dissolved \(O_2\) in the coolant. In the meantime, the dissolved \(O_2\) in the coolant was not fully depleted until the \([H_2]_{FW}\) at 120% power reached 2.0 and 1.5 ppm at the upper downcomer outlet and the bottom lower plenum outlet, respectively. On the other hand, the \([O_2]\) at the upper plenum outlet (Fig. 5(a)) at all power levels never went down to zero even with a 2.0 ppm \([H_2]_{FW}\). It was clearly demonstrated that the effectiveness of HWC on reducing the \([O_2]\) in a BWR might vary from region to region along the PCC due to different degrees of radiolysis in these regions. In addition to the radiolysis effect, changes in power level would be expected to influence the HWC effectiveness.

In view of the effect of power level, we found that at low \([H_2]_{FW}\)s ranging from 0 to 0.2 ppm, increases in power level led to decreases in \([O_2]\) at all selected locations. One exception was that the \([O_2]\) at the recirculation system outlet, shown in Fig. 5(c), decreased with increasing power level at all \([H_2]_{FW}\)s. For the case of \([H_2]_{FW}\) being equal to 0, the difference in \([O_2]\) could be as much as 30 ppb between the power levels of 100% and 120%. However, when the \([H_2]_{FW}\) was greater than 0.2 ppm, certain power levels would induce particularly higher \([O_2]\)s, such as those seen at 108% and 115% power at the upper downcomer outlet. In fact, the \([O_2]\) at the upper downcomer outlet at 108% or 115% power never went below 5 ppb even with a 2.0 ppm \([H_2]_{FW}\) while the \([O_2]\)s at the other power levels became much lower than 5 ppb, shown in Fig. 5(b). Similar results were also observed at the upper plenum outlet and the bottom lower plenum outlet. It was therefore foreseen that a power uprate of 8% or 15% causing undesirably higher \([O_2]\)s at higher \([H_2]_{FW}\)s would eventually influence the effectiveness of HWC on...
corrosion mitigation in Kuosheng-1, and it was indeed proven so based upon the predicted ECP results discussed later.

3.1.3. Concentrations of H2O2

The other important oxidizing species in the BWR coolant is H2O2, a direct radiolysis product. Fig. 6 exhibits variations in H2O2 concentration ([H2O2]) as a function of [H2]FW at the four selected locations. In contrast to the [O2], the [H2O2] did not decrease monotonously as the [H2]FW increased. Except for the upper plenum outlet, the [H2O2]s were predicted to increase first and then decrease later on with increasing [H2]FW. Four chemical reactions were speculated responsible for this unique outcome, and they are

\[
\begin{align*}
\text{H} + \text{OH} & \leftrightarrow \text{H}_2\text{O}, \\
\text{OH} + \text{H}_2 & \leftrightarrow \text{H} + \text{H}_2\text{O}, \\
\text{OH} + \text{H}_2\text{O}_2 & \leftrightarrow \text{HO}_2 + \text{H}_2\text{O}, \text{ and} \\
\text{H} + \text{H}_2\text{O}_2 & \leftrightarrow \text{OH} + \text{H}_2\text{O}.
\end{align*}
\]

Eq. (3) with the greatest rate constant of all dominated the concentrations of species H and OH. When a mild amount of H2 was added into the reactor coolant, Eq. (4) started taking effect and more H was produced. More H then led to more consumption of OH via Eq. (3), which in turn led to less consumption of H2O2 via Eq. (5). Although some H2O2 could have reacted with H via Eq. (6), the decrease in [H2O2] was comparatively less significant. Once the [H2]FW increased to an effectively high level, the concentration of H generated via Eq. (4) became vital and Eq. (6) started to dominate.

The [H2O2] then promptly decreased via both Eqs. (5) and (6) as seen in Fig. 6. Since H2O2 is a highly oxidizing species and a few ppb H2O2 could keep the ECP well above the Ecrit, it is essential to eliminate all H2O2 in the coolant to achieve considerably low ECPs in the PCC of a BWR. At NWC, the [H2O2]s at some locations near to core reduced with increasing power level due to the degree of radiolysis. As [H2]FW gradually increased, the competition between the consumption and the production of [H2O2] would be obvious. However, due to differences in degree of radiolysis, the [H2O2] at various locations responded to the [H2]FW quite differently at selected power levels.

For a fixed power level, the [H2O2] at the upper plenum outlet, shown in Fig. 6(a), steadily decreased as the [H2]FW increased from 0 to 0.2 ppm and then slowly decreased with increasing [H2]FW. The [H2O2] at this location would be more than 20 ppb at 2.0 ppm [H2]FW at most power levels, except at 100% and 107% power levels. In view of the impact of power level, we found that the [H2O2] decreased with increasing power level at 0 or 0.1 ppm [H2]FW. However, the [H2O2] did not show consistent changes with increasing power level when the [H2]FW became higher. One distinct example was that the [H2O2] remained at more than 40 ppb at 108% and 115% power levels with 2.0 ppm [H2]FW while those at the other power levels went down to below 30 ppb at the same [H2]FW. This unique phenomenon highlighted our argument that a combined effect of enhanced radiolysis and huge recombination upon a power uprate could arbitrarily alter the effectiveness of HWC.

At the upper downcomer outlet, the response of [H2O2] to [H2]FW was quite different, shown in Fig. 6(b). Variations in power...
Fig. 6. Variations in [H₂O₂] as a function of [H₂]FW at four selected locations of Kuosheng-1 with operating power levels ranging from 100% to 120% of the rated power.

level did not cause any significant change in [H₂O₂] at NWC. Irregularity in [H₂O₂]S of different power levels became discernable at >0.1 ppm [H₂]FWS. For the base case of 100% power level, a 2.0 ppm [H₂]FW was required to scavenge nearly all H₂O₂ in the coolant at this location. Power levels of 104%, 107%, 114% and 120% would be expected to lead to the same H₂O₂ response. However, a [H₂]FW of the same level was not enough to reduce the [H₂O₂] to be below 20 ppb at 108% and 115% power levels. The outcome implicated that small changes in power and hence in degree of radiolysis and recombination could result in significant changes in HWC effectiveness.

At the recirculation system outlet, the [H₂O₂], shown in Fig. 6(c), decreased with the increasing power level. Changes in [H₂O₂] at different power levels became distinct when the [H₂]FW was greater than 0.1 ppm. The HWC application exhibited tremendous effectiveness at this location in terms of H₂O₂ reduction. The required [H₂]FW to effectively lower the [H₂O₂] at the recirculation system outlet was 0.5 ppm at 100% rated power, but it would be only 0.3 ppm at 115%, 116%, or 120% power levels. In other words, the required [H₂]FW to effectively lower the [H₂O₂] was reduced as the power level increased at this location.

Similar to what happened at the upper downcomer outlet, variations in power level did not cause any significant change in [H₂O₂] at low [H₂]FWs at the bottom lower plenum outlet, shown in Fig. 6(d). On the other hand, the required [H₂]FW to effectively lower the [H₂O₂] at this location was 1.7 ppm at the original rated power, but this required [H₂]FW level became 1.8 and 1.5 ppm at 108% and 120% power levels, respectively, which again highlighted the sensitivity of HWC to the reactor operating power.

Summarizing the concentration results from the two oxidizing species, we found that for the Kuosheng-1 BWR an 8% or 15% power uprate tended to promote a more oxidizing coolant environment for the structural components located at or near the top guide, the belt area of the core shroud and jet pump risers, the recirculation piping, and the core shroud base and support than the others. Increases in the concentrations of H₂O₂ and O₂ at these particular uprate levels would pose a significant impact on ECP according to the mixed potential model (Macdonald, 1992). Therefore, a similar outcome is expected to appear in the ECP response to power uprate.

3.2. ECP

In the current study, the well-recognized ECP of −0.23 V_SHE was selected as the E_crit of highly sensitized Type 304 stainless steels in typical BWR environments. Based upon this criterion, a component is considered protected from IGSCC and the HWC technique is considered effective if the predicted ECP is below the E_crit. Fig. 7 shows variations in ECP as a function of [H₂]FW and power level at the four selected locations.

At the upper plenum outlet, one important phenomenon to note was that the ECP at all simulated power levels never went below the E_crit even though the [H₂]FW was as high as 2.0 ppm, shown in Fig. 7(a). Similar situation occurred at the upper downcomer outlet (Fig. 7(b)), but the ECP would likely be reduced to below the E_crit when the [H₂]FW reached 2.0 ppm and the power level was maintained at 100%, 104%, 107%, 114%, or 120%, exactly consistent with the [H₂O₂] response at this location. The ECP response to [H₂]FW
Fig. 7. Variations in ECP as a function of $[H_2]_{FW}$ at four selected locations of Kuosheng-1 with operating power levels ranging from 100% to 120% of the rated power.

and power level at the recirculation system outlet was comparatively simple. The ECP monotonously decreased with increasing power level, shown in Fig. 7(c). Except for the power levels above 114% at which an effective ECP reduction at 0.3 ppm $[H_2]_{FW}$ was observed, a 0.4 ppm $[H_2]_{FW}$ was required at all uprated power levels. The HWC effectiveness on ECP reduction at this location was slightly improved at higher power uprate levels. ECP variations at the bottom lower plenum outlet, shown in Fig. 7(d), behaved quite similar to those at the upper downcomer outlet. A 1.7 ppm $[H_2]_{FW}$ was required to reduce the ECP effectively at 100% power level. A higher 1.8 ppm $[H_2]_{FW}$ at 108% power level but a lower 1.5 ppm $[H_2]_{FW}$ at 120% power level both enabled effective ECP reductions. In general, the overall ECP responses agreed in trend with the $[H_2O_2]$ variations under different $[H_2]_{FW}$S and power levels at all four evaluated locations.

Summarizing the predicted ECP results at these four locations, we noted that no significant ECP differences due to power uprate were observed when the $[H_2]_{FW}$ was either much less or greater than the critical concentration at which the ECP markedly decreased to below the $E_{crit}$. A particular uprate percentage, however, would be expected to induce a relatively more oxidizing environment and hence led to a poorer HWC efficiency that was commonly seen at most of the evaluated locations of Kuosheng-1 with a 108% or 115% power level. On the other hand, the HWC efficiency would be slightly improved at the upper downcomer outlet and the bottom lower plenum outlet at certain higher power levels of 107%, 114% and 120%. Finally, it is important to note that the uniquely oxidizing environment at the uprated power level of 108% or 115% was applicable to Kuosheng-1 only. A BWR with a different power density and different physical dimensions may experience a similar outcome at a different uprated power level. An individual analysis on the impact of power uprate on the corrosion mitigation effectiveness of HWC in a BWR is therefore necessary.

4. Conclusions

The responses of water chemistry and ECP to HWC at some selected locations in Kuosheng-1 BWR under different postulated uprated power levels were successfully evaluated. Upon a power uprate, the degree of radiolysis and coolant residence time in the core of a BWR may vary, causing changes in radiolytic species concentrations and resulting in varied HWC efficiency at different locations.

For the Kuosheng-1 BWR, an 8% or 15% power uprate would tend to promote a more oxidizing coolant environment for the structural components and therefore lead to downgraded HWC effectiveness in terms of ECP reduction and corrosion mitigation. In contrast, the HWC efficiency would likely be slightly improved at higher power levels of 107%, 114% and 120% for the four selected locations. No consistent trend could be found for changes in the effective $[H_2]_{FW}$ as a function of uprated power level.

Based upon the predicted results, the impact of power uprate on the HWC effectiveness in a BWR is expected to vary from location to location and eventually from plant to plant due to different radiation dose rates and physical dimensions. The outcome derived
in this work for Kuosheng-1 may not be applicable to other BWRs of the same type, and a new, full-scale analysis is highly recommended.

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