In-service Subsea Pipeline Anode Life Prediction in Selected Area of Gulf of Thailand (GoT) by Numerical Method.

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ABSRACT

Marine structures in oil and gas industry such as jacket platform structure and subsea pipeline need to be designed to protect from corrosion problem. External coating combined with sacrificial anode (Al-Zn-In) are widely used to serve corrosion protection in subsea pipeline. In this research, remaining life of sacrificial anode under selected subsea pipelines in Gulf of Thailand (GoT) area was predicted using the existing mathematical models. The calculation result of anodes depletion was compared with subsea pipelines inspection results by Remotely Operating Vehicle (ROV) with interpreted by qualify inspectors. As a result, the average accuracy percentage of the calculation was 81.78% in case of the Fusion Bonded Epoxy (FBE) coating with 6% of Coating Break Down factor. For the concrete and asphalt enamel coating with 4% coating break down factor, the average accuracy was 73.53%.

Key word: Pipeline, Anode depletion, Anode retrofit, Coating Break Down

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INTRODUCTION

One of common problem for structural steel located in corrosive environmental such as offshore area is corrosion problem. Since, subsea pipeline is a key facility in oil and gas industry to transfer oil and gas from production platform to central processing platform and then transfer to shore for further refinery process. So, subsea pipeline was widely applied external coating and sacrificial anode to protect corrosion problem as same as in Gulf of Thailand (GoT). Regarding to in-service condition, codes and recommended practices suggest that anode condition and pipeline Cathodic Potential (CP) shall be monitored and inspected by General Visual Inspection (GVI) with Cathodic Protection reading (CP reading) to ensure the workability of anode that installed with subsea pipeline. For the ageing subsea pipeline, anode retrofit is required, if the anode is unable to contribute it function to protect subsea pipeline from corrosion. However, before anode retrofit project will be set up, the inspection campaign shall be performed to confirm actual condition of anode, but cost of mobilization and demobilization of inspection vessel and inspector crew are quite high. If there are any methods to predict or calculate the remaining life of anode, the cost of vessel and working crew mobilization will be saved. Due to inspection will be performed in a proper time before anode fully depleted. Thus, this study is performed to predict the remaining life of anode by utilizing of existing mathematic models (Bethune and Hartt, 2001) and then the calculation results were compared with inspection results to observe the accuracy of mathematic models.

METHODOLOGY

The existing mathematical model used in this study is shown in equation 1 and it was developed from classical equation called Slope Parameter (Hartt *et al.,* 1998). Also, the accuracy of existing mathematical model was verified by comparing the results with Attenuation equation (Hartt *et al., 2001*).

$$T=\frac{w\times C\times u\times \alpha\times \gamma}{(\varphi_{corr}-\varphi_{c})\times 2\pi\times r_{p}\times L_{as}} \qquad (1)$$

Where

T is anode design life (unit is hours), W is weight of consumed individual anode (unit is kg), u is utilization factor. α is polarization resistance (unit is ohm-m^2). γ is the ratio of total to bare pipe surface area or $1/f_c$. φ_{corr} is pipe corrosion potential (unit is mV). φ_c is closed circuit pipe potential (unit is mV). r_p is outer radius of subsea pipeline (unit is m). L_{as} is anode spacing or 2L (unit is m), and C is electrochemical capacity (unit is m Amp-hr / kg). Especially for Coating Break Down factor, If the pipeline coated with single layer of epoxy and located in trawling area, there is a chance that external coating damaged around 4 % of total area (Gro Ostensen Lauvstad *et al.,* n.d.). So, the Coating Break Down factor in this study were applied from 1 - 11%, due to the previous study is only based on epoxy coating and the location is not located in Gulf of Thailand (GoT) which is more frequencies of trawling activity.

In order to calculate the anode weight depletion, the equation 1 is converted to be equation 2 to make it simple for calculation.

$$W=\frac{T\times(\varphi_{corr}-\varphi_{c})\times 2\pi\times r_{p}\times L_{as}}{C\times u\times\alpha\times\gamma} \quad (2)$$

The statics data of three subsea pipelines are tubulated in table 1, also calculation and study methodology are summarized as a flow chart in figure 1

Table 1 Subsea pipelines statics data.

Pipeline name	Outside Diameter (Inch)	Year installed	Year inspected	Anode weight installed (kg)	External coating type
A	10-3/4”	2008	2012	55	FBE
B	20”	2007	2017	79	Concrete and Enamel asphalt
C	8-5/8”	2007	2017	43	FBE

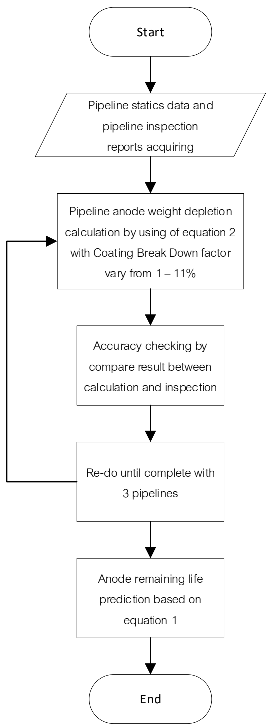

Figure 1 Work flow of anode weight depletion calcuation and accuracy checking.

RESULTS AND DISCUSSION

1. Calculated anode depletion Vs. Inspected anode depletion

The results demonstrate that pipeline A coated with FBE has the highest accuracy around 95.38% when compare between calculated result and inspected result with the correspondence Coating Break Down factor at 6%. The accuracy percentage generated from figure 2 shown that the calculated result from equation 2 is out of actual range from inspection only 3 points from 65 points of anode along pipeline. Thus, the error of calculation result is around 4.62%. Whereas, the pipeline C which was coated by FBE as well has the highest accuracy at 68.18% or the calculated result is out of range of inspection 7 points from totally 22 points of anode installed along pipeline C with Coating Break Down factor 6% as same as pipeline A. This result shown in figure 3 as per below.

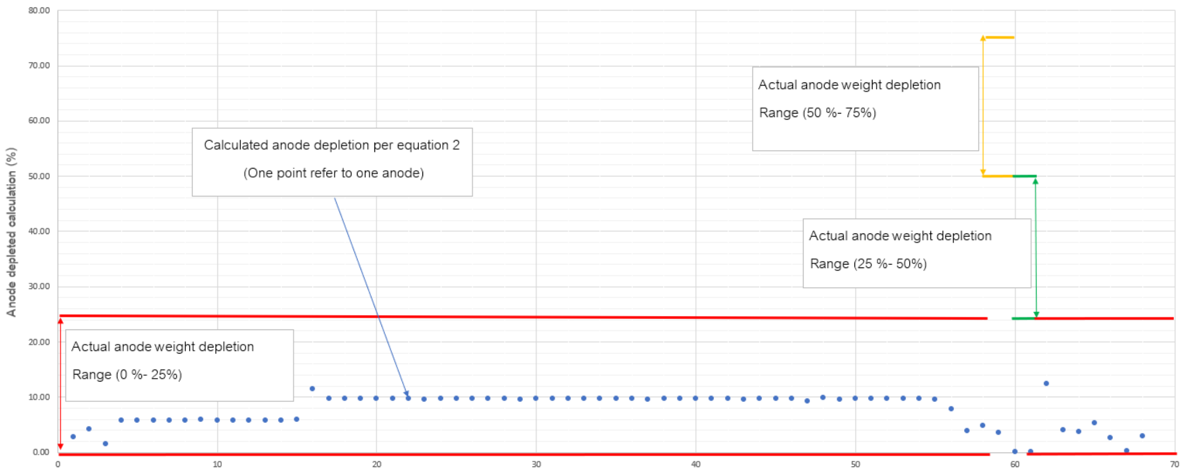

Figure 2 Pipeline A calculated anode depletion Vs. Inspected anode depletion with Coating Break Down factor 6%.

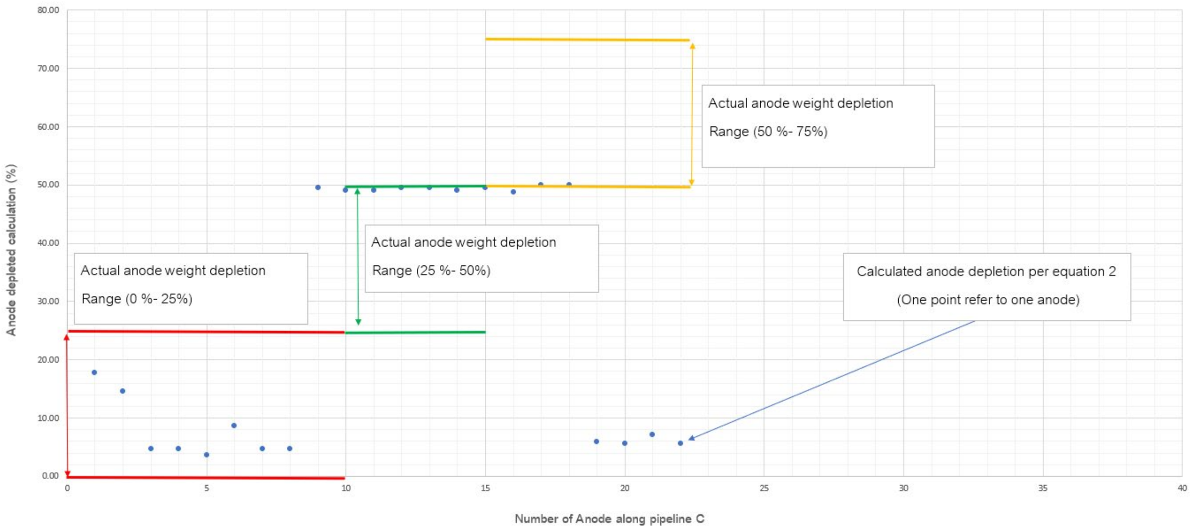

Figure 3 Pipeline C calculated anode depletion Vs. Inspected anode depletion with Coating Break Down factor 6%

For pipeline B coated by concrete with enamel asphalt, the result illustrates that the highest accuracy is 73.53% with correspondence Coating Break Down factor at 4 %. The calculation result is out of range 9 points from 34 points of anode installed along pipeline. Figure 4 shown the calculation result against with inspection result that was reported as a range (25-50% and 50-75%).

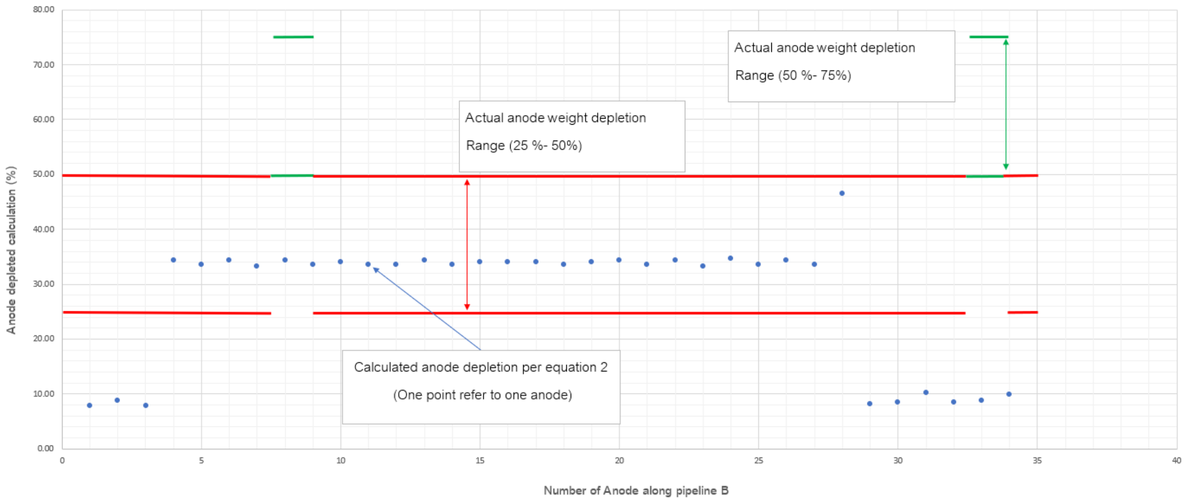

Figure 4 Pipeline B calculated anode depletion Vs. Inspected anode depletion with Coating Break Down factor 4%

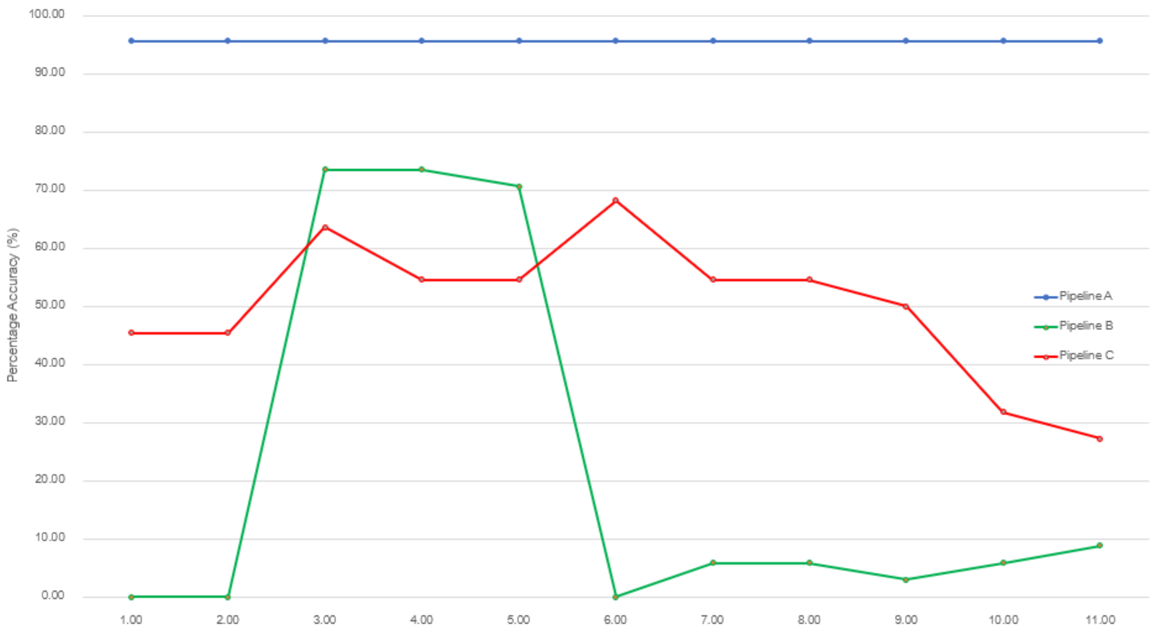

Figure 5 Summary of accuracy percentage of each pipeline with Coating Break Down factor from 1- 11%.

The most appropriate Coating Break Down factor for FBE coating pipeline is 6% which is higher than previous study around 4% and Coating Break Down of 4% is suitable to applied for concrete with enamel coating based on calculation results which is still in range of previous study. Figure 5 shown the highest accuracy percentage of each pipeline with different Coating Break Down factor. The reason that contribute lower number in term of Coating Break Down factor for concrete coating is thickness of this coating type is generally thicker than FBE. The thickness of concrete coating is around 45 mm, but the FBE coating is basically around 0.3 mm. Also, the cause to lead coating broken down during in-service condition could be trawling activity from ship. So, the thicker external coating should be better than the thinning such as FBE in term of impact of abrasion resistance.

2. Existing mathematical model conservativism checking based on calculated anode depletion Vs. actual inspected anode weight depletion results

Figure 6 to 8 demonstrate the values of anode depletion from calculation based on equation 2 against with actual anode depletion from ROV inspection. The ideal line (diagonal line) represent the most accurate results that can be occurred. For example, if the inspection result shows 12.5% of anode depletion, the calculation result shall be 12.5% to generate point on ideal line. From 3 graphs below can be observed that almost the calculated depletion values are under ideal line. It was implied that calculation results from equation 2 are not in conservative way. Due to there is totally 0% of calculated anode depletion of pipeline A located above the ideal line. Pipeline B consist only 2.94% or only 1 point from 34 points that located above the ideal line. For pipeline C, there is 40.91% or 9 from 22 points calculated anode depletion result of pipeline C located above ideal line. Thus, existing mathematical model is not completely conservative to be used to calculate the remaining life of anode in in-service subsea pipeline.

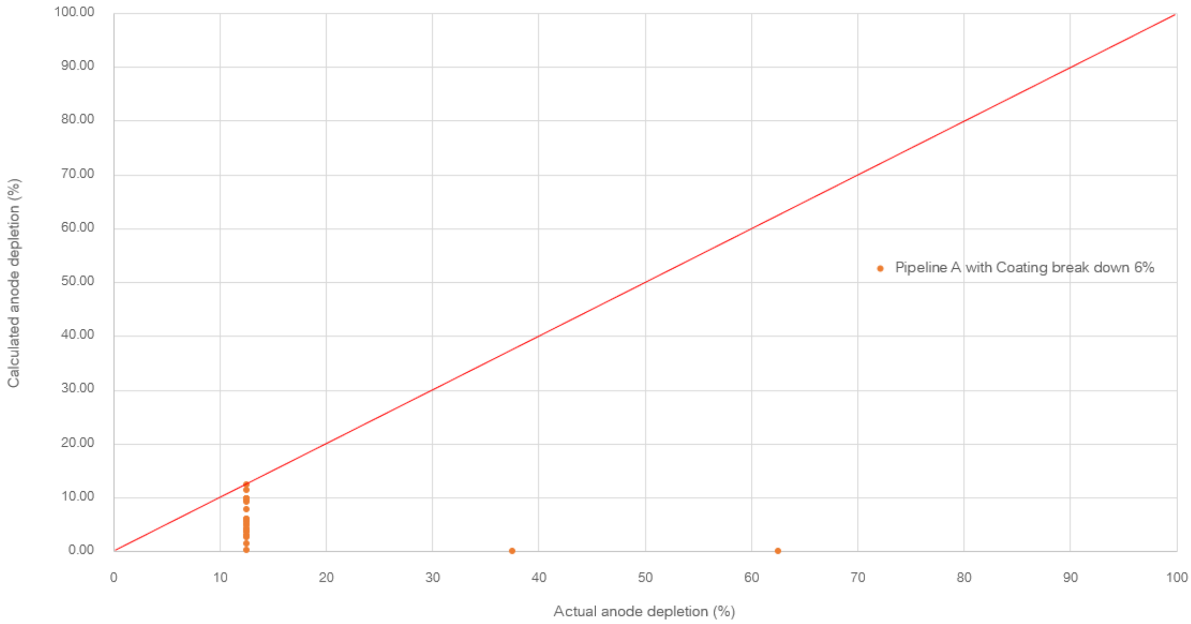

Figure 6 Anode weight depletion from calculation Vs. Anode weight depletion from inspection with ideal line of pipeline A with Coating Break Down factor 6%.

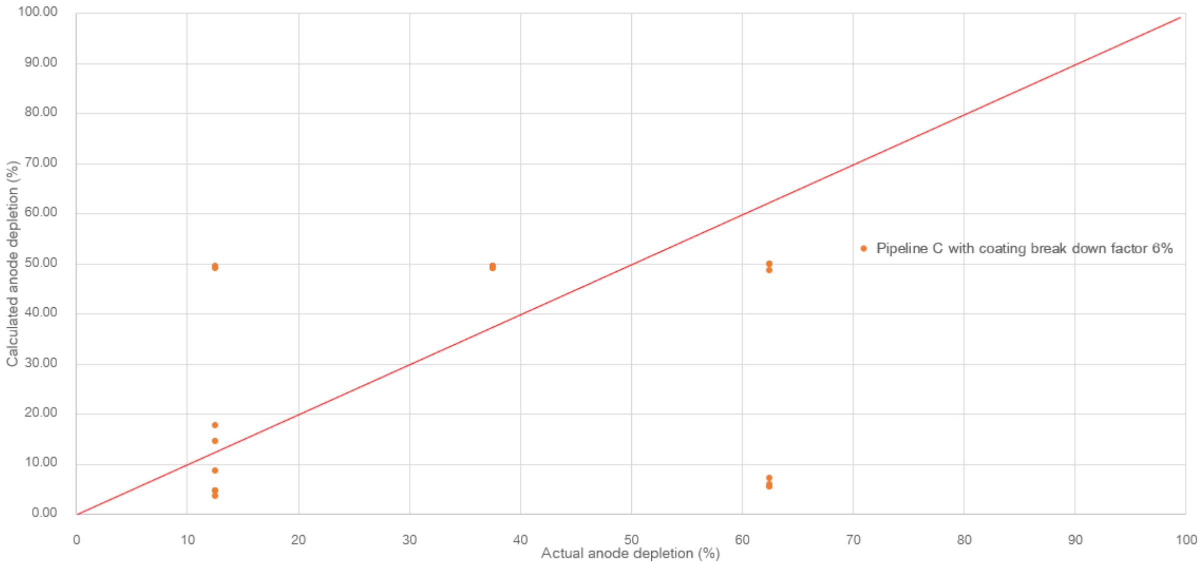

Figure 7 Anode weight depletion from calculation Vs. Anode weight depletion from inspection with ideal line of pipeline C with Coating Break Down factor 6%.

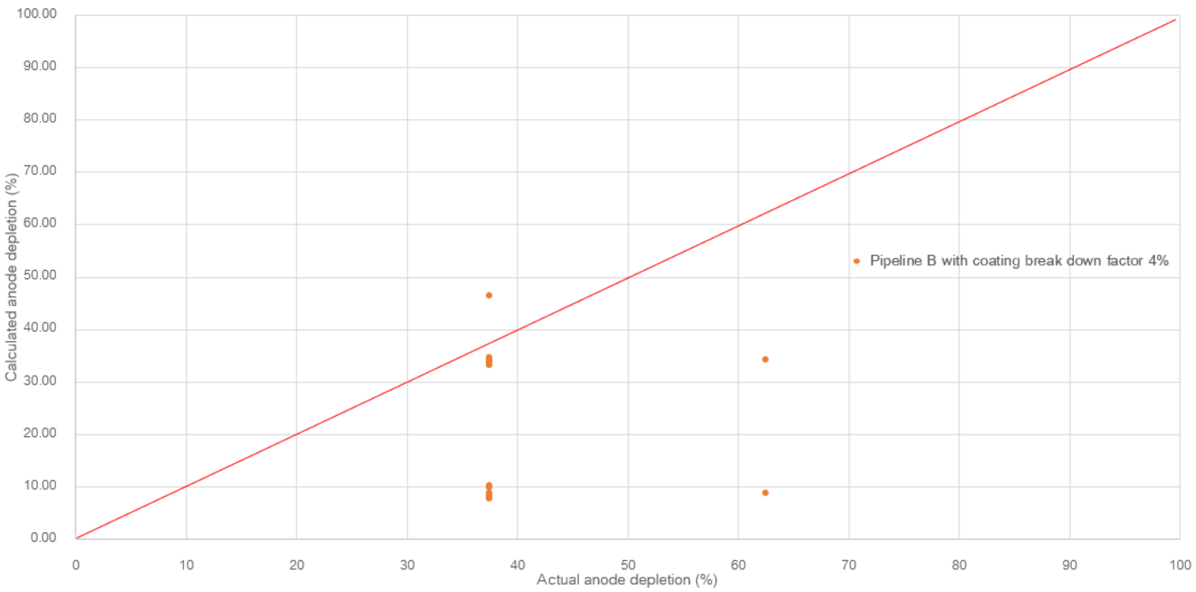

Figure8 Anode weight depletion from calculation Vs. Anode weight depletion from inspection with ideal line of pipeline B with Coating Break Down factor 4%.

3. Anode remaining life prediction

The Anode remaining life was calculated bases on mathematical model and tubulated in table 2. This information will be used for inspection and anode retrofit planning.

Table 2 Calculated remaining life of anode for each pipeline.

Pipeline	Coating Break Down factor	Anode weight at inspectad year (kg)	Expected remaing anode weight (kg)	Remaining life from last inspection
A	6	20.89	9.38	38.3
B	4	52.17	10.43	19.82
C	6	20.89	4.18	9.89

CONCLUSION

1. Accuracy of mathematical model compared with inspection result

The accuracy of pipeline A coated with FBE is 95.38% and pipeline C is 68.18%. So, the average accuracy for pipelines that coated with FBE is 81.78% with 6% of Coating Break Down factor and pipeline that coated with concrete and enamel asphalt get the accuracy around 73.53% with 4% of Coating Break Down factor.

2. Anode remaining life

The remaining life of anode calculated bases on mathematical model which is 38.30, 19.82 and 9.89 years for pipeline A, B and C respectively. These number will be used to plan for detailed and closed visual inspection to ensure condition of anode before anode retrofit project will be performed. However, since the results of mathematical model is not conservative to be used with in-service pipeline condition. Thus, the anode depletion calculation shall be performed more frequently during pipeline operation to monitor depletion rate of anode with inspection campaign carried out to confirm actual condition of anode.

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