A New Prediction Method for Deterioration of the Corrosion Protection System of the Oil Storage Barges

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SUMMARY
The Kamigoto and Shirashima Oil Storage Bases in Japan have been in operation since 1988 and 1996, respectively. The first one of five oil storage barges at Kamigoto Base installed at mooring site in 1986, and it is almost used for 20 years. However, problems such as prediction of deterioration of the corrosion resistance of barge hull structure and accurate prediction of the durability of the fittings have been left in order to expect in future long-term use considering life cycle maintenance. JOGMEC and SRC carried out the research in order to solve these problems. Corrosion protection system for immersed parts of the Oil Storage Barges consists of both painting and cathodic protection system. In this paper, a new prediction method for deterioration of the corrosion protection system of the Oil Storage Barges is reported.

1. INTRODUCTION
Crude oil stockpiling activities in Japan have been carried out both in private sector and in the public sector through JOGMEC. The amount of crude oil stockpiles are now 41 million kl and 48 million kl in private sector and public sector, respectively in 2007. Two of the ten (10) public storage bases are the Kamigoto and Shirashima bases having a storage capacity of 10 million kl correspond to 20 percent of stockpile of the public sector. These two bases, the first of its kind in the world, are very large-scale oil storage systems formed by floating offshore structures where each oil storage barges lined up side by side.

The Kamigoto oil storage base has been in operation since 1988. All five storage barges were dry-docked once for detailed inspection and maintenance until 2004. The second dry-docking for each barge started in 2007. The Shirashima oil storage base started operation in 1996 and were inspected, surveyed and repaired in detail one by one at the mooring site after gas-freeing the tanks in 2000 and 2005. In 1997, there is the change of the rule applied to the storage barges, and the system of inspection and maintenance are also changed, in which maximum five(5)-years intervals of Docking Survey for representative barges is ruled.[1],[2],[3],[4].

However, problems such as prediction of deterioration of the corrosion resistance of barge hull structure and accurate prediction of the durability of the fittings have been left in order to expect in future long-term use considering life cycle maintenance.

In this paper, a new prediction method for deterioration of the corrosion protection system consists of painting and cathodic protection in immersed part of the Oil Storage Barges is reported.

2. OUTLINE OF OIL STORAGE BARGES
The aerial photograph of the Kamigoto oil storage base is shown in Figure 1. Storage barges and barge mooring facilities are arranged in water area while power generation plant, water supply facilities, other utility facilities and etc. are placed in the land. Floating oil fences have been placed double around storage barges to prevent oil contamination. Breakwaters are also arranged to reduce affection of waves.

Figure 1 Kamigoto Oil Storage Base

The sectional view of the structure of the Kamigoto storage barge is shown in Figure 2. The inside of the barge has been divided into 9 subdivisions by longitudinal and transverse bulkheads. For prevention of crude oil
spill and fire control, the structure system of the partition is the double hull and double bottom structures, and those tanks with are always filled with seawater.

In order to prevent the fire in the oil storage tanks, the upper space of oil tanks is filled with inert gas.

![Structure of Kamigoto Storage Barge](L:390m,B:97m,D:27.6m)

**Figure 2** Structure of Kamigoto Storage Barge

### 3. DIAGNOSTIC SYSTEM FOR CORROSION PROTECTION SYSTEM

#### 3.1 Corrosion protection system

Specification for corrosion protection system of the oil storage barges are as shown in Table 1.

1. Considering stowage condition of oil storage tank, tar epoxy paint (T/E) is applied to ceiling part exposed to inert gas and bottom part exposed to sludge sedimentation.
2. Water sealing tanks are protected by tar epoxy paint (250μm) and cathodic protection system with aluminum anodes (5mA/m²-10 years).
3. Tar epoxy paint (400μm) and cathodic protection system with aluminum anodes (10mA/m²-10 years) are applied to bottom and side shell (to the draft in a half cargo).

#### Table 1  Corrosion Protection System for Kamigoto Oil Storage Barges

<table>
<thead>
<tr>
<th>Location</th>
<th>System</th>
</tr>
</thead>
<tbody>
<tr>
<td>Oil storage tank</td>
<td>Upper T/E 250μm</td>
</tr>
<tr>
<td></td>
<td>Middle no paint</td>
</tr>
<tr>
<td></td>
<td>Bottom T/E 250μm</td>
</tr>
<tr>
<td>Water tank</td>
<td>T/E 250μm Aluminum anode</td>
</tr>
<tr>
<td>Side and bottom shell</td>
<td>Topside P/E 400μm P/E 400μm Aluminum Anode Immersed T/E 400μm Aluminum anode</td>
</tr>
<tr>
<td>Upper deck</td>
<td>IZ 75μm P/E 100μm P/U 40μm</td>
</tr>
</tbody>
</table>

**Note:**

T/E: Hi-built Tar Epoxy Paint
P/E: Pure Epoxy Paint
IZ: Inorganic Zinc Paint
P/U: Polyurethane paint

#### 3.2 Deterioration pattern of corrosion protection system

Tar epoxy paint and cathodic protection system are applied to immersed bottom shell, side shell and water sealing tank. Therefore, deterioration pattern of total corrosion protection performance could be assumed as shown in Figure 3. As far as cathodic protection with enough protective currents density is available, fully protection would be expected in spite of progress of paint deterioration. If anodes have lost current to keep adequate potential, corrosion could have occurred instantaneously in this case. Prediction of life of corrosion protection system is very important technology for those oil storage barges.

**Figure 3** Deterioration Pattern of Total Corrosion Performance

![Deterioration Pattern of Total Corrosion Performance](image)

#### 3.3 Procedure of diagnosis

Deterioration diagnosis flow for the immersed shell plate is shown in Figure 4, for example.[5],[6],[7].

In deterioration diagnosis of the corrosion protection system, collecting additional data (in periodic investigation and by monitoring in the mooring site) are required to examine the correct life of the system in addition to data obtained normally in the periodic inspection and survey.

Measured data are also correlated to corresponding laboratory test data to predict the life of corrosion protection system.

#### 3.4 Deterioration data

Deterioration data (impedance) of the tar epoxy paint immersed in seawater obtained by accelerated aging tests in our laboratory are shown in Figure 5 together with
actual data for Kamigot storage barge obtained in tanks at the time of docking survey.
Also current density and paint resistance data for test specimens, actual paint in tank and monitoring specimens are shown in Figure 6 and Figure 7.
Data of Loss of anode weight is also obtained in actual tanks.
Those test data are correlated to actual data obtained by investigation of the storage barges dry-docked, in order to determine deterioration curves for actual corrosion system.

3.5 Results of prediction for deterioration of corrosion protection system
Results of prediction for deterioration of corrosion protection system in one of sea water tanks of the Kamigoto No.1 Barge is shown in Figure 8, for example. In Figure 8, solid line indicates prediction of loss of anode weight in water tank (No.1S) considering of paint deterioration. Loss of anode weight can be calculated by integration of current density of actual tank paint coating, protection area and other factor. Two actual tank data points are obtained in tanks at the time of docking survey in 1997 and 2002. In this case life of anode is predicted about 45 years. In other tanks, these estimated lines vary depend on actual data for each tank.

Figure 5 Impedance Data of Accelerated Aging Tests and Actual Tank

Figure 6 Current Density Data of Accelerated Aging Tests and Actual Tank

Figure 7 Paint Resistance Data of Aging Tests and Actual Tank Data
3.6 Simulation of corrosion protection system

The potential measurement used widely in offshore structures is comparatively simple as monitoring technique of the anticorrosive condition. However, it is difficult to obtain polarization curve of the deteriorated surface of the coated plate in order to estimate the coating condition. Here, simulation of potential of deteriorated surface is carried out using assumed polarization curves. Boundary Element Method is applied to analyze potential for various surface condition and arrangement of anode. Computer Code used in this simulation has been developed by Prof. K. Amaya of Tokyo Institute of Technology.[8]. A simulation model for side and bottom of Kamigoto Oil Storage Barge is shown in Figure.9.

The example of simulation results is shown in Figure 10. It is shown that distribution of potential scatters widely in accordance with progress of deterioration of coated plate. Also it is shown that the potential becomes less-noble at distant position from anode location in case of large deterioration of paint.

Figure 8  Prediction of Loss of Anode Weight (Example)

Figure 9  Simulation Model for Outside Shell and Bottom Shell of Kamigoto No.2 Barge

Figure 10  Results of Potential Simulation

Estimation curve to determine paint deterioration condition is shown in Figure 11. Here, maximum difference of potential is a parameter to decide paint deterioration condition. Degree of deterioration can be easily detected by measurement of maximum and minimum potential in the Oil Storage Bases compared with dry-dock measurement.
CONCLUSIONS

Conclusions are as follows.

(1) Deterioration of master curves of paint system by accelerated aging tests is defined.
(2) Actual deterioration data of both painting and anode are collected.
(3) Method of determine correlation between master curve by tests and actual barge data by measurement at dry-docked survey is established.
(4) Prediction of a life of present corrosion protection system of immersed portion of the Oil Storage Barges become possible.
(5) Estimation curve to determine paint deterioration condition using potential measurement is established.

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AUTHORS’ BIOGRAPHIES

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