

Durability Test of Coating Film with Simulated Defect  
and  
Corrosion Test of Uncoated Steel Plate  
– Outline of Report –

JFE Engineering Corporation

## 1. Test condition

The recommendation by GESAMP BWWG was that all of the corrosivity and coating degradation testing be repeated with adequate control throughout the testing to maintain the TRO concentrations between 15 mg/L and 20 mg/L. The reason for this was fact that the TRO value of the day 5 data in the land-based tests was about 15mg/L. This high TRO value at day 5 was mainly caused by the low temperature during the land-based tests. Such high TRO has never been observed at day 5 at normal temperature.

Therefore, a durability test of the coating film with a simulated defect and a corrosion test of the uncoated steel plate were conducted at 5°C for 180 days. However, for reference, the same tests were also performed at 40°C for 90 days while keeping the TRO value higher than 15 mg/L.

### 1.1 Test Specimen

Coating film was painted in accordance with Performance Standards for Protective Coatings (PSPC).

( ref. RESOLUTION MSC.215(82), MSC 82/24/Add.1 )

### 1.2 Test Temperature

- Immersion : 5°C (Control by Open type low temperature circulating water equipment)
- Drying condition : 5°C (kept in refrigerator)
- The test results after 9 test cycles at temperature 40°C are also shown in the figures. These tests were conducted using the same procedures as 5°C.

### 1.3 Test Solution

#### a. Natural seawater

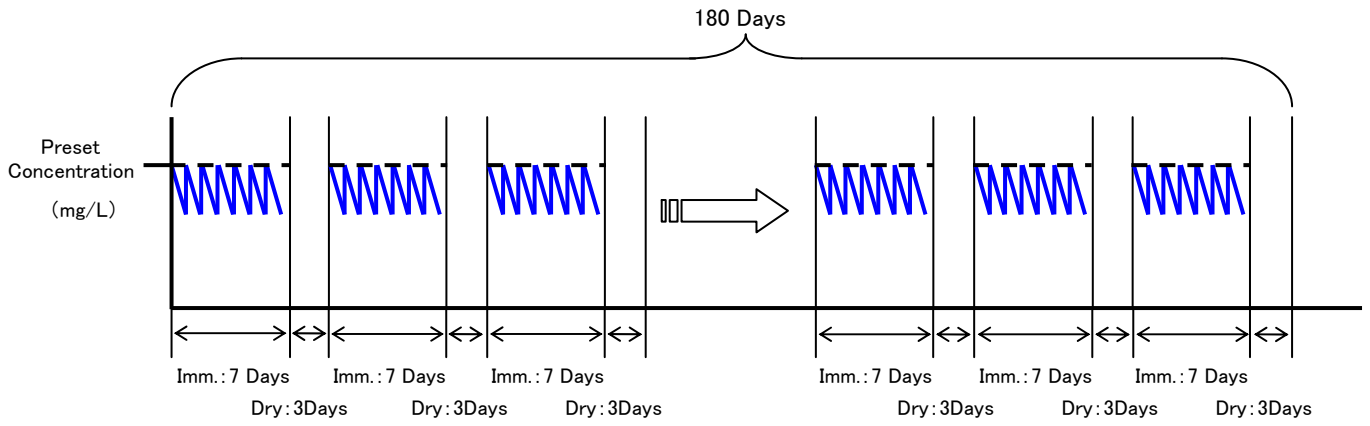
(Sampled from the mooring quay of Universal Shipbuilding Corporation at Tsurumi Yokohama)

#### b. Natural seawater +20mg/L NaClO (TG Ballastcleaner<sup>®</sup>, Product of TG Corporation)

### 1.4 Test period

One test cycle consists of 7days immersion and 3days drying conditions and 18 test cycles were repeated. Initial effective chlorine concentration of test solution was set at 20mg/L and TRO concentration was controlled above 15mg/L to compensate the decrease of TRO with time.

(This test condition is based on the recommendation by GESAMP-BWWG in MEPC60/2/12 ANNEX 5, p.36)



## 2. Test results

### 2.1 Uncoated test specimen

#### 2.1.1 Observation of External Appearance

- Natural seawater : red rust, whole surface corrosion
- Natural seawater + 20mg/L NaClO : red rust, whole surface corrosion
- No difference was observed due to the difference of test solution.

#### 2.1.2 Weight measurement

After removal of rust, the weight of each specimen was measured and the corrosion speed was calculated. The results are shown in Table 1 and Fig. 1. The test results for 40°C after 9 test cycles are also shown in Fig. 1.

Table 1 Results of weight measurement (Test temp. : 5°C)

Average corrosion speed (mm/year)			
Natural seawater		Natural seawater + 20mg/L NaClO	
9 cycles	18 cycles	9 cycles	18 cycles
0.062	0.065	0.080	0.076

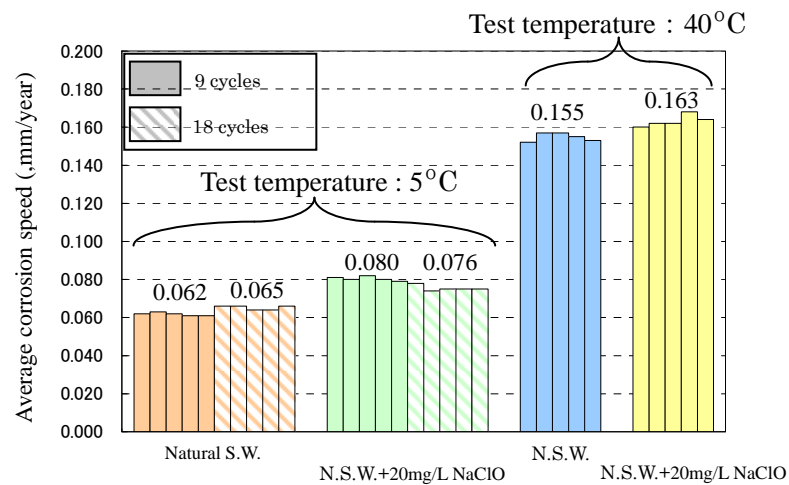


Fig.1 Corrosion speed for different test conditions

## 2.2 Painted test specimens

### 2.2.1 Observation of External Appearance

No defect such as bleach or bulge was observed for both tar epoxy resin coating and modified epoxy resin coating.

### 2.2.2 Measurement of paint film thickness

Under both natural seawater at 5°C test temperature and natural seawater with effective chlorine concentration 20mg/L conditions, decreasing tendency of paint film thickness were observed for both kinds of test specimens. The test results are shown in Fig. 2.

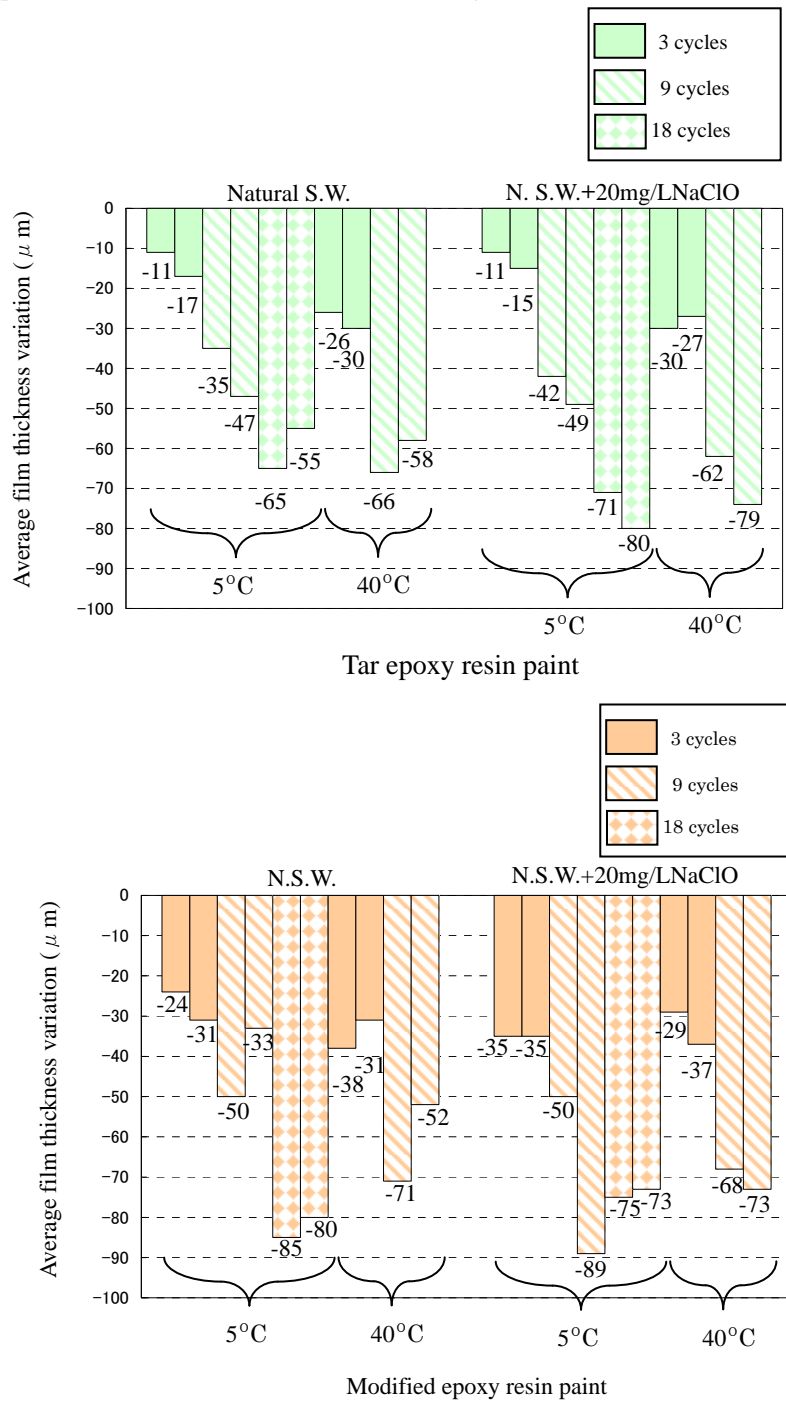


Fig.2 Relation between test condition and averaged film thickness

### 2.2.3 Cross-Cut Adhesion Test

Slight separations were observed at X cut part for the tar epoxy resin paint film in both natural seawater and natural seawater+20mg/L chlorine at test temperature 5°C.

Table 3 Scoring in tape peel test

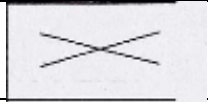
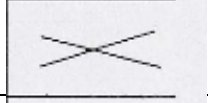
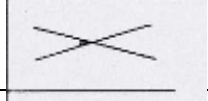
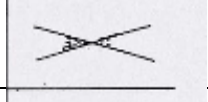
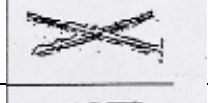

Evaluation score	Condition of crosscut part	Phenomenon
10	No peeling	
8	No peeling at the point of intersection; very slight peeling at crosscut parts.	
6	Peeling of less than 1.5mm in either direction from the intersection of the crosscut parts.	
4	Peeling of less than 3.0mm in either direction from the intersection of the crosscut parts.	
2	Peeling at most of the crosscut part where the tape was applied.	
0	Peeling larger than the crosscut part.	

Table 2 Results of crosscut adhesion test

Type of specimen	Test Solution	Test Temp.	Tests Cycles	点数
Tar epoxy	Natural seawater	5°C	18	6、6
	N.S.W. + 20 mg/L NaClO	5°C	18	6、4
Modified epoxy	Natural seawater	5°C	18	10、4
	N.S.W. + 20 mg/L NaClO	5°C	18	10、10

### 2.2.4 Scratch test

The hardness of the lead of a pencil for tar epoxy resin paint slightly decreased for both natural seawater and natural seawater + 20 mg/L effective chlorine solution. Whereas no decrease of the hardness of the lead of a pencil for modified epoxy resin paint was observed for both solution condition.

Table 3 Scratch test results

Type of specimen	Test Solution	Temp	hardness of pencil lead	
			Before test	After 18 cycles
Tar epoxy	Not tested	—	3B	—
	N.S.W.	5°C	—	7B
	N.S.W. 20 mg/L NaClO	5°C	—	7B
Modified epoxy	Not tested	—	3H	—
	N.S.W.	5°C	—	3H
	N.S.W. 20 mg/L NaClO	5°C	—	3H

※) pencil lead : 9H>8H>7H>6H>5H>4H>3H>2H>H>F>HB>B>2B>3B···  





Hard
↔
Soft

2.2.5 Adhesion tests

Comparing not tested specimens and tested specimens, the adhesive forces of both tar epoxy resin paint and modified epoxy resin paint decrease. But no difference in adhesive force for the different test solution.

Ruptures of tar epoxy resin paint film between base plate and the first layer were observed for both natural seawater and natural seawater + 20 mg/L TRO solution conditions paint at 5°C. Whereas ruptures of modified epoxy resin paint both in the paint film and at the boundary of base plate and the first layer were observed for both natural seawater and natural seawater + 20 mg/L TRO solution conditions at 5°C. The ruptured area of in-layer destruction were more than 50%.

The results of the adhesion tests are shown in Table 4 and Fig. 3. Photos of the adhesion test specimens are shown in Photo 1.

Table 4 Results of adhesion test

Type of specimen	Test Solution	Test Temp	Tests Cycles	Averaged Adhesive force (N/mm <sup>2</sup> )
Tar epoxy	Non tested	—	—	1.6
	Natural seawater	5°C	3	1.7
			9	1.2
			18	0.6
	N.S.W.+20 mg/L NaClO	5°C	3	1.9
			9	0.6
18			0.9	
Modified epoxy	Non tested	—	—	4.2
	Natural seawater	5°C	3	4.1
			9	1.6
			18	3.3
	N.S.W.+20 mg/L NaClO	5°C	3	3.3
			9	2.5
18			3.6	

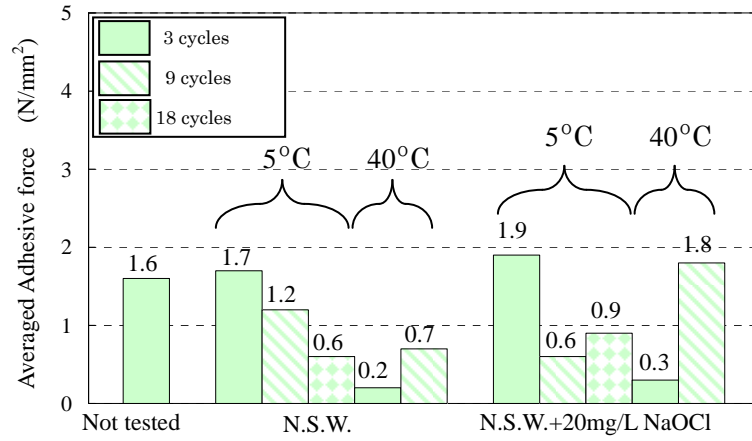


Fig.3 Relation between Test Solution and Adhesive force  
(Tar epoxy resin paint)

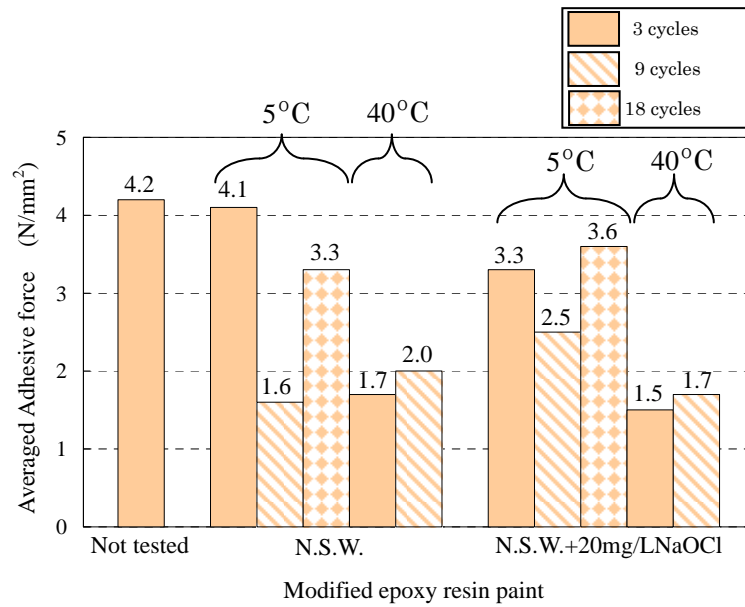

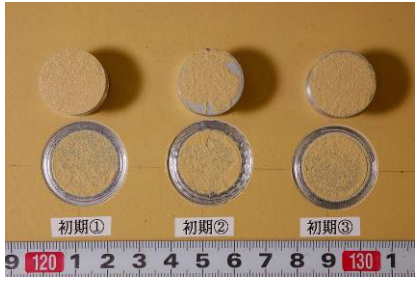
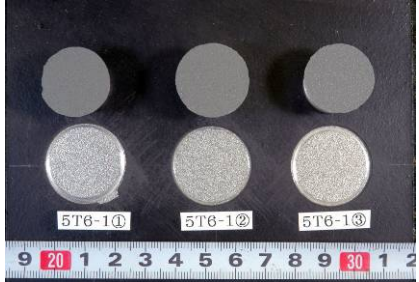

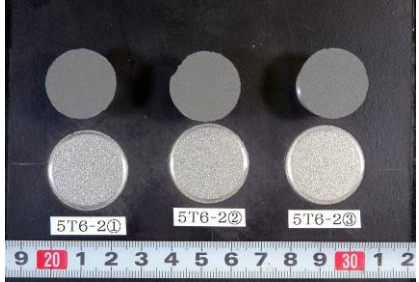
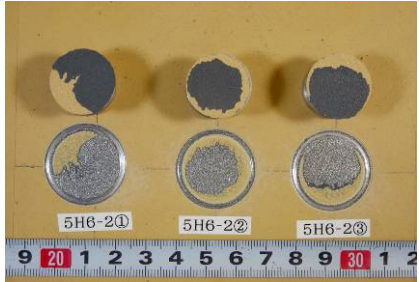
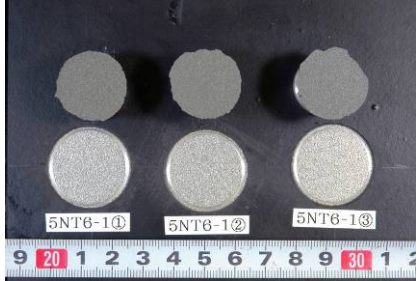

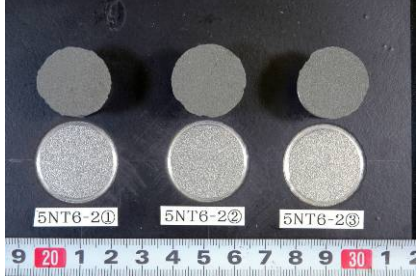



Fig.4 Relation between Test Solution and Adhesive Force  
(Modified epoxy resin paint)

Photo 1 Lists of external appearance after adhesion tests 【Test Temp. : 5°C, after 18 test cycles】

Test Solution	Specimen No.	Tar epoxy resin paint	Specimen No.	Modified epoxy resin paint
Not Tested	—		—	
Natural Seawater	5T6-1		5H6-1	
	5T6-2		5H6-2	
N.S.W. + 20mg/L NaClO	5NT6-1		5NH6-1	
	5NT6-2		5NH6-2	

### 3. Conclusions

Effects of sodium hypochlorite on the endurance of paint coating films and non coated steel plates were investigated by the immersion tests. The facts summarized below become clear from the test results obtained.

#### (1) Uncoated test specimen

- Specimen surfaces of both natural seawater and natural seawater+20mg/L sodium hypochlorite at 5°C condition were covered with the brown rust. After removing the rust from specimen surface, both specimens showed the whole surface corrosion. The difference of surface condition due to the different test solution were not observed. The results at 40°C after 9 test cycles were almost the same as the results at 5°C after 18 test cycles.
- Averaged corrosion speed for natural seawater was 0.065mm/year and for natural seawater +20mg/L chlorine was 0.076mm/year at 5°C. Further, the averaged corrosion speed for natural seawater was 0.155mm/year and for natural seawater +20mg/L chlorine was 0.163mm/year at 40°C after 9 test cycles. The effect of 20mg/L chlorine decreased greatly compared to the 5°C case.

#### (2) Coated test specimen

- No occurrence of failure such as crack, separation and blistering was observed on the test specimens with tar epoxy resin paint and modified epoxy resin paint for natural seawater and natural seawater+20mg/L sodium hypochlorite at 5°C condition. The results at 40°C were almost the same as the results at 5°C.
- Decrease of both tar epoxy resin and modified epoxy resin paint film thickness was observed for the natural seawater and natural seawater + 20 mg/L sodium hypochlorite solution at 5°C condition. The results at 40°C were almost the same as the results at 5°C.
- No apparent effect of a TRO concentration between 15 and 20 mg/L in natural seawater was observed in the durability tests of the tar epoxy paint film and modified epoxy paint film after 180 days (18 test cycles) under the 5°C condition. The results at 40°C after 90 days were almost the same as the results at 5°C.