

Corrosion-resistant Steels, NSGP™-1, -2 for Crude Oil Tankers and their Performance

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Outline

1. Introduction

- IMO requirements for corrosion protection of COT
- Benefits of Corrosion-resistant Steel (CRS)
- Environment and corrosion in COT

2. NSGP™-1 for bottom plates

- Mechanical properties
- Onboard Investigation results

3. NSGP™-2 for upper deck

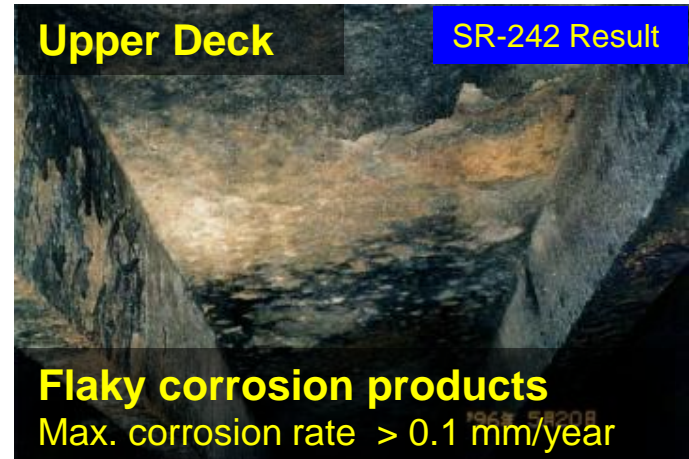
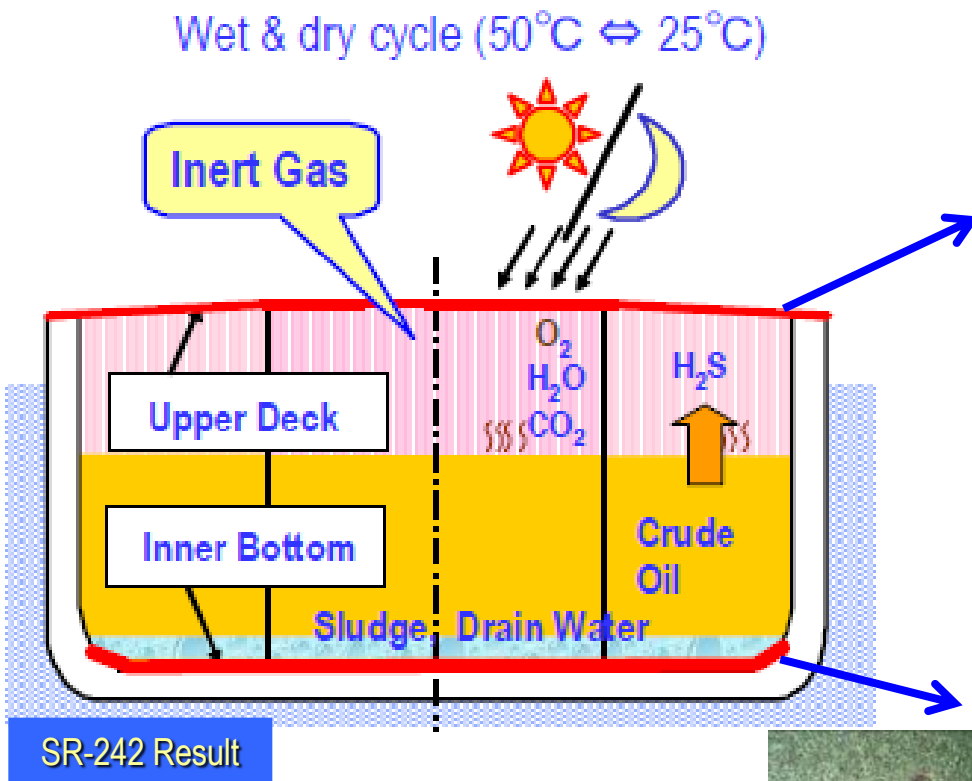
- Mechanical properties
- Onboard Investigation results

4. Conclusions

Benefit of using CRS

1. No need for a protective coating, that is a benefit for the global environment by not using volatile organic compounds.
2. There is no concern about dispersion of coating quality before completion of ship building.
3. There is no concern about damage for protective coating during sludge removal work, that leads to minimize repair work and maintenance cost which are heavy in periodical dock inspection/expense items for ordinary VLCCs.

Environment and Corrosion in the COT



Environment : Not only crude oil, but also sludge, drain water (brine), and severe gases.
Corrosion: There are 2 types. 1) pitting corrosion (bottom), 2) general corrosion (upper deck)

NSGPTM-1 for Bottom Plates

(1) Typical composition and mechanical properties

(2) Onboard Investigation results

Typical Composition of NSGP™-1

(mass %)

	C	Si	Mn	P	S	Ceq.
NSGP™-1 (AH32)	0.12	0.26	0.96	0.014	0.007	0.331
Conventional steel (AH32)	0.14	0.20	1.09	0.018	0.006	0.322
IACS Standard (AH32)	≤0.18	≤0.5	0.9~1.6	≤0.035	≤0.035	≤0.36

- A very small quantity of alloying elements is added to improve corrosion resistance.
- The composition of the developed steel fully satisfies IACS standards.

Mechanical Properties of NSGP™-1

Mechanical properties

	YP (N/mm ²)	TS (N/mm ²)	EL (%)	E ₋₂₀ (J)
NSGP™-1 (t=25mm)	462	554	22	273
D36 Spec.	≥ 355	490-620	≥ 20	≥ 34

Impact test results of welded joint

Welding procedure : FAB					
Notch position	WM	FL	HAZ 1mm	HAZ 3mm	HAZ 5mm
E ₀ (J)	117	103	103	193	208

Good mechanical properties

Onboard Evaluation Results for VLCCs Using **NSGP-1** for COT **Bottom Plates**

Onboard Investigations of VLCCs Applying NSGP™-1



(1) The first NSGP™-1 applied NYK's VLCC will be at the 5th inspection (Over 12 year Service Period)

(2) NSGP™-1 subsequently applied NYK's 8 VLCCs to all COTs and their service periods are ranged from 5 years to 8 years.

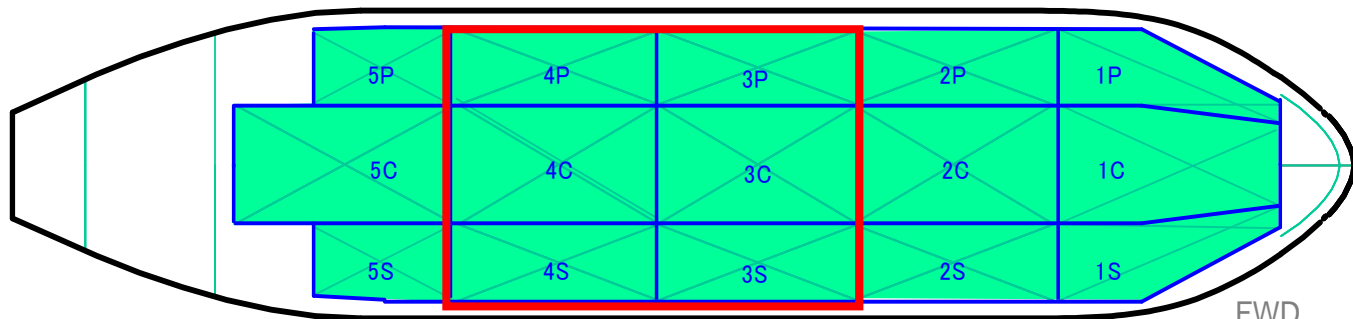
Table 1: List of VLCCs provided with NSGP™-1

	Service period	Main route	Application of CRS
VLCC-A	12.2 years	Middle East / Japan	All COTs bottom Plates, 6 COTs unpainted
VLCC-B	8.0 years	Middle East / East Asia / South America / North America	All COTs bottom plates, all COTs unpainted
VLCC-C	7.6 years	Middle East / East Asia / Southeast Asia / North America	
VLCC-D	6.8 years	Middle East / East Asia	
VLCC-E	6.9 years	Middle East / Southeast Asia	
VLCC-F	5.3 years	Middle East / East Asia / Southeast Asia	
VLCC-G	5.0 years	Middle East / East Asia / Southeast Asia	

Onboard Evaluation Results of VLCC using NSGP™-1 at 10years



The CRS applied 6 tanks without protective coating: **Inspection area**



FWD

NSGP™-1 Showed Good Pitting Corrosion Resistance Even After 10 Years Service

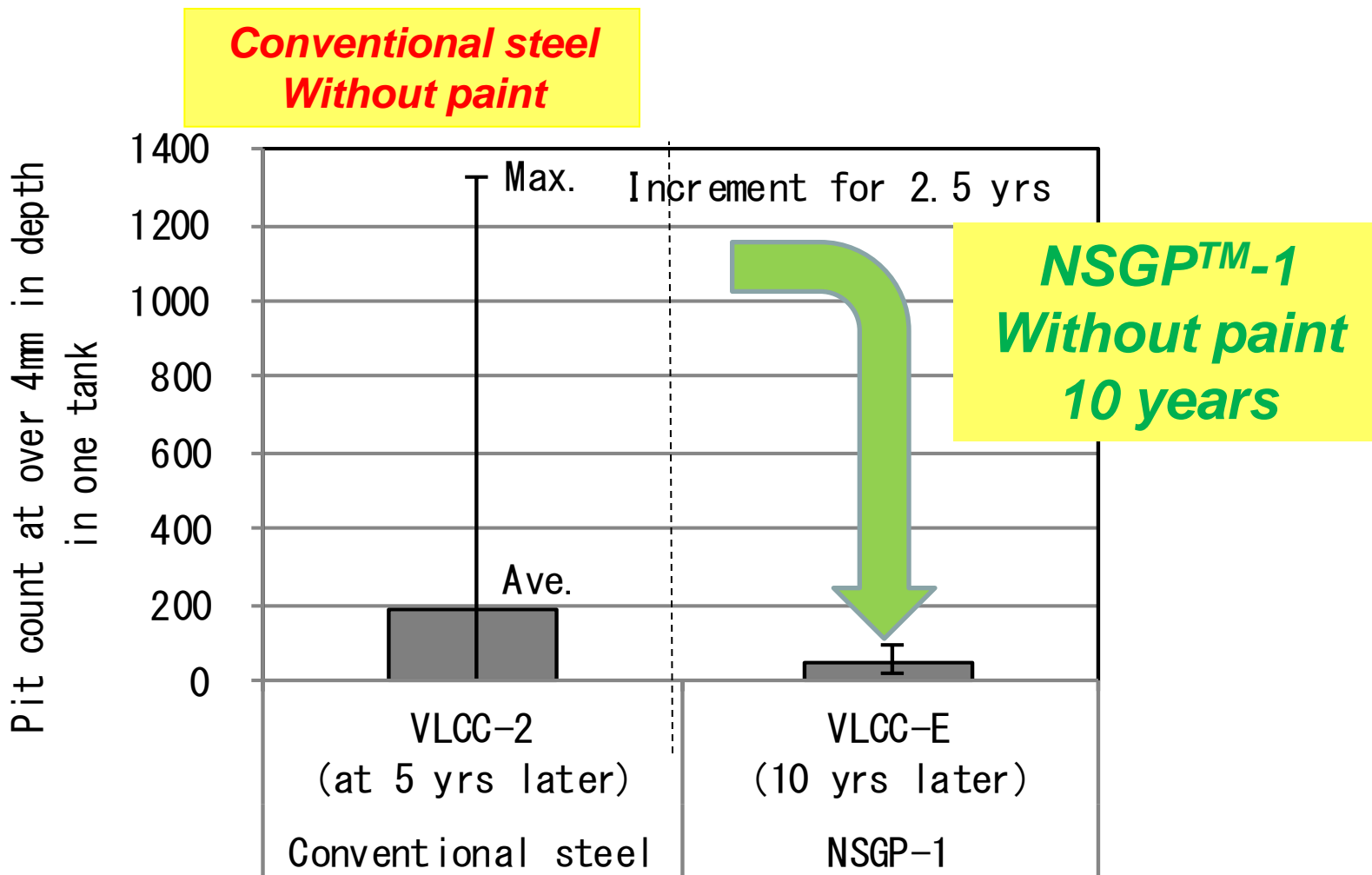


Fig. Observed pit count at over 4 mm in depth for conventional steel and NSGP™-1

NSGP™-1 Showed Good Pitting Corrosion Resistance in all 6 VLCCs

**Conventional steel
Without paint**

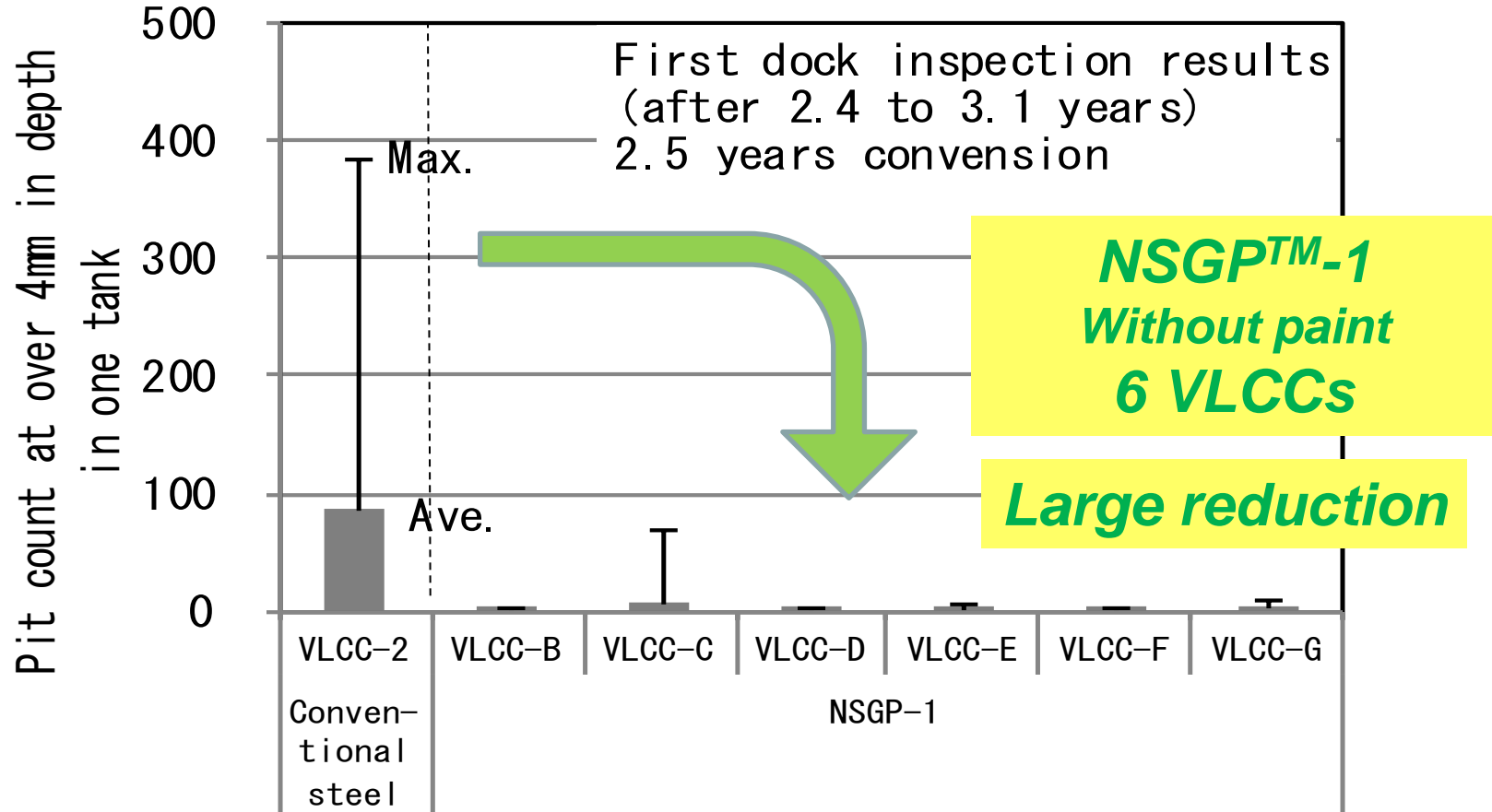


Fig. Observed pit count at over 4 mm in depth for conventional steel and NSGP™-1

Termination of Pit Growth at an Inspection Dock

Direct Evidence of Termination of Pit Growth for NSGP™-1

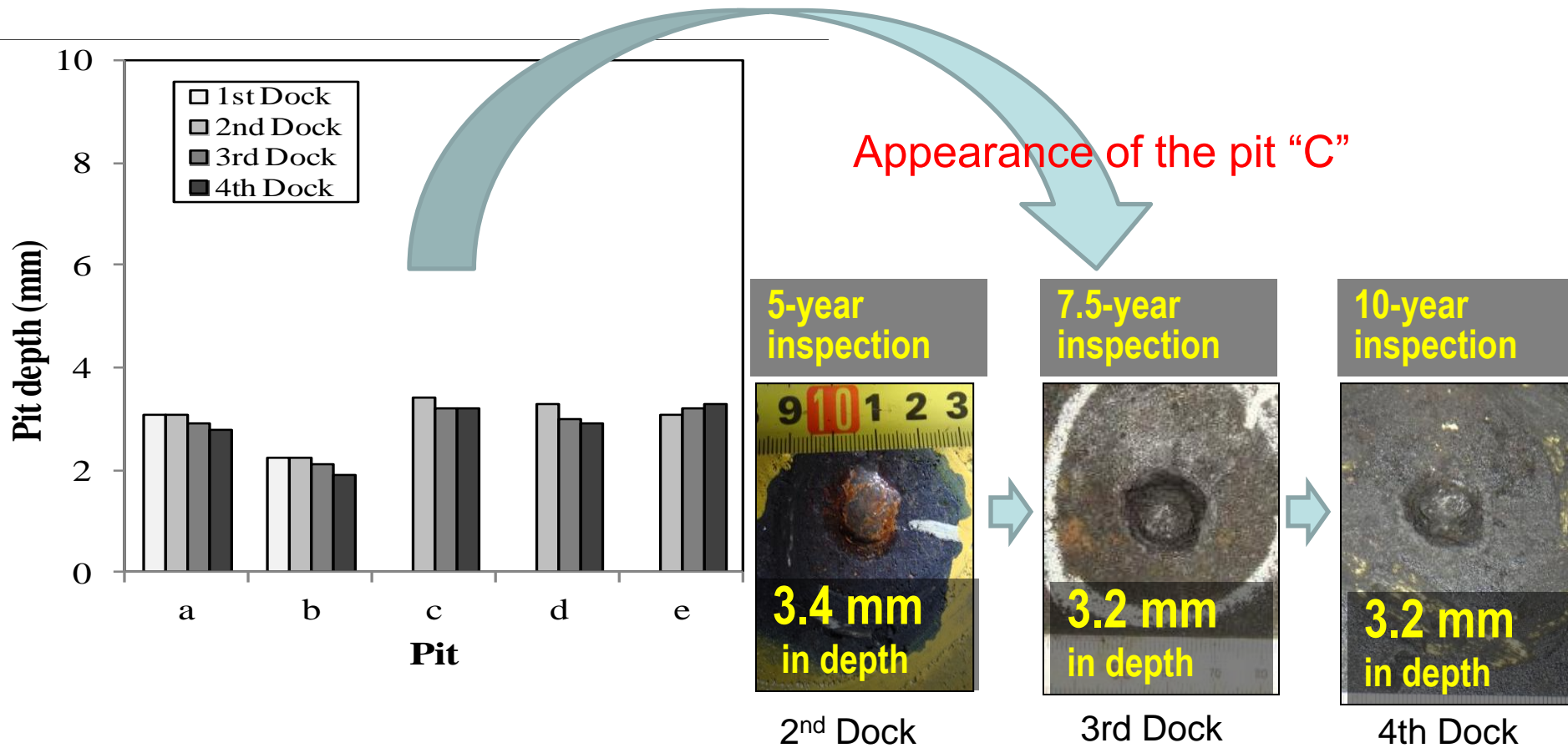


Figure Pit depth at the first, the second, the third and fourth dockings and appearance of pit "c" observed at 2nd, 3rd and 4th Dock Inspections.

Pit growth stops after dock inspection, no longer deepened.

NSGP™-2 for Upper Deck

- (1) Mechanical properties
- (2) Onboard Investigation results

Mechanical Properties of NSGP™-2

Mechanical properties

	YP (N/mm ²)	TS (N/mm ²)	EL (%)	E ₋₂₀ (J)
NSGP™-2 (t=16.5)	432	504	24	258
DH36 Spec.	≥355	490-620	≥20	≥34

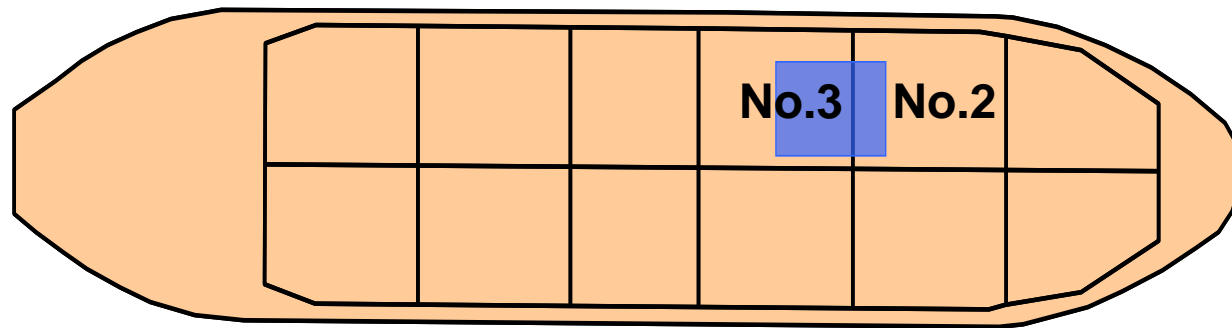
Impact test results of welded joint

Welding procedure : SAW (3 – electrode FCB)					
Notch position	WM	FL	HAZ 1mm	HAZ 3mm	HAZ 5mm
E ₀ (J)	174	132	172	224	250

Good mechanical properties

Onboard Investigation of Tanker Applying NSGP™-2

Upper deck



NSGP™-2 was applied to an Aframax tanker for No. 2 and 3 COT's upper deck plates.

Onboard investigation at 2.7, 5.0, 8.1 and 10 years

Onboard Evaluation Results of Conventional Steel and NSGP™-2

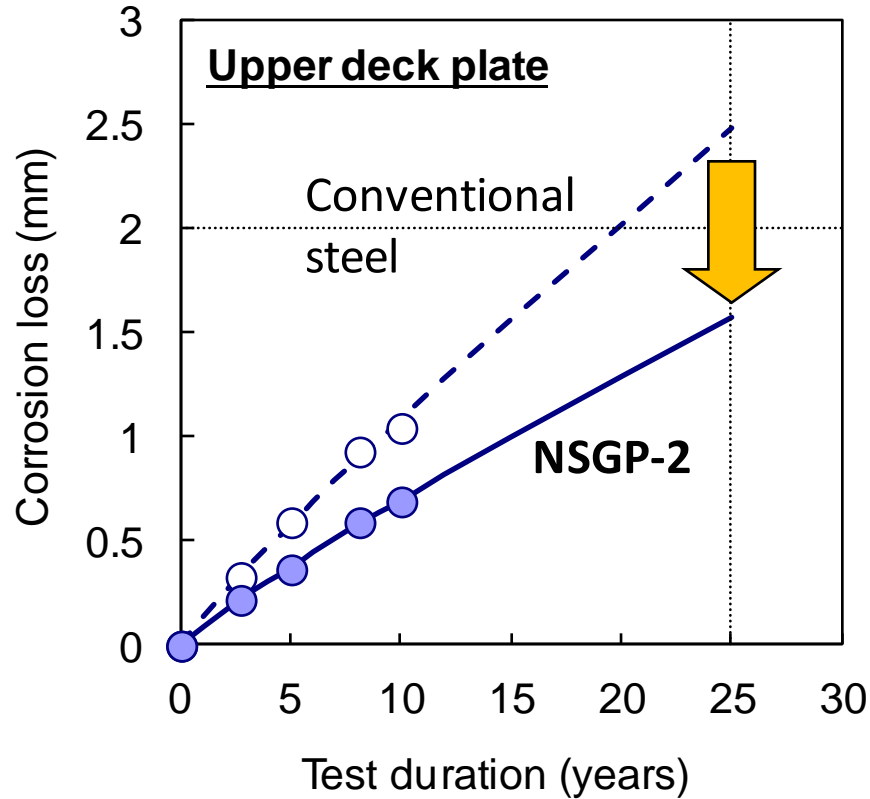


Fig. Results of the exposure test on the upper deck of an Aframax tanker

- Corrosion loss is less than 0.7 mm/10years.
- It is considered that the corrosion loss will not exceed 2 mm after 25 years.

Conclusions

1. NSGP™-1 for Bottom Plate

- Pit count of VLCCs applying the NSGP™-1 was much lower than that of VLCCs using conventional steel. **And structural countermeasure was found to be effective against pits.**
- Direct evidence for termination pit growth was observed.
- Approved for CRS from Class NK and ABS.

2. NSGP™-2 for Upper Deck

- Corrosion loss for deck plate was 38% down to conventional steel (less than 2 mm / 25year) by onboard investigation.
- It is thought that the corrosion loss will not exceed 2 mm after 25 years.
- Approved for CRS from LR, Class NK and ABS.

3. The application of such CRSs has been very effective in minimizing repair work and the risk of failure in structural integrity.

4. NYK decided to use CRS on our new tankers from 2004 and shares the continuous dock inspection result with NSSMC.

