Corrosion-Resistant Steel for COT of Crude Oil Tankers

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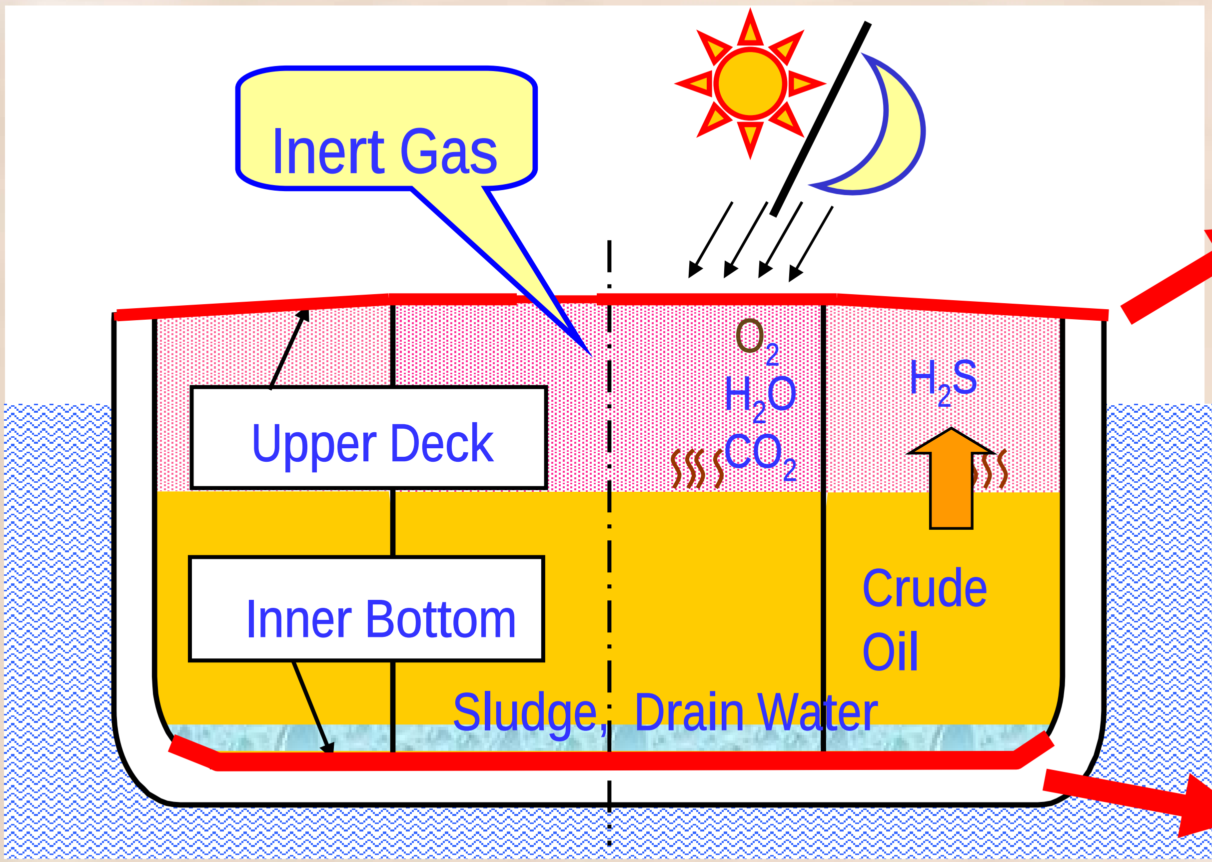
Japan Ship Technology Research Association

Corrosion problems in COT of tankers

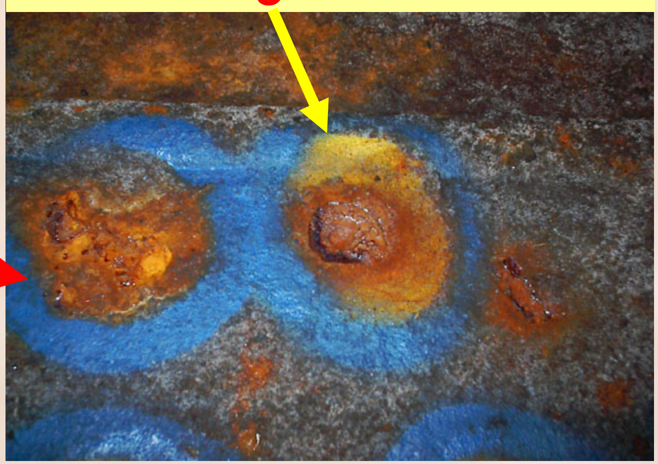
Cyclic Temp. Change

Wet & dry cycle (50°C ⇔ 25°C)



Upper Deck
⇒ General Corrosion

Bottom
⇒Pitting Corrosion



How to overcome the problem?

- Apply Protective coating (epoxy paint) on steel ;
- Construct by corrosion resistant steel; or
- Other alternatives (future technologies)

What is "Corrosion Resistant Steel"?

- Steel which has sufficient corrosion resistant performance to
  - Protect the structure of the top of the COT and/or
  - Prevent leakage of oil from the bottom of the COT.

Facts of the corrosion problem in COT

Outcome of SR242 Project (April 1999～March 2002)

Intensive field investigations have been carried out for technical understanding on corrosion in COT

University & National Laboratory
Osaka University
Tokyo Institute of Technology
Ship Research Institute

SHIP OWNER
Nippon Yusen Kaisya
Mitsui O.S.K., Lines
NYK Logistics Technology Institute
The Japanese Shipowners' Association

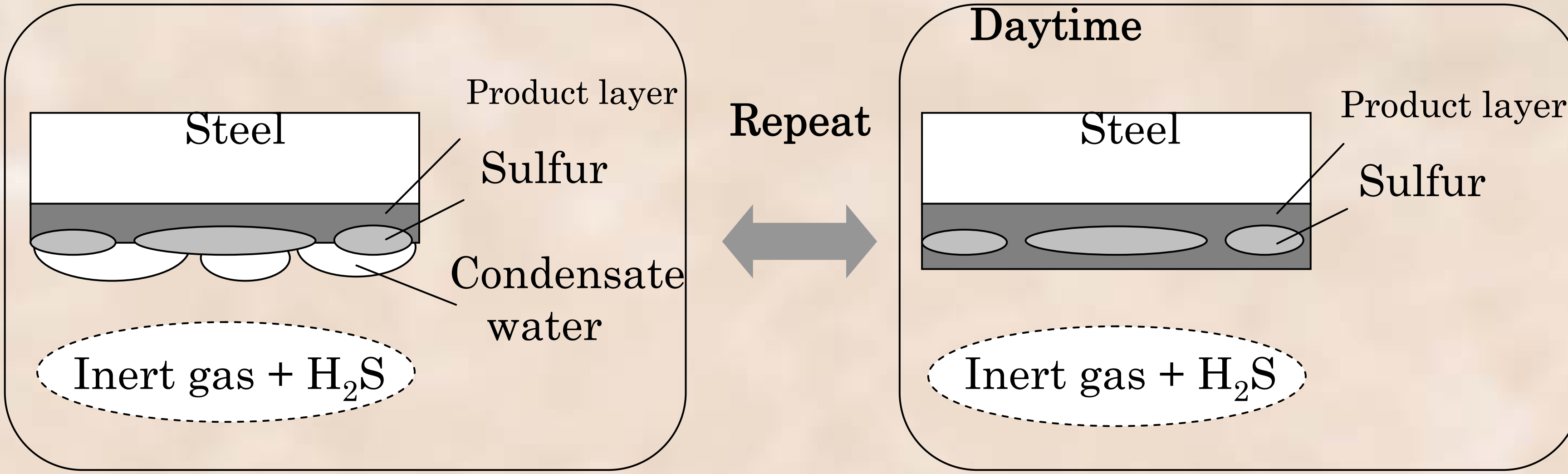
CLASS
Nippon Kaiji Kyokai
ABS Pacific
Det Norske Veritas

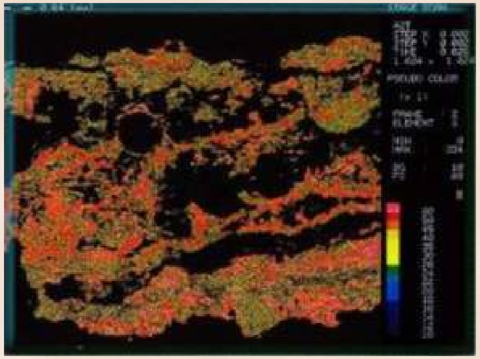
STEEL MAKER
Nippon Steel Corp.
Kobe Steel
Sumitomo Metal Corp.
NKK Corp.
Kawasaki Steel Corp.

SHIIPYARD
Sumitomo Heavy Ind.
Mitsubishi Heavy Ind.
Kawasaki Heavy Ind.
Ishikawajima-Harima Heavy Ind.
Mitsui Eng. & Shipbuilding Co.
NKK Corp.

Over 10 VLCCs with conventional steel were examined

Key facts found by SR242 on Upper Deck Corrosion





- H_2S gas exdists in high concentration
- Co-existence of O_2 and CO_2 with H_2S
- Cyclic temperature change ⇔ Wet and Dry cycle

- Upper deck corrosion is uniform corrosion
- Product layer is flaky and 60 wt.% of it is Elemental S
- Corrosion rate is not so high (Almost less than 0.1mm/y)

Key facts found by SR242 (on Bottom Plate Corrosion)

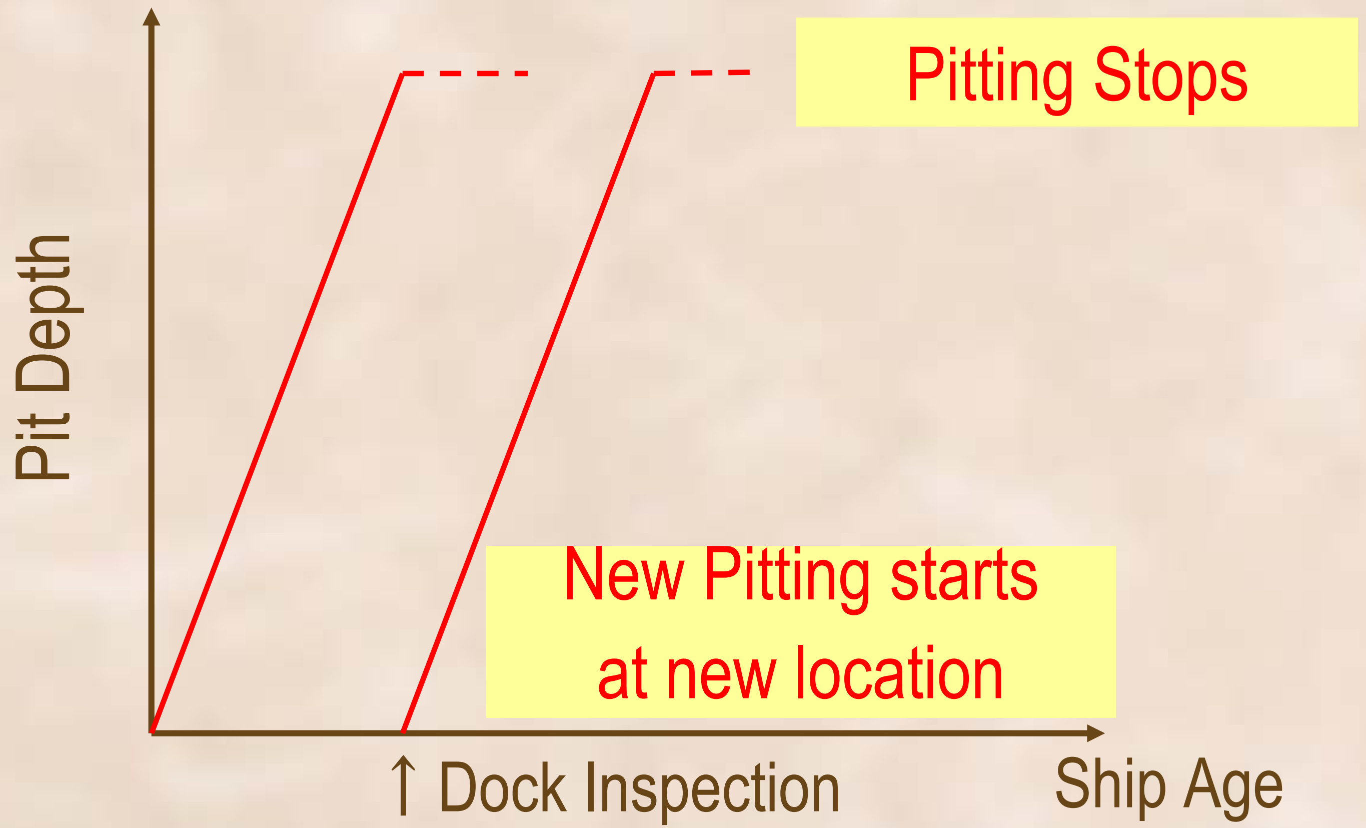
Oil-coating exists around pit …

…. and pitting starts at oil-coating defect

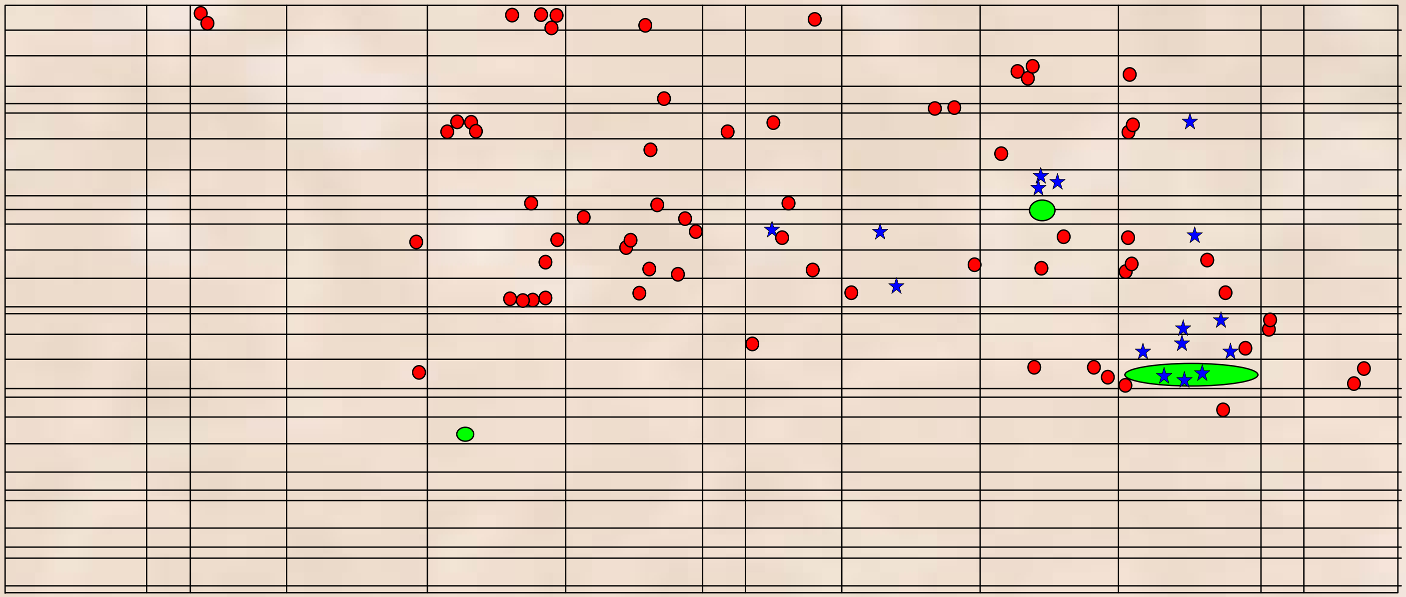
SR-242 Result

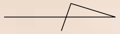
Key facts found by SR242 (on Bottom Plate Corrosion)

Pit Growth Stops at a dock(tank cleaning)



Change of pitting location -1





3S

★ : Pits over 4mm at 1st inspection (repaired)

■ : Pits less than 2mm at 1st inspection (NOT repaired)

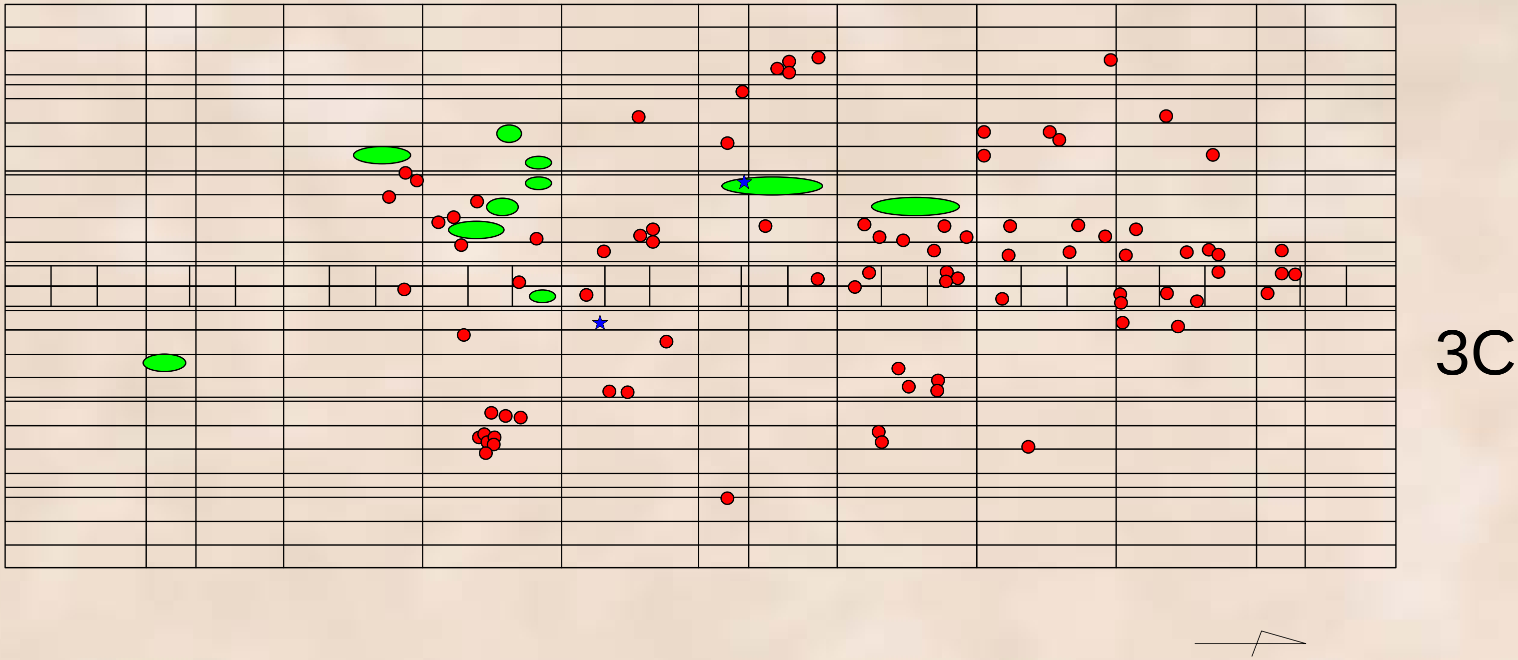
● : Pits over 4mm at 2nd inspection (repaired)

Old pits(■) did not grow!

New pits(●) appear at different points.

SR-242 Result

Change of pitting location -2



★ : Pits over 4mm at 1st inspection (repaired)

■ : Pits less than 2mm at 1st inspection (NOT repaired)

● : Pits over 4mm at 2nd inspection (repaired)

Old pits(■) did not grow!

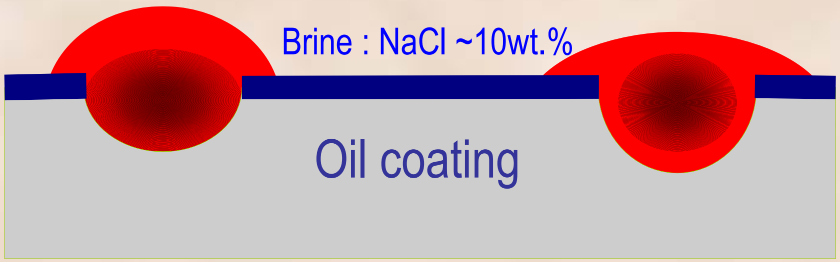
New pits(●) appear at different points.

SR-242 Result

Generation of a Pitting

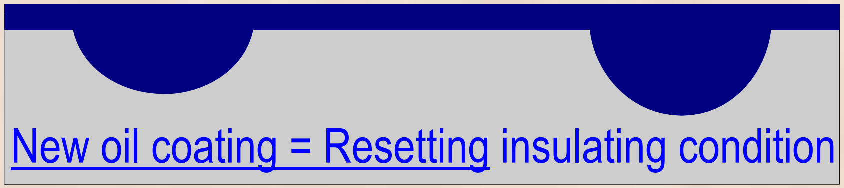
(1) Under servicing condition

Sludge & Corrosion products



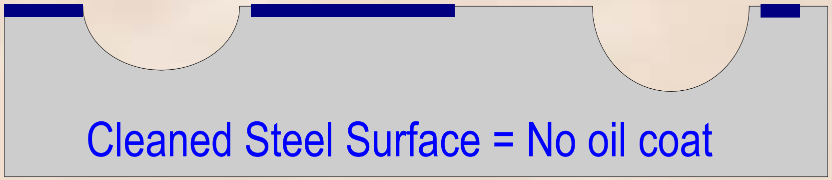
(3) Re-Start of service

Cleaned and dried pits are
re-coated by new crude oil



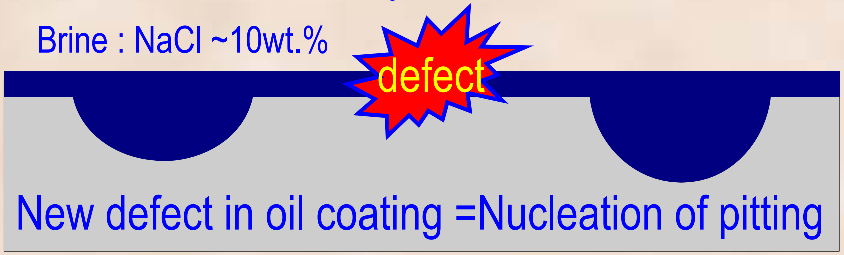
(2) Dock cleaning for inspection

Oil coating ,Sludge & Corrosion products
are cleaned and dried for inspection



(4) Nuclear of new pit

New defect : by COW, Brine .....



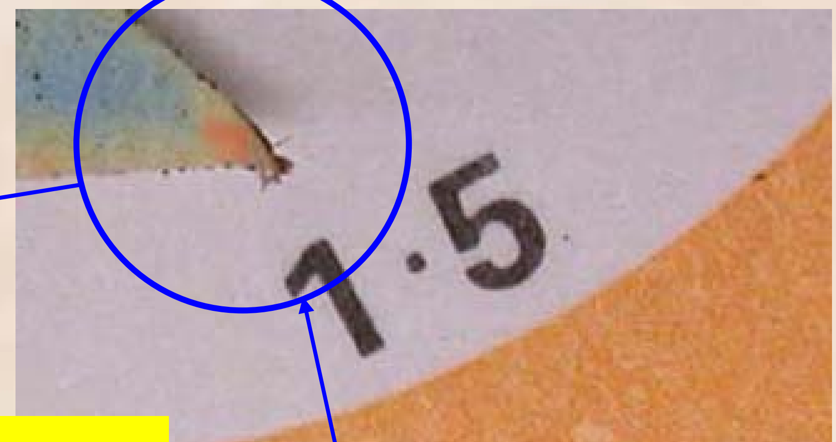
Corrosion condition would be reset after Dock inspection
→Pitting growth stops at dock cleaning

SR-242 Result

Key facts found by SR242 (on Bottom Plate Corrosion)

Strong Acid environment

Actual Vessel



pH of PIT inside: <1.5

→Unfavorable for MIC (SRB active pH : 6~9)

Development of Corrosion-Resistant Steel

1998 2000 2002 2004 2006

1990~ Shift to Double Hull Tanker

1999~2002 **Panel SR242 Investigation**
(The Shipbuilding Research Association of Japan)

Scientific Research & understanding of the corrosion phenomena (Over 10 VLCC s)

Basis for Corrosion-Resistant Steel
Corrosion test method

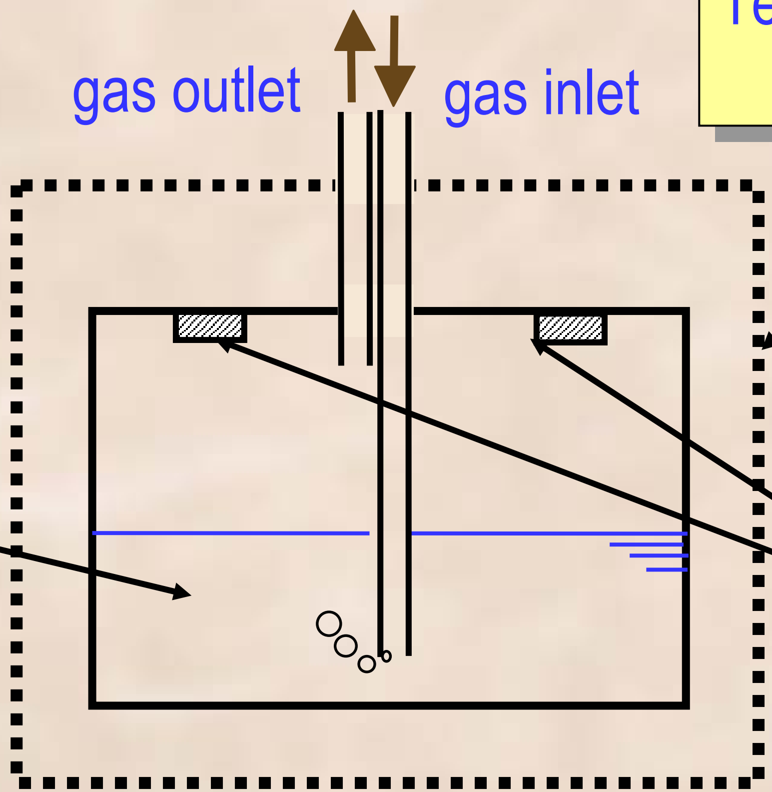
Development of Corrosion-Resistant Steel and Laboratory Tests 2002~

Field Test on actual Vessels 2003~

Evaluation of Corrosion-Resistant Steel

Corrosion test for upper deck

Reproduced COT gas environment
($13\%CO_2$-$5\%O_2$-$0.01\%SO_2$-bal.N_2-H_2S 0.3%)

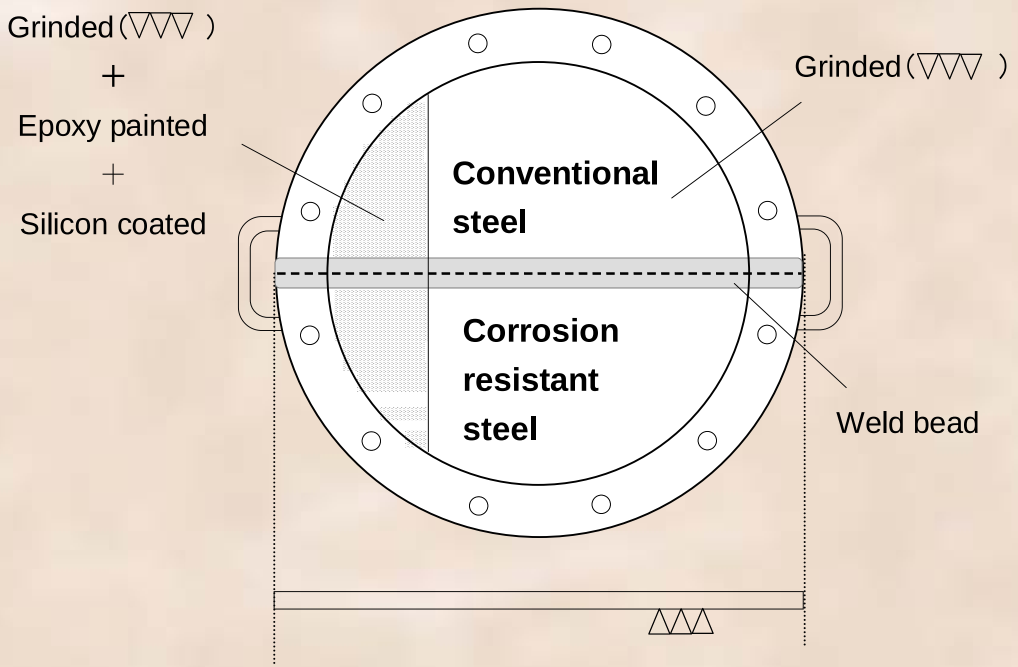


Temperature controlled vessel
(50℃ ⇔ 20℃)

Distilled water
(36℃)

Specimens
25mm × 50mm × 4mm
Surface policed : #600

An example of on board test of upper deck

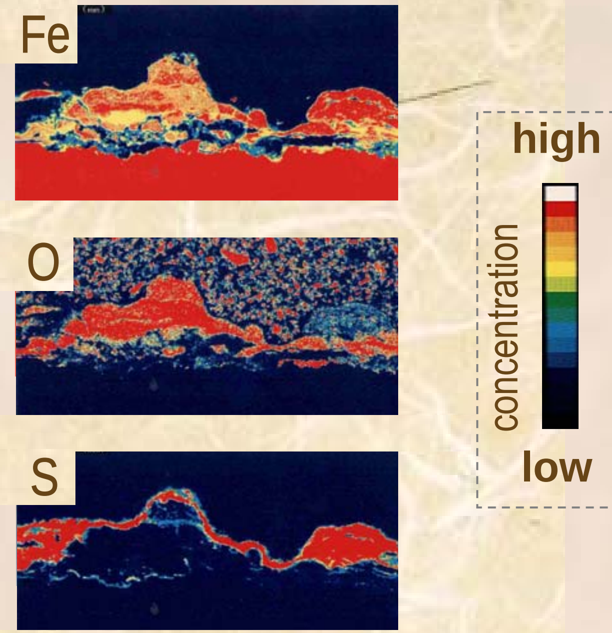


Test coupons were exposed in vapor space of COTs of 2 aframax tankers for 1 year

Corrosion environment of upper deck (Labo vs field)

Cross sectional analysis of corrosion product formed on conventional steel after test in reproduced corrosion environment in laboratory.

Distribution of elements

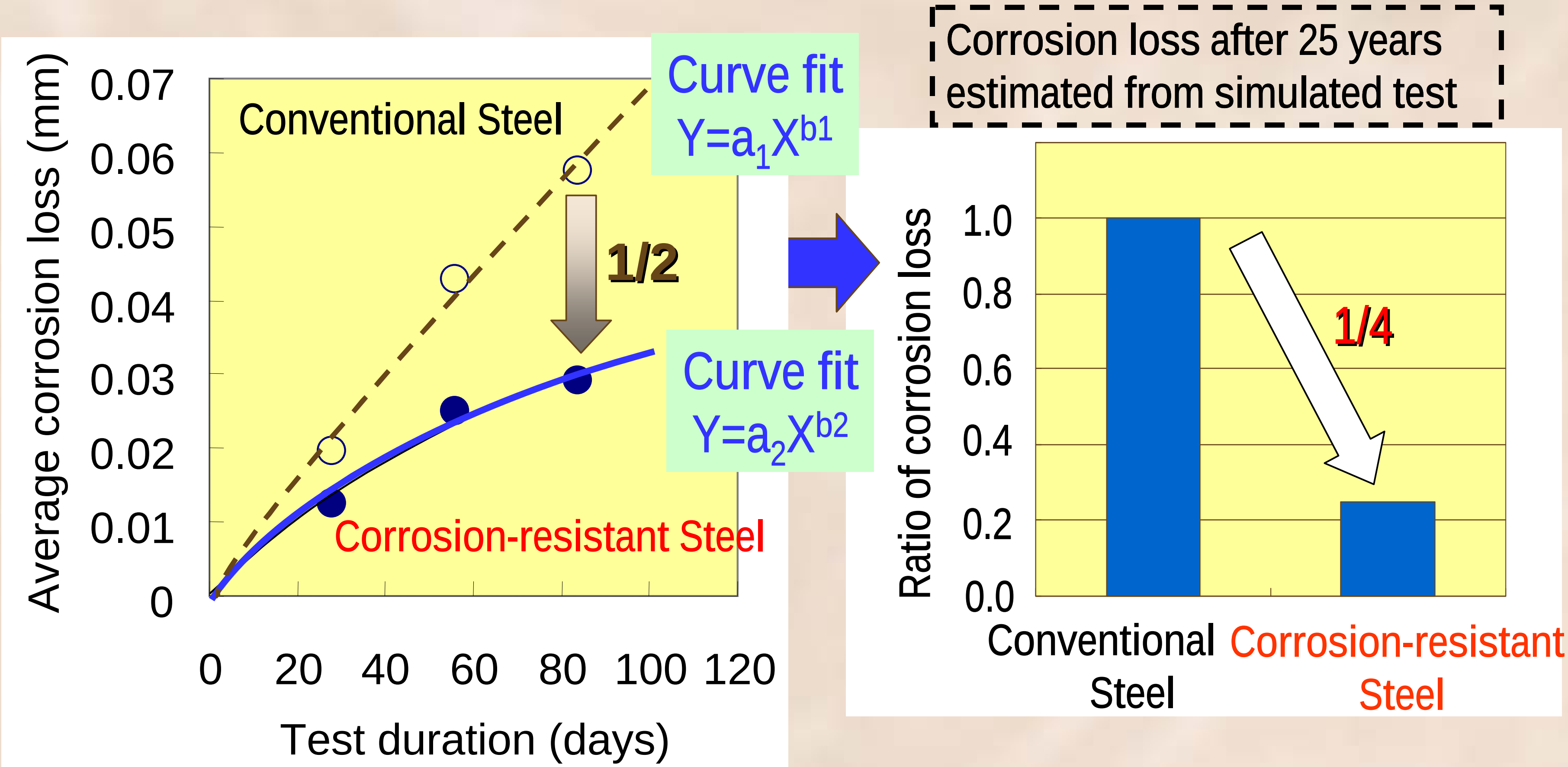


Corrosion product after laboratory test – Upp. DK -

	α-FeOOH	γ-FeOOH	Fe_3O_4	Elemental S	Others
COT	37	8	0	12	43
Simulated test	30	3	8	21	38

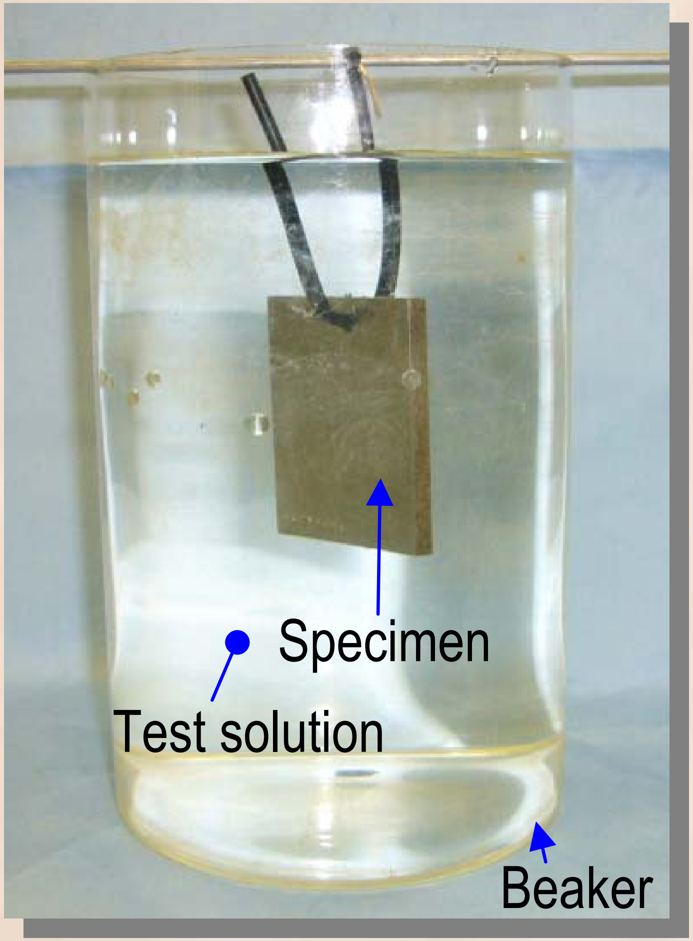
Laboratory corrosion test reproduces corrosion phenomena at upper deck of actual COTs.

An example of corrosion test result of upper deck

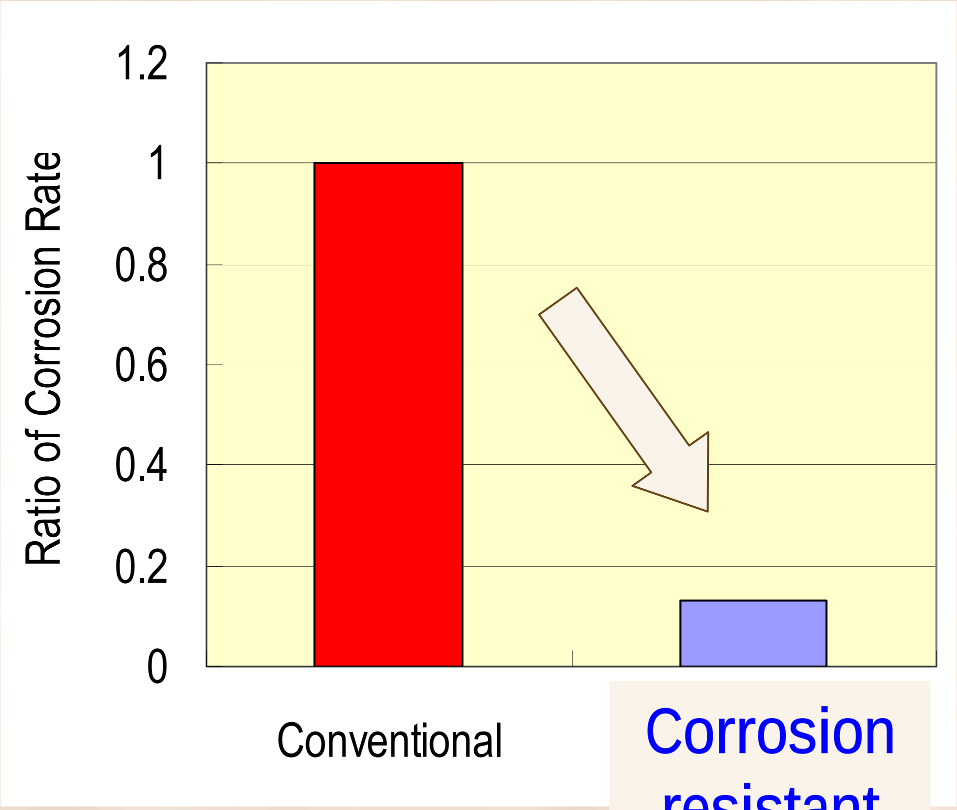


Corrosion test for inner bottom plate

		Condition	Notice
Solution	NaCl	10 mass%	
	pH	0.85	Adjust by HCl
	Amount	$20 cc/.cm^2$ or more	
	Change	Every 24 to 48 hours	
Gas		Air open	
Temperature		30°C	
Specimen	Size	40mm x 50mm x t	t: less than 4mml
	Surface	#600 emery paper	Follow JIS G0591
	repeat	n=3 or more	
Duration		77hours	
Immersion		Dipping specimen	Follow JIS G0591



An example of corrosion test result of bottom plate

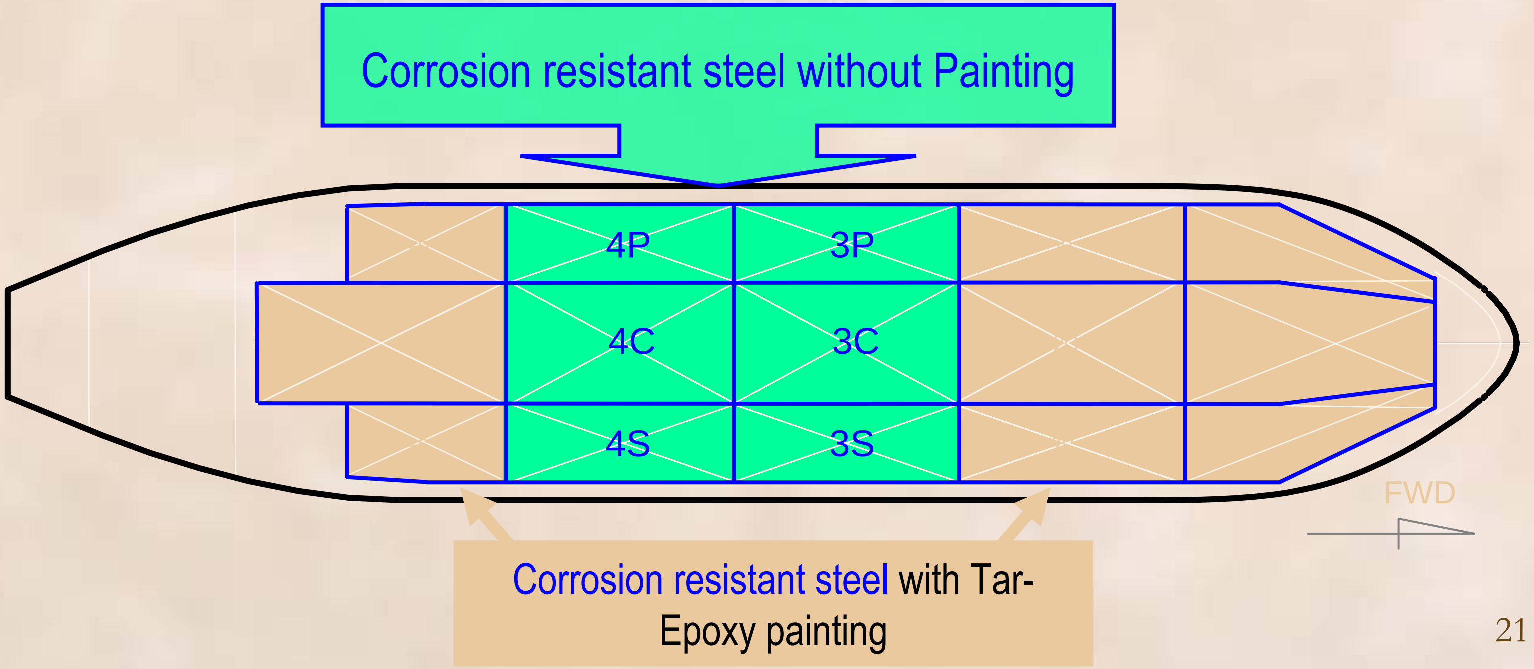


Corrosion resistant steel

An example of on board test of bottom plate

VLCC

First dock inspection was carried out at 2 year and 3 month after launching



An example of on board test result of bottom plate

Conventional steel

Frequent deep Pits

Corrosion Resistant Steel

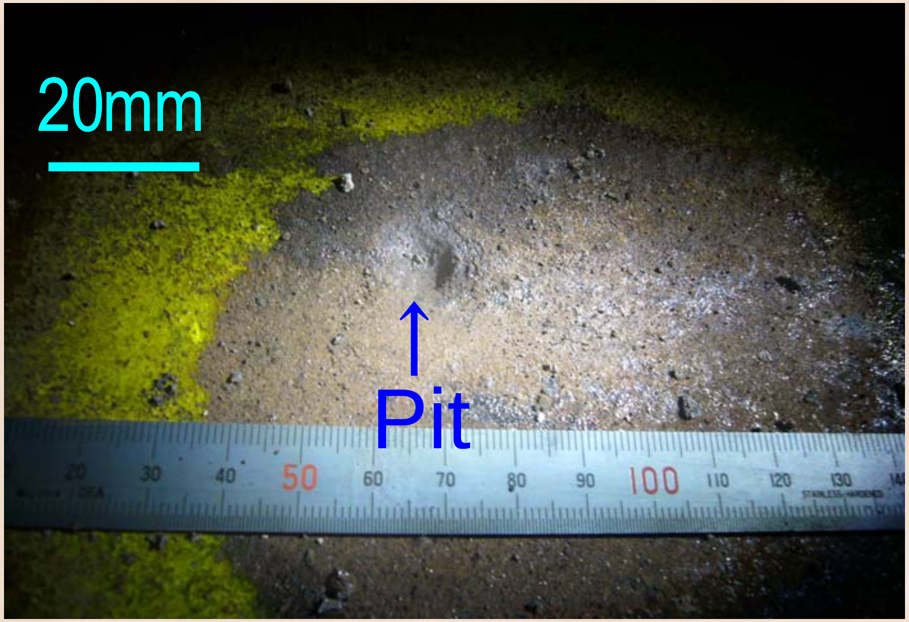
No Pit observed

An example of on board test result of bottom plate

Conventional steel

Depth: 7.2mm

Corrosion Resistant Steel



Depth: 2.8mm

An example of on board test result of bottom plate

Corrosion Resistant Steel

No Pit around Weld

No pit has been observed also on conventional steel

Evaluation of Corrosion-Resistant Steel

Summary

- Based on the findings of SR242, steel manufactures have developed corrosion resistant steel
- Test methods have been established.
- The performance could be evaluated by laboratory tests for upper deck and bottom plate, respectively.

Discussion at IMO

At MSC81 in Dec 2006, twenty one European countries, IACS and NGOs jointly proposed a mandatory requirement of "protective coating" to COT of tankers.

IACS/JWG has been developing Performance Standard for Protective Coating for COT of oil tankers, which will be submitted to DE51 in 2008.

Japan has proposed "corrosion-resistant steel" and its performance standard (PS) as an option for corrosion prevention.

DE and its Correspondence Group (CG) are discussing the issue with a target completion year of 2009.

Draft SOLAS Amendment Developed at the CG

3 All cargo oil tanks of crude oil tankers shall be:

.1 coated during the construction of the ship in accordance with the Performance standard for protective coatings for cargo oil tanks of crude oil tankers, adopted by the Maritime Safety Committee by resolution MSC.(...) …, or

.2 protected by alternative means of corrosion protection, the effectiveness of which [shall be no less than is achieved by meeting the requirements under paragraph 3.1] is approved in accordance with the appropriate Performance standard adopted by the Organization.

Main issues to be discussed at DE51:

How can a new measure like "Corrosion-Resistant Steel" be evaluated to be "no less than is achieved by meeting the requirements under paragraph 3.1(coating)"?

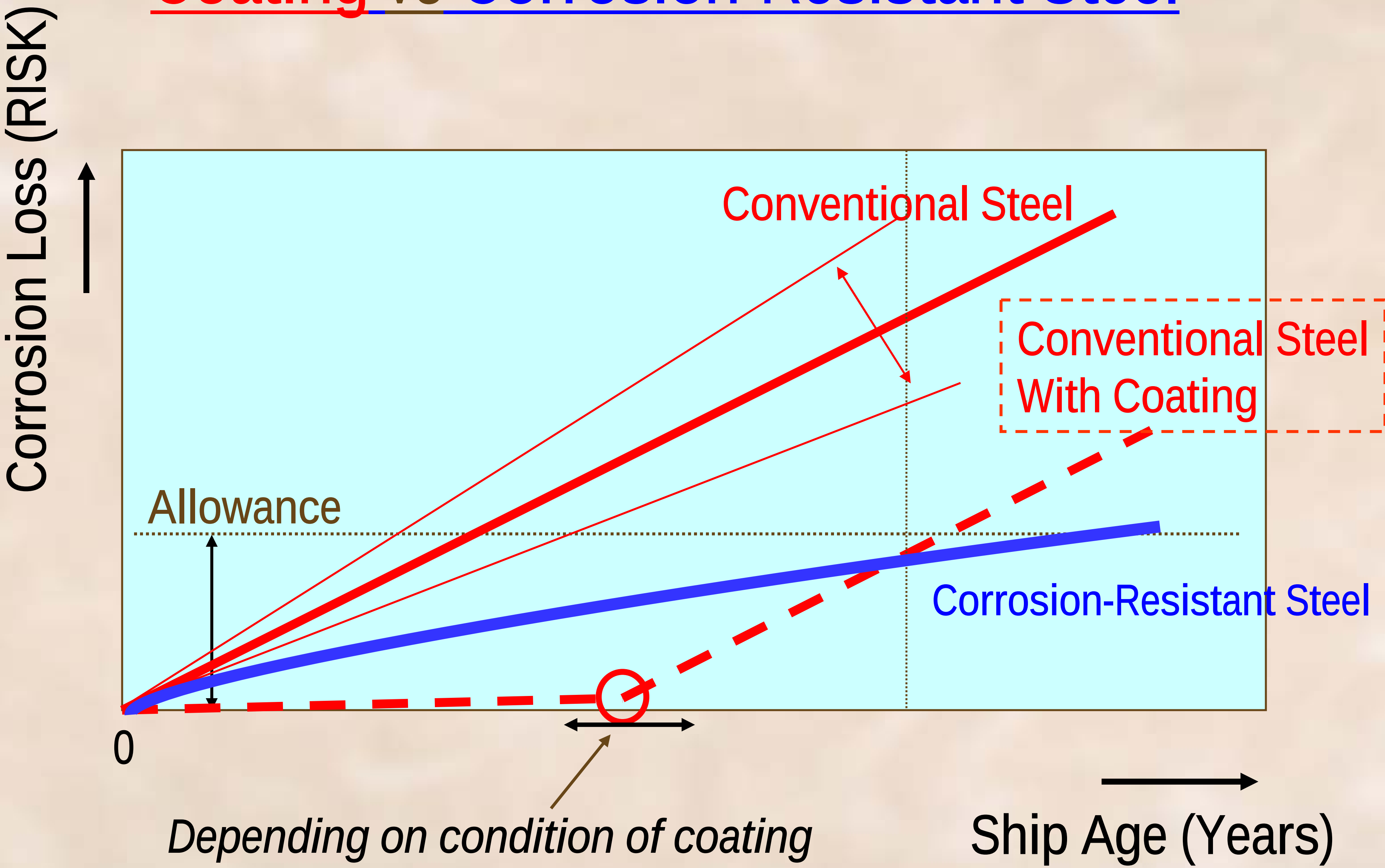
(i.e. Coating ≦ Corrosion resistant Steel)

Should "Corrosion-Resistant Steel" be specified in SOLAS or treated as one of the "alternatives"?

Coating vs Corrosion-Resistant Steel

Item	Coating	Corrosion-Resistant Steel
Target	15 years, - "GOOD" condition	25 years, - diminution within allowance - no leakage
Inspector	Qualified coating inspector	None
Additional work during construction	-Edge treatment -Surface treatment (blasting, cleaning, etc.) -Multiple coating application -Measurements of salts, Dry film thickness etc. -Repair of Defects	
Additional work after construction	-Inspection of coating condition -Repair by recoat, weld, steel renewal	None (Less Maintenance and Possibility of no repair)

Coating vs Corrosion-Resistant Steel



A lot of benefits are expected in Corrosion-Resistant Steel

BUT

No one can define and the effectiveness of coating in COT....

No one can evaluate the effectiveness of corrosion resistant steel by comparison with coating....

No one can conduct field test for evaluation of new measure unless the equivalency is proved....

Corrosion prevention system is not only coating!

IMO should pursue more general Goal Based Approach ,

~~rather than a Prescriptive Approach~~
~~(Coating: epoxy, 200 micro, Blast Sa2.5, Salt, edge etc.)~~

The "GOAL" of the corrosion prevention should be to
- Maintain ship structure
- Prevent oil leakage

The options of "coating" , "corrosion resistant steel" or "others" should be left to the choice of shipwoners and shipbuilders taking into account their construction and maintenance strategies.

Draft SOLAS Amendment (Japan's proposal to DE51)

3 All cargo oil tanks of crude oil tankers shall be protected against corrosion to ensure that <u>net scantlings required meeting structural strength and watertight integrity are maintained throughout the specified design life</u> in accordance with the <u>Performance standard for corrosion prevention</u> for cargo oil tanks of crude oil tankers,

Consistent with GBS

Concluding remark

IMO should not close the door for new technologies!

First comes, first served.

Better comes, equally served.