Corrosion, Inspection and Maintenance of Oil Tankers

Prepared for:

Enbridge Northern Gateway Project

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1 INTRODUCTION

Interveners have filed evidence regarding such issues as double hull oil tanker design, corrosion, construction and maintenance and the oversight for each process. Among the interveners filing this evidence are:

- Coastal First Nations
- Forest Ethics
- Gitxaala Nation
- Living Oceans Society
- Raincoast Conservation Foundation

This report replies to certain aspects of the intervener evidence referenced above and reviews the steps taken to mitigate and protect against corrosion in oil tankers, and the inspection and maintenance regimes for detecting and repairing structural damage and excessive corrosion of the steel structure. It describes significant standards and practices that have been implemented to reduce the likelihood that corrosion or structural failure will lead to a release of oil into the environment. Refer to report No. 2012-020-1, Design and Construction of Oil Tankers, for background information on the structural design of tankers.

2 CORROSION OF TANKERS

2.1 Corrosion of Tanker Structures

Prior to development of the Common Structural Rules (CSR), gross scantlings were calculated based on class society rules and steel renewal requirements were based on a percentage of degradation from this original thickness. The CSR takes a net scantling approach. That is, the net scantlings are the minimum thickness required for safe operation of the vessel and are to be maintained through the life of the ship. Local scantlings are determined such that the net scantling is sufficient to bear the entire load within the acceptance criteria. The cargo hold finite element analysis and the hull girder ultimate strength analysis are carried out assuming that the entire structure has degraded by an amount equal to 50% of the corrosion addition, the rationale being that all elements do not corrode uniformly.

The corrosion additions as shown in Figure 1 are added to the net scantling to determine the minimum required gross thickness of the steel. As explained in Section 4.1, should the actual scantlings approach the net scantling value, the steel must be renewed to full thickness (net scantling plus corrosion addition).

The corrosion additions were determined by the International Association of Classification Societies (IACS) based on over 600,000 thickness measurements of existing ships, covering all parts of the cargo tanks and ballast tanks. A statistical analysis of this data was performed to determine corrosion additions associated with a probability of 90% of not being exceeded over a 25 year service life. As this analysis was based on historical data for both coated and uncoated tanks, it is anticipated that modern oil tankers will experience less actual corrosion due to the enactment of requirements for coating ballast tanks (effective for new ships contracted for
construction after 1 July 2008) and the tops and bottoms of cargo tanks (effective for new ships contracted for construction after 1 January 2013).

Figure 1  Corrosion Addition for Typical Tanker Structure (mm)
Source: Common Structural Rules for Oil Tankers, 2012 [ref. 1]

2.2 Protecting Against Corrosion

Many factors influence the corrosion rate within the ballast tanks and cargo tanks of oil tankers, including the coating standard, preparation of structure, quality of application, coating maintenance, the temperature profile, percentage of time the tank is empty or full, frequency of cleaning, etc. Different parts of each tank corrode in different ways at different rates. This is the reason why the corrosion additions shown in Figure 1 vary with location and type of tank. Projected corrosion rates over the 25 year service life range from 0.10 mm/year to 0.16 mm/year and, accordingly, corrosion additions (additional steel thickness) range from 2.5 to 4.0 mm.

The most common means for mitigating corrosion in tanks is:

- Coatings: Coatings isolate the steel from the corrosive environment. Properly applied and maintained epoxy based paints can have a service life of 15 years.

- Anodes: Sacrificial anodes are typically fitted within ballast tanks. These can provide relief from corrosion where damage to coating or localized breakdown of the coating occurs.
With effective maintenance, steel replacement should not be required over the 25 year service life. However, as explained in Section 3.2, should the thickness of any member approach the net scantling due to accelerated corrosion, the affected plating must be replaced to the original “as built” thickness.

**Ballast Tanks**

Ballast tanks are a corrosive environment due to the periodic exposure to seawater (wet and dry conditions). These tanks merit special attention. Although a well-maintained older ship can be just as safe as a newer ship, a poorly maintained ship will deteriorate with age. Examples of failures related to accelerated corrosion include the tankers ERIKA and CASTOR. The ERIKA, which was a single-hull construction having uncoated segregated ballast tanks, broke in half in 1999 at age 25. The CASTOR, having poorly maintained segregated ballast tanks, sustained a severe fracture across the main deck in 2001 at age 24. These and other incidents led to the adoption of International Maritime Organization (IMO) regulations regarding coating of ballast tanks and cargo tanks.

Effective for new ships contracted for construction after 1 July 2008, IMO adopted amendments to Safety of Life at Sea (SOLAS), regulation II-1/3-2 [ref. 2], requiring coating of ballast tanks for all ship types including oil tankers. Coatings are to conform to the IMO Maritime Safety Committee (MSC) resolution MSC 215(82), Performance Standards for Protective Coatings (PSPC) [ref. 3], which prescribes standards for coating type and thickness, coating application, and coating inspection during construction. The CSR moved forward the enforcement date for oil tankers, requiring all oil tankers contracted for construction as of 8 December 2006, to comply with the IMO PSPC.

The PSPC calls for a certified paint inspector to verify compliance with the PSPC regarding paint system selection, surface preparation, environmental conditions, coating application, and repair of damaged coatings. The certified paint inspector is responsible for documenting all inspections and reporting any defects or required rework.

**Cargo Tanks**

Corrosion of cargo tanks is principally confined to horizontal surfaces and generally related to temperature profiles, sludge accumulation, and residual water. Where sludge accumulates, mainly on the tank bottom, microbial action can lead to pitting. Industry practice is to coat the tops and bottoms of cargo tanks on crude oil carriers, whereas the sides of these tanks are rarely coated. The entire boundary of cargo tanks on product tankers are usually coated in order to accommodate the variety of refined products and chemicals carried on these vessels.

Incidents of accelerating corrosion in the tops and bottoms of cargo tanks led to SOLAS regulation II-1/3-11, Corrosion Protection of Cargo Oil Tanks of Crude Oil Tankers [ref. 4], adopted by Resolution MSC.291(87) [ref. 5]. Effective for new ships contracted for construction after 1 January 2013, coatings must be applied to the tops and bottoms of cargo tanks and upper and lower portions of bulkheads, unless corrosion-resistant steels or alternative means for mitigating corrosion are applied.
3 INSPECTION AND MAINTENANCE DURING OPERATING LIFE

3.1 Inspection Requirements

Oil tankers are subject to a through-life inspection regime involving periodic surveys which rotate on a five year basis. This includes annual surveys, intermediate surveys (approximately midway between special surveys), special surveys every 5 years (also referred to as class renewal), and docking surveys. Also included are tailshaft surveys, boiler surveys, and machinery surveys. Survey requirements are specified in IMO Resolution A.997(25) “Survey Guidelines Under the Harmonized System of Survey and Certification, 2007” adopted in November 2007 and IMO Resolution A.744(18), “Guidelines on the Enhanced Programme of Inspections During Surveys of Bulk Carriers and Oil Tankers”. This regulation was adopted in 1993 with subsequent amendments. IACS document “Requirements concerning Survey and Certification” [ref. 6], last revised in 2011, elaborates upon the IMO requirements. This document contains a comprehensive description of survey requirements and procedures.

The following is a brief overview of the survey and inspection process. Surveys required over the first 20 years of a tanker’s life are listed in Table 1.

Class Renewal (Special Survey): Special Surveys are conducted at five year intervals prior to expiration of the Classification Certificate. In addition to the requirements of the Annual Survey, the Special Survey includes detailed inspection of hull and related piping. This encompasses visual inspection of all cargo tanks, ballast tanks, voids, outer hull and decks, which are supplemented by close up surveys and thickness measurements at specified locations. The required extent of thickness measurements (gauging) increases with ship age. At each special survey, a dry dock (out-of-water) survey is required. Special Surveys may take several weeks or up to a month, depending on the size and age of the vessel.

Intermediate Survey: Intermediate Surveys are conducted approximately halfway between Special Surveys. For ships 5 – 10 years of age, visual inspection of all ballast tanks is required. For ships 10 years and older, the extent of survey is similar to the Special Survey. For oil tankers 15 years and older, a dry dock survey is required during the Intermediate Survey.

Annual Survey: Annual Surveys involve examination of hull, machinery, steering gear, firefighting, and other critical systems. If during a Special or Intermediate Survey it is determined that coatings are not in good condition, examination of ballast tanks is required during subsequent Annual Surveys. In such case, thickness measurements are to be carried out at the discretion of the surveyor.

When a survey results in the identification of structural defects or excessive corrosion, remedial measures must be undertaken within a specified timeframe defined by class in order to retain class. Failure to do so may result in the ship’s classification being suspended or revoked. If, in the opinion of the surveyor, a defect will impair the vessel’s fitness for continued service, remedial measures must be implemented before the ship continues in service.

Ships may also be subject to occasional independent inspection by their flag state and by port states.
### Table 1  Survey Schedule

<table>
<thead>
<tr>
<th>Year</th>
<th>Type of Survey</th>
<th>Drydocking?</th>
<th>Ballast tank inspection requirements</th>
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<td>close up survey of tanks with thickness measurements</td>
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<td>if ballast coatings less than GOOD condition</td>
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<td>7</td>
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<td>visual of representative tanks</td>
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</table>

#### 3.2  Class Requirements for Steel Renewal

In accordance with the CSR, certification of class requirements stipulate that a structural element or field of plating be renewed to required gross scantlings if during inspection it is found to be within 0.5 mm of the net thickness. 0.5 mm is the approximate expected corrosion over 2.5 years, the time between Intermediate and Special Surveys where close up inspection of ballast tanks is required. This approach reduces risk that the scantlings will fall below the net thickness requirement.

The net thickness is not a minimum thickness at which failure is expected. Rather, safety margins are applied when determining the net thickness to ensure a safe and robust hull structure even if wastage of the entire “corrosion addition” occurs.
In addition to potential failure of local structure, corrosion can degrade the strength of the overall hull girder. To insure adequate primary strength throughout the service life, the CSR requires that if diminution of the upper or lower flange of the hull girder exceeds 10% then steel must be restored to at least 90% of the original hull girder strength.

Data for gauging of over 2000 oil tanker cargo hold sections are shown in Figure 3. The diminution of the hull girder section modulus (HGSM) is plotted as a function of the ship’s age. The capacity of the hull girder to withstand bending moments is proportional to its section modulus. These represent existing oil tankers, both single hull and double-hulled, built over the last 30 years. It was found that few tankers exceed 10% diminution of the hull girder during their lifetime. This is in part due to the requirements that local structure be renewed if the corrosion allowance is exceeded. As the hull girder consists of a large number of local elements that do not corrode uniformly, rarely does the overall section experience 10% degradation. This is even more unlikely for oil tankers designed to the CSR, as the corrosion allowance has been increased and coating requirements for ballast tanks mandated.

Figure 2 Corrosion before renewal

Figure 3 Hull Girder Section Modulus Loss vs. Ship Age
Source: IACS Presentation on Development of CSR [ref. 7]
3.3 Maintenance and Inspection Processes

The ship owner is responsible for arranging for certified crews to conduct thickness measurements, manufacturer representatives or other technicians to support the inspection of machinery and equipment, and the selection of the shipyard for drydocking. Where defects are found or damage occurs, the ship owner is responsible for proper and timely repair. Major repairs such as blasting, coating replacement, and plating renewal are typically carried out during a dry dock period.

If a vessel or its machinery is damaged, as a condition of class the owner is required to notify the classification society. The classification society surveyor will perform a damage survey to determine the extent of damage and necessary repairs to return to full compliance with class rules, or if necessary, the temporary repairs needed to enable the vessel to proceed to an appropriate repair facility.

3.4 Discretionary Surveys

Tankers may undergo discretionary surveys, primarily for commercial reasons. The two most popular programs are the Ship Inspection Report (SIRE) program and the Condition Assessment Program (CAP).

Extensive vetting of oil tankers is carried out by the oil majors and other charterers. The SIRE Program, first established in 1993 by the Oil Companies International Marine Forum (OCIMF), involves the pooling of the reports of these vettings. Under SIRE, a uniform vessel inspection procedure has been established, to which all submitted reports are expected to comply. The reports are made available to OCIMF members as well as qualified third parties such as charterers, terminal operators, and government agencies. The intent of SIRE is to reduce redundant inspections, increase the pool of available data, and enhance safety.

CAP involves extensive thickness measurement and strength and fatigue assessment, to ascertain the overall condition of the ship’s structure. Functional tests of cargo systems, main and auxiliary machinery, and other essential equipment are also carried out. Ratings are determined ranging from (1) newbuilding quality (2) good (3) satisfactory (4) poor. Whereas SIRE inspections are conducted by OCIMF members (primarily the vetting branches of the major oil companies), CAP surveys are conducting by classification societies at the request of the ship owner.
4 REFERENCES

1. ABS. *Rules for Building and Classing Steel Vessel Rules (2012), Part 5A, Common Structural Rules for Double Hull Tankers*. Section 6 Part 3, Figure 6.3.1.


