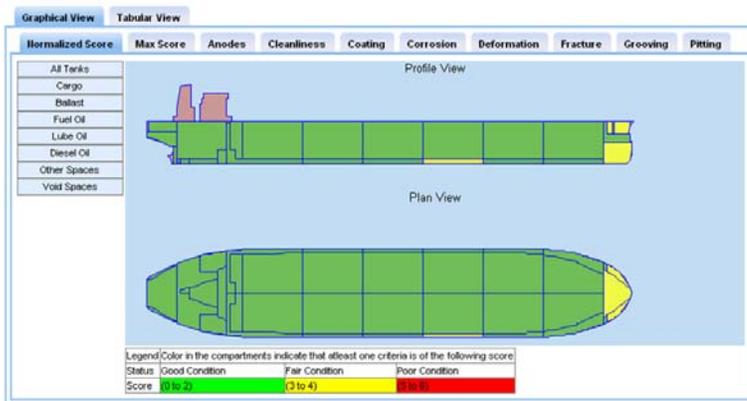


# Hull Inspection and Maintenance Systems

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Function	Compartment Space	Inspection	Normalized Score	Score Maximum	Score	Interval	Last Insp Date	Due Date
Ballast	AFT PEAK TK	🟢	8	8	8	12	30-Jun-2008	30-Jun-2009
Ballast	FORE PEAK TANK	🟢	11.83	8	8	12	09-Jul-2008	09-Jul-2009
Ballast	NO.1 WBT P	🟢	7.83	4	4	12	04-Jul-2008	04-Jul-2009
Ballast	NO.1 WBT S	🟢	8.57	8	8	12	15-Jul-2008	15-Jul-2009
Ballast	NO.2 WBT P	🟢	8.71	8	8	12	14-Jul-2008	14-Jul-2009
Ballast	NO.2 WBT S	🟢				12		
Ballast	NO.3 WBT P	🟢	8.25	8	8	12	31-Jul-2008	31-Jul-2009
Ballast	NO.3 WBT S	🟢	14	8	8	12	30-Jun-2008	30-Jun-2009
Ballast	NO.4 WBT P	🟢	0.79	1	1	12	02-Jul-2008	02-Jul-2009
Ballast	NO.4 WBT S	🟢				12	17-Jul-2008	17-Jul-2009
Ballast	NO.5 WBT P	🟢				12		
Ballast	NO.5 WBT S	🟢				12		
Ballast	NO.6 WBT P	🟢				12		
Ballast	NO.6 WBT S	🟢	10.5	2	2	12	30-Jun-2008	30-Jun-2009
Cargo	NO1 COT P	🟢				60		

## Abstract

Ship owners and managers strive to maintain a high level of structural integrity. The ship crews and shore staff perform inspections of hull structure on a regular basis to assess the hull condition. The inspection regimes require easy identification of problems. Besides owners, inspections and surveys are carried out by many agencies such as classification societies, insurers, vetting agencies, cargo surveyors, port state, coastal state and flag state authorities. All have an interest in the safe operation of the ship and ensuring that it is properly maintained. The effectiveness of these inspections is being continually challenged by the ever decreasing time that these vessels remain in port. In this paper a holistic, simple and quantifiable approach is proposed. This methodology employs the application of risk-based decision-making techniques. Risk-based techniques have demonstrated great potential in identifying key structural elements and focusing resources for maintenance and inspection. The proposed methodology for rationalizing the hull inspection program is via the development of a vessel-specific inspection program which includes a scoring system for identified inspection criteria and a list of target inspection areas (critical structural areas) for each compartment. The condition for each inspection criteria, depending upon the score, is displayed within the context of a simple traffic light system. This methodology can be applied by a trained and qualified owners' representative. The scoring system can be utilized and analyzed to view the condition status of compartments, vessels, and a fleet. The scoring system also utilizes a system to trigger anomaly list generation, which can be used to manage the damages and repairs as well as create a repair list for future repair / drydock events.

## KEY WORDS

Hull inspection; risk-based approach; inspection criteria; critical structural area; compartment scoring system; anomaly.

## INTRODUCTION

The shipping industry needs a rationalized approach to perform inspections of hull structure and a methodology on what to inspect, when to inspect, where to inspect and how much to inspect. The benefits of hull inspection are usually well answered and known to all the inspection agencies. Traditionally ship owners and vessel managers have their in-house hull inspection schemes and programs to track, assess and maintain the hull structure. Inspections to assess hull condition are also performed by many agencies such

as classification societies, insurers, vetting agencies, cargo surveyors, port state, coastal state and flag state authorities. All inspection data is collected in various forms, checksheets and reports. The ship owner is required in most cases to maintain a record of maintenance activities carried out on the hull structure. All the inspection data require the owner to have an effective inspection management system.

Classification societies and most of the other agencies perform inspection in a prescriptive manner or on an as-needed basis to assess the hull condition. The selected compartments are inspected based on the experience and work instructions provided to the inspector by their respective agencies. The presence of critical areas and suspect areas in a compartment may or may not be highlighted by the inspection agencies.

Ideally the inspection results from the various agencies are to be analyzed by the owners / managers and compiled into a repair / drydock specification list. Most of the inspection data may not be formatted to permit owners / managers to convert it easily into a repair specification as it may lack sufficient detail. This requires the owner to have a repair management system. At the time of repair there may be some unknowns and surprises as the compartment condition is not completely known.

IACS PR33 encourages ship owners to have their own hull inspection and maintenance programs and schemes. Most of the major classification societies offer some form of hull inspection to be implemented by the owners' representative.

In the following sections of this paper the various stakeholders on hull condition assessment and the various inspection regimes commonly found in marine industry are identified.

## **STAKEHOLDERS - HULL CONDITION**

Stakeholders for a vessels' hull condition are identified as follows:

- Owner / Operator / Manager
- Ship Crew
- Builder / Shipyard (repair yard)
- Classification Society
- Insurers / Underwriters (of cargo and vessel)
- Charterers (including vetting agencies)
- Flag State
- Port States
- Public (including competitors, prospective clients, prospective buyer)

All have one common interest: the safe operation of the ship and ensuring that it is properly maintained. Among all the stakeholders, the inspection and maintenance management of the vessel rests with the owners and managers. Each stakeholder also has their own inspection regime depending upon their role in the vessels' operation.

## **DRIVERS AND OPPORTUNITIES**

Owners / managers need an inspection regime to help systematically examine and grade the hull structure and identify and record any defects (anomalies). A

program supporting a holistic, proactive, preventative maintenance scheme for the ship addressing the following issues:

- Identification of potential problem areas, so that preventive measures can be taken to remain in conformance with the applicable Classification Rule requirements;
- Focused inspection and condition reporting on structurally critical areas;
- Easier development of repair dry-dock specifications;
- Detection of anomalies or maintenance trends across fleet;
- Potential to lessen disruption of normal ship operations; and,
- Improved efficiency in the use of inspection results to satisfy the inspection requirements of other stakeholders.

## **TRADITIONAL HULL INSPECTION**

Most of the inspections involve compartment inspections carried out by the inspector with a checklist. These checklists are designed to collect textual descriptions of the conditions found. This includes finding anomalies relative to material degradation and deformation. These inspections apply the following examination techniques:

- Overall inspection;
- Close up visual inspections;
- Suspect areas examination;
- Critical area (fatigue hotspot) inspection;
- Coating condition assessment; and
- Anode inspection.

The inspectors usually look for defects or assess condition based on their work process instructions, their judgment, and experience. The recording of their findings is usually textual and in some cases quantified as 'good', 'fair' or 'poor'. There may be further quantifiable parameters reported based on the extent of the condition or damage found. Usually the traditional inspections assess the compartment condition based on the entire compartment with a focus on the coating condition.

Classification societies perform surveys and record the coating condition in the compartment. Anomalies are recorded as conditions of class.

Except for Condition Assessment Program (CAP) inspections, where the grades 1 to 5 are applied for a compartment, the quantifiable attribute for all compartments on a vessel is usually the coating condition and the presence or absence of anomalies.

Most of the inspections rely on the experience of the inspectors to identify the conditions in the compartment.

In all cases the owners' inspector has to gather detailed information of the compartment and send it to the shore office along with detailed specifications for any material replacement or activities that need to be carried out by a shore crew or drydock crew.

### PROPOSED HULL INSPECTION

A compartment is divided into zones similar to the 'area of consideration' as per IACS Recommendation 87: Coating Guidance. All compartments are divided into zones that can be inspected and graded for the inspection criteria. Six inspection criteria have been identified for each compartment. These are inspected for each zone. Critical structural areas (if any) are identified for a compartment/zone based on engineering analysis and in-service experience. The inspection criteria are graded with a score (rating) from 0 to 6. A traffic light status (red – 5 to 6, yellow – 3 to 4, green – 0 to 2) is assigned to each zone for each criterion. These scores are added for each zone and rolled up to get a normalized score for the compartment. A red signifies the presence of an anomaly which needs to be documented for resolution/rectification. Each compartment will have two checksheets: general inspection criteria and critical area.

These inspections are to be done by qualified and trained inspectors which may include ship crew.

#### Six Inspection Criteria for Hull Structure

The six inspection criteria identified for assessing the condition of hull structure are:

- Coating condition
- General Corrosion
- Pitting/Grooving
- Deformation
- Fractures
- Cleanliness (housekeeping)

#### Coating

The Coating Condition as defined by IMO/IACS reference documents and the *ABS Guide for Inspection, Maintenance and Application of Marine Coatings* for Good, Fair and Poor condition is subdivided and given the following scores:

Condition	Color	Score Assigned
GOOD	Green	0 to 2 both inclusive
FAIR	Yellow	3 or 4
POOR	Red	5 or 6

#### General Corrosion

General or Overall Corrosion appears as non-protective rust which can uniformly occur on tank internal surfaces that are uncoated, or where coating has totally deteriorated. This inspection criterion as defined in the referenced IMO/IACS documents is also assigned a score from 0 to 6 depending upon the amount of rust, light scale and hard scale.

#### Pitting and Grooving

Localized corrosion occurs on bottom plating, and other horizontal surfaces producing deep and relatively small diameter pits that can lead to penetration of the steel member in isolated random places in the tank. Grooving is a localized, linear corrosion which occurs at structural intersections in welds or heat affected zones. This corrosion is sometimes referred to as "in line pitting attack" and can also occur on vertical members and flush sides of bulkheads in way of flexing. Depending upon the average diameter of pits and the intensity of pitting/grooving the scores are assigned from 0 to 6.

#### Deformation

Deformation is caused by impact loads, contact, or overloading. Deformation may be local (deformation of panel or stiffener) or global (deformation of a beam, frame, girder or floor including associated plating). Deformation is given a score from 0 to 6 depending upon its extent and severity.

#### Fractures

Fractures are categorized based on the location of the fracture and that local structure's contribution to overall hull integrity.

**Housekeeping/Cleanliness**

This criterion is used to evaluate the general condition of the compartment for cleanliness and house-keeping. This will be judged based on the following:

- Amount of sediments and dredge/sludge remaining in the tank;
- Wastage of the anodes and their perceived effectiveness;
- General cleanliness of the space;
- Condition of the piping and its supports;
- Condition of access hatches, manholes, entry spaces, ladders, and other means of access; and,
- Loose scale and plugged drainage openings in the structure (rat holes / scallops).

**Compartment Zones**

The tank is divided into zones to permit the inspector to judge the entire tank to particular inspection criteria. IACS Recommendation 87: Coating Guidance has the cargo and ballast tanks divided into ‘areas of consideration’. In our methodology, the ‘zones’ are similar to the ‘areas of consideration’ and every inspection criterion is rated for each zone. Each cargo tank is divided into 14 zones. Similarly the ‘J’ shaped ballast tanks are also divided into 14 zones. The forepeak tank is divided into 3 zones and aftpeak tank into 2 zones. The zones for a cargo tank are listed in Table 1 and illustrated in Figure 1.

Table 1: Typical Cargo Tank Zones

1	T	Tanktop- Inner Bottom
2	LP	Lower - Port Long Bhd
3	LF	Lower - Fwd Trans Bhd
4	LS	Lower - Stbd Long Bhd
5	LA	Lower - Aft Trans Bhd
6	MP	Middle - Port Long Bhd
7	MF	Middle - Fwd Trans Bhd
8	MS	Middle - Stbd Long Bhd
9	MA	Middle - Aft Trans Bhd
10	UP	Upper - Port Long Bhd
11	UF	Upper - Fwd Trans Bhd
12	US	Upper - Stbd Long Bhd
13	UA	Upper - Aft Trans Bhd
14	D	Deck

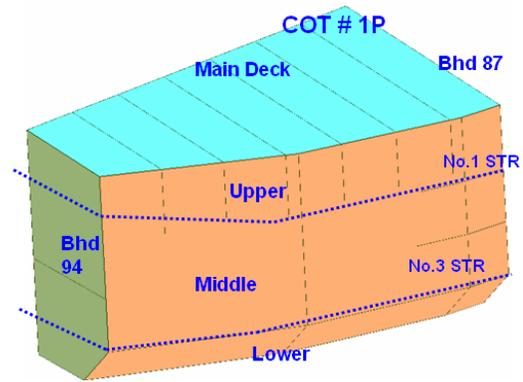


Figure 1 : Sample Cargo Tank Zones

Similarly the ‘J’ side ballast tank is divided into 14 zones as shown in Figure 2 and Table 2.

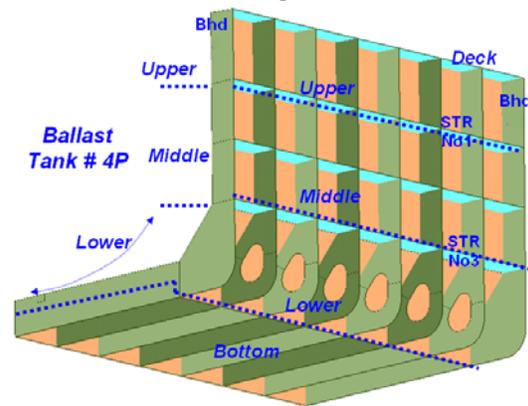


Figure 2: Sample 'J' Ballast Tank Zones

Table 2: Typical ‘J’ Ballast Tank Zones

1	T	Bottom
2	LP	Lower - Port (Inner Long Bhd + Inner Bottom /Sideshell)
3	LF	Lower - Fwd Trans Bhd
4	LS	Lower - Stbd (Inner Long Bhd + Inner Bottom /Sideshell)
5	LA	Lower - Aft Trans Bhd
6	MP	Middle - Port (Inner Long Bhd /Sideshell)
7	MF	Middle - Fwd Trans Bhd
8	MS	Middle - Stbd (Inner Long Bhd /Sideshell)
9	MA	Middle - Aft Trans Bhd
10	UP	Upper - Port (Inner Long Bhd/Sideshell)
11	UF	Upper - Fwd Trans Bhd
12	US	Upper - Stbd (Inner Long Bhd /Sideshell)
13	UA	Upper - Aft Trans Bhd
14	D	Deck

The Forepeak tank is divided into three zones; Upper, Middle and Lower (see Figure 3).

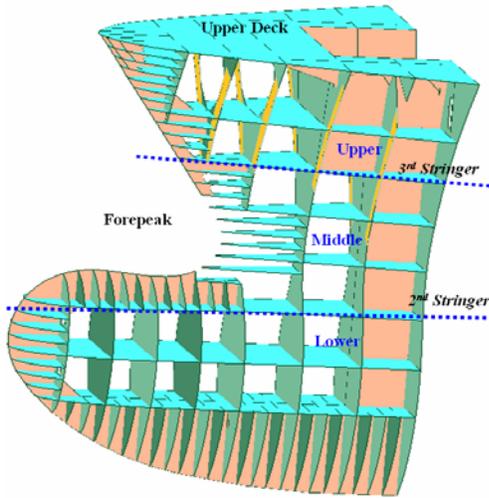


Figure 3: Sample Forepeak Tank

### COMPARTMENT SCORING SYSTEM

Each zone in a compartment is rated and assigned points by the qualified inspectors for each inspection criteria. Adding the scores for all zones in the compartment for a particular criterion will give the inspection criterion (IC) total score. The compartment total score is the sum of the six inspection criterion total scores.

Table 3 demonstrates an example of the point scoring for a compartment with three (3) zones. Each inspection criteria is assigned a score from zero (0) for excellent / good condition to a score of six (6) signifying worst / poor condition. The scores 0 to 2 signify ‘Good’ condition (green). The scores 3 to 4 are for ‘Fair’ condition (yellow) and the scores 5 to 6 are for ‘Poor’ condition (red).

The inspection criterion total score for each criterion when divided by the number of zones will provide the average condition of the compartment in a 0 to 6 score for that inspection criterion. This is the normalized score for an inspection criterion.

$$\text{Normalized IC Score} = \frac{\text{IC Total Score}}{\text{No. of zones}}$$

The compartment total score, aggregate of all the inspection criteria scores for all the zones, when divided by the number of zones is the normalized compartment score.

$$\text{Normalized Compartment Score} = \frac{\text{Sum of all six IC Total Scores}}{\text{No. of zones}}$$

‘Red’ for any inspection criteria indicates a structural deficiency and the inspector should create an anomaly. ‘Yellow’ indicate a progression towards an anomalous condition and serves as an early warning and at the discretion of the inspector / superintendent may be addressed at the next repair / dry-dock schedule.

Table 3: Sample Scoring Table

Compt with 3 zones	Lower	Middle	Upper	Sum zones (1+2+3)	Max. Zone Score	Avg Score of all Zones (1+2+3)/3
Zone IDs	1	2	3	IC Totals		Normalized IC Score
Coating	2	4	3	9	4	3
General Corrosion	3	3	5	11	5	3.7
Pitting / Grooving	1	2	1	4	2	1.3
Deformation	3	1	0	4	3	1.3
Fracture	0	3	0	3	3	1
Cleanliness	5	2	0	7	5	2.3
Total Zone Score	14	15	9			
Total Compt Score				38		
Normalized Compt Score						12.7 (38 / 3)

A sample general inspection criteria checksheet is illustrated in Figure 4. The check sheet has compartment graphics depicting zones, a table for scoring the inspection criteria for each zone, and description of anomalies.

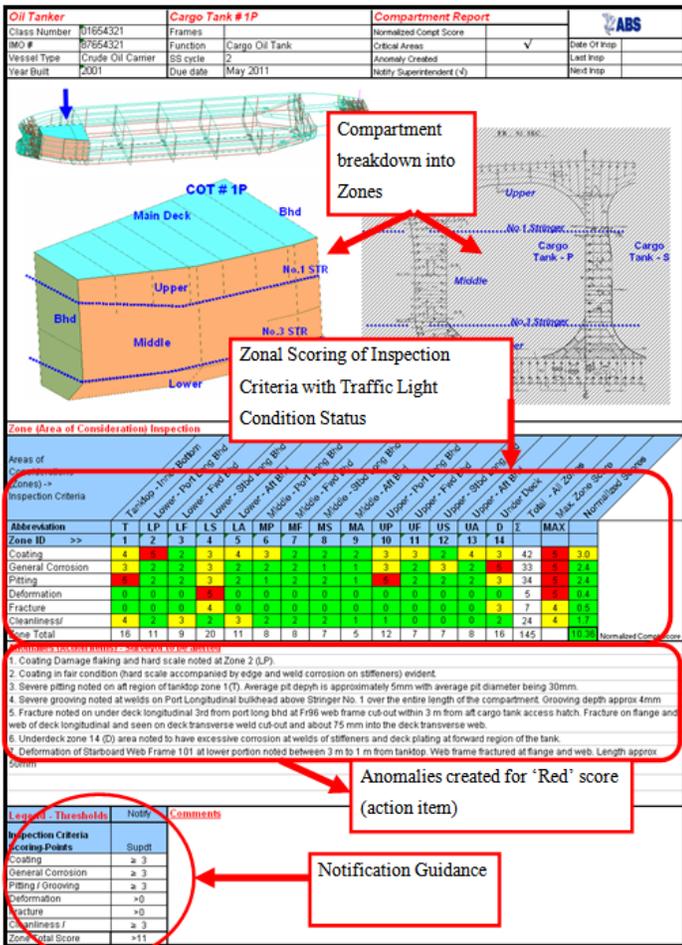
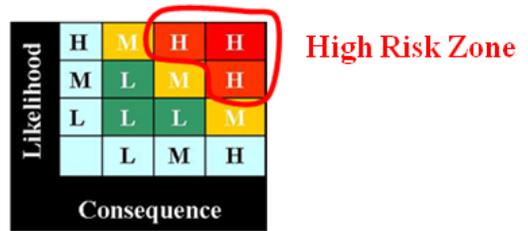


Table 4: Criticality Matrix



“Specific Critical Areas” are defined based on evidence from the existing hull structural analysis that certain areas within the hull have a particularly high risk of failure (a combination of likelihood and consequence of failure). Specific critical areas may also be identified where the structure is of unusual design or based on a novel concept.

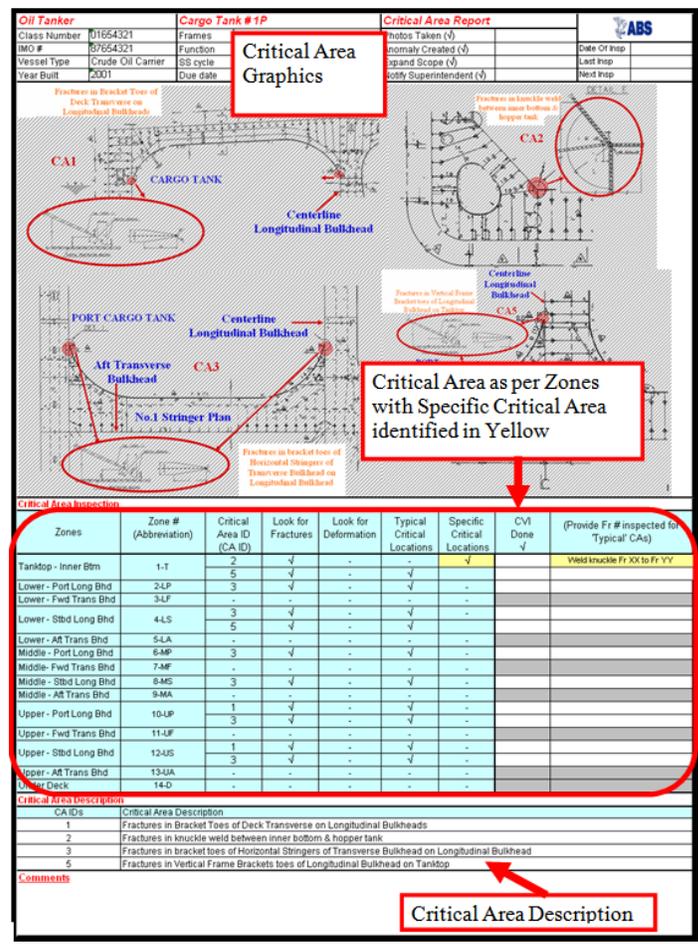


Figure 4: Sample Inspection Criteria Checksheet

**CRITICAL AREAS INSPECTION**

The critical areas were selected based on in-service experience and engineering analysis tools. The in-service experience is based on the historical maintenance/inspection records on the vessel and similar ships. The engineering analysis tools used were ABS Safehull Phase A/B, DLA/SFA. The critical areas are also gathered from the documentation from IACS and TSCF noted in the references.

The critical areas identified for compartments include “typical” critical areas and “specific” critical areas based on a criticality matrix (See Table 4).

“Typical Critical Areas” are the target areas generic to oil tankers of that class, elaborated in various IACS publications as noted in the references. Typical critical areas for compartments are to be inspected randomly by subjecting at least 10 to 25% of such critical areas (not less than four locations or web frames) for close-up visual inspection.

Figure 5: Sample Critical Area Checksheet

All areas which have been identified as high criticality or high risk (red boxes) require a 100% close visual inspection of that particular location every time the tank or compartment is entered. The likelihood of failure is evaluated on the basis of a calculated fatigue life or strength or buckling unity check (UC). In

addition, the consequence of failure has been ascertained based on the qualitative judgment for the detail in question. A sample critical area inspection check-sheet is illustrated in Figure 5.

## **INSPECTION DATA PROCESSING**

Each compartment has a general inspection criteria checksheet (Figure 4) and a critical area checksheet (Figure 5), if any critical areas exist.

### **Compartments**

These checksheets contain the inspection criteria which are to be ranked by the qualified inspector as per the point rating system described earlier. The final rating for the compartment will be based on the total points assigned during inspection by the qualified inspector. The critical area locations noted in the checksheet will be inspected as per the recommended sampling percentage. The inspector records any defect or anomalies in the checksheet with accompanying photographs or sketches attached to the checksheet. Inspectors may recommend corrective actions for anomalies.

### **Recording Anomalies**

Anomalies are noted to be any condition that deviates from the “normal”. Therefore, any zone with a red score should have a complete description in writing of the anomaly found. Typically anomalies are deficient conditions which require action(s) by the ship’s crew. The anomalies noted by the qualified inspector are typically of damage or failures which require rectification and repair to return the structure or arrangement to its original condition. Anomalies involving damage or failures and any temporary repairs must be presented to an attending Class Surveyor at the next port of call and before final repairs are carried out.

Anomalies should be recorded on a separate form known as an Anomaly Report, appended to the checksheets. The inspector may take photographs (or make a sketch) to be attached to the anomaly sheet. Until the action is taken to resolve an open anomaly, the open anomaly is to be treated as a ‘pending’ item by the ship’s crew.

### **BENEFITS**

Anomalies identified for the compartment will assist the operator in managing and controlling the repair

specifications and drydock planning. This will enable the Class surveyor to better focus the survey and allocate time for each compartment.

### **Fleet Management and Trending**

This concept and methodology applied to an oil tanker can be applied to all the vessels in an owner’s fleet. The scoring system will allow the comparison of tanks and allow the owner to recognize the condition of various tanks in a particular vessel and overall condition of vessels in a fleet.

This concept leads to a traffic light status display at a higher level with the basic building blocks being the score (0 to 6) assigned to individual criterion in each zone.

Such a system will assist owners to monitor their fleet condition.

The inspection data collected for a large fleet of similar vessels will permit the owner to make queries for vessel condition, identify trends so as to better forecast repair requirements and manage resources.

### **TRAINING**

It is crucial for the owners’ inspectors to become qualified in hull inspection and undergo periodic training for successful implementation of this concept. The training program should include introduction to the ship structures, inspection criteria and on the job training to have a consistent scoring methodology among inspectors. The details of the suggested training may be seen in the ABS Hull Inspection and Maintenance Program (HIMP) Guide, noted in the references. As guidance to the inspectors a grading booklet may be developed describing the condition description for each inspection criteria score with pictures and images.

### **CONCLUSIONS**

The concept and methodology of the ABS HIMP Guide presents a method for hull inspection to move towards more rationalized structural integrity management. This concept can be applied by a small fleet operator with simple spreadsheets. For an operator with a large fleet, a sophisticated ‘dashboard’ application monitoring the condition of the fleet with features and tools of trending and querying the collected condition data that could identify systemic problems.

## **ACKNOWLEDGEMENTS**

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