

GENERAL SPECIFICATION

CORROSION

GS EP COR 002

Corrosion control on production facilities: Field operations
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10	10/2018	Complements to the Corrosion Management manual and to inhibitor and biocide treatments
09	08/2016	New Painting Maintenance guidelines (Appendix 2) + new Table (Appendix 4, n° 4.3) about microbial monitoring practices + minor corrections
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1. Scope

This document is related to Corrosion Control on offshore and offshore Production Facilities. It is applicable to field operation activities, from production start-up to field abandonment.

This document specifies the main activities of Corrosion entities in charge of field operations in operating subsidiaries, based on a defined Corrosion Management policy. It also specifies practical methodologies and requirements for:

- Performing internal corrosion assessments on operated facilities
- Defining corrosion mitigation and corrosion monitoring programs
- Applying these programs during normal field operations
- Running exceptional operations with no adverse corrosion impact.

Preliminary remarks: Due to the wide variety of parameters and solutions applicable to corrosion control, this document not only include general specifications but also some indicative or applicative tables to be used within defined application limits. *Some comments and explanations are also given in italics, with no prescriptive value.*

2. Reference documents

The reference documents listed below form an integral part of this General Specification.

External Documents

Unless otherwise stipulated, the applicable version of these documents, including relevant appendices and addendums, is the latest revision published at the effective date of this document.

Reference	Title
Not applicable	

Total General Specifications

Unless otherwise stipulated, the applicable version of these documents, including relevant appendices and addendums, is the latest revision published.

Reference	Title
GS EP COR 001	Corrosion control on production facilities: Design and construction
GS EP COR 451	Corrosion and Coatings Integrity Inventory for Offshore Installations
GS EP COR 560	Physical and chemical treatment of hydrostatic test water

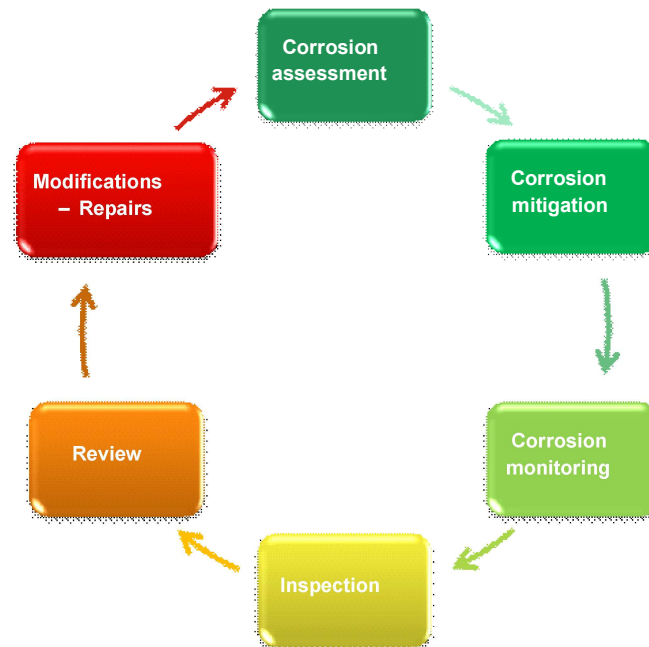
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3. Definitions

The **Corrosion Management System (CMS)**: Represents the policy, the organisation, the people, the processes and actions put in place in the corrosion control domain, in order to assure the technical integrity of operated assets and facilities. It also includes the whole documentation needed to support the formal Corrosion Management.

The **Corrosion Management policy** represents the upper level of the CMS, i.e. the strategic decision and expression from the operational management of the Affiliate that a formal Corrosion Management System is put in place.

The **Corrosion management loop**: The main technical steps of the Corrosion Management process for any production facility is summarized in the following loop, which is applicable both during design and construction and during Production:



The **Corrosion entity**: Represent the group of person(s) which are competent and in charge of managing the necessary knowledge and actions needed to assure a satisfactory corrosion control, according to the CMS. The present document does not specify at which position this “entity” is placed, nor the number of persons it represents.

Preventive actions for corrosion mitigation, i.e. *all actions undertaken during operation to control the corrosion of susceptible materials and equipment* include, though not limited to:

- Metallic and non-metallic material selection
- Chemical treatments dedicated to corrosion mitigation: Corrosion inhibition, biocide treatments, oxygen scavenging, chlorination, pH stabilization
- Physical treatments applicable to corrosion mitigation: Dehydration, de-oxygenation, H₂S and/or CO₂ removal, operational pigging, etc.

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- Cathodic protection
- Painting and coating
- Thermal insulation and fire-proofing materials, with respect to their potential impact on external corrosion.

Corrosion Monitoring activities, *i.e. all actions regularly undertaken to verify the implementation and efficiency of preventive actions* include, though not limited to:

- Follow-up of chemicals injection rates
- Follow-up of Cathodic protection equipment
- Potential and current measurements for cathodic protection
- Coupons and corrosion probes
- Chemical analyses (inhibitor, iron, oxygen, pH ...)
- Bacterial counts (kits, bioprobes, etc.)
-
- Others, when available.

Corrosion Loop: A collection of components of a production facility grouped together, generally for the purpose of a Risk Based Inspection analysis. These components have comparable characteristics with respect to the materials, to fluid and process conditions and finally to corrosiveness. Depending on its size and complexity, an oil & gas production and injection facility is currently made of 15 to 40 corrosion loops.

4. The "Corrosion Management Manual"

The entity in charge of Corrosion Control of a subsidiary shall develop and implement a Corrosion Management System and formalize it in a "Corrosion Management Manual".

This Corrosion Management Manual is the "mother document" specifying how corrosion is managed within the subsidiary throughout the production period. It defines the organization, the responsibilities and the technical bases used to control corrosion on all facilities. It supports Application Documents which are established (per area and/or per assets/facilities) to assure the proper implementation of the strategy. A minimal content of this document and an indicative list of application documents are given in Appendix 1.

The next paragraphs define the main requirements related to this corrosion management during field operations, essentially on corrosion assessment, corrosion mitigation, corrosion monitoring and review tasks. Inspection and maintenance activities are not covered apart for their strict corrosion part as they are dealt with in other documents.

For operating subsidiaries facing sand production issues, a Sand Management Policy and Manual may be put in place. The Sand Management Manual is considered as a specific and separate document, even though the Corrosion Management Manual may contain specific points related to erosion or erosion-corrosion assessment and control.

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4.1 Organisation

The corrosion management Manual shall define, if not already done in an upper level document, the organisation in charge of corrosion control of the facilities during field operation:

- Tasks to be managed, i.e.:
 - Periodic corrosion assessment
 - Corrosion mitigation programs and implementation
 - Corrosion monitoring programs and implementation
 - Review of inspection programs and results, in close relationship with the inspection entity
 - Exceptional operations with a possible corrosion impact.
- Responsibilities, accountabilities, interfaces between entities in charge
- Human resources
- Competence, experience, qualification and training.

4.2 Corrosion register and documentation

A formal Corrosion register shall be established. The associated documentation shall be made easily accessible and up-dated.

The Corrosion Register defines how and where the necessary information and documentation can be found in all corrosion management activities during field operations, i.e. the Corrosion Management Policy, the Corrosion Management Manual and all Application Documents indicated in Appendix 1, including as-built documentation such as P&IDs, equipment data sheets, MSDs...

The documentation itself has to be filed according to the corrosion register and made available to all interested parties in the most up-to-date version.

4.3 Corrosion assessment during operations

A Corrosion assessment shall be established and regularly up-dated to evaluate the need for applying preventive solutions or to improve the solutions in place as well as to set the efficiency target of these solutions.

It shall be consistent with the formal Corrosion Assessment, if any, which might be included in the RBI tools used for preparing inspection programs.

The corrosion assessment aims at evaluating whether corrosion is well controlled or not and at which rate it is likely to proceed, in case of insufficient control.

It shall be used for revising corrosion mitigation, corrosion monitoring, and inspection programs, and is a key input for the definition of planned maintenance & repairs.

The deliverables of this Corrosion Assessment are in two parts:

1. The Natural Corrosion Likelihood, i.e. without any applied mitigation: This Natural Corrosion Likelihood is particularly used to define whether additional mitigation solutions are needed or not and to evaluate how quick problems might be experienced if such mitigation was not applied or inefficient.

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2. The final Corrosion Likelihood, which also accounts for:

- The efficiency of preventive solutions used, if any
- The corrosion monitoring and inspection results
- The last known or expected condition of the equipment considered (extent of corrosion damages if any, repairs, etc.).

Note: For new facilities, the Natural corrosion assessment during field operations is based on similar tools and methodologies as those used during design (cf. **GS EP COR 001**). The First Natural Corrosion Likelihood evaluation is the one elaborated within the Project phase.

Corrosion Assessments shall be regularly revised, and as a minimum in case of:

- After ~1 year of operations on a new facility, in order to adjust the assessment done during the Project phase with real data gathered during the 1st year.
- Any significant change in operating conditions, such as but not limited to:
 - Start-up of a new field using existing facilities or equipment
 - Implementation of a new process unit which modifies the service conditions of existing facilities or equipment
 - A change in production rates by more than 50%.
- Unexpected corrosion events likely to re-occur at other locations and not covered by existing corrosion assessment results.
- Corrosion monitoring results regularly in contradiction with the corrosion assessment.

4.4 Corrosion mitigation

A Corrosion Mitigation Program shall be established and regularly updated. This program shall specify all necessary actions to be undertaken during operational life to prevent corrosion failures of any important equipment before its expected end of service.

The bases of internal corrosion and its mitigation shall be defined in the "Corrosion Management Manual for all production and injection facilities".

"Corrosion Mitigation Programs" shall include all relevant solutions as described in § 3. A typical structure to be followed is shown in Appendix 2.

For any preventive action of the corrosion mitigation program, the following shall, as a minimum, be specified:

- The method to be used
- The location where it will be used
- The equipment to be used
- The requirements for use (dose rates, potential values, flow rates, etc.)
- The quantitative efficiency levels targets
- The relevant application procedures.

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The corrosion mitigation program is to be formally delivered to all entities in charge of its implementation, together with all relevant procedures needed to allow its correct application.

The availability of the necessary material and human resources for the implementation of the corrosion mitigation program shall be verified.

The Corrosion mitigation program is to be updated regularly, and as a minimum:

- Every year
- For physical and chemical treatments: when production rates are changed by more than $\pm 25\%$, or new fields or new process facilities are added
- When corrosion monitoring results are regularly in contradiction with expectations, or quickly drifting from previous average values
- When inspection results are in contradiction with expectations, based on the supposed performance of preventive actions.

A corrosion inhibitor product selected and used on a field/ asset shall only be changed for one of the four following major reasons:

- Documented lack of efficiency
- Clearly demonstrated detrimental process/ production impact
- Incompatibility with local authorities recommendations, particularly its impact on environment
- Cost saving (at least 20% less than the previous treatment).

The new product shall be subjected to a qualification process, unless already qualified in comparable operating conditions by a documented positive field experience.

The bases for a typical corrosion mitigation program are given in Appendix 3 for:

- Table 3.1: Typical corrosion inhibitor treatments for oil and gas production facilities
- Table 3.2: Typical biocide treatments for oil and gas production facilities
- Table 3.3: Typical pH stabilisation treatments for gas production facilities
- Table 3.4: Anticorrosion treatment of water injection facilities
- Table 3.5: Corrosion treatment of process tanks (settling tanks, produced water tanks)
- Table 3.6: Anticorrosion treatment of closed loop cooling water facilities
- Table 3.7: Anticorrosion treatment of pressurised hot water facilities
- Table 3.8 Typical guidelines for the water quality of natural circulation boilers
- Table 3.9: Typical guidelines for operational pipeline pigging for corrosion purpose
- Table 3.10: Typical guidelines for definition of painting maintenance programs.

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4.5 Corrosion monitoring

A corrosion monitoring program shall be established and regularly updated, aiming at either:

- 1. Verifying the effective use and the performance of preventive actions, if any**
- 2. Verifying that corrosion likelihood remains below the maximal acceptable level, when no preventive action is deemed necessary.**

A formal corrosion monitoring program shall be established as a minimum for physical and chemical treatments, and for cathodic protection (internal and external).

Corrosion monitoring results shall be regularly gathered and reviewed (typically on a monthly basis).

***Note:** Corrosion monitoring is different from inspection. It aims at evaluating the performance of preventive actions within short time delays (days to months depending on the technique) but without any direct indication of the physical condition of the equipment considered. Inspection is focused on the corrosion status of equipment on a longer term basis (months to years).*

The monitoring program shall cover all relevant production and injection facilities. A typical list of monitoring techniques is given in Appendix 4, Table 4.1.

Among the various preventive actions undertaken, corrosion monitoring activities will be focused on cathodic protection and physical and chemical treatments, whereas painting-coating and corrosion resistant materials are mostly covered by Inspection programs.

The Corrosion Monitoring program is a formal document defining all activities and measurements to be handled to cover the objectives listed here above.

For each measurement / activity the following shall be included, as a minimum:

- The monitoring technique used
- The location where it is used
- The relevant application procedure
- The measurement frequency
- The entity in charge of the activity
- The threshold acceptance values
- The actions to be undertaken when threshold values are exceeded.

All application procedures necessary to the satisfactory application of the corrosion monitoring program must also be made available to the entities in charge.

The Corrosion monitoring program is regularly up-dated, as a minimum when:

- New facilities are installed or existing facilities are closed
- Process modifications are made, which may modify the corrosiveness of the fluids which are monitored or the efficiency of the applied mitigation

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- Changes are made on the applied mitigation programs
- Corrosion monitoring or inspection results are regularly in contradiction with expectations.

As long as chemical treatments are concerned, the corrosion monitoring program shall include:

- The verification of injection specifications (flow rates, dose rates, continuity or frequency and duration), based on typical guidelines indicated in Appendix 4, Table 4.2.
- Indicative parameters related to treatments' efficiency, as per reference documents (coupons, probes, titrations, bacterial counts, etc.). A sound corrosion monitoring program requires combining several monitoring techniques in parallel.
- Table 4.3 indicates typical monitoring guidelines for the monitoring of boilers' water quality.
- Table 4.4 indicates typical guidelines for microbial monitoring on production, water injection and Utility facilities.

4.6 Inspection activities related to corrosion control

The corrosion entity in charge shall:

- **Maintain a permanent and close relationship with the inspection department, with systematic and mutual exchange of information on significant corrosion events experienced, inspection results involving corrosion damages, poor corrosion monitoring results, etc.**
- **Be involved in the definition of RBI type inspection programs for the Corrosion Likelihood evaluation of the concerned equipment.**
- **Be involved in the implementation of inspection programs where corrosion is the essential reason for inspection, particularly when the objective of the inspection is to establish the painting maintenance program.**

For RBI programs, the Corrosion entity is in charge of validating the Corrosion Likelihood evaluation used in the RBI tool. This evaluation shall be consistent with the Corrosion Assessment defined in § 4.3.

The Corrosion entity shall check that the planned inspection programs are adequate with respect to corrosion assessment and corrosion threats, and consistent with any additional information regarding corrosion events, corrosion monitoring results, etc.

Inspection results shall be reviewed with respect to their possible impact on any other equipment potentially subjected to similar corrosion damages.

Inspection results are to be analysed in view of adjusting, if necessary, corrosion mitigation and monitoring programs, particularly when unpredicted corrosion damages are detected by inspection.

The Corrosion entity is directly involved in Painting Maintenance activities, as detailed in Appendix 3:

1. Definition of the Painting maintenance strategy, as part of the Corrosion Management strategy
2. Performance of "Corrosion and Coating Integrity Inventories" as per [GS EP COR 451](#)
3. Definition of pluri-annual painting programs

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4. Qualification of contractors
5. Checking, inspection and acceptance of painting works.

4.7 Corrosion impact of exceptional operations

A detailed review of exceptional operations likely to have a detrimental corrosion impact on production facilities shall be carried out.

The necessary mitigation actions needed to minimize the corrosion impact are to be defined in close relationship with the entity in charge of the operation. This has to be carried out within a timeframe which guarantees the practical implementation of these mitigation actions during the operation, and with consideration to operational limitations and constraints.

An indicative list of operations requiring to be reviewed is given in Appendix 5.

4.8 Review - Reporting - Filing

Mitigation and monitoring results shall be gathered through a formal corrosion monitoring system which shall include:

- The collection of monitoring data from all sources
- The regular analysis of results
- The review of alarms and results exceeding threshold values
- The calculation of key performance indicators (KPI).

The process of the periodic review of prevention and monitoring results has to be formalized (frequency, entities involved, deliverables, action follow-up process...).

Mitigation and monitoring data shall be archived throughout the whole service life of the relevant facilities.

A periodic report shall be issued. This report shall include:

- What has been implemented on corrosion mitigation
- The main monitoring results, with a particular emphasis on results exceeding threshold levels
- KPIs
- Inspection results of key consequence for corrosion control
- A list of anomalies and a follow-up of corrective actions, if any.

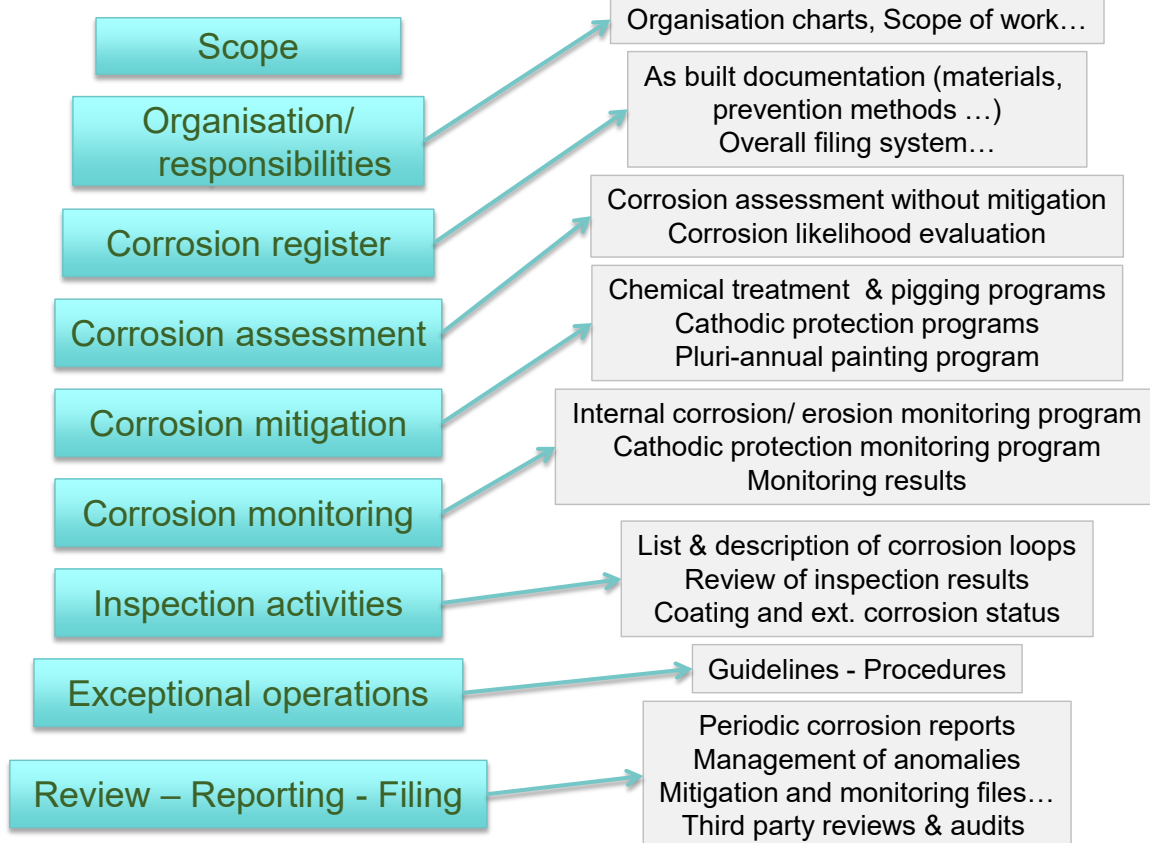
The most important results shall be reported on a graphical basis versus time (*usually over a one year sliding period of time*).

Appendix 1 Tentative structure of the Corrosion Management Manual and associated application documents

This appendix defines the minimal content of the Corrosion Management during Field Operations document of a production subsidiary and an indicative list of associated application documents (programs, procedures, methodologies, etc.). This list is not exhaustive: depending on the size of the subsidiary, a number of additional documents can be added.

The Corrosion Management doc.

Application documents (per asset/ field/ facility...)



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Appendix 2

Appendix 2 Typical structure of "Corrosion Mitigation Programs"

* Preventive solutions usually implemented at design/construction stages and not requiring any more activity during operation are indicated in italics.

System...	...generally including:	Typical preventive methods*
Physical and chemical treatments		
Production wells	Tubing, well-head, flowline	<i>CRAs</i> Rarely corrosion inhibition
Crude oil and gas trunklines	Risers and pipelines, receiving separators	Corrosion inhibition, biocides, operational pigging, pH stabilization, CRA or composite materials
Liquid lines downstream crude separation process	Water and liquid lines, water disposal facilities, crude dehydration and stabilisation	Top up of corrosion inhibitor and/or biocides, if part is lost due to oil/ water partitioning
Water injection network (Produced & Sea Water)	Topside piping, flowlines, risers and pipelines, wells	Chlorination, filtration, physical and chemical de-aeration of SW, biocide treatment, corrosion inhibitors
Wet gas compression process	Topside piping, exchangers, water knock out drums, compressors	<i>CRAs</i>
Glycol dehydration process	Contactor, regenerator, exchangers, topside piping	CS, pH control, <i>CRAs</i> for specific parts
Gas-lift or gas injection network	Topside piping, gas-lift pipelines and flowlines, wells	Inhibitors or <i>CRAs</i> if wet condensing gas. Nothing if dry gas
Utilities: Cooling water network	Piping, exchangers, vessels, surge tanks	Multi-functional inhibitors (O ₂ scavenger, pH control, protective scaling, dispersant) + biocide, N ₂ or fuel gas blanketing of surge tanks
Utilities: Pressurised hot water network	Piping, exchangers, vessels, boilers, surge tanks	Multi-functional inhibitors (O ₂ scavenger, pH control, protective scaling, dispersant) + biocide, N ₂ or fuel gas blanketing of surge tanks
External cathodic protection (CP)		
Offshore structures (immersed or buried)	Jackets, FPSO, subsea modules, anchors	CP with sacrificial anodes, rarely impressed current
Immersed or buried pipelines	Risers, pipelines, subsea modules and valves	CP with sacrificial anodes (offshore) or impressed current (onshore)

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Appendix 2

System...	...generally including:	Typical preventive methods*
Storage tank floors	Side of the floor in contact with the soil	CP with sacrificial anodes or impressed current + <i>painting</i> + <i>soil preparation</i>
Internal Cathodic Protection		
Pressure vessels	Separators, water injection and utility vessels	Sacrificial anodes + Internal coating
Tanks	Onshore storage tanks, FSO/ FPSO storage tanks, ballasts, slop tanks, etc.	Sacrificial anodes + Internal coating
Painting and coating		
Pipelines	External surface	<i>3 layers PE or PP, occasionally FBE</i>
	Internal surface	<i>Occasionally internal coatings</i>
Immersed structures	Jackets (buried part or splash zone)	<i>Painting</i>
	Subsea facilities (templates, Xtrees, manifolds, etc.)	<i>Painting. No maintenance</i>
	Hull of FSU, FPSO, etc.	<i>Painting. No maintenance for the immersed surfaces</i>
Aerial structures and facilities	Structural elements, piping, vessels, tanks, valves, etc.	<i>Painting. Passive Fire Protection in some areas. Periodic maintenance</i>
	Internal surface of tanks (storage, ballast, slop) and vessels	<i>Internal coating. Periodic maintenance</i>