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1. **Introduction**

Lloyd's Register operates a three-stage Approval Scheme for containment systems for the carriage of liquefied gases in bulk in gas ships in compliance with the IGC Code and the Rules, as follows:

- **Approval in Principle (AiP)** ~ This is a feasibility level of approval which recognises that the proposed design is capable of being developed into a safe and viable containment system without any major changes to the basic arrangements.

- **General Approval for Ship Application (GApp)** ~ This level of approval acknowledges that the containment system design has been progressed as far as practical before ships incorporating it are ordered to Lloyd's Register class.

- **Approval for Particular Ship Application (PSApp)** ~ This level of approval signifies that the containment system has been appraised for suitability for installation into a particular ship and complies in every respect with the IGC Code and Rules.

The requirements for each stage of approval are described in Sections 2 to 5 of this Scheme. Section 2 covers AiP, Section 3 covers GApp for membrane systems, Section 4 covers GApp for Type B systems and Section 5 covers PSApp. The final Section contains references to Lloyd's Register's guidance and procedures which may be applicable.

Seeking approvals under this Scheme is voluntary. The AiP and GApp stages are particularly relevant for a containment system design which is being developed over a period of time before the ship is ordered to Lloyd's Register class. The PSApp stage follows successful review of all the drawings and supporting calculations required to be submitted for all types of containment systems on gas ships classed by Lloyd's Register. This usually takes place after the ship is ordered to Lloyd's Register class.

Designers of new containment systems (excluding structural parts of Type A and C tanks, which are practical to design after the shipbuilding order is placed) are encouraged to obtain AiP first and then to progress to GApp after AiP has been granted. It is strongly recommended that GApp be obtained before ships incorporating the proposed system are ordered to Lloyd's Register class.

When the approval of revised containment system designs is sought, updated approval should be obtained within the terms of this Scheme. For example, if significant design amendments are made (e.g. changes of material, securing arrangements, joining processes, arrangement in localised areas, etc) but the underlying design philosophy remains the same, updated GApp is applicable. In such cases, only those aspects which have changed since the earlier GApp was granted need to be considered.

At Lloyd's Register's discretion, AiP and GApp may be granted to a distinct part of the containment system rather than to the system as a whole. Where the AiP or GApp is sought for the insulation arrangements of Type A and C tanks, guidance on the information to be submitted should be sought from the appropriate Lloyd's Register plan approval office.

A form of AiP and GApp is also available for auxiliary equipment associated with the containment system, e.g. reliquefaction plant, gas combustion plant, etc. Guidance on the information to be submitted should be sought from the appropriate Lloyd's Register plan approval office.
AiP and GApp are granted by the issuing of a suitably worded Design Appraisal Document (DAD), the content of which is described later. PSApp is normally implicit from the issuing of the Certificate of Class on delivery of the ship.

When requested, appraisal will also be made against the requirements of USCG CFR 46 Part 154 and this will be recorded in the DAD, where applicable.

Section 2: Approval in Principle (AiP)

2.1 General:

This Section is applicable to all types of containment system for which AiP is sought.

2.2 Details to be submitted:

The following information is to be submitted to Lloyd's Register:

- Declaration of the type of containment system involved in accordance with Section 4.2 of the IGC Code, including a statement of:
  - which liquefied gas cargoes are to be carried,
  - the design vapour pressure as defined in 4.2.6 of the IGC Code, and
  - the design temperature as defined in 4.2.7 of the IGC Code.
  If the proposed containment system does not conform to one of the defined types, an outline justification of how the proposed design is at least as safe as one of the defined types will be required.
- Drawings of the containment system showing:
  - the structural arrangement of the component materials for representative flat, corner and curved regions, as applicable,
  - provision that has been made for inert gas circulation, and
  - incorporation of temperature sensors to the extent required by the IGC Code and Rules for the type of containment system being considered.
- Drawings showing the method of support/attachment of the containment system in the ship.
- An outline general arrangement of the form of the ship into which it is intended that the containment system will be installed.

2.3 Review by Lloyd's Register:

Appraisal will include the following aspects:

(a) **Arrangement:** Assessment to confirm that the outline design meets the IGC Code/Gas Ship Rules with regard to arrangement, e.g. provision of primary and secondary barriers to the required extent, location within the ship, access for survey and testing, etc.

(b) **Operating Safety Systems:** Assessment to confirm that the outline design has the potential for meeting the requirements for the operational safety provisions, e.g. that the system incorporates suitable channels for inerting of the insulation and interbarrier spaces, leak detection, etc.

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1 Drawings may be outline in nature but should be in the form of engineering drawings rather than finite element plots, rough sketches, etc. They should give sufficient detail so that the principles of the arrangements can be identified.
(c) **Materials**: Assessment to confirm that materials proposed for construction are fit for purpose in respect of temperature, strength, insulating properties, etc and are available products. Where it is intended to use special materials which are at an advanced state of development, evidence that they will exhibit the necessary properties will be required for examination. Materials will be expected not to have been phased out by international agreement, e.g. as is the case for certain insulation blowing agents.

(d) **Fabrication Processes**: Assessment to confirm that the intended fabrication and installation processes reflect existing proven technology. Where this is not the case, e.g. if advanced unproven welding processes are proposed, evidence of suitability will be required for assessment.

(e) **Practicality of Construction**: Assessment to confirm that the intended construction process is practical, e.g. the installation sequence is physically possible, components have sufficient strength to be lifted/fitted into position without damage due to self-weight, reliance is not placed on impractically tight tolerances, etc.

(f) **Ship Design**: If the proposed containment system requires a design of ship which is significantly different to one of the established types of LNG ship, the design arrangement of the ship will be assessed to ensure that it is practical and that the materials of construction of the inner hull are able to withstand the temperatures imposed on it by the containment system in the design condition.

2.4 **Granting of Approval:**

On satisfactory completion of the appraisal, a DAD will be issued confirming that the proposed Containment System has been granted AiP. At Lloyd's Register's discretion, guidance may be included indicating aspects of the design which will require particular attention before GApp can be contemplated.

■ **Section 3: General Approval for Ship Application (GApp) – Membrane Containment Systems**

3.1 **General:**

This section describes the GApp requirements for membrane containment systems. Section 4 deals with Type B independent tanks for which the IGC Code and Rule requirements differ in some respects.

3.2 **Details to be submitted:**

The following information is required to be submitted:

- Information as required for AiP, updated as necessary.
- Statement of any design or operational limitations such as ship size/shape/form, cooling rates, filling ranges, interaction stresses, etc.
- Fully detailed drawings of representative flat and corner regions, including dimensions and tolerances, as fitted into the midship region tanks.
- Fully detailed drawings of representative flat and corner regions, including dimensions and tolerances, as fitted into fore or after region tanks, if different from the midship region tanks.
- Fully detailed drawings for domes and any other special regions, including dimensions and tolerances.
- Fully detailed drawings showing the method of support/attachment of the containment system in the ship, including dimensions and tolerances.
- Fully detailed drawings of pump towers or other major structures inside the cargo tanks.
- Drawings showing the layout of the containment system throughout each cargo hold.
• Drawings of a typical basis ship into which the containment system will be fitted. This is to cover sufficient extent of the structure for evaluation of interaction stresses/deflections resulting from ship accelerations.

• Temperature calculations demonstrating the thermal adequacy of the containment system with the cargo at the secondary barrier.

• Ship motions analysis if the tanks are to be designed on the basis of accelerations derived from direct calculation rather than using the guidance formulae in Section 4.12 of the IGC Code.

• Structural analysis for assessment against permissible stress levels, and/or other suitable calculations or tests of selected regions of the containment system including flat and corner regions. This is to incorporate fixing/securing arrangements and sufficient loading conditions to investigate the effects of:
  − imposed strain due to hull girder bending,
  − transverse and local inner hull deflections applicable when the cargo tanks are loaded,
  − transverse and local inner hull deflections applicable when the adjacent ballast tanks are loaded,
  − 30° static heel, if significant compared to other loadings,
  − collision loading,
  − self weight, if significant compared to other loadings,
  − cargo dynamic pressure loading,
  − vapour pressure, including any increased vapour pressure to be applied during an emergency discharge procedure,
  − loading due to thermal gradients, including the design condition when the primary barrier has failed and the secondary barrier is containing the leakage,
  − overpressure of insulation spaces in relation to each other and the cargo space, and
  − failure of any particular region of primary barrier. This should not lead to consequential failure of the secondary barrier and vice versa.

• Sloshing analysis or studies to confirm the strength of the containment system against sloshing loads.

• Strength testing of any distinct load bearing components within the containment system for which strength cannot readily be established by calculation.

• Fatigue analysis of identified regions of the membranes and insulation to encompass both normal operation and the design condition when the primary barrier has failed and the secondary barrier is containing the leakage.

• Calculations to confirm that the containment system will not be susceptible to vibration caused by the main engines, propellers or other sources of excitation.

• Structural analysis, including vibration check, of the pump tower and its incorporation into and interaction with the adjacent hull structure.

• Specifications for component materials containing sufficient strength and thermal property requirements to enable the above analyses and studies to be conducted.

• Test results to confirm that any complex joining processes, such as new technology welding processes or gluing processes, can be carried out reliably.

• Test results for any new or novel materials or components, including those of a composite nature, for which no reliable data exists in relation to the physical, mechanical, fatigue and thermal properties.

• Test results for any new or novel insulation materials in relation to the properties described in paragraphs 4.9.5 to 4.9.7.1 of the IGC Code.
• Test procedures to confirm the tightness of the membranes during construction and in-service.
• Details of the form and extent of a mock-up of the containment system.
• If any major aspect is particularly different from other existing systems in a way which could affect quality assurance methods, weld procedure qualification, design details, materials, construction, inspection and production testing of components or, if there is any reason to believe that the analyses and tests do not fully assess the integrity of the containment system, then the construction of a model tank for the purpose of testing under representative loading conditions may be required.

All analyses and testing should be preceded by the submission of procedures describing the proposed methodology.

3.3 Review by Lloyd's Register:

Although the appraisal will make particular reference to Chapters 4 and 6 of the IGC Code and Rules, compliance with all relevant parts of the Code/Rules will be confirmed. In the case of testing, witnessing by a Lloyd's Register Surveyor may be required. A Surveyor will require to be present at the mock-up. It will also be confirmed that no concern has arisen on the aspects described in 2.3 above for AiP.

3.4 Granting of Approval:

On satisfactory completion of the appraisal, a DAD will be issued confirming that the proposed Containment System has been granted GApp. At Lloyd's Register's discretion, particular aspects or regions may be excluded from the approval. Such exclusions will be listed in the DAD. Guidance may be provided indicating aspects of the design which will require particular attention for PSAApp.

Section 4: General Approval for Ship Application (GApp) – Type B Independent Tank Containment Systems

4.1 General:

This section describes the GApp requirements for Type B containment systems. Section 3 deals with membrane tanks for which the IGC Code and Rule requirements differ in some respects.

4.2 Details to be submitted:

The following information is required to be submitted:

• Information as required for AiP, updated as necessary.
• Statement of any design or operational limitations such as ship size/shape/form, cooling rates, temperature gradients, filling ranges, interaction stresses, etc.
• Fully detailed drawings for all regions of tanks fitted into the midship region.
• Fully detailed drawings for all regions of tanks fitted in the fore and aft cargo holds if different from those in the midship region.
• Fully detailed drawings for domes and any other special regions.
• Fully detailed drawings showing the method of support/attachment of the containment system in the ship.
• Fully detailed drawings of any pump towers or other major structures inside the cargo tanks.
• Fully detailed drawings of the insulation system and partial secondary barrier arrangements fitted to the cargo tanks and of the supports/attachments.
• Drawings showing the layout of the containment system throughout each cargo hold.
• Comprehensive constructional tolerances for the tanks and their supporting structures.
• Drawings of a typical basis ship into which the containment system will be fitted. This is to cover sufficient extent of the structure for evaluation of interaction stresses/deflections resulting from ship accelerations.

• Temperature calculations for the support/attachment arrangements and adjacent hull structure with the cargo at the partial secondary barrier.

• Ship motion analysis if the tanks are to be designed on the basis of accelerations derived from direct calculation rather than using the guidance formulae in Section 4.12 of the IGC Code.

• Structural analysis for assessment against permissible stress levels and buckling criteria for the cargo tank and support/attachment arrangements including any structurally incorporated pump tower structure. Sufficient loading conditions are to be considered to investigate the effects of:
  - hull interaction loading via the support/attachment arrangements,
  - self weight,
  - cargo dynamic loading for a range of full and partial load conditions,
  - 30° static heel, if significant compared to other loadings,
  - collision loading,
  - flotation loading in the event of the flooding of a hold space,
  - flow of cargo past the structurally incorporated pump tower, if fitted,
  - vapour pressure, including any increased vapour pressure to be applied during an emergency discharge procedure,
  - loading due to thermal gradients in both steady state and transient conditions,
  - relative vacuum of the cargo tank in relation to the hold space,
  - vibration sources (including main engine and propellers) on the structurally incorporated pump tower, if fitted, and any other potentially susceptible structure in the containment system, and
  - proposed pressure test parameters.

• Analysis of structural details for the factors described above to the extent considered necessary.

• Sloshing analysis or studies to confirm the strength of the containment system against sloshing loads.

• Fatigue analysis.

• Crack growth analysis.

• Leak rate analysis.

• Fully detailed drawings of the insulation and partial secondary barrier.

• Strength analysis of the insulation/partial secondary barrier to demonstrate that it can sustain thermal gradients and cargo tank deflections.

• Test results for any new or novel materials or components incorporated into the insulation/partial secondary barrier and any materials of a composite nature for which no reliable data exists in relation to the physical, mechanical, fatigue, thermal and other properties, as required by paragraphs 4.9.5 to 4.9.7.1 of the IGC Code.

• Calculations to confirm the capability of the partial secondary barrier to contain and/or evaporate envisaged leakage over a period of 15 days.

• Structural analysis, including vibration check, of any pump tower which is not incorporated into the main structure of the containment system.

• Outline pressure test procedures.
• Outline proposals for strain gauging/prototype testing.
• If any major aspect is particularly different from other existing systems, or there is any reason to believe that the analyses and tests do not fully assess the integrity of the containment system, then the construction of a model tank for the purpose of testing under representative loading conditions may be required.

Procedures describing the methodology to be used for all analyses and testing are to be submitted to Lloyd's Register for review and comment in good time prior to commencement.

4.3 Review by Lloyd's Register:

Although to appraisal will make particular reference to Chapters 4 and 6 of the IGC Code and Rules, compliance with all relevant parts of the Code/Rules will be confirmed. In the case of testing, witnessing by a Lloyd's Register Surveyor may be required. It will be confirmed that no concern has arisen on aspects described in 2.3 above for AiP.

4.4 Granting of Approval:

On satisfactory completion of the appraisal, a DAD will be issued confirming that the proposed Containment System has been granted GApp. At Lloyd's Register's discretion, particular aspects or regions may be excluded from the approval. Such exclusions will be listed in the DAD. Guidance may be provided indicating aspects of the design which will require particular attention for PSApp.

Section 5: Approval for Particular Ship Application (PSApp)

5.1 General:

A check will be made that the assumptions and design parameters used for GApp have not been exceeded or contradicted for the particular ship under consideration. In this respect it should be noted that the loadings on any containment system are largely dependent on the size and configuration of the ship into which they are fitted.

Where it is identified that the GApp is not fully representative, the work done at GApp will need to be repeated for application on the particular ship. Similarly, any aspects or regions recorded as excluded from the GApp will need to be reviewed for application on the particular ship.

Where no AiP or GApp has preceded this stage, full submission of all drawings of the containment system, its supporting arrangements and associated insulation will be required.

5.2 Details to be submitted:

The following information is required to be submitted:

• Fully detailed drawings of the containment system in the arrangement in which it will be fitted in the particular ship. These should include full details of the primary and secondary barriers and the insulation.
• Fully detailed drawings of special regions of the containment system, such as domes, structurally incorporated pump towers, etc.
• Fully detailed drawings of any pump tower which is not incorporated into the main structure of the containment system.
• Drawings showing the means of access for inspection and survey.
• Analyses considered necessary to confirm the acceptability of the particular arrangement of containment system over and above the analyses carried out at GApp.
• Boil-off calculations.
• Relief valve calculations.
• Full details of equipment for the temperature and pressure control of the containment system, e.g. reliquefaction plant, gas combustion plant, etc.
• Local temperature calculations, where applicable.
• Detailed specifications of all component materials not covered in the Rules for Materials, Testing and Certification of Materials.
• Details of the inerting, gas detection and temperature measurement systems.
• Installation procedures.
• Welding procedures and/or adhesive bonding procedures, as applicable, including operator qualification procedures.
• Proposed details and extent of enhancement measures, such as grinding of welds to improve fatigue life.
• NDE procedures.
• Production test plan/procedures.
• QA/QC procedures.
• Repair procedures.
• Test procedures, including tightness and pressure testing as applicable.
• Construction, Testing and Inspection plan.

5.3  Review by Lloyd’s Register:

The above information should be submitted by the shipyard or by a design contractor on behalf of the shipyard. This will be examined by Lloyd’s Register together with the structural, engineering, drawings etc as part of the normal plan approval process for the ship.

5.4  Granting of Approval:

On satisfactory completion of the appraisal of each drawing or calculation, a DAD will be issued. This will confirm approval of the drawing or, examination and ‘retention for information’ of supporting calculations and analyses, in the usual way.

5.5  Approval for Subsequent Series of Ships:

For subsequent series of ships, consideration will be given to accepting previously accepted component material specifications and particular calculations. This is subject to the specifications remaining applicable and a statement to this effect being made by the shipbuilder, referring back to the previously approved documents. All other documents should be re-submitted for subsequent series of ships in order to provide a set of documents for reference by the attending surveyors and for record purposes. Also, to give the opportunity for revision to incorporate any improvements which have come to light since the earlier ships were approved.

Section 6: Relevant Lloyd’s Register Guidance and Procedures

The following reference documents may be applicable in association with this scheme:

• Draft Guidance Notes for the Non-destructive Examination of the Hull Structure of Membrane Type Gas Ships.\(^2\)
• ShipRight Additional Design Procedures – Procedure for Analysis of Pump Mast and Pump Mast Base.
• ShipRight Additional Design Procedures - Comparative Sloshing Analysis of LNG Ship Containment Systems.
• Approval Schemes for Component Materials of NO96 and MkIII Membrane Systems.\(^2\)

\(^2\) Documents available from local Lloyd’s Register office on request.