SSC Project Recommendation for FY 2022

Structural Integrity Assessment of Tanks and Adjacent Hull Structures for Alternative Fuels

1.0 OBJECTIVE.

1.1 The objectives of this project are to develop:

- a guideline for material selection of liquefied gas fuel containment systems considering material compatibility and cryogenic temperature of various alternative fuels (e.g. Methane, Hydrogen, Ammonia, Methanol, etc.),
- a guideline for steel grade selection of adjacent hull structures of the fuel tank experiencing very low temperature; and
- a guideline for strength assessment of independent fuel tank and its supporting structures on gas fueled ships.

2.0 BACKGROUND.

2.1 The International Maritime Organization (IMO) set ambitious targets in April 2018 in the Marine Environmental Protection Committee (MEPC) Resolution MEPC.304(72) to decarbonize the global fleet. The IMO strategy includes initial targets to reduce the average carbon dioxide (CO_2) emissions per transport work from 2008 levels by at least 40 percent by 2030 and 70 percent by 2050. These targets also seek to reduce the total annual greenhouse gas (GHG) emissions from shipping by at least 50 percent by 2050. Many technologies are being considered to reduce carbon emissions from shipping including marine fuel selection. Available maritime fuel options for decarbonization include methane, hydrogen, ammonia, methanol, and other alternative fuels. There is a growing number of liquified natural gas (LNG) powered vessels entering operation. Vessels powered by other alternative fuels such as ammonia and hydrogen are currently under development.

2.2 In the International Code of Safety for Ships using Gases or other Low-flashpoint Fuels (IGF Code), the liquefied gas fuel containment systems are categorized as independent type and membrane type systems.

- For an independent type of fuel tank (e. g. Type A, Type B, and Type C), one of the technical challenges is the material selection of tank wall structures containing various alternative fuels based on their material compatibility and cryogenic temperature. For example, for ammonia, NH_3 has a relatively narrow flammability range compared to other fuels being considered and is toxic and very reactive. Additionally, anhydrous ammonia may, under certain conditions, cause stress corrosion cracking in containment and process systems constructed from susceptible materials. For hydrogen, the primary safety concern is its flammable properties and wide flammability range. Certain metallic materials exposed to hydrogen gas may suffer from hydrogen embrittlement. Hydrogen embrittlement occurs when hydrogen is absorbed by metal and collects at grain boundaries, creating weak spots within the material. Hydrogen absorption can lead to brittle failure mechanisms, microscopic fractures, material cracks and leakage. Therefore, the requirements for selecting the materials that can be used to contain different alternative fuels should be specified.
- For a membrane-type fuel tank, the material selection of primary & secondary barriers also needs to be considered in a similar way to that for independent tanks.

2.3 Adjacent hull structures of the liquefied gas fuel tank may experience very low temperature due to the impact of the cryogenic temperature of the fuel (e. g. ~ -253^0 C for liquefied hydrogen and -162^0 C for LNG) during the service. The appropriate steel grades must be selected for adjacent steel plates for the hull to reduce the risk of causing the material brittleness. A fuel tank can be designed as either an independent type or a membrane type. A guideline for heat transfer analysis to determine hull temperature distribution needs to be developed with consideration of adjacent hull structure and its work environment together with the fuel containment system and liquified fuels.

2.4 In the current market, the most popular design of fuel tanks for gas fueled ships is the independent Type C system due to its flexibility of Boil-off Gas (BOG) management. It is also known as "pressure vessel" and is designed and built to meet the requirements of recognized pressure vessel standards such as the ASME BPVC supplemented by additional Class Society requirements and statutory regulations. In general, there are two categories of Type C tanks applied in gas fueled ships: a foam-insulated single-shell tank (e.g., cylindrical, bi-lobe, tri-lobe, etc.) and a vacuum-insulated double-shell tank. The liquefied gas fuel tank and its supporting structures must be designed to sustain all possible static and dynamic loads (e.g., weight, wave-induced loads, sloshing loads, etc.) they may experience during the service life. Therefore, a guideline needs to be developed for assessing the strength of the independent fuel tank and its supporting structures.

3.0 REQUIREMENTS.

3.1 Scope.

3.1.1 The Contractor shall conduct a literature review of industry standards for material selection of liquefied gas fuel containment systems.

3.1.2 The Contractor shall develop a guideline for heat transfer analysis on adjacent hull structure together with fuel containment systems for steel grade selection.

3.1.3 The Contractor shall develop a guideline for strength assessment of independent fuel tank and its supporting structures.

3.2 Tasks.

3.2.1 The Contractor shall undertake a comprehensive literature review of relevant technical documents including available industry standards and research papers, focusing on the material compatibility and cryogenic temperature of alternative fuels such as LNG, hydrogen, ammonia, methanol, etc.

3.2.2 The Contactor shall develop a guideline for material selection of tank wall structure for independent tanks or primary & secondary barriers for membrane type systems based on the material compatibility with different alternative fuels.

3.2.3 The Contractor shall identify the affected region in hull structures near the liquefied gas fuel tank, for example, adjacent compartments and the compartments in the ship which house the fuel tank, etc.

3.2.4 The Contractor shall categorize various fuel containment systems (e. g. either independent type or membrane type) and develop a guideline with a procedure for heat transfer analysis on adjacent hull structure with fuel containment systems to determine hull temperature distribution.

3.2.5 The Contactor shall provide a guideline for steel grade selection of adjacent hull structures of the fuel tank experiencing a very low temperature.

3.2.6 The Contractor shall provide a guideline for determining design loads including both static and dynamic loads (e. g. inertia induced loads, sloshing loads, etc.) the fuel tank may experience during its marine service life.

3.2.7 The Contractor shall develop a guideline for structural analysis including detailed requirements for finite element (FE) analysis on fuel tank and its supporting structures under design loads.

3.2.8 The Contactor shall develop a guideline for acceptance criteria for yielding, buckling, and fatigue.

3.2.9 The Contractor shall develop a guideline for strength assessment of independent fuel tank and its supporting structures.

3.3 Project Timeline.

	Month											
Task	1	2	3	4	5	6	7	8	9	10	11	12
3.2.1												
3.2.2												
3.2.3												
3.2.4												
3.2.5												
3.2.6												
3.2.7												
3.2.8												
3.2.9												
Report												

4.0 <u>GOVERNMENT FURNISHED INFORMATION</u>.

4.1 Standards for the Preparation and Publication of SSC Technical Reports.

5.0 <u>DELIVERY REQUIREMENTS</u>.

5.1 The Contractor shall provide quarterly progress reports to the Project Technical Committee, the Ship Structure Committee Executive Director, and the Contract Specialist.

5.2 The Contractor shall provide a print ready master final report and an electronic copy, including the above deliverables, formatted as per the SSC Report Style Manual.

6.0 <u>PERIOD OF PERFORMANCE</u>.

6.1 Project Initiation Date: date of award.

6.2 Project Completion Date: 12 months from the date of award.

7.0 <u>GOVERNMENT ESTIMATE</u>. These contractor direct costs are based on previous project participation expenses.

7.1 Project Duration: *12* months.

7.2 Total Estimate: $100,000

8.0 <u>REFERENCES</u>.

8.1 IMO IGC Code: The International Code for the Construction and Equipment of Ships Carrying Liquefied Gases in Bulk.

8.2 IMO IGF Code: The International Code of Safety for Ships using Gases or other Low-flashpoint Fuels.

1.0 <u>SUGGESTED CONTRACTING STRATEGY</u>.

1.1 Direct contracting with American Bureau of Shipping.