SSC Project Recommendation for FY 2024

Exploring the Feasibility of Applying Methods from the Pipeline and Pressure Vessel Industries to Marine Vessels Using/Transporting Alternative Fuels

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1.0 OBJECTIVE.

1.1 The objective of this project is to explore the feasibility of applying accepted structural design and assessment methods from the pipeline and pressure vessel industries to the design and assessment of marine vessels using or transporting alternative fuels.

1.2 This project will contribute to the development of processes facilitating the design and regulatory approval of marine vessels using or transporting alternative fuels. These processes will lessen the burden upon technology designers to demonstrate regulatory compliance, thus promoting and speeding innovation.

1.3 Consideration will be given to methods facilitating the design and approval of new/innovative designs, the use of novel materials, the conversion of existing designs/vessels, and the use of safety systems such as structural health monitoring.

2.0 BACKGROUND.

2.1 There is growing demand for the transportation and use of alternative fuels (such as hydrogen and liquefied gases). This demand requires the development of innovative designs, maintenance techniques, and monitoring systems for marine vessels. Due to the novelty of such efforts, there is often a lack of ***prescriptive*** guidance from existing standards to facilitate the demonstration of safety and reliability. This can create a regulatory bottleneck in the approval of either novel structural designs/techniques/systems or novel applications of well-established designs/techniques/systems. The result is a slowing of innovation within the industry.

2.2 Since this problem is not unique to marine vessels, it is prudent to promote efficiency by drawing from the experiences (both failures and successes) of adjacent industries. Adjacent industries that are of particular interest regarding the use and transportation of alternative fuels are the pipeline and pressure vessel industries. Adapting large portions of the pipeline and pressure vessel industries for the storage and transport of alternative fuels is of critical importance for their large-scale use. Therefore, much attention and investment have already been expended in these industries, making them a promising source of insights.

2.3 A review should be conducted to examine current methods used in the marine vessel, pipeline, and pressure vessel industries. The results should then be assessed for the feasibility of applying promising methods to the marine vessel industry. It is important to note that, for a method to be successfully applied, it must be both rigorous enough to be defensible and simple or general enough to be practically applicable in a wide range of situations. Thus, the review should not only explore the methods themselves, but also how they have been adopted and integrated into the regulatory processes of adjacent industries.

2.4 Some examples of accepted structural design and assessment methods applied in the pipeline and pressure vessel industries include:

2.4.1 **Prescriptive risk-based / limit state design criteria.** This approach seeks to provide prescriptive design criteria such that all infrastructure following the criteria will operate with a consistent, generally acceptable, level of risk. Ideally, it follows a very simple and practical process that eliminates over- and under-conservatism that may result from the use of conventional experience-based design criteria. An example from the pipeline industry is the safety class system being introduced as an optional design method in Annex C of CSA Z226. (1,2)

2.4.2 **Quantitative risk-based design and assessment guidance, with established risk targets**. This is a more rigorous method that is broadly applicable to all designs. Guidance may include instructions that outline the required steps and considerations needed to ensure that the characterization of risk is complete and sufficiently objective to be compared with targets. Risk targets should be calibrated to ensure that the risk is either broadly acceptable or as low as reasonably practicable (ALARP). These risk targets may be based on the generally accepted risk implied by current design codes, historical failure data, or cross-industry risk comparisons. An example from the pipeline industry is the quantitative risk assessment guidance and individual, societal, and environmental risk targets being introduced as an optional assessment method in Annex B of CSA Z662. (1,3)

2.4.3 **Quantitative reliability-based design and assessment guidance, with established reliability targets**. This method is similar to quantitative *risk-based* design and assessment, but simplifies the process by focusing upon *reliability* (i.e. the complement of failure rate). A conservative dependency may be established between reliability targets and parameters that are highly correlated with failure consequences (e.g. product type, containment pressure, vessel size), allowing failure consequences to be accounted for by proxy. An example from the pipeline industry is the reliability targets for leakage, ultimate, and serviceability limit states included as optional design criteria in Annex O of CSA Z662. (1,4) These reliability targets vary with pipeline pressure, diameter, product type, and surrounding population density.

2.4.4 **Quantitative or semi-quantitative risk-based inspection (RBI) procedures**. This method applies quantitative or semi-quantitative risk estimates to inform inspection procedures. RBI assessments may include identifying risk drivers, selecting inspection methods, defining inspection extent, defining re-inspection intervals, and quantifying residual risk remaining after inspection. Examples of industry standards applying this approach in the pipeline and pressure vessel industry are API 580 and API 581. (5,6)

2.5 The following examples illustrate ways in which successful and practical application of the above-described design and assessment methods may streamline innovation and regulatory approval of marine vessels designed to use or transport alternative fuels:

2.5.1 **Unconventional threats**. Use and transportation of alternative fuels introduces safety threats (e.g. due to product toxicity or fire/explosion behaviour upon release) that differ from threats associated with conventional fuels. Therefore, existing prescriptive design constraints used to mitigate conventional threats may not be applicable. The use of a quantitative risk-based design and assessment method, with established risk targets, would allow these threats to be assessed and mitigated in a structured and comprehensive fashion to demonstrate compliance with accepted standards of safety, i.e. by providing a standard of evidence required to demonstrate safety and a framework for how to produce that evidence.

2.5.2 **Design using novel materials.** Due to compatibility requirements, the use and transportation of alternative fuels may require novel/specialized materials. In accordance with the previous point, such materials may be susceptible to unconventional threats (i.e. unconventional damage mechanisms and failure modes). Additionally, such novel materials may introduce unique design constraints for economically practical use. This may include design geometries/configurations that cannot be anticipated by prescriptive design rules. Moreover, these designs may pose difficulties for applying standard maintenance and inspection processes. The use of quantitative or semi-quantitative risk and reliability targets decouple design requirements from standard design geometries, maintenance, and inspection requirements. For example, structural reliability methods could be used to inform quality assurance/control requirements during construction to limit the size and frequency of resident manufacturing flaws such that the reliability of the novel design will be equivalent to a standard geometry with standard maintenance and inspection practices designed to code.

2.5.3 **Structural health monitoring systems.** The use of advanced structural health monitoring systems is one way to mitigate any additional risk due to unconventional fuels. Quantitative or semi-quantitative risk and reliability guidance and criteria can help demonstrate the effectiveness, or prescribe the minimum-required performance, of structural health monitoring systems. For example, the ability of the system to detect sub-critical damage may be evaluated such that the probability of significant/catastrophic failure is sufficiently low to meet a reliability target.

2.5.4 **Repurposing/conversion of conventional designs and existing assets.** The introduction of alternative fuels may be facilitated by the repurposing/conversion of existing designs and assets, rather than exclusively designing and constructing new assets. This conversion will require an assessment of existing damage, especially that which might be exacerbated by interaction with an alternative fuel (for example, hydrogen is known to increase the threat of crack-like flaws in steel). Common practice sometimes allows such conversion by using conventional design constraints with greatly increased safety factors. However, this approach may lead to prohibitive level of over-conservatism, making conversion of existing assets uneconomical. Risk- and reliability-based methods allow for the safety of repurposing/conversion to be demonstrated so that over-conservatism may be avoided. These methods may also inform what modifications might be appropriate/necessary if the safety of using the original asset or design is not demonstrated.

3.0 REQUIREMENTS.

3.1 Scope.

3.1.1 The Contractor shall work with the Project Technical Committee to **identify the key challenges in the marine vessel industry** that would benefit most from this project.

3.1.2 The Contractor shall **perform a review of relevant publications** and standards in the marine vessel industry, as well as in adjacent industries.

3.1.3 The Contractor shall **identify notable methods** that are successfully applied in adjacent industries, but not yet successfully applied in the marine vessel industry.

3.1.4 The Contractor shall **evaluate the feasibility of applying the notable methods** to the marine vessel industry.

3.2 Tasks.

3.2.1 The Contractor shall work with the Project Technical Committee to identify the key challenges in the marine vessel industry that would benefit most from this study.

3.2.2 The Contractor shall review applicable methods currently available in publications and standards of the marine vessel industry.

3.2.3 The Contractor shall review applicable methods currently available in publications and standards of the pipeline and pressure vessel industries.

3.2.4 The Contractor shall document and present the preliminary findings of Tasks 3.2.1 to 3.2.3 as part of the first quarterly update.

3.2.5 The Contractor shall identify notable methods that are successfully applied in the pipeline and pressure vessel industries, but not yet applied in the marine vessel industry.

3.2.6 The Contractor shall evaluate the feasibility of applying the notable methods to the marine vessel industry.

3.2.7 The Contractor shall synthesize the findings of Tasks 3.2.1 to 3.2.7, including any feedback on preliminary findings from the Project Technical Committee.

3.2.8 The Contractor shall document the findings in a Final Report.

3.3 Project Timeline: See Enclosure A

4.0 GOVERNMENT FURNISHED INFORMATION.

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

5.0 DELIVERY REQUIREMENTS.

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 final presentation with key research findings to the Project Technical Committee, the Ship Structure Committee Executive Director, and the Contract Specialist based on the project results.

5.3 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 PERIOD OF PERFORMANCE.

6.1 Project Initiation Date: date of award.

6.2 Project Completion Date: 6 months (26 weeks) from the date of award.

7.0 GOVERNMENT ESTIMATE. These Contractor direct costs are based on previous project participation expenses.

7.1 Project Duration: 6 months (26 weeks).

7.2 Total Estimate: $50,000

7.3 The Independent Government Cost Estimate: To be provided with full proposal.

8.0 REFERENCES.

1. CSA Group. Oil and gas pipeline systems. Toronto (ON): CSA Group; 2019. CSA Z662-19.
2. Adianto R, Nessim M, Ngandu B. Risk-based hoop stress factors for pressure design. Proceedings of the International Pipeline Conference; 2022 Sep 26-30; Calgary, AB. New York (NY): American Society of Mechanical Engineers; 2022. IPC2022-86815.
3. Nessim M, Kariyawasam S. Safety risk acceptance criteria for pipelines. Proceedings of the International Pipeline Conference; 2020 Sep 28-30; online. New York (NY): American Society of Mechanical Engineers; 2020. IPC2020-9274.
4. Nessim M, Stephens M, Adianto R. Safety levels with the ultimate limit state reliability targets in Annex O of CSA Z662. Proceedings of the International Pipeline Conference; 2012 Sep 24-38; Calgary, AB. New York (NY): American Society of Mechanical Engineers; 2012. IPC2012-90450.
5. [API] American Petroleum Institute. Risk-based inspection. 3rd ed. Washington (DC): API; 2016. API Recommended Practice API 580
6. [API] American Petroleum Institute. Risk-based inspection methodology. 3rd ed. Washington (DC): API; 2016. API Recommended Practice 581.

9.0 SUGGESTED CONTRACTING STRATEGY.

9.1 A Contractor, or collaborative group of Contractors, should be sought that has experience in the marine vessel, pipeline, and pressure vessel industries so that insights might be drawn from multiple industries and synthesized.

Enclosure A: Project Timeline

	Week												
Task	1-2	3-4	5-6	7-8	9-10	11-12	13-14	15-16	17-18	19-20	21-22	23-24	25-26
3.2.1													
3.2.2													
3.2.3													
3.2.4													
3.2.5													
3.2.6													
3.2.7													
3.2.8													
Report / Update							x						x