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Research summary – Marine Transport of Energy Storage Systems: Hazard Assessment and Regulatory Analysis

Transportation of Dangerous Goods | Research Development, Promotion and Coordination Division

SUMMARY

This research evaluated the hazards of commercially available energy storage system (ESS) types for transportation by the marine mode in enclosed vessel spaces according to the current *International Maritime Dangerous Goods* (IMDG) *Code.* Enclosed spaces, such as container cargo holds or closed roll-on/roll-off (ro-ro) spaces, were considered. In the context of this hazard assessment study, the ESS types considered are those being transported as dangerous goods (i.e., not used for propulsion of the vessel). Research results indicate that these commodities are viewed as posing a high degree of hazard given the current regulatory requirements, which has led to shippers taking precautions above and beyond what is prescribed by the current regulations.

BACKGROUND

An energy storage system is defined as an energy storage device consisting of an outer casing containing a large-format power cell (e.g., battery) as well as the necessary ancillary subsystems for physical support, protection, thermal management, and control. As many of these systems are manufactured overseas, they will likely be transported globally to Canada and other countries as cargo by the marine mode. These systems may also be transported within Canada on marine vessels. Given the confined nature of a vessel's cargo hold, the restricted access or inaccessibility to the area by response personnel, and the reduced number of response resources at sea compared to on land, an incident at sea where an ESS becomes unstable (e.g., catches fire or releases hazardous gases or liquids) could require a different response than those for land-based incidents. Consequently, it is imperative to perform a proper evaluation of the hazards these ESS may pose during a marine voyage and determine any knowledge gaps and potential issues to ensure that a proper regulatory framework for their transport is in place to promote public safety.

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OBJECTIVE

The objective of this research was to conduct a hazard assessment of ESS in enclosed cargo spaces during marine transport.

METHODS

Commercially available ESS types and related regulations were reviewed. Information on the various vessel types and the physical and chemical properties of each identified ESS type were gathered. Using all this information, a hazard assessment (HAZID) was conducted to identify possible failure modes for each type of ESS and potential consequences, along with a review of existing safeguards designed to mitigate the risk for the identified hazardous scenarios. Based on input from the HAZID workshop, interviews with subject matter experts, and insights from those with experience shipping ESS via marine vessels, knowledge gaps and regulatory elements were identified, and possible paths forward were suggested with an aim to increase safety.

RESULTS

The analysis resulted in the following key findings regarding transport of ESS by the marine mode:

- A survey of commercially available ESS revealed that there are seven (7) types based on different power cell technologies, including: lithium ion batteries (LIB), sodium ion batteries (SIB), lead-acid and nickel-based, zinc-based, and sodium-based batteries (excluding SIBs), flow batteries, electro-chemical capacitors, phase-change materials (PCM), and thermochemical heat storage (TCHS).
- Most of the input suggested that LIBs are the primary area of concern for marine transport. There are a number of abuse conditions that have the potential to disrupt the typically balanced chemical structures of LIBs which, in turn, can generate enough heat to trigger exothermic chemical reactions that can lead to thermal runaway. Thermal runaway, characterized as an uncontrolled self-heating phenomenon, may result in fire or explosion due to the release of flammable and possibly toxic gases. The severity and intensity of thermal runaway in a LIB is dependent on its state of charge (SOC). LIBs are transported with a non-zero SOC, so this hazard is still present during transport.
- Although SIBs are new to the market, evidence suggests they pose many of the same hazards as LIBs in their worst-case scenarios. However, some types of SIBs are more stable in regard to thermal runaway and can be transported at 0% SOC, which lowers the safety risk considerably.
- The main hazard identified for ESS consisting of lead-acid batteries, nickel-based batteries, zinc-based batteries, sodium-based batteries, or flow batteries during marine transport was the hazard posed by their specific electrolytes. The electrolytes (if regulated) and the batteries are addressed in the IMDG Code when they are transported separately. However, these ESS types cannot be transported as a complete cargo transport unit (CTU)-sized ESS under current regulations. In countries where the transport of such ESS types is contemplated, authorities may evaluate requests for alternative compliance measures for their safe transport.

- Electro-chemical capacitors must be either non-hazardous or part of a power-optimized ESS (i.e., covered through the other ESS included in this study). The potential for capacitors to self-discharge is high, so they are transported at close to 0% SOC.
- PCM and TCHS type ESS were included in the scope of this study, but the hazards they pose are very technology-specific depending on the actual chemicals being used. Therefore, it was not possible to list any general hazards for these ESS types.

Findings that could potentially impact the safe transport of ESS included:

- The SOC is an important risk factor for many types of battery energy storage systems (BESS). The higher the SOC, the more sensitive and reactive the BESS will be. Some types of BESS can be transported at 0% SOC without being damaged, which lowers the hazards and risks they pose considerably. Despite this fact, the SOC is not currently regulated for transport in the IMDG Code. However, targeting an SOC of approximately 30% for LIBs classified as UN 3480 and UN 3481 in some instances is a common best practice, and it is mandatory for air transport in accordance with the International Civil Aviation Organization (ICAO) *Technical Instructions for the Safe Transport of Dangerous Goods by Air*.
- While the IMDG Code permits stowing BESS under deck, interviews with manufacturers and shipping operators revealed that the preferred practice is shipping LIBs on deck for containerships or in a ro-ro space. Justification for this position is provided in the following points, which were expressed during the HAZID and interviews, and echoed in the knowledge gap and regulatory analysis of this project:
    - The crew is typically not allowed in containership cargo holds, which means that they cannot inspect the cargo or take any manual action in case of emergency apart from discharging the available fixed fire-extinguishing systems, most commonly carbon dioxide systems, which might not be effective on battery fires and represent a one-shot mitigation approach.
    - Ro-ro spaces and cargo spaces on deck can be inspected, making manual mitigation measures possible. Fixed fire-extinguishing systems, most often water-based systems, are also available in ro-ro spaces.
    - If a BESS goes into failure mode, many will vent gases, including hydrogen and methane, which can accumulate in enclosed spaces and create an explosive atmosphere.
- The detection of ESS failures and onboard firefighting response capabilities that meet the current minimum requirements are insufficient in enclosed cargo spaces for the hazards that ESS represent. Based on interviews with vessel operators, it has been determined that enhanced means of detection and evaluation of

hazardous conditions within cargo containers or cargo spaces should be considered. Examples of such means include fixed and manual gas detection, as well as infrared (IR) cameras. Firefighting response tools are not currently regulated for specific ESS cargoes, so additional tools and practices could also be considered.
- There is uncertainty regarding the requirements for the outer housings of large-format LIB ESS. The outer housing of ESS transported under UN 3536 “Lithium batteries installed in cargo transport unit: lithium-ion batteries or lithium metal batteries,” might not necessarily comply with the same requirements as a freight container, and the regulations for outer housings are ambiguous.
- Shipping lines expressed concern with transporting used or recycled batteries.

CONCLUSION

An overarching finding from this project is the recognition that most vessels and protective systems (fire safety, detection, suppression, protection, etc.) have not been designed for these particular types of dangerous goods, based on a review of the literature, incidents, and regulations, completion of the HAZID, and interviews with both manufacturers and vessel operators. Specifically, these vessels are not uniquely designed to facilitate or address the need to safely manage explosion hazards or handle the significant amounts of firefighting water that would be required in the event of an ESS-related incident. In addition, vessel crews have not universally received sufficient training to enable them to safely and effectively respond to an incident, given the lack of a means for early detection and the limitations associated with the current means for fire suppression.

In light of the above findings, the research concluded that ESS shipped as cargo in enclosed spaces aboard vessels are viewed as posing a high degree of risk. Manufacturers and vessel operators take additional precautions regarding ESS stowage location.

FUTURE ACTION

Transport Canada (TC) will use the findings from this research to inform discussions regarding this topic with various regulatory bodies for the transportation of dangerous goods by the marine mode.

REFERENCES

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CONTACT

To obtain a copy of the report, please contact us:

TDG Research Development, Promotion and Coordination Division
TC.TDGResearchDevelopment-DeveloppementderechercheTMD.TC@tc.gc.ca

KEYWORDS

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