# Attachment E:

# Preliminary HAZID for Emission Control Barge
# (“ABS Study”)

TECHNICAL REPORT:
TR-2021- 4572251-1 Rev 4

# Preliminary HAZID for Emission Control Barge

Date: 28 July 2022

SUBMITTED TO:
**STAX Engineering**

SUBMITTED BY:
American Bureau of Shipping
1701 City Plaza Dr,
Spring, TX 77389

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The mission of ABS is to serve the public interest as well as the needs of our members and clients by promoting the security of life and property and preserving the natural environment.

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We will respond to the needs of our members and clients and the public by delivering quality service in support of our Mission that provides for the safety of life and property and the preservation of the marine environment. We are committed to continually improving the effectiveness of our health, safety, quality and environmental (HSQE) performance and management system with the goal of preventing injury, ill health and pollution. We will comply with all applicable legal requirements as well as any additional requirements ABS subscribes to which relate to HSQE aspects, objectives and targets.

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## Revision History

| Revision | Date | Description |
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| 0 | 02-Jul-2021 | Initial Preliminary Release for feedback/comments |
| 1 | 6-Jul-2021 | Client feedback and comments addressed |
| 2 | 30-Sep-2021 | 2nd HAZID workshop input |
| 3 | 10-Jan-2022 | Client comment and internal comment addressed |
| 4 | 28-Jul-2022 | Client comments addressed |

## Executive Summary

ABS was selected by STAX Engineering to perform a preliminary Hazard Identification (HAZID) study as part of the safety assessment for the application of a capture and control system (C&C system) as an Alternative Emission Control Technology for tanker vessels calling at California ports. The C&C system is to be placed on a barge moored near a tanker vessel and will connect its capture arm to the exhaust pipe of the tanker vessel to capture exhaust gas and divert to a purification unit mounted on the barge. ABS facilitated a What-if/Hazard identification (HAZID) assessment for various operational scenarios of barge to identify major hazards.

The What-if/Hazard Identification (HAZID) assessment was undertaken for the concept design stage of the barge-based C&C system. A multi-disciplinary team from STAX Engineering, Marathon Petroleum / Tesoro Logistics (TLO), South Coast Air Quality Management District (South Coast AQMD), California Air Resources Board (CARB) and American Bureau of Shipping (ABS) participated in the HAZID workshop conducted on 30 June 2021 through an online web meeting. The workshop was facilitated and scribed by ABS. Refer to Table 3 and Table 4 for a list of attendees.

After the initial release of this report a second workshop was conducted on 30 September 2021 through an online web meeting to obtain additional input. This workshop included additional participants from USCG, Marathon Petroleum and Crowley Marine. This report has been updated to reflect the additional input.

Using structured brainstorming, potential safety, health, and environmental impacts to the asset (the tanker) and its operations were documented by the multi-disciplinary team. Asset loss or operational risks were considered only in the context of abnormal operations with potential major impacts to Safety, Health, and Environment.

The C&C system barge will be positioned near the tanker during C&C operation. The power for operating the capture arm and the C&C system is supplied from the power source on the barge. The study considered a total of five operating configurations (scenarios) of the barge relative to the tanker and interface with the tanker/barge system. Various operational aspects were studied in the workshop to identify safety concerns related to activities such as barge mooring, C&C connection, tanker operations, C&C disconnect, unmooring the barge and departure, and support by tug.

For each of the five operating configurations consideration was given to normal, upset and emergency operation with respect to internal/external hazards and attention to tanker safety as it contains hazardous cargo. A few of the risks identified were not ranked but the activities associated with those scenarios were discussed and where feasible recommendations were recorded. As the design

progresses the risks identified in the HAZID Register (Appendix E) are to be addressed, considering the recommendations noted in this report.

Eight (8) system and operational level nodes listed in section 2.7 and Appendix D, along with various scenarios for each nodes were discussed and seventy four (74) recommendations documented in the report based on the scenarios identified during the HAZID workshop (see Table 6). The HAZID register created during the workshop identifies the hazards and documents the recommendations captured during the discussions. There were twenty-one (21) high risk ranked scenarios initially identified in the five mooring scenarios that will require mitigation as the design progresses. See summary in Table 1, below.

| Key system level HAZID nodes | Risk Ranking of Hazards Identified | | | |
|---|---|---|---|---|
| | Low | Medium | High | Extreme |
| Scenario 1: Barge moored alongside of tanker | 3 | 14 | 4 | 0 |
| Scenario 2: Barge spudded alongside of tanker | 10 | 11 | 5 | 0 |
| Scenario 3: Barge spudded off stern quarter | 11 | 12 | 2 | 0 |
| Scenario 4: Barge spudded astern of tanker | 9 | 9 | 1 | 0 |
| Scenario 5: Barge tied to pier astern of tanker | 9 | 12 | 6 | 0 |
| Structure | 1 | 1 | 2 | 0 |
| Safety System | 1 | 3 | 1 | 0 |
| Deck System | 1 | 2 | 0 | 0 |

**Table 1: HAZID Risk ranking summary**

There were no unresolvable or unmitigable risks identified during the HAZID that would prevent further successful development of the concept. The high risk-ranked scenarios were mostly related to barge mooring and positioning.

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# 1 Introduction

ABS was contracted by STAX Engineering to facilitate risk assessment for the application of a capture and control system (C&C system) as an Alternative Control Technology for tanker vessels to meet the emission standards set for auxiliary engines and boilers in the amended CARB At Berth Regulation (CCR Title 17 Sections 93130 through 93130.22) adopted in August 2020.

The tanker vessel will have crude oil and petroleum product as a cargo and may be unloading or loading cargo at terminal. A C&C connect system and purification units are installed on a barge, with a size of approximately 160’ X 40’. The barge will be towed to operation site by tug, with the tug connected to the barge in a side-by-side configuration for tow. The barge will be located in various positions alongside or aft of the tanker during C&C operation.

A C&C system will connect its capture arm to the exhaust pipes to capture exhaust gas and divert it to a purification unit to remove NOx, PM2.5, reactive organic gases (ROG) and diesel particulate matter (DPM) emissions. It is also required to reduce greenhouse gas (GHG) emissions that are generated by the C&C system using a grid-neutral strategy to avoid a net increase of GHG based on the grid emission rate. The requirement is that the barge will operate at an equivalent GHG emission rate as the California Grid. The generation of electricity on the barge should not increase GHG any more than if the electricity were provided by the grid.

The purpose of this study is to identify potential hazards relative to operational configuration of barge and tanker vessel at early stage of concept development, review the effectiveness of selected safety measures and, where required, incorporate safety measures to achieve a tolerable residual risk. This report provides the process and results of the preliminary HAZID study conducted through an online meeting conducted on 30 June 2021 and a second online meeting conducted on 30 September 2021. The initial meeting attendees included South Coast AQMD, STAX Engineering, Marathon Petroleum / Tesoro Logistics (TLO), California Air Resources Board (CARB) and American Bureau of Shipping (ABS). The subsequent meeting included USCG, Marathon Petroleum and Crowley Maritime. Both workshops were facilitated and scribed by ABS. Refer to Table 3 and Table 4 for a list of attendees.

## 1.1 Concept of Operations (CONOPS) for Emissions Control Barge

South Coast AQMD and STAX Engineering along with their partners are designing a barge with a capture arm to capture exhaust gas from the tanker vessel exhaust pipes and divert it to a purification unit from auxillary engine and boilers. This barge is to be operated in a port where tanker vessels are berthed for cargo operations. The details of the CONOPS are as follows:

- Tanker vessel moors to the terminal
- Once moored, a small tug places the barge in position (barge is waiting)
- Barge is either moored or spudded
- The tug departs, and remains on call
- The system is connected to the active exhaust (typically within an hour after mooring)
- The system begins controlling emissions (typically within 10 minutes of connecting)
- The barge and arm are constantly monitored and compensated for relative motion
- The barge maintains constant communications with tanker and terminal personnel
- The tug returns approximately an hour prior to departure and is secured to the barge
- Once the tanker vessel completes its cargo operations, the C&C arm is disconnected (approximately 30 minutes before departure)

- The tug moves the barge away (the arm can be moved while extended)

The CONOPS considers five (5) operational scenarios based on the positioning of the barge with respect to the tanker vessel. These scenarios are as follows:

- Scenario 1: Barge Tied Alongside Tanker vessel
- Scenario 2: Barge Spudded Alongside Tanker vessel
- Scenario 3: Barge Spudded Off Stern Quarter of Tanker vessel
- Scenario 4: Barge Spudded Astern of Tanker vessel
- Scenario 5: Barge Moored Astern of Tanker vessel

## 1.2 Acronym List

| | |
|---|---|
| ABS | American Bureau of Shipping |
| AQMD | Air Quality Management District |
| C&C | Capture and Control |
| CA | California |
| CARB | California Air Resources Board |
| CONOPS | Concept of Operations |
| DPF | Diesel Particular Filter |
| E-Stop | Emergency Shutdown |
| FF | Fire Fighting |
| FFA | Fire Fighting Appliances |
| HAZID | Hazard Identification study |
| JSA | Job Safety Analysis |
| LA | Los Angeles |
| LB | Long Beach |
| LEL | Lower Explosion Limit |
| LSA | Life Saving Appliances |
| MBR | Maritime Broadband Radio |
| MSDS | Material Safety Data Sheet |
| NOx | Nitrogen Oxides |
| OSHA | Occupational Safety and Health Administration |
| PM | Particulate matter |
| POLA | Port of Los Angeles |
| POLB | Port of Long Beach |
| PST | Pacific Standard Time |
| RCC | Remote Control Center |
| ROG | Reactive Organic Gases |
| SCR | Selective Catalytic Reduction |
| USCG | United States Coast Guard |
| VHF | Very High Frequency |

# 2 HAZID Study - Approach

The Hazard Identification (HAZID) study is a technique for early identification of hazards and threats, and can be applied at the conceptual or detailed design stage. Early identification and assessment of hazards provides essential input to concept development decisions at a time when a change of design has a minimal cost penalty. A HAZID study is carried out by an experienced multi-discipline team using a structured approach based on a checklist of potential hazards. Potential problems are highlighted for action outside the meeting. Typical hazards considered include environmental, geographical, process, fire and explosion, and health.

This HAZID study is a preliminary study based on the concept proposed in the objectives and scope sections of this report.

## 2.1 HAZID Objectives

The preliminary HAZID study identified the risks of a barge performing Emission Control Operation on tanker vessels berthed at an oil terminal in port while loading/unloading oil. Furthermore, the study verifies the proposed concept will satisfy the intent of all goals and functional requirements in concept of operation document. The study also provided recommendations to mitigate risks arising from such concept by reviewing provisions or absence of adequate safety barriers / requirements. The study objectives were to:

1. Identify hazards associated with the Oil Tanker Emission Control Operation at oil terminal in port while loading/unloading oil.
2. Develop hazard scenarios related to operations and identify potential causes, assess the related consequences, and identify the existing safeguards that can eliminate, mitigate or control the hazard and its consequences.
3. Suggest opportunities of alternative options towards an inherently safer design or identify risk mitigation measures to reduce, replace or transfer the estimated risk.
4. Determine potential consequences of the hazards.
5. Propose recommendations, as needed, to eliminate, prevent, control, or mitigate hazards.
6. Provide early safety and risk input into design and safety management requirements.
7. Compare operational scenarios to current practice.

The outcome of the study is the hazard register which includes the following:

- Potential hazardous scenarios developed including causes, consequences, and existing safeguards.
- The risk of each developed scenario was evaluated with respect to severity of the consequence and likelihood based on experience or participant or data available.
- Opportunities for safer design or risk mitigation measures to reduce the estimated risk.

## 2.2 HAZID Study Procedure

The study method is a combination of identification, analysis and brainstorming by the HAZID team members. Guidewords were used in order to identify possible potential and hazardous effects as well as threats as noted in 2.3.1 and 2.3.2. Furthermore, the team analyzed the appropriate controls that should be put in place in order to prevent or control each identified threat.

The analysis of HAZID was conducted on a session basis, grouping the study in various arrangements, processes, and operations.

## 2.3 HAZID Scope

As stated earlier this concept study is divided into various phases. This preliminary HAZID study scope covers only concept of operation related hazards for various operating configurations of barge with respect to tanker vessel.

The scope focused on the hazards related to:

- Concept of operation for barge with respect to tanker vessel
- Barge mooring arrangement and procedure
- Various modes of operation and operational procedure – normal, upset and emergency in each mode of operation
- Operation of emission control barge with oil tanker in port
- Emergency on oil tanker or barge
- Barge/tanker support - tug
- Weather and external event
- Communication and vision
- Safety systems

### 2.3.1 Grouping of Systems/Areas for HAZID

The modes of operation considered were as follows:

- Barge moored alongside of tanker
- Barge spudded alongside of tanker
- Barge spudded off stern quarter at any angle to the vessel
- Barge spudded astern of tanker
- Barge tied to pier astern of tanker

Among the details of operation, considerations were given to:

- Barge arrival to tanker
- Mooring of barge – spudded, mooring with tanker, mooring with pier
- Hooking up control arm with tanker exhaust
- Detaching control arm from tanker exhaust
- Barge departure
- Tug support
- Emergency/upset situation

### 2.3.2 Hazards

The list of hazards used to guide the team in identifying potential loss scenarios were as follows:

## A. Internal Hazards

- Sensor error/failure
- Loss of communication
- Data error
- Power failure
- Software malfunction
- Technical fault e.g., mechanical failure, equipment failure
- Fuel, oil hazard
- Human error
- Navigation equipment failure
- Position reference equipment failure
- Vision equipment failure/error
- Loss of system control
- Flooding
- Fire risk
- Ignition of electrical equipment or wiring
- Ergonomic hazard

## B. External Hazards

- Oil and liquid hydrocarbon product vapor
- Hydrogen Sulfide ($H_2S$)
- Severe weather, Heavy weather/sea conditions/rain/fog/wind
- Strong current
- Waterway navigation – other vessel, shallow water, underwater object, obstacles, floating object
- Mooring
- Humidity
- Sun light, glare, rain, fog etc.
- Cybersecurity risk

## C. Example List of Hazards

Examples of Hazards are listed below:

- Contact with pier
- Collision/ allisions / contact
  - Tanker
  - Barge
  - Tug
  - Pier
- Another vessel
- Spud failure
- Mooring line failure
- Tow line break
- Propeller entanglement
- Control arm failure
- Emission control system failure
- Fire/explosion on tanker / barge
- Oil release tanker/oil pollution
- Emergency on port
- Grounding
- Lost stability or capsizing imminent
- Flooding
- Capsizing/sinking
- Lost weathertight integrity (Weather damage)
- Structural failure/ damage control
- Power blackout
- Temporary or degraded or permanent loss of connectivity/communication
- Loss of communication / control (e.g., missing camera stream from certain cameras, obstruction, restricted view

## 2.4 Assumption

There were a number of critical assumptions made during the workshop. They are based on current documentation. Most assumptions are considered as safeguards in the workshop records. The critical assumptions noted were as follows:

1. Barge will be designed and built-in compliance with Class / Statutory regulations, as applicable.
2. Barge will be manned by a 2-person crew.
3. Barge will comply with port authority requirements.
4. Barge has two spud system.
5. Barge crane and capture arm will be design, built to appropriate recognized standards.
6. Functionality of crane boom will be fully qualified by appropriate verification and validation.
7. Barge has no accommodation.
8. Barge has rest area for crew.
9. Crew transfer will be by small boat.
10. Tug on standby and available for service at request from barge.
11. Barge will have permanent ballast and no ballast operations required.
12. Barge will comply with all regulatory requirements.
13. C&C system hood and related arm has no physical contact or connection with the tanker vessel funnel/exhaust stack.
14. Chemical tanker is not within the scope of study

## 2.5 Methodology

A HAZID is an extremely useful tool for undertaking high level risk assessments of specific systems. ABS has used this approach in numerous risk assessment projects, both as a standalone approach, and for comparative purposes for assessing similar situations.

The study started by identifying the major hazards associated with normal operations of the barge and aspects of operation being controlled by the Remote-Control Center (RCC). Findings of the workshop were recorded into a HAZID Register.

A facilitated preliminary HAZID study was conducted on June 30, 2021, from 0900 to 1700 hours PST. A second workshop was held on 30th September 2021 with additional participant. Both workshop was held using the Microsoft Teams online meeting platform. After the workshop, a brief review was conducted with the participants. See session details and schedule in the following sections of this report. Overall HAZID flow diagram is shown in Figure 1.

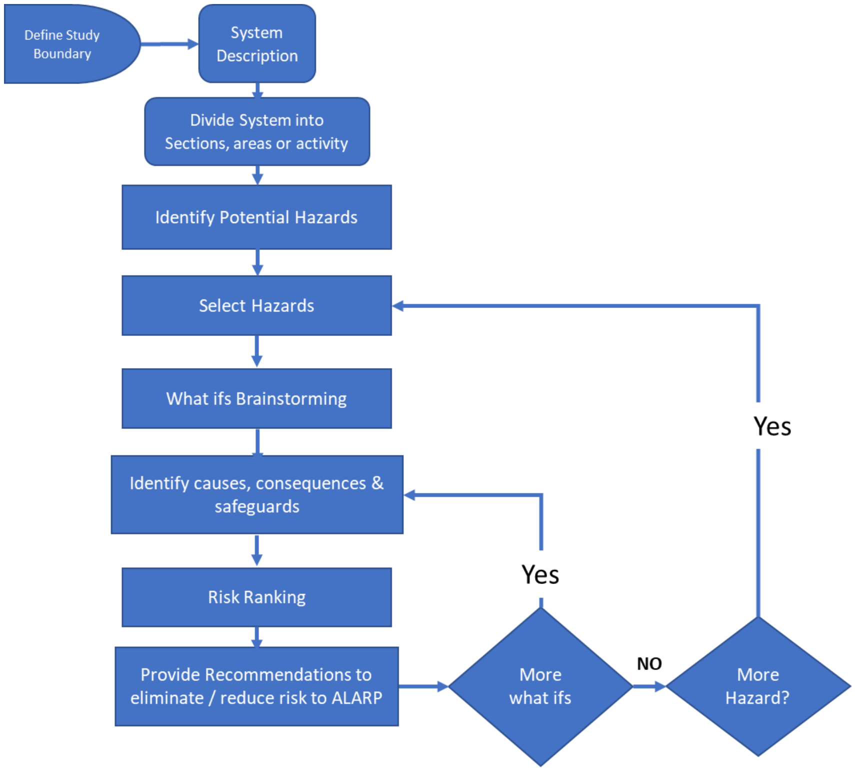



**Figure 1: HAZID Process**

During the workshop, an ABS facilitator guided subject matter experts through a structured discussion to identify and risk-rank hazards. Participants were asked to provide input on the preloaded scenarios (e.g., modifying, adding, or removing risk scenarios) within the hazard register as well as discussing the location of the scenario on the risk matrix. The discussions by participants guided the focus areas, nodes and relevant hazards to be considered to confirm study completeness.

## 2.6 Risk Ranking

A risk matrix located in Appendix B, was used in the study for evaluating the risk of each identified hazardous scenario at a high level.

The risk-ranking procedure used is as follows:

- **Consequence review:** For the worst most credible undesirable outcome on each scenario, the team determined its location along the consequence axis.
- **Likelihood review:** The team determined the location along the frequency axis for the undesired final outcome, considering the probability of failure of the various preventive, detection and recovery safeguards designed to ensure that the final outcome does not take place.
- **Risk:** The intersection of the likelihood and consequence selections indicates the risk of that particular hazardous scenario.

- **Action**: Use the risk ranking to help to assess whether the current controls and safeguards are considered adequate, if not then look to identify additional safeguards/controls to help reduce the risk (or identify areas where further review or analysis is required to better understand the risk and potential mitigating measures) and record these as 'Actions'.

## 2.7 System and Operational Level Nodes

The following major nodes at system and operational level nodes were considered for the preliminary HAZID study based on information made available and discussions.

1) Modes of operation
    - Scenario 1: Barge moored alongside of tanker
    - Scenario 2: Barge spudded alongside of tanker
    - Scenario 3: Barge spudded off stern quarter (can be rotated)
    - Scenario 4: Barge spudded astern of tanker
    - Scenario 5: Barge tied to pier astern of tanker
2) Barge mooring and operation details (included mostly in operational scenarios)
    - Barge arrival to tanker
    - Mooring of barge – spudded, mooring with tanker, mooring with pier
    - Positioning of control arm with tanker exhaust
    - Retrieval of control arm from tanker exhaust
    - Barge departure
    - Tug support
    - Upset Situation – parameter outside normal operating condition
        - Barge
        - Tanker
3) Emergency Situations and Failures including structure
    - Fire / explosion / any situation requiring evacuation.
    - Fire on barge
    - Structural failure on barge
    - Spud's failure
    - Tanker - oil spill
    - Fire on tanker
    - Tanker mooring line failure
    - Emergency disconnect
4) Safety System
    - Firefighting
    - Communication
5) Deck System
    - Spud winch failure
    - Mooring winch failure
    - Control arm failure

## 2.8 Session and Participants

### 2.8.1 First Workshop

The HAZID study was held on 30 June 2021. Workshop was conducted remotely using Microsoft Team meeting, with participants from South Coast AQMD, STAX Engineering, Marathon Petroleum / Tesoro Logistics (TLO), CARB and ABS.

The session was attended by a team that had experience in both the design and operations of tankers and barges, emission control, port operations, and harbor operations related experience. The agenda is listed in Table 2.

**Table 2: HAZID Agenda**

| Topic | Lead | Time in PST |
|---|---|---|
| Safety Moment | ABS | 9:00 Am to 9:10 AM |
| Introduction | All | 9:10 AM to 9:30 AM |
| What-if/HAZID Presentation | ABS | 9:30 AM to 9:50 AM |
| Terminal Operation – ppt | STAX Engineering | 9:50 AM to 10:30 AM |
| Break | | 10:30 AM to 10:40 AM |
| HAZID Session - 1 | Facilitator: ABS | 10:40 PM to 12:00 PM |
| Break | | 12:00 AM to 1:00 PM |
| Summary / Recap | STAX / ABS | 1:00 PM to 1:15 PM |
| HAZID Session - 2 | Facilitator: ABS | 1:15 PM to 3:00 PM |
| Break | | 3:00 PM to 3:10 PM |
| Summary / Closing / Wrap up / Action Items | ABS | 3:10 PM to 4:00 PM |
| Reserved if needed | | 4:00 PM to 5:00 PM |

Mr. Harish Patel from ABS facilitated the study. Table 3 provides a complete listing of the HAZID study participants.

**Table 3: HAZID Participants**

| # | *HAZID Participant* | *Company / Organization* |
|---|---|---|
| 1 | Bob Sharp | STAX |
| 2 | John Holmes | STAX |
| 3 | Mike Walker | STAX |
| 4 | Randall Pasek | STAX |
| 5 | Rob McCaughey | Consultant |
| 6 | Mei Wang | South Coast Air Quality Management District |

| # | HAZID Participant | Company / Organization |
|---|---|---|
| 7 | Jacob Goldberg | Port of Los Angeles |
| 8 | Rose Szoke | Port of Long Beach |
| 9 | Jim Tomlinson | Marathon |
| 10 | John Schneider | Marathon |
| 11 | Mark H Nielsen | Marathon |
| 12 | Patrick G Kelly | Marathon |
| 13 | Amber Coluso | Port of Los Angeles |
| 14 | Dmitri Smith | California Air Resources Board |
| 15 | Jonathan Foster | California Air Resources Board |
| 16 | Nicholas Storelli | California Air Resources Board |
| 17 | Nicole Light Densberger | California Air Resources Board |
| 18 | Alex Huo | ABS |
| 19 | Harish Patel | ABS |
| 20 | Sameer Kalghatgi | ABS |

The discussions held during the study were recorded in worksheets to summarize the nature of the hazard, its causes and consequences, the safeguards in place, risk ranking, and recommendations for any actions required. The complete Hazard Register can be found in Appendix E.

### 2.8.2 Second Workshop

A second HAZID workshop was conducted with additional participants from USCG, Marathon Petroleum and Crowley Marine to obtain additional input on 30-September-2021. The workshop was conducted remotely using Microsoft Teams.

The session was attended by a team that had experience in both the design and operations of tankers and barges, emission control, port operations, and harbor operations. The agenda for second workshop was listed in Table 2, with the aim to update the HAZID report with input from the additional participants.

Mr. Harish Patel from ABS facilitated the study. Table 4 provides a complete listing of the HAZID Workshop 2 study participants.

**Table 4: HAZID Workshop 2 Participants**

| # | HAZID Participant | Company / Organization |
|---|---|---|
| 1. | Bob Sharp | STAX |
| 2. | John Holmes | STAX |
| 3. | Mike Walker | STAX |
| 4. | Rob McCaughey | Consultant |
| 5. | Mei Wang | South Coast Air Quality Management District |
| 6. | Elizabeth Melgoza | California Air Resources Board |
| 7. | Dmitri Smith | California Air Resources Board |

| # | *HAZID Participant* | *Company / Organization* |
|---|---|---|
| 8. | Nicholas Storelli | California Air Resources Board |
| 9. | Rose Szoke | POLB.com |
| 10. | Jim Tomlinson | Marathon Petroleum |
| 11. | John Schneider | Marathon Petroleum |
| 12. | Mark H Nielsen | Marathon Petroleum |
| 13. | Patrick G Kelly | Marathon Petroleum |
| 14. | Stephen D Ernst. | Marathon Petroleum |
| 15. | Kevin Schroder | Crowley Marine |
| 16. | Derek Walsh | Crowley Marine |
| 17. | Kelly Baughman | Crowley Marine |
| 18. | Griffin Patrick | Crowley Marine |
| 19. | Laura McCormack | Crowley Marine |
| 20. | Chip Perkins | Crowley Marine |
| 21. | Matthew Arnold | Crowley Marine |
| 22. | VSL American Freedom Cheng | Crowley Marine |
| 23. | Joshua Lordan | Crowley Marine |
| 24. | Thomas MacKrell | Andeavor.com |
| 25. | James Benjamin | Crowley Marine |
| 26. | Robert Cope | Crowley Marine |
| 27. | LCDR Tim McNamara | USCG |
| 28. | Alex Huo | ABS |
| 29. | Harish Patel | ABS |
| 30. | Nathan Seward | ABS |

The discussions held during the study were recorded in worksheets to summarize the nature of the hazard, its causes and consequences, the safeguards in place, risk ranking, and recommendations for any actions required. The complete Hazard Register can be found in Appendix E.

# 3 Conclusions and Recommendations

The overall project is at the preliminary concept stage and for the workshop to be practical certain conditions were assumed and are listed in Section 2.4. For some nodes not enough information was available resulting in no risk ranking of the hazards, but the activities associated with those scenarios were discussed, and where feasible, recommendations were made.

The results of the HAZID workshop are to be analyzed and incorporated during further development of the concept. Key findings from the Hazard register (Appendix E) are noted in section 3.1.

Eight (8) system and operational level nodes listed in section 2.7 and Appendix D, along with various scenarios for each nodes were discussed and seventy four (74) recommendations have been documented in the report based on the scenarios identified during the HAZID workshop (see Table 6). The HAZID register created during the workshop identifies the hazards and documents the recommendations captured during the discussions. Twenty-one (21) 'high' risk ranked scenarios identified and these will require mitigation as the design progresses. See summary in Table 5 below.

**Table 5: HAZID Risk ranking summary**

| Key system level HAZID nodes | Risk Ranking of Hazards Identified | | | |
|---|---|---|---|---|
| | Low | Medium | High | Extreme |
| Scenario 1: Barge moored alongside of tanker | 3 | 14 | 4 | 0 |
| Scenario 2: Barge spudded alongside of tanker | 10 | 11 | 5 | 0 |
| Scenario 3: Barge spudded off stern quarter | 11 | 12 | 2 | 0 |
| Scenario 4: Barge spudded astern of tanker | 9 | 9 | 1 | 0 |
| Scenario 5: Barge tied to pier astern of tanker | 9 | 12 | 6 | 0 |
| Structure | 1 | 1 | 2 | 0 |
| Safety System | 1 | 3 | 1 | 0 |
| Deck System | 1 | 2 | 0 | 0 |

There were no unresolvable or unmitigable risks identified during the preliminary HAZID that would prevent further successful development of the barge with emission control system.

## 3.1 Recommendations

The HAZID study recommendations are listed from the HAZID register (Appendix E) for the major nodes at system and operational level. These recommendations are based on the discussions with the participants of the preliminary HAZID study. The key recommendations are noted in the following section 3.1.1 and Table 6.

### 3.1.1 HAZID Recommendations

Table 6, below, provides a summary of the recommendations from HAZID register with applicable nodes for various HAZID scenarios.

**Table 6: HAZID Recommendations**

| System Level Nodes - Hazard Scenario | Recommendations (R#) |
|---|---|
| Node # 1: Modes of operation | **1** In next phase of study, it is recommended that experts from the Port of Long Beach, USCG, State Lands and vessel operator be invited. **[ Recommendation is resolved. Experts were invited and participated in the 2nd HAZID session held on September 30, 2021]**<br>2 Tug requirements to safely handle the barge are to be developed<br>3 The products carried on the tanker vessel need to be assessed for compatibility with barge safety and appropriate mitigation measures identified.<br>4 Once the design is developed, operational risk is to be assessed and operational procedures are to be developed.<br>5 Crew change procedures and communication with tanker to be developed. |
| **1.1 Scenario 1: Barge moored alongside of tanker**<br>1.1.1 Barge is brought alongside the tanker - Collision / Contact<br>**1.2 Scenario 2: Barge spudded alongside of tanker**<br>1.2.1 Barge is brought near the side of the tanker - Collision / Contact<br>**1.3 Scenario 3: Barge spudded off stern quarter (can be rotated)**<br>1.3.1 Barge is brought near the side of the tanker - Collision / Contact<br>**1.4 Scenario 4: Barge spudded astern of tanker**<br>1.4.1 Barge is brought near the stern of the tanker - Collision / Contact<br>**1.5 Scenario 5: Barge tied to pier astern of tanker**<br>1.5.1 Barge is positioned near the tanker - Collision / Contact | 6 Determine safe operating consensus with operators at each terminal prior to operation and ensure that these procedures are consistent with the Harbor Safety Plan.<br>7 STAX to evaluate barge procedures, maneuverability and control of barge by tug(s) for all operating conditions (e.g., high wind, high current, wave etc.). |
| **1.1 Scenario 1:** Barge moored alongside of tanker<br>1.1.1 Barge is brought alongside the tanker - Collision / Contact | 8 Conduct testing of side-by-side tanker mooring configuration. |
| **1.1 Scenario 1: Barge moored alongside of tanker**<br>1.1.2 Man overboard<br>**1.2 Scenario 2: Barge spudded alongside of tanker** | 9 Man overboard rescue procedures and training to be developed considering incident occurring |

<table>
<tr><th>System Level Nodes - Hazard Scenario</th><th>Recommendations (R#)</th></tr>
<tr><td>1.2.2 Man overboard<br>1.3 Scenario 3: Barge spudded off stern quarter (can be rotated)<br>1.3.2 Man overboard<br>1.4 Scenario 4: Barge spudded astern of tanker<br>1.4.2 Man overboard<br>1.5 Scenario 5: Barge tied to pier astern of tanker<br>1.5.2 Man overboard</td><td>inside oil containment boom area and outside boom containment area.</td></tr>
<tr><td>1.1 Scenario 1: Barge moored alongside of tanker<br>1.1.3.1 Release of Oil /petroleum products/chemical product from Vessel – Oil Hazards<br>1.1.3.4 - Release of Oil /petroleum products/chemical product from Vessel – Electrical Shutdown<br>1.1.4 Night operation<br>Loss of power and lighting at night<br>1.2 Scenario 2: Barge spudded alongside of tanker<br>1.2.3.1 Release of Oil/petroleum products/chemical product from Vessel – – Oil Hazards<br>1.2.3.4 Release of Oil/petroleum products/chemical product from Vessel – Electrical Shutdown – Deenergizing electrical equipment<br>1.2.4 Night operation - Loss of power and lighting at night<br>1.3 Scenario 3: Barge spudded off stern quarter (can be rotated) 1.3.3 Release of Oil/petroleum products/chemical product from Vessel<br>1.3.3.1 – Oil Hazards<br>1.3.3.4 - Electrical Shutdown – Deenergizing electrical equipment<br>1.3.4 Night operation - Loss of power and lighting at night<br>1.4 Scenario 4: Barge spudded astern of tanker<br>1.4.3 Release of Oil/petroleum product/chemical product from Vessel<br>1.4.3.1 – Oil Hazards<br>1.4.3.4 – Electrical Shutdown – Deenergizing electrical equipment<br>1.4.4 Night operation - Loss of power and lighting at night<br>1.5 Scenario 5: Barge tied to pier astern of tanker<br>1.5.3 Release of Oil/petroleum products/chemical products from Vessel<br>1.5.3.1 – Oil Hazards<br>1.5.3.4– Electrical Shutdown – Deenergizing electrical equipment<br>1.5.4 Night operation - Loss of power and lighting at night</td><td>10 Emergency procedures considering oil spill and/or vapor release from the petroleum product to be developed with considerations to rescue equipment compliance with hazardous zone and explosive atmosphere during tanker vessel oil spill as applicable. Also, consider local regulatory requirements<br>11 Evaluate barge system for exposure to hazardous atmosphere in all operating and emergency conditions (e.g. in oil spill situation)<br>12 Evaluate emergency lighting on barge<br>13 Consideration to include in procedures actions / usage of battery powered equipment (MBR/Radio / VHF/ Cell phones</td></tr>
</table>

| System Level Nodes - Hazard Scenario | Recommendations (R#) |
|---|---|
| **1.1 Scenario 1**: Barge moored alongside of tanker<br>1.1.3.3 Release of Oil/petroleum products/chemical product from Vessel – Release of toxic vapor(special consideration)<br>**1.2 Scenario 2: Barge spudded alongside of tanker**<br>1.2.3.2 - Release of Oil/petroleum products/chemical product from Vessel – Toxic Vapor<br>**1.3 Scenario 3: Barge spudded off stern quarter (can be rotated)**<br>1.3.3.3 Release of Toxic Vapor<br>**1.4 Scenario 4: Barge spudded astern of tanker**<br>1.4.3 Release of Oil/petroleum product/chemical product from Vessel<br>1.4.3.3 Release of Toxic Vapor<br>1.5.3 Release of Oil/petroleum products/chemical products<br>1.5.3.3 Release of Toxic Vapor | 14 Appropriate PPE and procedures are to be developed in the case of product release to the sea considering the product carried by the tanker vessel<br>15 Appropriate risk based on the tanker product to be identified and additional risk to be analyzed<br>16 Tanker owners to provide a list of the products and Material Safety Data Sheets (MSDS) for further study to incorporate into the safety procedures<br>17 Coast Guard to be consulted for additional guidance for the barge in such operation<br>18 Gas and hazard detectors for the product are to be installed.<br>19 Written smoking policy to be developed. |
| **1.1 Scenario 1: Barge moored alongside of tanker**<br>1.1.3.4 Release of Oil/petroleum products/chemical product from Vessel – Release of toxic vapor<br>**1.1.4** Night operation<br>Loss of power and lighting at night | 20 When barge is inside the boom area, the crew change procedures are to be evaluated. |
| **1.1 Scenario 1:** Barge moored alongside of tanker<br>1.1.5 Mooring Operations between barge and vessel. Breaking away | 21 Mooring line maintenance and inspection plan to be developed.<br>22 Tanker vessel hull curvature at stern area, parallel middle body and its interaction with respect to positioning of barge and distance of funnel top from barge crane to be studied further. (Applies to Scenario 1 only).<br>23 Freeboard difference between barge and tanker to be considered during mooring |

| System Level Nodes - Hazard Scenario | Recommendations (R#) |
|---|---|
| **1.1 Scenario 1: Barge moored alongside of tanker**<br>1.1.6 Positioning articulated boom capture arm. Exhaust capture hood contact with vessel.<br>**1.2 Scenario 2: Barge spudded alongside of tanker**<br>1.2.6 Positioning articulated boom capture arm. Exhaust capture hood contact with vessel.<br>**1.3 Scenario 3: Barge spudded off stern quarter (can be rotated**)<br>1.3.6 Positioning articulated boom capture arm. Exhaust capture hood contact with vessel.<br>**1.4 Scenario 4: Barge spudded astern of tanker**<br>1.4.6 Positioning articulated boom capture arm. Exhaust capture hood contact with vessel.<br>**1.5 Scenario 5: Barge tied to pier astern of tanker**<br>1.5.6 Positioning articulated boom capture arm. Exhaust capture hood contact with vessel. | 24 Placement system to be verified and validated on other vessel type(s) prior to use on tankers for all operating conditions.<br>25 Operational parameters and limits to be developed for the initial positioning of articulated boom capture arm and continuous operation. Operational parameters such as wind, waves, weather, lighting conditions, marine vessel traffic, and other vessels docking next to the proposed vessel may restrict vessel operations.<br>26 Capture arm technology to be tested and verified.<br>. |
| **1.1 Scenario 1**: **Barge moored alongside of tanker – Passing Vessels**<br>1.1.7.1 Barge struck by a passing vessel.<br>**1.2 Scenario 2: Barge spudded alongside of tanker**<br>1.2.7.1 Passing Vessel – Barge struck by a passing vessel.<br>**1.3 Scenario 3: Barge spudded off stern quarter (can be rotated)**<br>1.3.7.1 Barge struck by a passing vessel. | 27 Procedure and training to be conducted regarding preferred barge placements. |
| **1.1 Scenario 1: Barge moored alongside of tanker – Passing Vessels**<br>1.1.7.2 Barge extends into navigational channel<br>**1.2 Scenario 2**: **Barge spudded alongside of tanker**<br>1.2.7.2 Barge extends into navigational channel<br>**1.3 Scenario 3: Barge spudded off stern quarter (can be rotated)**<br>1.3.7.2 Barge extends into navigational channel | 28 Depending upon the positioning of the barge, it may impact navigation through the channel and it needs to be considered in barge placement. |

| System Level Nodes - Hazard Scenario | Recommendations (R#) |
|---|---|
| **1.1 Scenario 1: Barge moored alongside of tanker – Passing Vessels**<br>**1.1.7**.3 Excessive relative motion between positioning arm and vessel<br>**1.2 Scenario 2: Barge spudded alongside of tanker**<br>**1.2.7.3** Excessive relative motion between positioning arm and vessel<br>**1.4 Scenario 4: Barge spudded astern of tanker**<br>**1.4.7.3** Excessive relative motion between positioning arm and vessel<br>**1.5 Scenario 5: Barge tied to pier astern of tanker**<br>**1.5.7.3** Excessive relative motion between positioning arm and vessel | 29 System to be tested to verify performance in case of large movement of arm/barge considering wind/wave effect. |
| **1.1 Scenario 1: Barge moored alongside of tanker**<br>1.1.8.1 Overboard discharge - Ballast overboard from Vessel<br>1.7.8.2 – Overboard Discharge – Inert Gas overboard discharge<br>**1.2 Scenario 2: Barge spudded alongside of tanker**<br>1.2.8.1 Tanker Overboard Discharge - Ballast overboard from Vessel<br>1.2.8.2 – Tanker Overboard Discharge – Inert Gas Overboard Discharge<br>**1.3 Scenario 3**: Barge spudded off stern quarter (can be rotated)<br>**1.3.8** Tanker Overboard Discharge<br>1.3.8.1 Ballast overboard from Vessel<br>1.3.8.2 Inert Gas Overboard Discharge | 30 Inform and confirm the barge mooring location well ahead of vessel call such that overboard discharges are avoided onto the barge. |

| System Level Nodes - Hazard Scenario | Recommendations (R#) |
|---|---|
| **1.1 Scenario 1: Barge moored alongside of tanker**<br>1.1.9 Disengaging / retrieval of boom – Tug moves barge before boom is retrieved<br>**1.2 Scenario 2: Barge spudded alongside of tanker**<br>1.2.9 Disengaging / retrieval of boom – Tug moves barge before boom is retrieved<br>1.2.10 Tug moves barge before spud was retrieved<br>**1.3 Scenario 3**: Barge spudded off stern quarter (can be rotated)<br>1.3.9 Disengaging / retrieval of boom – Tug moves barge before boom is retrieved<br>1.3.10 Tug moves barge before spud was retrieved<br>**1.4 Scenario 4: Barge spudded astern of tanker**<br>1.4.9 Disengaging / retrieval of boom – Tug moves barge before boom is retrieved<br>1.4.10 Tug moves barge before spud was retrieved<br>**1.5 Scenario 5: Barge tied to pier astern of tanker**<br>1.5.9 Disengaging / retrieval of boom – Tug moves barge before boom is retrieved<br>1.5.10 Tug moves barge before spud was retrieved | 31 CONOPS to be reviewed by vessel operators / pilot /captain and involved terminal operators for all operational scenarios. |
| **1.1 Scenario 1: Barge moored alongside of tanker**<br>1.1.11 Barge exhaust gas (both from cleaned vessel exhaust and barge genset)<br>**1.2 Scenario 2: Barge spudded alongside of tanker**<br>1.2.13 Barge exhaust gas (both from cleaned vessel exhaust and barge genset)<br>**1.3 Scenario 3: Barge spudded off stern quarter (can be rotated)**<br>1.3.13 Barge exhaust gas (both from cleaned vessel exhaust and barge genset)<br>**1.4 Scenario 4: Barge spudded astern of tanker**<br>1.4.13 Barge exhaust gas (both from cleaned vessel exhaust and barge genset)<br>**1.5 Scenario 5: Barge tied to pier astern of tanker**<br>1.5.13 Barge exhaust gas (both from cleaned vessel exhaust and barge genset) | 32 As part of operational procedure, seek immediate feedback if fumes are noticed on the vessel.<br>33 Spark arrestor for generator exhaust to be provided, if required.<br>34 STAX to consider number of exhaust pipe in vent stack on the tanker vessel and ensure that the prototype can process all exhaust emissions |

| System Level Nodes - Hazard Scenario | Recommendations (R#) |
|---|---|
| **1.1 Scenario 1: Barge moored alongside of tanker**<br>**1.1.12.1** Obstructing tanker lifeboat launch<br>**1.1.12.2** Obstructing tanker rescue boat launch<br>**1.2 Scenario 2: Barge spudded alongside of tanker**<br>**1.2.12.1** Obstructing tanker lifeboat launch<br>**1.2.12.2** Obstructing tanker rescue boat launch<br>**1.3 Scenario 3: Barge spudded off stern quarter (can be rotated)**<br>**1.3.13.1** Obstructing tanker lifeboat launch<br>**1.3.13.2** Obstructing tanker rescue boat launch | 35 For each vessel, lifeboat and rescue boat arrangement to be considered to ensure compliance with (USCG/State land) requirements. |
| **1.2 Scenario 2**: **Barge spudded alongside of tanker**<br>1.2.5 Spud Operation<br>1.2.5.1 Unable to lower spud<br>**1.3 Scenario 3: Barge spudded off stern quarter (can be rotated)**<br>1.3.5.1 Spud Operation – Unable to lower spud<br>**1.4 Scenario 4: Barge spudded astern of tanker**<br>1.4.5 Spud Operation<br>1.4.5.1 Unable to lower spud<br>**1.5 Scenario 5: Barge tied to pier astern of tanker**<br>1.5.5.1 Spud Operation Unable to lower spud<br>1.5.5.1 Unable to lower spud | 36 Develop proper maintenance and inspection procedures for spuds and spud machinery.<br>37 CARB to develop more guidance when CNC barge is unable to service tanker vessel.<br>38 Soil conditions and buried utilities are to be considered when spudding the barge at oil terminals. |
| **1.2 Scenario 2: Barge spudded alongside of tanker**<br>1.2.5.2 Spud Operation – Too much penetration<br>1.2.5.4 Spud Operation – No penetration in soil<br>**1.3 Scenario 3: Barge spudded off stern quarter (can be rotated)**<br>1.3.5.2 Too much penetration<br>1.3.5.4 No penetration in soil<br>**1.4 Scenario 4: Barge spudded astern of tanker**<br>1.4.5.2 Too much penetration<br>1.4.5.4 No penetration in soil<br>**1.5 Scenario 5: Barge tied to pier astern of tanker**<br>1.5.5.2 Too much penetration<br>1.5.5.4 No penetration in soil | 39 Spud testing to be conducted prior to operation. Concept uses two spuds, testing to be performed to determine the adequacy of the design considering all loads. |
| **1.2 Scenario 2: Barge spudded alongside of tanker**<br>1.2.53 Spud Operation – Unable to Retrieve Spud<br>**1.3 Scenario 3: Barge spudded off stern quarter (can be rotated)**<br>1.3.5.3 Unable to retrieve spud<br>**1.4 Scenario 4: Barge spudded astern of tanker**<br>**1.3.5.**3 Unable to retrieve spud<br>**1.5 Scenario 5: Barge tied to pier astern of tanker**<br>**1.5.5.**3 Unable to retrieve spud | 40 Procedures to be developed to address risk of unable to retrieve spud scenario.<br>41 Discuss with tug operator to see if tanker can be moved if the barge is stuck. |

| System Level Nodes - Hazard Scenario | Recommendations (R#) |
|---|---|
| **1.2 Scenario 2:** Barge spudded alongside of tanker<br>1.2.11 Spud Retrieval – Unable to retrieve spud<br>**1.3 Scenario 3:** Barge spudded off stern quarter (can be rotated)<br>1.3.11 Spud Retrieval – Unable to retrieve spud<br>**1.4 Scenario 4:** Barge spudded astern of tanker<br>1.4.11 Spud Retrieval<br>Unable to retrieve spud<br>**1.5 Scenario 5:** Barge tied to pier astern of tanker<br>1.5.11 Spud Retrieval<br>Unable to retrieve spud | 42 Spud retrieval time / procedures to be developed.<br>43 Overall time required to move barge away in spudded configuration to be studied to meet regulation requirement of an emergency move.<br>44 Spud powering requirements (including emergency power) to be developed. |
| **1.4 Scenario 4:**<br>**Barge spudded astern of tanker** | 45 MOTEMS diagram to be obtained from terminal operator to study the mooring lines and other obstacles for astern arrangement. |
| **1.4 Scenario 4: Barge spudded astern of tanker**<br>**1.4.**5 Spud Operation<br>**1.4.5.1** Unable to lower spud | 46 In cases where this scenario is considered, an analysis needs to be conducted to determine if mooring lines are interfering with the spuds or the articulated arm. |
| **1.5 Scenario 5: Barge tied to pier astern of tanker**<br>1.5.1.2 – Space between the two tankers<br>1.5.1.3 – Interference with mooring line | 47 In cases where this scenario is considered the spacing between the tankers needs to be analyzed in regard to the barge being astern. |
| **1.5 Scenario 5:** Barge tied to pier astern of tanker<br>1.5.6.1 Tanker Mooring line breakage | 48 Develop training of mooring line failure risk. |
| **1.5 Scenario 5:** Barge tied to pier astern of tanker<br>1.5.14 Obstruction by vessel mooring lines | 49 Mooring arrangement of vessel and tug to be analyzed for each berth location to identify restriction and limitations. |
| **Node # 2 : Emergency Situation** | |
| 2.1 Emergency Situation | 50 Emergency procedures to be developed for all configuration and operational modes of barge. |
| **2.2 Emergency on other tanker** | 51 Emergency procedures and plan need be developed and need to consider emergencies on other tankers and at the terminal. |
| **Node # 3: Structure** | |
| 3.1. Structural failure on Barge | 52 Develop inspection and maintenance plan for the barge to prevent corrosion and/or fatigue issues. |

| System Level Nodes - Hazard Scenario | Recommendations (R#) |
|---|---|
| 3.2.1 Spud failure | 53 Spud design to be reviewed, tested and operational envelope to be developed to identify various parameters such as wind, wave, depth, soil parameter etc.<br>54 Procedure for crane boom to be developed to avoid contact with spuds and explore provision of proximity sensors.<br>55 Be familiar with the depth, soil type and any obstructions prior to operations.<br>56 Develop inspection and maintenance plan for the spud system to prevent corrosion and/or fatigue issues. |
| 3.2.2 Spud failure | 57 Develop emergency procedures for stuck-spud retrieval. |
| **Node # 4 : Safety System** | |
| | 58 Safety checklist to be developed by operator and barge. Guidance to be provided by Capture and Control barge and vessel owners considering all applicable rules and regulation. |
| 4.1 Fire<br>4.1.1 Fire on barge | 59 Provide equipment and develop firefighting procedures in accordance with regulatory and terminal requirements.<br>60 Firefighting requirements to be studied and firefighting equipment to be provided to meet regulatory requirements.<br>61 Crew should be trained to fight fires.<br>62 Consider fire and smoke detectors for fire detection. |
| 4.2.2 Fire on tanker | 63 Procedures to be developed for barge action when vessel / tanker has fire event and also consider tanker procedure.<br>64 Procedures need to be developed to allow the tanker to meet the California State Lands Commission emergency requirements. |
| 4.3.3 Communication | 65 Develop communication protocols and procedures for barge engagement, operations and disengagement |
| 4.4.4 Camera / Video/monitoring Not working / partially working | 66 Boom system to be tested, verified and validated prior to use for all operating conditions.<br>67 Operational limits to be developed for initial positioning of boom and continuous operation. |
| 4.4.5 Electrical system earthing between vessel and barge | 68 Separation and isolation from electrical continuity between barge and vessel to be evaluated. |

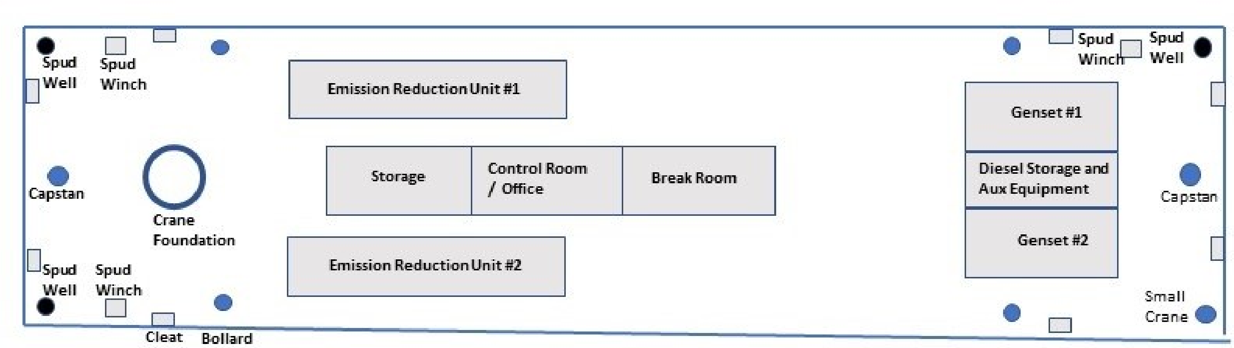
| System Level Nodes - Hazard Scenario | Recommendations (R#) |
|---|---|
| 4.4.7 Ventilation for barge office space/ release of vapor or H2S from tanker | 69 Oil vapor and H2S monitoring/gas detectors to be provided as required by OSHA and US Coast Guard regulations.<br>70 Consider study and provide appropriate gas and hazard detection equipment. |
| **Node # 5 : Deck System** | |
| 5.3 Control capture arm - Failure | 71 Develop appropriate safety procedures when alarms are initiated upon detection of oil vapors and H2S.<br>72 Procedures to be developed for safe retraction of control arm and subsequently restore operation.<br>73 Develop procedures for moving barge away with control arm failure with boom deployed. |

# Appendix A – Key Documents / Sketches / Drawings

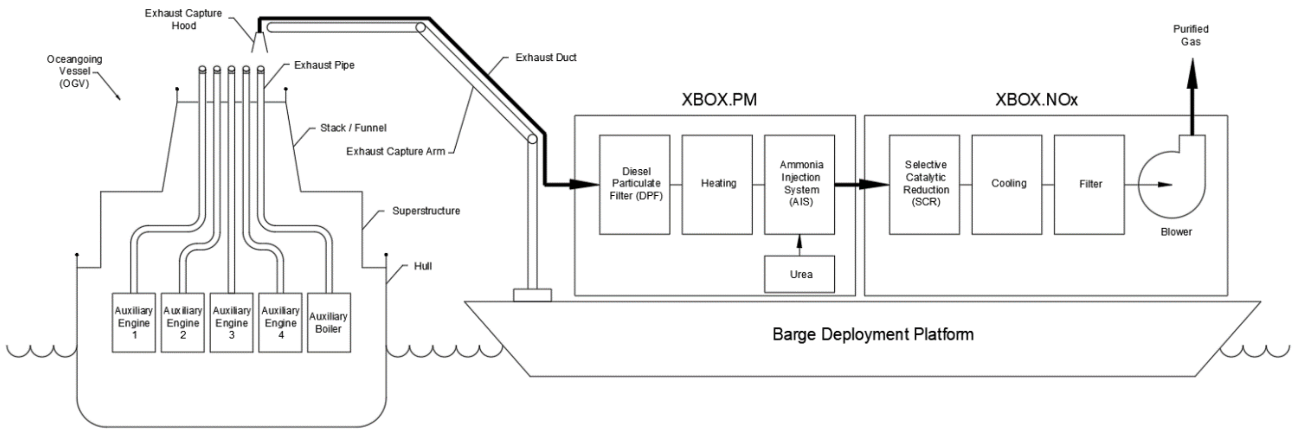
**Barge Type and Configuration**

- Deck barge 40-50 feet by 150-180 feet with approx. 10’ freeboard

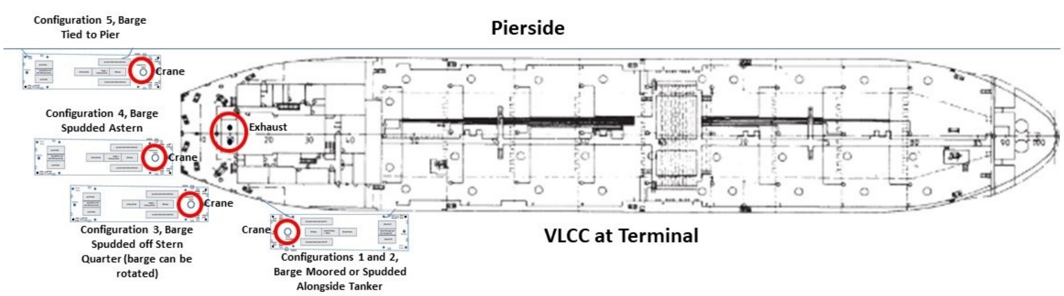
Diagram below is based on 40’X160’ with approximately 10’ freeboard




**Emission Reduction System**




### CONOPS Scenarios



# Appendix B – List of Documents:

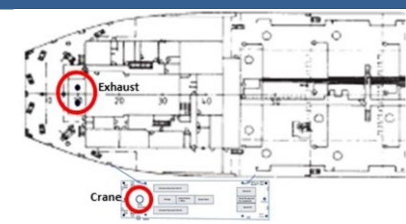
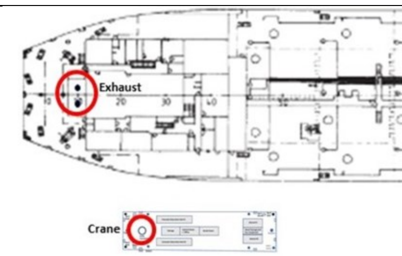
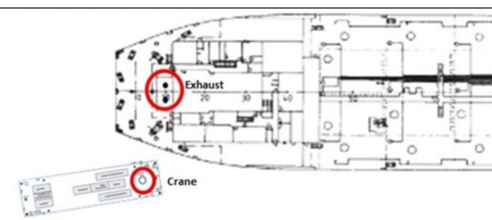
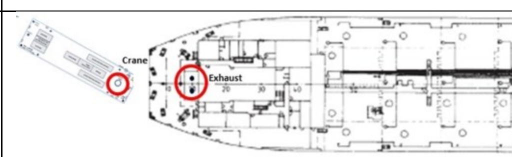
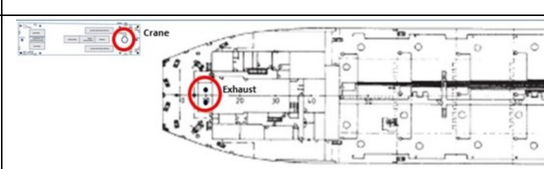
| ***Dwg. / Document #*** | ***Description*** |
|---|---|
| *STAX ABS Presentation 6-29 on ConOps* | Outline of ConOps and operational scenarios |
| *STAX Tanker CONOPS.001* | Concept of operations |

## Appendix C – HAZID Matrix

| Category | | | Consequence Severity | | | | |
|---|---|---|---|---|---|---|---|
| Asset | | | No shutdown, costs less than $10,000 to repair | No shutdown, costs less than $100,000 to repair | Operations shutdown, loss of day rate for one month and/or repair costs of up to $1,000,000 | Operations shutdown, loss of day rate for three month days and/or repair costs of up to $10,000,000 | Operations shutdown, loss of day rate for more than three month and/or repair more than $10,000,000 |
| Environmental Effects | | | No lasting effect. Low level impacts on biological or physical environment. Limited damage to minimal area of low significance. | Minor effects on biological or physical environment. Minor short-term damage to small area of limited significance. | Moderate effects on biological or physical environment but not affecting ecosystem function. Moderate short-medium term widespread impacts e.g. oil spill causing impacts on shoreline. | Serious environmental effects with some impairment of ecosystem function e.g. displacement of species. Relatively widespread medium-long term impacts. | Very serious effects with impairment of ecosystem function. Long term widespread effects on significant environment e.g. unique habitat, national park. |
| Community/ Government/ Media/ Reputation | | | Public concern restricted to local complaints | Minor, adverse local public or media attention and complaints. Significant hardship from regulator. Reputation is adversely affected with a small number of site focused people. | Attention from media and/or heightened concern by local community. Criticism by NGO's. Significant difficulties in gaining approvals. Environmental credentials moderately affected. | Significant adverse national media/ public/ NGO attention. May lose license to operate or not gain approval. Environment/ management credentials are significantly tarnished. | Serious public or media outcry (international coverage). Damaging NGO campaign. License to operate threatened. Reputation severely tarnished. Share price may be affected. |
| Injury and Disease | | | Low level short-term subjective inconvenience or symptoms. No measurable physical effects. No medical treatment required. | Objective but reversible disability/impairment and /or medical treatment, injuries requiring hospitalization. | Moderate irreversible disability or impairment (<30%) to one or more persons. | Single fatality and/or severe irreversible disability or impairment (>30%) to one or more persons. | Short- or long-term health effects leading to multiple fatalities, or significant irreversible health effects to >50 persons. |
| | | | Low | Minor | Moderate | Major | Critical |
| | | | 1 | 2 | 3 | 4 | 5 |
| Likelihood | Almost Certain (E) Occurs 1 or more times a year | E | High | High | Extreme | Extreme | Extreme |
| | Likely (D) Occurs once every 1-10 years | D | Moderate | High | High | Extreme | Extreme |
| | Possible (C) Occurs once every 10-20 years | C | Low | Moderate | High | Extreme | Extreme |
| | Unlikely (B) Occurs once every 20-50 years | B | Low | Low | Moderate | High | Extreme |
| | Rare (A) Occurs once every 50-100 years | A | Low | Low | Moderate | High | High |

| Action Key | | |
|---|---|---|
| | Low | No action is required, unless change in circumstances |
| | Moderate | No additional controls are required, monitoring is required to ensure no changes in circumstances |
| | High | Risk is high and additional control is required to manage risk |
| | Extreme | Intolerable risk, mitigation is required |

# Appendix D – Summary of Scenarios

| *Scenario* | *Sketch* | *Summary* | *Number of Risk Rankings* |
|---|---|---|---|
| Node 1.1<br>**Scenario 1:**<br>Barge moored alongside of tanker |  | Tying the barge up alongside the tanker in the opposite orientation as the tanker. In this mode the bow of the barge is facing the stern of the tanker and the bow crane is slightly forward of the stacks. Mooring the barge alongside is the proven method for use of emissions control barges on container vessels. | **Low (3)**<br>**Moderate (11)**<br>**High (3)**<br>**Extreme (none)** |
| Node 1.2<br>**Scenario 2:**<br>Barge spudded alongside of tanker |  | Using the barge spuds to moor the vessel alongside the tanker in the opposite orientation as the tanker. In this mode the bow of the barge facing the stern of the tanker and the bow crane is equal to or slightly forward of the stacks. Although the location of the barge is similar to Scenario 1 no line handling is required of the tanker crew. | **Low (9)**<br>**Moderate (9)**<br>**High (3)**<br>**Extreme (none)** |
| Node 1.3<br>**Scenario 3:**<br>Barge spudded off stern quarter (can be rotated) |  | Using the barge spuds to moor the barge off the stern quarter of the tanker with the barge in the same orientation as the tanker. In this mode the bow crane is abeam of or slightly aft of the stacks of the vessel. This scenario also requires no line handling by the tanker crew. | **Low (11)**<br>**Moderate (8)**<br>**High (1)**<br>**Extreme (none)** |
| Node 1.4<br>**Scenario 4:**<br>Barge spudded astern of tanker |  | Using the barge spuds to moor the barge astern of the vessel. In this mode the barge is in the same orientation as the tanker and it can be moored either with the bow crane directly astern of the stacks, or with the barge moored on the outboard side of the stern of the vessel with the bow crane slightly outboard of the stacks. The barge may be oriented at any angle between parallel to perpendicular to the vessel. | **Low (9)**<br>**Moderate (8)**<br>**High (none)**<br>**Extreme (none)** |
| Node 1.5<br>**Scenario 5:**<br>Barge tied to pier astern of tanker |  | Tying the barge up astern of the tanker in the same orientation as, or perpendicular to the tanker. In this mode the bow of the barge is facing the stern of the tanker. Mooring the barge astern of the vessel is a tested method for use of emissions control barges on bulk carriers. For larger tankers, this scenario could include tying the barge perpendicular to the dock with the bow of the barge facing outward. | **Low (8)**<br>**Moderate (11)**<br>**High (3)**<br>**Extreme (none)** |

## Appendix E – Hazard Register

| System Level Nodes - Hazard Scenario | Potential Cause | Consequences | Effective Safeguard | Category | Risk Ranking S | L | RR | Recommendations (R#) | Comments |
|---|---|---|---|---|---|---|---|---|---|
| **Node # 1: Modes of operation** | | | | | | | | 1. In next phase of study, it is recommended that experts from Port of Long Beach, USCG, State Lands and vessel operator are to be invited. **[Recommendation is resolved. Experts were invited and participated in the 2nd HAZID session held on September 30, 2021]**<br>2. Tug requirements to safely handle the barge are to be developed and further studied.<br>3. Product carried on tanker vessel need to be studied for compatibility with barge safety.<br>4. Once the design is developed, operational risk is to be assessed and operational procedures to be developed<br>5. Crew change procedures and communication with tanker to be developed. | **Note: Purple lettering denotes items specific to a scenario.** |
| **1.1 Scenario 1: Barge moored alongside of tanker** | | | | | | | | | • Barge is alongside the vessel, containment boom will be deployed outside barge.<br>• Heat sources are deep inside the box and covered in insulation. Heat sources are in contact with process / exhaust gas and not exposed to environment. In a power outage (e-stop) crane boom hood automatically retracts.<br>• Barge has supplies to go on for a week without supplies.<br>• No berthing on the barge. Only crew rest areas. |
| **1.1.1** Barge is brought alongside the tanker - Collision / Contact | • Loss of control by tug<br>• Relative motion between vessel and barge due to wake due to passing vessels<br>• Wave action due to weather<br>• High Current (in some Northern CA terminals) | • Minor damage to vessel (e.g., paint) and barge | • Fenders deployed between vessel and barge<br>• Operational procedures and training<br>• Slow speed operation<br>• Small approach angle – barge to vessel to | Asset | 1 | D | 1D | 6. Determine safe operating consensus with operators at each terminal prior to operation and ensure that these procedures are consistent with the Harbor Safety Plan.<br>7. STAX to evaluate barge procedures, maneuverability and control of barge by tug(s) for all operating conditions (e.g., high wind, high current, wave etc.). | • Tug is physically connected/attached to barge on side tow. Tow plans are per approved procedure. Normal operations as per procedures.<br>• Total of four mooring lines between Barge and Vessel. Mooring lines / tug - barge lines are passed via capstans and capstans are controlled to adjust the mooring lines. |
| | | • Moderate damage to vessel hull (e.g., dent) and barge | | Asset | 2 | B | 2B | | |
| | | • Damage to bunker tank / side shell causing oil spill | | Environment | 3 | A | 3A | | |

| System Level Nodes - Hazard Scenario | Potential Cause | Consequences | Effective Safeguard | Category | Risk Ranking S | Risk Ranking L | Risk Ranking RR | Recommendations (R#) | Comments |
|---|---|---|---|---|---|---|---|---|---|
| | | | minimize forces on vessel<br>• Require single tugs to have two engines | | | | | 8. Conduct testing of side-by-side tanker mooring configuration. | • Damage to bunker tank / side shell possible based on momentum. Could be loss of propulsion on escort tug.<br>• Barge is divided in compartment. Meer USCG stability requirements.<br>• Currently for container ships, side by side moored operations are being conducted successfully |
| **1.1.2** Man overboard | • Due to impact of collision<br>• Snapback of mooring lines<br>• Human error<br>• Trip, slip, fall | • Injury, fatality<br>• Man possibly caught between vessel and barge | • Barge has handrails<br>• PPE supplied to crew on barge.<br>• All Terminal / USCG / OSHA LSA requirements provided.<br>• Life rings provided on barge | Human | 3 | C | 3C | 9. Man overboard rescue procedures and training to be developed considering incident happen inside oil containment boom area and outside boom containment area. | • Mooring arrangements done by a system operator on barge and lines man. Maintaining lines all time. Small transfer boat used for crew changes and any assistance to barge. Man overboard procedures to be included in Emergency procedures.<br>• OSHA requirements will be met. |
| **1.1.3** Release of Oil /petroleum products/chemical product from Vessel<br><br>1.1.3.1 Oil Hazard | • Loss of cargo piping integrity<br>• Cargo transfer hose/arm failure<br>• Loss of containment tanker vessel<br>• Cargo tank over pressurization | • Fire or explosion due to barge igniting oil on the water from the tanker<br>• The barge is "trapped" for an extended period of time inside the oil containment boom in the presence of spilled oil | • Intrinsically safe emergency lighting<br>• LEL detectors on barge deck and in upstream process gas.<br>• Barge powers down automatically upon e-stops and LEL detection.<br>• E-stops throughout barge.<br>• Evacuation of barge | Asset | 4 | A | 4A | 10. Emergency procedures considering oil spills and/or vapor release from the petroleum product to be developed with considerations to rescue equipment compliance with hazardous zone and explosive atmosphere during tanker vessel oil spill as applicable. Also, consider local regulatory requirement<br>11. Evaluate barge system for exposure to hazardous atmosphere in all operating and emergency condition (e.g. oil spill situation).<br>12. Evaluate emergency lighting on barge<br>13. Consideration to include in procedures actions / usage of battery powered equipment (MBR/Radio / VHF/ Cell phones). | • Boom is installed / deployed after barge is moored in Scenario 1<br>• Barge cannot be moved in oil spill situation as it is surrounded by oil spill containment boom.<br>• Any emergency on vessel, will result in shutdown of all operations of barge |
| 1.1.3.2 Environmental Hazard | | • Release of pollutants | | Environment | n/a* | n/a* | n/a* | | • * A tanker spill is an environmental category for the vessel, but out of scope for the barge |
| 1.1.3.3 Release of Toxic Vapor(special consideration) | | • Release of hazardous material toxic vapor | • PPE Provided for oil spill/petroleum product and vapor release | Human | 3 | D | 3D | 14. Appropriate PPE and procedures are to be developed in the case of product release to the sea considering all products carried by tanker vessel<br>15. Appropriate risk based on the tanker product to be identified and additional risk to be analyzed<br>16. Tanker owners to provide a list of the products and Material Safety Data Sheets (MSDS) for further study to incorporate into the safety procedures<br>17. Coast Guard to be consulted for additional guidance for the barge in such operation<br>18. Gas and hazard detectors for the tanker product are to be provided. | • Project covers all petroleum products, not just oil, that can be carried on tanker vessel. List of all possible products to be provided<br>• Some products may have the potential for $H_2S$ vapor release and will require special consideration<br>• Potential of $H_2S$ vapor release(special consideration) due to over pressurization from high temperature. Vapor can migrate towards the barge depending on atmospheric conditions<br>• The barge could have rig savers installed to protect against $H_2S$ |

| System Level Nodes - Hazard Scenario | Potential Cause | Consequences | Effective Safeguard | Category | Risk Ranking S | L | RR | Recommendations (R#) | Comments |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | 19. Written smoking policy to be developed. | release. Common equipment on drillships.<br>• Current scope is for oil tankers, chemicals carrier may be in the future but not at this stage |
| 1.1.3.4 Electrical Shutdown – Deenergizing electrical equipment | • Barge powered down due to oil spill | • Difficulty for crew to move around<br>• Injury | • Class I Div. I lighting arrangements on barge<br>• Intrinsically safe flash / torch lights provided. | Human | 2 | A | 2A | 20. When barge is inside the boom area, the crew change procedures are to be evaluated.<br>• See recommendation #10 | • In this configuration the boom will be immediately alongside the barge which will allow trugs or a rescue vessel to come alongside unhindered.<br>• The barge is likely kept on location until oil spill clean is completed. Tug may or may not be able rescue crew on barge. Small transfer boat or raft (unpowered) for escape. |
| **1.1.4** Night operation<br>Loss of power and lighting at night | • Electrical fault<br>• Blackout<br>• Tanker vessel spill requires barge to be shut down and de-energized | • Difficulty for crew to move around<br>• Injury | • Intrinsically safe flash / torch lights provided. | Human | 2 | C | 2C | | • Barge can be moved if needed as it is outside Oil containment boom perimeter.<br>• Tug may not be able rescue crew on barge. Small transfer boat needs to be used (row) to escape. |
| **1.1.5** Mooring Operations between barge and vessel.<br>Breaking away | • Mooring line failure<br>• Overload<br>• Passing vessel creates large wake<br>• Maintenance issues<br>• Mooring equipment rating inadequate<br>• High current<br>• Collision | • Damage to exhaust stack of vessel due to barge movement<br>• Snap back and injury to personnel onboard the barge | • The boom and exhaust capture hood are designed so the likelihood of unwanted contact is unlikely.<br>• Yokohama fenders used<br>• Barge crew monitors the mooring lines at all times and tension maintained<br>• LA, Long Beach area does not experience significant current and barge will be ballasted<br>• Single line failure will be tolerated per design | Asset | 2 | C | 2C | 21. Mooring line maintenance and inspection plan to be developed<br>22. Tanker vessel hull curvature at stern area, parallel middle body and its interaction with respect to positioning of barge and distance of funnel top from barge crane to be analyzed. (Applies to Scenario 1 only).<br>23. Freeboard difference between barge and tanker to be considered during mooring Applies to this scenario only. | • Exhaust capture hood could hit the exhaust stack of the vessel.<br>• 4 lines used to moor the barge. Bow, stern and 2 spring lines. Failure of one line will not compromise mooring.<br>• Barge tries to moor at the flat side of the vessel hull and avoids the curved stern area. If cannot be avoided, then a spacer is used.<br>• Ballasted barge will have negligible movement with respect to vessel unless there is a large wake from a passing vessel.<br>• In regards to mooring, as the vessel draft and trim changes, will they be monitoring as our trim changes and also, on the stern getting caught in the rake. Answer: (In Scenario 1 only) the deckhands on the barge are tasked with monitoring the lines every 10 minutes. We are also considering winches with auto tensioning as an alternative to powered capstans. |
| **1.1.6** Positioning articulated boom capture arm.<br>Exhaust capture hood contact with vessel. | • Operator error<br>• Weather condition – high wind, wave<br>• No direct line of sight from control room | • Damage to funnel / exhaust stack of vessel<br>• Unable to perform exhaust capture operation | • Camera / vision / infra-red video cameras<br>• Wind speed sensors at the top of the capture arm | Asset | 2 | C | 2C | 24. Placement system to be verified and validated on other vessel type(s) prior to use on tankers for all operating conditions.<br>25. Operational parameters and limits to be developed for the initial positioning of articulated boom capture arm and | • System is warming up at low flow on the way to the vessel. As the exhaust capture hood approaches the exhaust pipe, dynamic flow adjustment matches exhaust flow rate during operations using sensors. |

| System Level Nodes - Hazard Scenario | Potential Cause | Consequences | Effective Safeguard | Category | Risk Ranking S | L | RR | Recommendations (R#) | Comments |
|---|---|---|---|---|---|---|---|---|---|
| | | | • Arm controllable using portable control unit from deck to have clear line of sight<br>• Crew assistance to position<br>• Operational procedures | | | | | continuous operation. Operational parameters such as wind, waves, weather, lighting conditions, marine vessel traffic, and other vessels docking next to the proposed vessel may restrict vessel operations.<br>26. Capture arm technology to be tested and validated | • What are dimensional limitations? How different stacks can be covered? What about uneven base surfaces? Answer: In reviewing this question, understand the uneven surface aspect. STAX approach does not rely on a hood extending all the way to the "floor". STAX rejected this approach because there is typically pressurized engine room air that enters around the base of the exhaust pipe which causes dilution and other problems. STAX hood only covers the top aspect of the exhaust pipe.<br>• Positioning is a joystick operation. A 'gentle' downward force keep hood in position. Hood will retract back to top of boom in case of power outage / technical issues.<br>• Infrared cameras to determine which exhaust pipes are in operation.<br>• Crane operation is done by a portable remote-control system on the barge to gain the best line of sight. Control room also has augmented reality and screens to provide clear view from the control room by another crew member.<br>• Ample reach of boom measured form barge crane center at deck level to the vessel exhaust stack funnel.<br>• C&C system is designed to accommodate any tidal condition |
| **1.1.7 Passing Vessels** | | | | | | | | | |
| **1.1.7.1** Barge struck by a passing vessel. (Scenarios 1 & 2 only) | • Loss of control of another vessel<br>• Lack of attention by passing vessel<br>• Visibility (e.g., fog)<br>• Narrow channel | • Collision with barge and/or tanker causing vessel hull damage and barge hull damage (e.g., puncture)<br>• Flooding of barge | • Barge is fitted with required navigational lights.<br>• Barge deck and arm has adequate lighting | Asset | 3 | B | 3B | 27. Procedure and training to emphasize preferred barge placement. | • This is highly dependent on the terminal / channel width – this rating is worst-case with a narrow channel<br>• Barge is divided in compartment. To Meet USCG stability requirements |
| **1.1.7.2** Barge extends into navigational channel (Scenarios 1 & 2 only) | • Barge extending into navigational channel | • Delays in operations<br>• Disrupting port operations<br>• Unable to perform exhaust capture operations | • The pilot's dispatchers notify all pilots and commercial traffic of any obstructions to channels or waterways.<br>• Training | Asset | 2 | C | **2C** | 28. Depending upon the positioning of the barge, it may impact navigation through the channel and it needs to be considered. | • This is highly dependent on the terminal / channel width – this rating is worst-case with a narrow channel<br>• Barge position will be dependent on many factors including channel width. |
| **1.1.7.3** Excessive relative motion between positioning arm and vessel | • Passing vessel at high velocity causes unusually large wake or surge | • Barge rolling motion causes positioning arm to move relative to the vessel | • Ballast, low free board, low draft<br>• C&C system monitoring and sensor | Asset | 3 | D | **3D** | 29. System to be tested to verify performance in case of large movement of arm/barge considering wind/wave effect | • The largest angular motion during a wake is the rolling motion about the shortest barge dimension |

| System Level Nodes - Hazard Scenario | Potential Cause | Consequences | Effective Safeguard | Category | Risk Ranking S | Risk Ranking L | Risk Ranking RR | Recommendations (R#) | Comments |
|---|---|---|---|---|---|---|---|---|---|
| | | • Alongside (parallel orientation) combined up/down and fore/aft relative motion is more pronounced than when barge is positioned astern of vessel. | will pull system back to safe position | | | | | | • Alongside (parallel orientation) barge rolling translates to an up/down motion at the positioning arm tip, which is not present when positioned astern of the vessel.<br>• Alongside (parallel orientation) during a very large wake, there will also be fore/aft motion, which is typically absent. Fore/aft motion may damage sensitive equipment forward of the vessel's exhaust pipes. |
| **1.1.8** Overboard Discharge from Tanker<br><br>1.1.8.1 Ballast overboard from 8essel (Scenario 1 & 2) | • Location of vessel overboard discharges onto barge | • Disrupt barge operations<br>• Impacts visibility | • Use of spacer barge | Asset | 2 | C | 2C | 30. Inform and confirm the barge mooring location well ahead of vessel call such that overboard discharges are avoided onto the barge | • Also, ballast treatment and cooling water systems may have overboard discharges.<br>• The vessels' stern is a safe location from overboard discharges. |
| **1.1.8.2 Inert Gas Overboard Discharge** | • Location of discharge on tanker | • Discharge IG water on barge (IG water discharge | • Barge freeboard is approximately 10 feet | Asset | 2 | A | 2A | | • Position of barge to be avoided underneath of IG discharge. |
| **1.1.9** Disengaging / retrieval of boom - Tug moves barge before boom is retrieved | • Miscommunication<br>• Emergency situations | • Damage to vessel funnel / exhaust pipe | • Operational procedures and communication protocols<br>• Exhaust capture hood is designed for breakaway | Asset | 2 | C | 2C | 31. CONOPS to be reviewed by vessel operators / pilot /captain and terminal operators for all operational scenarios | • After tanker completes discharged operation, exhaust capture hood(s) are lifted, and the boom is moved clear.<br>• This is only an issue if the tug connects with barge before Crane boom / collection device is moved.<br>• Moving of the barge by the tug in an emergency without exhaust capture hood retrieval not anticipated |
| **1.1.10** Loss of power | • Electrical / mechanical faults | • Unable to perform exhaust capture operations<br>• Hood(s) lift away naturally (mechanically) when power is removed<br>• Process blower shuts down | • At least one redundant power source (e.g., genset), each capable to handle entire load.<br>• Monitor and automatically anticipate fuel needs | Asset | 1 | D | 1D | | • The basic barge has two gensets<br>• Stand by genset automatically comes online<br>• Additional power sources are planned (e.g., hydrogen fuel cells) |
| **1.1.11** Barge exhaust gas (both from cleaned vessel exhaust and barge genset) | • Close proximity of exhaust and vessel inlet | • Exhaust gas in accommodation<br>• Health Haz | • High cleaning efficiency by barge | Human | 2 | C | 2C | 32. As part of operational procedure, seek immediate feedback if fumes are noticed on the vessel. | • The distance between the barge and the deck of the vessel is significant<br>• Two exhaust hoods planned for design (1-4 exhaust are standard). CE notes that up to 6 major exhaust producers may be running (3 gen sets, 1 HPU, 1 boiler)<br>Hood design is still going through the design process and will be presented upon completion |
| | | • Genset exhaust may have sparks | • Modern Tier 4F gensets have significant emissions equipment (DPF and SCR) between the engine and the genset exhaust pipe, making spark travel impossible. | Asset | 2 | A | 2A | 33. Spark arrestor for generator exhaust to be provided, if required<br>34. STAX to consider number of exhaust in vent stack on the tanker vessel and ensure that the prototype can process all exhaust emission. | |
| **1.1.12 Barge underneath of Lifeboat and Rescue Boat** | • Barge in way of tanker lifeboat launch | • Unable to launch tanker lifeboat | | Human | 3 | B | 3B | 35. For each vessel, lifeboat and rescue boat arrangement to be considered and to | • Regulations to be studied |

| System Level Nodes - Hazard Scenario | Potential Cause | Consequences | Effective Safeguard | Category | Risk Ranking S | Risk Ranking L | Risk Ranking RR | Recommendations (R#) | Comments |
|---|---|---|---|---|---|---|---|---|---|
| **1.1.12.1** Obstructing tanker lifeboat launch | | | | | | | | ensure compliance with (USCG/State land) requirements | |
| **1.1.12.2** Obstructing tanker rescue boat launch | • Barge in way of tanker rescue boat launch | • Unable to launch tanker rescue boat | | Human | 3 | B | 3B | | |
| **1.2 Scenario 2: Barge spudded alongside of tanker** | | | | | | | | | • In high current location barge position can be maintained by single tug.<br>• Barge will be outside the oil containment boom<br>• Greater space between vessel and barge and more likelihood of impeding the channel may be a concern in certain locations.<br>• Any damage greater than $50,000, oil spills, and any injury that requires more than first aid is reportable to USCG under 46 CFR part 4 |
| **1.2.1** Barge is brought near the side of the tanker - Collision / Contact | • Loss of control by tug<br>• Wave action due to passing vessels<br>• Wave action due to weather<br>• High current (in some Northern CA terminals) | • Minor damage to vessel (e.g., paint) | • Operational procedures and training<br>• Slow speed operation<br>• Small approach angle – barge to vessel to minimize forces on vessel<br>• Require single tugs to have two engines | Asset | 1 | C | 1C | See recommendation # 6 and 7 | • Tug is physically connected/attached to barge on side tow. Tow plans are per approved procedure. Normal operations as per procedures.<br>• Damage to bunker tank / side shell possible based on momentum. Could be loss of propulsion on escort tug. |
| | | • Moderate damage to vessel (e.g., dent) | | Asset | 2 | A | 2A | | |
| | | • Damage to bunker tank / side shell causing oil spill | | Environment | 3 | A | 3A | | |
| **1.2.2** Man overboard | • Due to impact of collision<br>• Human error<br>• Trip, slip, fall | • Injury, fatality<br>• No danger between barge and vessel as barge is spudded | • Barge has handrails.<br>• PPE supplied to crew on barge.<br>• All Terminal / USCG / OSHA - LSA requirements provided<br>• Life rings provided on barge | Human | 2 | C | 2C | See recommendation # 9 | • Small transfer boat used for crew changes and any assistance to barge. Man overboard procedures to be included in Emergency procedures.<br>• OSHA requirements will be met. |
| **1.2.3** Release of Oil/Petroleum products/chemical products from Vessel<br><br>1.2.3.1 Oil Hazard | • Loss of cargo piping integrity<br>• Cargo transfer hose/arm failure<br>• Loss of containment tanker vessel<br>• Cargo tank over pressurization | • Fire<br>• Explosion<br>• Barge is not trapped within containment | • Class I Div. I lighting arrangements on barge<br>• LEL detectors on barge deck and also in process boxes.<br>• Barge powers down automatically upon E-stops and LEL detection .<br>• E-stops throughout barge<br>• Evacuation of barge | Asset | 2 | A | 2A | • See recommendation # 10, 11, 12 and 13 | • Barge is outside oil containment boom perimeter.<br>• Barge cannot be moved if required<br>• Any emergency on vessel, will result in shutdown of all operations of barge.<br>• Bunker tank of tanker vessel not double hull |
| 1.2.3.2 Environmental Hazard | | • Release of pollutants | | Environment | n/a* | n/a* | n/a* | | • * - A tanker spill is an environmental category for the vessel, but out of scope for the barge |

| System Level Nodes - Hazard Scenario | Potential Cause | Consequences | Effective Safeguard | Category | Risk Ranking S | Risk Ranking L | Risk Ranking RR | Recommendations (R#) | Comments |
|---|---|---|---|---|---|---|---|---|---|
| 1.2.3.3 Release of Toxic Vapor(special consideration) | | • Release of hazardous material toxic vapor | • PPE Provided for oil spill/petroleum product and vapor release | Human | 3 | D | 3D | See comment # 14, 15, 16, 17, 18 and 19 | • Project covers all petroleum products, not just oil, that can be carried on tanker vessel. List of all possible products to be provided<br>• Some products may have the potential for $H_2S$ vapor release and those will require special consideration<br>• Potential of $H_2S$ vapor release (special consideration) due to over pressurization from high temperature. Need to determine if vapor can migrate towards the barge in certain atmospheric conditions<br>• the barge could have rig savers installed to protect against $H_2S$ release. Common equipment on drillships.<br>• Current scope is for oil tankers, chemicals carrier may be in the future but not at this stage |
| 1.2.3.4 Electrical Shutdown – Deenergizing electrical equipment | • Barge powered down due to oil spill | • Difficulty for crew to move around<br>• Injury | • Intrinsically safe emergency lighting turns on automatically.<br>• Intrinsically safe flash / torch lights provided. | Human | 2 | A | 2A | See recommendation # 10, 11, 12 and 13 | |
| **1.2.4** Night operation<br><br>Loss of power and lighting at night | • Electrical fault<br>• Blackout<br>• Tanker vessel spill requires barge to be shut down and de-energized | • Difficulty for crew to move around<br>• Injury | • Intrinsically safe flash / torch lights provided. | Human | 2 | C | 2C | | • Barge can be moved if needed as it is outside Oil containment boom perimeter.<br>• Tug may not be able rescue crew on barge. Small transfer boat needs to be used (row) to escape. |
| **1.2.5 Spud Operation**<br>**1.2.5.1** Unable to lower spud | • Mechanical fault (winch, control system etc.) | • Unable to perform exhaust capture operations | | Asset | 2 | B | 2B | 36. Develop proper maintenance and inspection procedures for spuds and spud machinery<br>37. CARB to develop more guidance when CNC barge is unable to service tanker vessel<br>38. Soil conditions and buried utilities are to be considered when spudding the barge at oil terminals. | • Is spud control system redundant? |
| **1.2.5.2** Too much penetration | • Soft soil | • Unable to perform exhaust capture operations<br>• Too much penetration can lead to insufficient length of spud | | Asset | 2 | B | 2B | 39. Spud testing to be conducted prior to operation. Concept uses two spuds, testing to be performed to determine the adequacy of the design considering all loads | • It is unlikely to be surprised by a soft soil condition once experienced<br>• Spud needs to be approximately 10 feet above weather deck after installation |
| **1.2.5.3 Unable to retrieve spud** | • Spud Stuck<br>• Wire Break<br>• Winch Break | • Barge cannot move away from tanker<br>• In case of emergency tanker can't move away | | Asset<br>Human | 3 | D | 3D | 40. Procedures to be developed to address risk of unable to retrieve spud scenario<br>41. Discuss with tug operator to see if tanker can be moved if the barge is stuck. | • Beam of barge is 40 feet<br>• In certain scenarios barge may inhibit passage through the channel for some vessels<br>• Possibility of crane vessel available to pull the spuds |

| System Level Nodes - Hazard Scenario | Potential Cause | Consequences | Effective Safeguard | Category | Risk Ranking S | Risk Ranking L | Risk Ranking RR | Recommendations (R#) | Comments |
|---|---|---|---|---|---|---|---|---|---|
| **1.2.5.4** No penetration in soil | • Object at bottom (pipeline, anchor, lost equipment etc. etc.)<br>• Soil too hard<br>• Not enough water depth | • Stability of barge movement cannot be achieved<br>• Unable to perform exhaust capture operations<br>• Possibility of spud entanglement with objects at bottom | | Asset | 2 | C | 2C | See recommendation # 39 | • Surveys are done regularly at POLA and POLB |
| **1.2.6** Positioning articulated boom capture arm.<br><br>Exhaust capture hood contact with vessel. | • Operator error<br>• Weather condition – high wind, wave<br>• No direct line of sight from control room | • Damage to funnel / exhaust stack of vessel<br>• Unable to perform exhaust capture operation | • Camera / vision / infra-red video cameras<br>• Wind speed sensors at the top of the capture arm<br>• Arm controllable using portable control unit from deck to have clear line of sight<br>• Crew assistance to position<br>• Operational procedures | Asset | 2 | C | 2C | See recommendation # 24, 25 and 26 | • System is warming up at low flow on the way to the vessel. As the exhaust capture hood approaches the exhaust pipe, dynamic flow adjustment matches exhaust flow rate during operations using sensors.<br>• What are dimensional limitations? How different stacks can be covered? What about uneven base surfaces? Answer: In reviewing this question, understand the uneven surface aspect. STAX approach does not rely on a hood extending all the way to the "floor". STAX rejected this approach because there is typically pressurized engine room air that enters around the base of the exhaust pipe which causes dilution and other problems. STAX hood only covers the top aspect of the exhaust pipe.<br>• Positioning is a joystick operation. A 'gentle' downward force keep hood in position. Hood will retract back to top of boom in case of power outage / technical issues.<br>• Infrared cameras to determine which exhaust pipes are in operation.<br>• Crane operation is done by a portable remote-control system on the barge to gain the best line of sight. Control room also has augmented reality and screens to provide clear view from the control room by another crew member.<br>• Ample reach of boom measured form barge crane center at deck level to the vessel exhaust stack funnel.<br>• C&C system is designed to accommodate any tidal condition |
| **1.2.7 Passing Vessels** | | | | | | | | | |
| **1.2.7.1** Barge struck by a passing vessel. (Scenarios 1 & 2 only) | • Loss of control of another vessel | • Collision with barge and/or tanker causing vessel hull damage and barge hull | • Barge is fitted with required navigational lights. | Asset | 3 | C | 3C | See recommendation # 27 | • This is highly dependent on the terminal / channel width – this rating is worst-case with a narrow channel |

| System Level Nodes - Hazard Scenario | Potential Cause | Consequences | Effective Safeguard | Category | Risk Ranking | | | Recommendations (R#) | Comments |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | S | L | RR | | |
| | • Lack of attention by passing vessel<br>• Visibility (e.g., fog)<br>• Narrow channel | damage (e.g., puncture)<br>• Flooding of barge | • Barge deck and arm has adequate lighting | | | | | | • Barge is divided in compartment. Meer USCG stability requirements |
| **1.2.7.2** Barge extends into navigational channel (Scenarios 1 & 2 only) | • Barge extending into navigational channel<br>• Delays in operations | • Disruption of port operations<br>• Unable to perform exhaust capture operations | • The pilot's dispatchers notify all pilots and commercial traffic of any obstructions to channels or waterways.<br>• Training<br>• Select another scenario | Asset | 3 | C | 3C | See recommendation # 28 | • In this Scenario 2, the barge may be positioned further into the channel, thus the higher likelihood (although this is not necessarily true)<br>• This is highly dependent on the terminal / channel width – this rating is worst-case with a narrow channel |
| **1.2.7.3** Excessive relative motion between positioning arm and vessel | • Passing vessel at high velocity causes unusually large wake or surge | • Barge rolling motion causes positioning arm to move relative to the vessel<br>• Alongside combined up/down and fore/aft relative motion is more pronounced than when barge is positioned astern of vessel. | • Select an alternative scenario | Asset | 3 | C | 3C | See Recommendation # 29 | • The largest angular motion during a wake is the rolling motion about the shortest barge dimension<br>• Alongside (parallel orientation) barge rolling translates to an up/down motion at the positioning arm tip, which is not present when positioned astern of the vessel.<br>• Alongside (parallel orientation) during a very large wake, there will also be fore/aft motion, which is typically absent. Fore/aft motion may damage sensitive equipment forward of the vessel's exhaust pipes.<br>• In spudded mode rolling motion may be limited due to spud/vessel interaction |
| **1.2.8** Tanker Overboard Discharge<br><br>1.2.8.1 - Ballast overboard from Vessel (Scenarios 1 & 2) | • Location of vessel overboard discharges onto barge | • Disrupt barge operations<br>• Impacts visibility | • Distance between vessel and spudded barge is enough to avoid any discharge water coming on board. | Asset | 2 | B | 2B | See recommendation # 30 | • Also, ballast treatment and cooling water systems may have overboard discharges.<br>• The vessels' stern is a safe location from overboard discharges |
| **1.2.8.2 - Inert gas overboard discharge** | • Location of discharge on tanker | • Discharge IG water on barge (IG water discharge | • Barge freeboard is approximately 10 feet | Asset | 2 | A | 2A | | • Position of barge to be avoided underneath of IG discharge |
| **1.2.9** Disengaging / retrieval of boom - Tug moves barge before boom is retrieved (Spud retrieved) | • Miscommunication<br>• Emergency situations | • Damage to vessel funnel / exhaust pipe | • Operational procedures and communication protocols<br>• Exhaust capture hood is designed for breakaway | Asset | 2 | C | 2C | See recommendation # 31 | • After tanker completes discharged operation, exhaust capture hood(s) are lifted, and the boom is moved clear.<br>• This is only an issue if the tug connects with barge before Crane boom / collection device is moved.<br>• Moving of the barge by the tug in an emergency without exhaust capture hood retrieval not anticipated<br>• System is designed for extreme tidal wave scenarios. |
| **1.2.10** Tug moves barge before spud was retrieved | | • Damage to spud, barge structure | | Asset | 2 | B | 2B | | |

| System Level Nodes - Hazard Scenario | Potential Cause | Consequences | Effective Safeguard | Category | Risk Ranking | | | Recommendations (R#) | Comments |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | S | L | RR | | |
| **1.2.11** Spud Retrieval Unable to retrieve spud | • Mechanical failure<br>• Spud stuck at bottom | • Unable to move barge<br>• Unable to move vessel | | Asset | 2 | C | 2C | 42. Spud retrieval time / procedures to be developed.<br>43. Overall time required to move barge away in spudded configuration to be studied to meet regulation requirement of an emergency move.<br>44. Spud powering requirements (including emergency power) to be developed. | • Barge is outside boom containment area<br>Spud retrieval time / procedures<br>• Spud retrieval power requirements to be ascertained. |
| **1.2.12** Loss of power | • Electrical / mechanical faults | • Unable to perform exhaust capture operations<br>• Hood(s) lift away naturally (mechanically) when power is removed<br>• Process blower shuts down | • At least one redundant power source (e.g., genset), each capable to handle entire load.<br>• Monitor and automatically anticipate fuel needs | Asset | 1 | D | 1D | | • The basic barge has two gensets<br>• Stand by genset automatically comes online<br>• Additional power sources are planned (e.g., hydrogen fuel cells) |
| **1.2.13** Barge exhaust gas (both from cleaned vessel exhaust and barge genset) | • Close proximity of exhaust and vessel | • Exhaust gases may trigger alarms in vessel accommodation | • High cleaning efficiency by barge | Human | 2 | C | 2C | See recommendation # 32 | • The distance between the barge and the deck of the vessel is significant<br>• Two exhaust hoods planned for design (1-4 exhaust are standard). CE notes that up to 6 major exhaust producers may be running (3 gen sets, 1 HPU, 1 boiler)<br>• Hood design is still going through the design process and will be presented upon completion |
| | | • Genset exhaust may produce sparks | • Modern Tier 4F gensets have significant emissions equipment (DPF and SCR) between the engine and the genset exhaust pipe, making spark travel impossible. | Asset | 2 | A | 2A | See recommendation # 33 and 34 | |
| **1.2.12 Barge underneath of Lifeboat and Rescue Boat**<br><br>**1.2.12.1** Obstructing tanker lifeboat launch | • Barge in way of tanker lifeboat launch | • Unable to launch tanker lifeboat | • | Human | 3 | B | 3B | See Recommendation # 35 | Local regulation to be studied |
| **1.2.12.2** Obstructing tanker rescue boat launch | • Barge in way of tanker rescue boat launch | • Unable to launch tanker rescue boat | • | Human | 3 | B | 3B | | |
| **1.3 Scenario 3:**<br>**Barge spudded off stern quarter (can be at any angle)** | | | | | | | | | • No additional risk found compared to scenario # 2<br>• Not as much into channel compared to scenario #2. Less impediment to navigation channel Spud getting stuck will not prevent the vessel to move away from the pier.<br>• Depending on the width of the channel, there may be restrictions on barge orientation (i.e. perpendicular to the tanker) to prevent navigational issues. |
| **1.3.1** Barge is brought near the side of the tanker - Collision / Contact | • Loss of control by tug<br>• Wave action due to passing vessels | • Minor damage to vessel (e.g., paint) | • Operational procedures and training | Asset | 1 | C | 1C | See recommendation # 6 and 7 | • Tug is physically connected/attached to barge on side tow. Tow plans are |

| System Level Nodes - Hazard Scenario | Potential Cause | Consequences | Effective Safeguard | Category | Risk Ranking | | | Recommendations (R#) | Comments |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | S | L | RR | | |
| | • Wave action due to weather<br>• High current (in some Northern CA terminals) | • Moderate damage to vessel (e.g., dent) | • Slow speed operation<br>• Small approach angle – barge to vessel to minimize forces on vessel<br>• Require single tugs to have two engines | Asset | 2 | A | 2A | | per approved procedure. Normal operations as per procedures.<br>• Damage to bunker tank / side shell possible based on momentum. Could be loss of propulsion on escort tug |
| | | • Damage to bunker tank / side shell causing oil spill | | Environment | 3 | A | 3A | | |
| **1.3.2** Man overboard | • Due to impact of collision<br>• human error<br>• Trip, slip, fall | • Injury, fatality<br>• No danger between barge and vessel | • Barge has handrails.<br>• PPE supplied to crew on barge.<br>• All Terminal / USCG / OSHA - LSA requirements provided.<br>• Life rings provided on barge | Human | 2 | C | 2C | See recommendation # 9 | • Small transfer boat used for crew changes and any assistance to barge. Man overboard procedures to be included in Emergency procedures.<br>• OSHA requirements will be met. |
| **1.3.3** Release of Oil/petroleum products/chemical product from Vessel<br><br>1.3.3.1 – Oil Hazards | • Loss of cargo piping integrity<br>• Cargo transfer hose/arm failure<br>• Loss of containment tanker vessel<br>• Cargo tank over pressurization | • Fire<br>• Explosion<br>• Barge is not trapped within containment | • Class I Div. I lighting arrangements on barge<br>• LEL detectors on barge deck and also in process boxes.<br>• Barge powers down automatically upon E-stops and LEL detection .<br>• E-stops throughout barge<br>• Evacuation of barge | Asset | 2 | A | 2A | See recommendation # 10, 11, 12 and 13 | • Barge is outside oil containment boom perimeter.<br>• Barge cannot be moved if required<br>• Any emergency on vessel, will result in shutdown of all operations of barge.<br>• Bunker tank of tanker vessel not double hull. |
| 1.3.3.2 – Environmental Hazards | | • Release of pollutants | | Environment | n/a* | n/a* | n/a* | | • * - A tanker spill is an environmental category for the vessel, but out of scope for the barge. |
| 1.3.3.3 Release of Toxic Vapor (special consideration) | | • Release of hazardous material toxic vapor | • PPE Provided for oil spill/petroleum product and vapor release | Human | 3 | D | 3D | See recommendation # 14, 15, 16, 17, 18 and 19 | • Project covers all petroleum products, not just oil, that can be carried on tanker vessel. List of all possible products to be provided<br>• Some products may have the potential for $H_2S$ vapor release and will be require special consideration<br>• Potential of $H_2S$ vapor release(special consideration) due to over pressurization from high temperature. Vapor can migrate towards the barge depending on atmospheric conditions<br>• the barge could have rig savers installed to protect against $H_2S$ release. Common equipment on drillships.<br>Current scope is for oil tankers, chemicals carrier may be in the future but not at this stage |
| 1.3.3.4 – Electrical Shutdown – Deenergizing electrical equipment | • Barge powered down due to oil spill | • Difficulty for crew to move around<br>• Injury | • Intrinsically safe emergency lighting turns on automatically. | Human | 2 | C | 2A | See recommendation # 10,11, 12 and 13 | |

| System Level Nodes - Hazard Scenario | Potential Cause | Consequences | Effective Safeguard | Category | Risk Ranking | | | Recommendations (R#) | Comments |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | S | L | RR | | |
| | | | • Intrinsically safe flash / torch lights provided. | | | | | | |
| **1.4.4** Night operation<br><br>Loss of power and lighting at night | • Electrical fault<br>• Blackout<br>• Tanker vessel spill requires barge to be shut down and de-energized | • Difficulty for crew to move around<br>• Injury | • Intrinsically safe flash / torch lights provided. | Human | 2 | C | 2C | | • Barge can be moved if needed as it is outside Oil containment boom perimeter.<br>• Tug may not be able rescue crew on barge. Small transfer boat needs to be used (row) to escape. |
| **1.3.5** Spud Operation<br>**1.3.5.1** Unable to lower spud | • Mechanical fault (winch, control system etc.) | • Unable to perform exhaust capture operations | | Asset | 2 | B | 2B | See recommendation # 36, 37 and 38 | • Is spud control system redundant?<br>• Spud will not be retrieved unless the arm is in the parked position.<br>• During transit operations the arm is in the parked position |
| **1.3.5.2** Too much penetration | • Soft soil | • Unable to perform exhaust capture operations<br>Too much penetration can lead to insufficient length of spud | | Asset | 2 | B | 2B | See recommendation # 39 and 40 | • It is unlikely to be surprised by a soft soil condition once experienced |
| **1.3.5.3 Unable to retrieve spud** | • Spud Stuck<br>• Wire Break<br>• Winch Break | • Barge cannot move away from tanker<br>• In case of emergency tanker can't move away | | Asset<br>Human | 3 | D | 3D | See recommendation # 41 and 42. | • Beam of barge is 42 feet<br>• Barge may inhibit passage through the channel for some vessels<br>• Possibility of crane vessel available to pull the spuds |
| **1.3.5.4** No penetration in soil | • Object at bottom (pipeline, anchor, lost equipment etc. etc.)<br>• Soil too hard<br>• Not enough water depth | • Stability of barge movement cannot be achieved<br>• Unable to perform exhaust capture operations<br>• Possibility of spud entanglement with objects at bottom | | Asset | 2 | C | 2C | See recommendation # 39 | • Surveys are done regularly at POLB |
| **1.3.6** Positioning articulated boom capture arm.<br><br>Exhaust capture hood contact with vessel. | • Operator error<br>• Weather condition – high wind, waves<br>• No direct line of sight from control room | • Damage to funnel / exhaust stack of vessel<br>• Unable to perform exhaust capture operation | • Camera / vision / infra-red video cameras<br>• Wind speed sensors at the top of the capture arm<br>• Arm controllable using portable control unit from deck to have clear line of sight<br>• Crew assistance to position<br>• Operational procedures | Asset | 2 | C | 2C | See recommendation # 24, 25 and 26 | • System is warming up at low flow on the way to the vessel. As the exhaust capture hood approaches the exhaust pipe, dynamic flow adjustment matches exhaust flow<br>• What are dimensional limitations? How different stacks can be covered? What about uneven base surfaces? Answer: In reviewing this question, understand the uneven surface aspect. STAX approach does not rely on a hood extending all the way to the "floor". STAX rejected this approach because there is typically pressurized engine room air that enters around the base of the exhaust pipe which causes dilution and other problems. STAX hood only covers the top aspect of the exhaust pipe. |

| System Level Nodes - Hazard Scenario | Potential Cause | Consequences | Effective Safeguard | Category | Risk Ranking S | L | RR | Recommendations (R#) | Comments |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | • Positioning is a joystick operation. A 'gentle' downward force keep hood in position. Hood will retract back to top of boom in case of power outage / technical issues.<br>• Infrared cameras to determine which exhaust pipes are in operation.<br>• Crane operation is done by a portable remote-control system on the barge to gain the best line of sight. Control room also has augmented reality and screens to provide clear view from the control room by another crew member.<br>• Ample reach of boom measured form barge crane center at deck level to the vessel exhaust stack funnel.<br>• C&C system is designed to accommodate any tidal condition |
| **1.3.7 Passing Vessels** | | | | | | | | | |
| **1.3.7.1** Barge struck by a passing vessel. (Scenarios 1 & 2 only) | • Loss of control of another vessel<br>• Lack of attention by passing vessel<br>• Visibility (e.g., fog)<br>• Narrow channel | • Collision with barge and/or tanker causing vessel hull damage (e.g., puncture)<br>• Flooding of barge | • Barge is fitted with required navigational lights.<br>• Barge deck and arm has adequate lighting | Asset | 2 | B | 2B | See recommendation # 27 | • This is highly dependent on the terminal / channel width – this rating is worst-case with a narrow channel<br>• Barge is divided in compartment. Meet USCG stability requirements<br>• Less likely less severe than Scenarios 1 or 2 |
| **1.3.7.2** Barge extends into navigational channel (Scenarios 1 & 2 only) | • Barge extending into navigational channel<br>• Delays in operations | • Disrupting port operations<br>• Unable to perform exhaust capture operations | • The pilot's dispatchers notify all pilots and commercial traffic of any obstructions to channels or waterways.<br>• Training<br>• Select another scenario | Asset | 2 | B | 2B | See recommendation # 28 | • In this Scenario 2, the barge may be positioned further into the channel, thus the higher likelihood (although this is not necessarily true)<br>• This is highly dependent on the terminal / channel width – this rating is worst-case with a narrow channel<br>• Less likely and sever than Scenarios 1 or 2 |
| **1.3.7.3** Excessive relative motion between positioning arm and vessel | • Passing vessel at high velocity causes unusually large wake or surge | • Barge rolling motion causes positioning arm to move relative to the vessel<br>• Alongside combined up/down and fore/aft relative motion is more pronounced than when barge is positioned astern of vessel. | • Select an alternative scenario | Asset | 3 | D | 3D | See recommendation # 29 | • The largest angular motion during a wake is the rolling motion about the shortest barge dimension<br>• Alongside (parallel orientation) barge rolling translates to an up/down motion at the positioning arm tip, which is not present when positioned astern of the vessel.<br>• Alongside (parallel orientation) during a very large wake, there will also be fore/aft motion, which is typically absent. Fore/aft motion may damage sensitive equipment forward of the vessel's exhaust pipes. |

| System Level Nodes - Hazard Scenario | Potential Cause | Consequences | Effective Safeguard | Category | Risk Ranking | | | Recommendations (R#) | Comments |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | S | L | RR | | |
| **1.3.8** Tanker Overboard Discharge<br><br>1.3.8.1 - Ballast overboard from Vessel (Scenarios 1 & 2) | • Location of vessel overboard discharges onto barge | • Disrupt barge operations<br>• Impacts visibility | • Distance between vessel and spudded barge is enough to avoid any discharge water coming on board. | Asset | 2 | B | 2B | See recommendation # 30 | • Also, ballast treatment and cooling water systems may have overboard discharges.<br>• The vessels' stern is a safe location from overboard discharge |
| **1.3.8.2 - Inert gas overboard discharge** | • Location of discharge on tanker | • Discharge IG water on barge (IG water discharge | • Barge freeboard is approximately 10 feet | Asset | 2 | A | 2A | | • Position of barge to be avoided underneath of IG discharge |
| **1.3.9** Disengaging / retrieval of boom - Tug moves barge before boom is retrieved | • Miscommunication<br>• Emergency situations | • Damage to vessel funnel / exhaust pipe | • Operational procedures and communication protocols<br>• Exhaust capture hood is designed for breakaway | Asset | 2 | C | 2C | See recommendation # 31 | • After tanker completes discharged operation, exhaust capture hood(s) are lifted, and the boom is moved clear.<br>• This is only an issue if the tug connects with barge before Crane boom / collection device is moved.<br>• Moving of the barge by the tug in an emergency without exhaust capture hood retrieval not anticipated<br>• System is designed for extreme tidal wave scenarios. |
| **1.3.10** Tug moves barge before spud was retrieved | | • Damage to spud, barge structure | | Asset | 2 | B | 2B | | |
| **1.3.11** Spud Retrieval Unable to retrieve spud | • Mechanical failure<br>• Spud stuck at bottom | • Unable to move barge<br>• Unable to move vessel | | Asset | 2 | C | 2C | See recommendation # 43, 44and 45. | • Barge is outside boom containment area<br>Spud retrieval time / procedures<br>• Spud retrieval power requirements to be ascertained. |
| **1.3.12** Loss of power | • Electrical / mechanical faults | • Unable to perform exhaust capture operations<br>• Hood(s) lift away naturally (mechanically) when power is removed<br>• Process blower shuts down | • At least one redundant power source (e.g., genset), each capable to handle entire load.<br>• Monitor and automatically anticipate fuel needs | Asset | 1 | D | 1D | | • The basic barge has two gensets<br>• Stand by genset automatically comes online<br>• Additional power sources are planned (e.g., hydrogen fuel cells) |
| **1.3.13** Barge exhaust gas (both from cleaned vessel exhaust and barge genset) | • Close proximity of exhaust and vessel | • Exhaust gases may trigger alarms in vessel accommodation | • High cleaning efficiency by barge | Human | 2 | B | 2B | See recommendation # 32, 33 **and 34** | • The distance between the barge and the deck of the vessel is significant<br>• Two exhaust hoods planned for design (1-4 exhaust are standard). CE notes that up to 6 major exhaust producers may be running (3 gen sets, 1 HPU, 1 boiler)<br>• Hood design is still going through the design process and will be presented upon completion |
| **1.3.13 Barge underneath of Lifeboat and Rescue Boat**<br><br>**1.3.13.1** Obstructing tanker lifeboat launch | • Barge in way of tanker lifeboat launch | • Unable to launch tanker lifeboat | | Human | 3 | B | 3B | See Recommendation # 35 | • Local regulation to be studied |
| **1.3.13.2** Obstructing tanker rescue boat launch | • Barge in way of tanker rescue boat launch | • Unable to launch tanker rescue boat | | Human | 3 | B | 3B | | |

| System Level Nodes - Hazard Scenario | Potential Cause | Consequences | Effective Safeguard | Category | Risk Ranking S | Risk Ranking L | Risk Ranking RR | Recommendations (R#) | Comments |
|---|---|---|---|---|---|---|---|---|---|
| **1.4 Scenario 4:**<br>**Barge spudded astern of tanker** | | | | | | | | | |
| **1.4.1** Barge is brought near the stern of the tanker<br><br>Collision / Contact | | | | | | | | 45. MOTEMS diagram to be obtained from terminal operator to study the mooring lines and other obstacles for astern arrangement | • Articulated boom is 85 meters long, so spud can be far aft depending on the vent mast<br>• Tug is physically connected/attached to barge on side tow. Tow plans are per approved procedure. Normal operations as per procedures. |
| | • Loss of control by tug<br>• High current (in some Northern CA terminals)<br>• Wave action due to passing vessels<br>• Wave action due to weather<br>• High current (in some Northern CA terminals) | • Minor damage to vessel (e.g., paint) | • Operational procedures and training<br>• Slow speed operation<br>• Small approach angle – barge to vessel to minimize forces on vessel<br>• Require single tugs to have two engines | Asset | 1 | B | 1B | See recommendation # 6 and 7 | |
| | | • Moderate damage to vessel (e.g., dent) | | Asset | 2 | A | 2A | | |
| | | • Damage to bunker tank / side shell causing oil spill | | Environment | 2 | A | 2A | | |
| **1.4.2** Man overboard | • Human error<br>• Trip, slip, fall | • Injury, fatality | • Barge has handrails.<br>• PPE supplied to crew on barge.<br>• All Terminal / USCG / OSHA - LSA requirements provided.<br>• Life rings provided on barge | Human | 2 | C | 2C | See recommendation # 9 | • Small transfer boat used for crew changes and any assistance to barge. Man overboard procedures to be included in Emergency procedures.<br>• OSHA requirements will be met. |
| **1.4.3** Release of Oil/petroleum product/chemical product from Vessel<br><br>1.4.3.1 – Oil Hazards | • Loss of cargo piping integrity<br>• Cargo transfer hose/arm failure<br>• Loss of containment tanker vessel<br>• Cargo tank over pressurization | • Fire<br>• Explosion<br>• Barge is not trapped within containment | • Class I Div. I lighting arrangements on barge<br>• LEL detectors on barge deck and also in process boxes.<br>• Barge powers down automatically upon E-stops and LEL detection .<br>• E-stops throughout barge<br>• Evacuation of barge | Asset | 2 | A | 2A | See recommendation # 10, 11, 12 and 13 | • Barge is outside oil containment boom perimeter.<br>• Barge cannot be moved if required<br>• Any emergency on vessel, will result in shutdown of all operations of barge.<br>• Bunker tank of tanker vessel not double hull |
| 1.4.3.2 – Environmental Hazards | | • Release of pollutants | | Environment | n/a* | n/a* | n/a* | | • * - A tanker spill is an environmental category for the vessel, but out of scope for the barge |
| 1.4.3.3 Release of Toxic Vapor(special consideration) | | • Release of hazardous material toxic vapor | • PPE Provided for oil spill/petroleum product and vapor release | Human | 3 | D | 3D | See recommendation # 14, 15, 16, 17, 18 and 19 | • Project covers all petroleum products, not just oil, that can be carried on tanker vessel. List of all possible products to be provided<br>• Some products may have the potential for $H_2S$ vapor release and will require special consideration<br>• Potential of $H_2S$ vapor release (special consideration) due to over pressurization from high temperature. Vapor can migrate towards the barge depending on atmospheric conditions |

| System Level Nodes - Hazard Scenario | Potential Cause | Consequences | Effective Safeguard | Category | Risk Ranking | | | Recommendations (R#) | Comments |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | S | L | RR | | |
| | | | | | | | | | • the barge could have rig savers installed to protect against $H_2S$ release. Common equipment on drillships.<br>Current scope is for oil tankers, chemicals carrier may be in the future but not at this stage |
| 1.4.3.4 – Electrical Shutdown – Deenergizing electrical equipment | • Barge powered down due to oil spill | • Difficulty for crew to move around<br>• Injury | • Intrinsically safe emergency lighting turns on automatically.<br>• Intrinsically safe flash / torch lights provided. | Human | 2 | C | 2A | See recommendation # 10, 11, 12 and 13 | |
| **1.4.4** Night operation<br><br>Loss of power and lighting at night | • Electrical fault<br>• Blackout<br>• Tanker vessel spill requires barge to be shut down and de-energized | • Difficulty for crew to move around<br>• Injury | • Intrinsically safe flash / torch lights provided. | Human | 2 | C | 2C | | • Barge can be moved if needed as it is outside Oil containment boom perimeter.<br>• Tug may not be able rescue crew on barge. Small transfer boat needs to be used (row) to escape. |
| **1.4.5** Spud Operation<br>**1.4.5.1** Unable to lower spud | • Mechanical fault (winch, control system etc.) | • Unable to perform exhaust capture operations | | Asset | 2 | B | 2B | 46. Study to be conducted to determine mooring lines are not interfering with the spuds or the articulated arm<br><br>See recommendation # 36, 37 and 38 | • Is spud control system redundant?<br>• Spud will not be retrieved unless the arm is in the parked position.<br>• During transit operations the arm is in the parked position |
| **1.4.5.2** Too much penetration | • Soft soil | • Unable to perform exhaust capture operations<br>Too much penetration can lead to insufficient length of spud | | Asset | 2 | B | 2B | See recommendation #39 and 40 | • It is unlikely to be surprised by a soft soil condition once experienced |
| **1.4.5.3 Unable to retrieve spud** | • Spud Stuck<br>• Wire Break<br>• Winch Break | • Barge cannot move away from tanker<br>• In case of emergency tanker can't move away | | Asset<br>Human | 3 | D | 3D | See recommendation # 41 and 42. | • Beam of barge is 42 feet<br>• Barge may inhibit passage through the channel for some vessels<br>• Possibility of crane vessel available to pull the spuds |
| **1.4.5.4** No penetration in soil | • Object at bottom (pipeline, anchor, lost equipment etc. etc.)<br>• Soil too hard<br>• Not enough water depth | • Stability of barge movement cannot be achieved<br>• Unable to perform exhaust capture operations<br>• Possibility of spud entanglement with objects at bottom | | Asset | 2 | C | 2C | See recommendation # 39 | • Surveys are done regularly at POLB |
| **1.4.6** Positioning articulated boom capture arm.<br><br>Exhaust capture hood contact with vessel. | • Operator error<br>• Weather condition – high wind, wave<br>• No direct line of sight from control room | • Damage to funnel / exhaust stack of vessel<br>• Unable to perform exhaust capture operation | • Camera / vision / infra-red video cameras<br>• Wind speed sensors at the top of the capture arm<br>• Arm controllable using portable control unit from deck to have clear line of sight | Asset | 2 | C | 2C | See recommendation # 24, 25 & 26 | • System is warming up at low flow on the way to the vessel. As the exhaust capture hood approaches the exhaust pipe, dynamic flow adjustment matches exhaust flow rate during operations using sensors.<br>• What are dimensional limitations? How different stacks can be covered? What about uneven base surfaces? Answer: In reviewing this question, understand the uneven surface aspect. STAX approach does |

| System Level Nodes - Hazard Scenario | Potential Cause | Consequences | Effective Safeguard | Category | Risk Ranking S | Risk Ranking L | Risk Ranking RR | Recommendations (R#) | Comments |
|---|---|---|---|---|---|---|---|---|---|
| | | | • Crew assistance to position<br>• Operational procedures | | | | | | not rely on a hood extending all the way to the "floor". STAX rejected this approach because there is typically pressurized engine room air that enters around the base of the exhaust pipe which causes dilution and other problems. STAX hood only covers the top aspect of the exhaust pipe.<br>• Positioning is a joystick operation. A 'gentle' downward force keep hood in position. Hood will retract back to top of boom in case of power outage / technical issues.<br>• Infrared cameras to determine which exhaust pipes are in operation.<br>• Crane operation is done by a portable remote-control system on the barge to gain the best line of sight. Control room also has augmented reality and screens to provide clear view from the control room by another crew member.<br>• Ample reach of boom measured form barge crane center at deck level to the vessel exhaust stack funnel.<br>• C&C system is designed to accommodate under any tidal condition |
| **1.4.7 Passing Vessels** | | | | | | | | | |
| **1.4.7.1** Barge struck by a passing vessel. | • Not applicable for this scenario | | | | | | n/a | | |
| **1.4.7.2** Barge extends into navigational channel | • Not applicable for this scenario | | | | | | n/a | | |
| **1.4.7.3** Excessive relative motion between positioning arm and vessel | • Passing vessel at high velocity causes unusually large wake or surge | • Barge rolling motion causes positioning arm to move relative to the vessel, but no fore/aft relative motion (safer) | | Asset | 2 | C | 2C | See recommendation # 29 | • The largest angular motion during a wake is the rolling motion about the shortest barge dimension<br>• Location astern of vessel translates rolling to a lateral motion and pitch (very rare) translates to lateral motion – not fore/aft motion |
| **1.4.8** Tanker Overboard Discharge from Vessel | • Not applicable for this scenario | | | | | | n/a | | |
| **1.4.9** Disengaging / retrieval of boom - Tug moves barge before boom is retrieved | • Miscommunication<br>• Emergency situations | • Damage to vessel funnel / exhaust pipe | • Operational procedures and communication protocols<br>• Exhaust capture hood is designed for breakaway | Asset | 2 | C | 2C | See recommendation # 31 | • After tanker completes discharged operation, exhaust capture hood(s) are lifted, and the boom is moved clear.<br>• This is only an issue if the tug connects with barge before Crane boom / collection device is moved. |
| **1.4.10** Tug moves barge before spud was retrieved | | • Damage to spud, barge structure | | Asset | 2 | B | 2B | | |

| System Level Nodes - Hazard Scenario | Potential Cause | Consequences | Effective Safeguard | Category | Risk Ranking S | L | RR | Recommendations (R#) | Comments |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | • Moving of the barge by the tug in an emergency without exhaust capture hood retrieval not anticipated<br>• System is designed for extreme tidal wave scenarios. |
| **1.4.11** Spud Retrieval Unable to retrieve spud | • Mechanical failure<br>• Spud stuck at bottom | • Unable to move barge<br>• Unable to move vessel | | Asset | 2 | C | 2C | See recommendation # 43, 44 and 45 | • Barge is outside boom containment area<br>Spud retrieval time / procedures<br>• Spud retrieval power requirements to be ascertained. |
| **1.4.12** Loss of power | • Electrical / mechanical faults | • Unable to perform exhaust capture operations<br>• Hood(s) lift away naturally (mechanically) when power is removed<br>• Process blower shuts down | • At least one redundant power source (e.g., genset), each capable to handle entire load.<br>• Monitor and automatically anticipate fuel needs | Asset | 1 | D | 1D | | • The basic barge has two gensets<br>• Stand by genset automatically comes online<br>• Additional power sources are planned (e.g., hydrogen fuel cells) |
| **1.4.13** Barge exhaust gas (both from cleaned vessel exhaust and barge genset) | • A relatively large distance between barge and vessel | • Exhaust gases may trigger alarms in vessel accommodation | • High cleaning efficiency by barge | Human | 1 | B | 2B | See recommendation # 32, 33 and 34 | • The distance between the barge and the deck of the vessel is significant<br>• Two exhaust hoods planned for design (1-4 exhaust are standard). CE notes that up to 6 major exhaust producers may be running (3 gen sets, 1 HPU, 1 boiler)<br>Hood design is still going through the design process and will be presented upon completion |
| **1.5 Scenario 5:<br>Barge tied to pier astern of tanker** | | | | | | | | | |
| **1.5.1** Barge is positioned near the tanker<br><br>1.5.1.1 Collision / Contact | • Loss of control by tug<br>• Wave action due to passing vessels<br>• Wave action due to weather<br>• High current (in some Northern CA terminals) | • Minor damage to vessel (e.g., paint) | • Operational procedures and training<br>• Slow speed operation<br>• Require single tugs to have two engines | Asset | 1 | B | 1B | See recommendation # 6and 7 | • Tug is physically connected/attached to barge on side tow. Tow plans are per approved procedure. Tug requirements specified in Harbor safety plan. Normal operations as per procedures.<br>• Vessel mooring lines are more of a concern than the vessel's hull |
| | | • Moderate damage to vessel (e.g., dent) | | Asset | 2 | A | 2A | | |
| | | • Damage to bunker tank / side shell causing oil spill | | Environment | 3 | A | 3A | | |
| 1.5.1.2 - Space between the two tankers | Not enough space between the two tankers | • Unable to bring the barge astern | | | | | | 47. At certain terminals, space between the tankers is limited and therefore consider the arrangement of pier/terminal, and if multiple tankers moored, the spacing between the two tankers to be analyzed in regard to the barge being astern. | Applies to 1.4 (any stern configurations) |
| 1.5.1.3 - Interference with mooring line | Spuds extended 80' in the air | • unable to bring the vessel to the pier | Boom length is 80 meters and may provide enough clearance | Asset | 2 | D | 2D | | Is spud control system redundant?<br>Spuds will be up in this configuration.<br>Spuds can be extended up 80-90 ft from waterline<br>Spuds are up at all times |
| **1.5.2** Man overboard | • Due to impact of collision<br>• human error<br>• Trip, slip, fall | • Injury, fatality<br>• No danger between barge and vessel | • Barge has handrails.<br>• PPE supplied to crew on barge.<br>• All Terminal / USCG / OSHA - LSA | Human | 2 | C | 2C | See recommendation # 9 | • Mooring arrangements done by a system operator on barge and lines man. Maintaining lines all time. Small transfer boat used for crew changes and any assistance to |

| System Level Nodes - Hazard Scenario | Potential Cause | Consequences | Effective Safeguard | Category | Risk Ranking S | L | RR | Recommendations (R#) | Comments |
|---|---|---|---|---|---|---|---|---|---|
| | | | requirements provided.<br>• Life rings provided on barge | | | | | | barge. Man overboard procedures to be included in Emergency procedures.<br>• OSHA requirements will be met. |
| **1.5.3** Release of Oil/petroleum products/chemical products from Vessel<br>1.5.3.1 – Oil Hazards | • Loss of cargo piping integrity<br>• Cargo transfer hose/arm failure<br>• Loss of containment tanker vessel<br>• Cargo tank over pressurization | • Fire<br>• Explosion<br>• Barge is not trapped within containment | • Class I Div. I lighting arrangements on barge<br>• LEL detectors on barge deck and also in process boxes.<br>• Powering down the barge.<br>• E-stop on barge.<br>• Evacuation of barge | Asset | 2 | A | 2A | See recommendation # 10. 11. 12 and 13 | • Barge is outside oil containment boom perimeter.<br>• Barge cannot be moved if required<br>• Any emergency on vessel, will result in shutdown of all operations of barge.<br>• Bunker tank of tanker vessel not double hull |
| 1.5.3.2 – Environmental Hazards | | • Release of pollutants | | Environment | n/a | n/a | n/a | | • A tanker spill is an environmental category for the vessel, but out of scope for the barge |
| 1.5.3.3 Release of Toxic Vapor(special consideration) | | • Release of hazardous material toxic vapor | • PPE Provided for oil spill/petroleum product and vapor release | Human | 3 | D | 3D | See recommendation # 14, 15, 16, 17, 18 and 19 | • Project covers all petroleum products, not just oil, that can be carried on tanker vessel. List of all possible products to be provided<br>• Some products may have the potential for $H_2S$ vapor release and will require special consideration<br>• Potential of $H_2S$ vapor release (special consideration) due to over pressurization from high temperature. Vapor can migrate towards the barge depending on atmospheric conditions<br>• the barge could have rig savers installed to protect against $H_2S$ release. Common equipment on drillships.<br>Current scope is for oil tankers, chemicals carrier may be in the future but not at this stage |
| 1.5.3.4 – Electrical Shutdown – Deenergizing electrical equipment | • Barge powered down due to oil spill | • Difficulty for crew to move around<br>• Injury | • Intrinsically safe emergency lighting turns on automatically.<br>• Intrinsically safe flash / torch lights provided. | Human | 2 | C | 2A | See recommendation # 10, 11, 12 and 13 | |
| **1.5.4** Night operation<br><br>Loss of power and lighting at night | • Electrical fault<br>• Blackout<br>• Tanker vessel spill requires barge to be shut down and de-energized | • Difficulty for crew to move around<br>• Injury | • Intrinsically safe flash / torch lights provided. | Human | 2 | C | 2C | | • Barge can be moved if needed as it is outside Oil containment boom perimeter.<br>• Tug may not be able rescue crew on barge. Small transfer boat needs to be used (row) to escape. |
| **1.5.5** Spud Operation<br>**1.5.5.1** Unable to lower spud | • Mechanical fault (winch, control system etc.) | • Unable to perform exhaust capture operations | | Asset | 2 | B | 2B | See recommendation # 36, 37, 38 and 47 | • Is spud control system redundant?<br>• Spud will not be retrieved unless the arm is in the parked position.<br>• During transit operations the arm is in the parked position |

| System Level Nodes - Hazard Scenario | Potential Cause | Consequences | Effective Safeguard | Category | Risk Ranking S | L | RR | Recommendations (R#) | Comments |
|---|---|---|---|---|---|---|---|---|---|
| **1.5.5.2** Too much penetration | • Soft soil | • Unable to perform exhaust capture operations<br>Too much penetration can lead to insufficient length of spud | | Asset | 2 | B | 2B | See recommendation # 39 and 40 | • It is unlikely to be surprised by a soft soil condition once experienced |
| **1.5.5.3 Unable to retrieve spud** | • Spud Stuck<br>• Wire Break<br>• Winch Break | • Barge cannot move away from tanker<br>• In case of emergency tanker can't move away | | Asset<br>Human | 3 | D | 3D | See recommendation # 41 and 42. | • Beam of barge is 42 feet<br>• Barge may inhibit passage through the channel for some vessels<br>• Possibility of crane vessel available to pull the spuds |
| **1.5.5.4** No penetration in soil | • Object at bottom (pipeline, anchor, lost equipment etc. etc.) | • Stability of barge movement cannot be achieved<br>• Unable to perform exhaust capture operations<br>• Possibility of spud entanglement with objects at bottom | | Asset | 2 | C | 2C | See Recommendation # 39 | • Surveys are done regularly at POLB |
| **1.5.6** Positioning articulated boom capture arm.<br><br>Exhaust capture hood contact with vessel. | • Operator error<br>• Weather condition – high wind, wave<br>• No direct line of sight from control room | • Damage to funnel / exhaust stack of vessel<br>• Unable to perform exhaust capture operation | • Camera / vision / infra-red video cameras<br>• No part of the barge will be under the mooring line<br>• Wind speed sensors at the top of the capture arm<br>• Arm controllable using portable control unit from deck to have clear line of sight<br>• Crew assistance to position<br>• Operational procedures | Asset | 2 | C | 2C | See recommendation # 24, 25 and 26 | • System is warming up at low flow on the way to the vessel. As the exhaust capture hood approaches the exhaust pipe, dynamic flow adjustment matches exhaust flow<br>• What are dimensional limitations? How different stacks can be covered? What about uneven base surfaces? Answer: In reviewing this question, I think I better understand the uneven surface aspect. Our approach does not rely on a hood extending all the way to the "floor". We rejected this approach because there is typically pressurized engine room air that enters around the base of the exhaust pipe which causes dilution and other problems. Our hood only covers the top aspect of the exhaust pipe.<br>• Rate during operations using sensors.<br>• Positioning is a joystick operation. A 'gentle' downward force keep hood in position. Hood will retract back to top of boom in case of power outage / technical issues.<br>• Infrared cameras to determine which exhaust pipes are in operation.<br>• Crane operation is done by a portable remote-control system on the barge to gain the best line of sight. Control room also has augmented reality and screens to |

| System Level Nodes - Hazard Scenario | Potential Cause | Consequences | Effective Safeguard | Category | Risk Ranking S | L | RR | Recommendations (R#) | Comments |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | provide clear view from the control room by another crew member.<br>• Ample reach of boom measured form barge crane center at deck level to the vessel exhaust stack funnel.<br>• As long as barge is positioned out of the mooring line interference, CNC arm can be deployed |
| **1.5.6.1 Tanker Mooring line breakage** | • Maintenance<br>• overload | • Damage to the arm<br>• Injury to barge personnel | • | Asset<br>Human | 4 | B | 4B | 48. Develop training of mooring line failure risk | |
| **1.5.7 Passing Vessels** | | | | | | | | | |
| **1.5.7.1** Barge struck by a passing vessel. | • Not applicable for this scenario | | | | | | n/a | | |
| **1.5.7.2** Barge extends into navigational channel | • Not applicable for this scenario | | | | | | n/a | | |
| **1.5.7.3** Excessive relative motion between positioning arm and vessel | • Passing vessel at high velocity causes unusually large wake or surge | • Barge rolling motion causes positioning arm to move relative to the vessel, but no fore/aft relative motion (safer) | | Asset | 2 | C | 2C | See recommendation # 29 | • The largest angular motion during a wake is the rolling motion about the shortest barge dimension<br>• Location astern of vessel translates rolling to a lateral motion and pitch (very rare) translates to lateral motion – not fore/aft motion |
| **1.5.8** Ballast overboard from Vessel (Scenarios 1 & 2) | • Not applicable for this scenario | | | | | | n/a | | |
| **1.5.9** Disengaging / retrieval of boom - Tug moves barge before boom is retrieved | • Miscommunication<br>• Emergency situations | • Damage to vessel funnel / exhaust pipe | • Operational procedures and communication protocols<br>• Exhaust capture hood is designed for breakaway | Asset | 2 | C | 2C | See recommendation # 31 | • After tanker completes discharged operation, exhaust capture hood(s) are lifted, and the boom is moved clear.<br>• This is only an issue if the tug connects with barge before Crane boom / collection device is moved.<br>• Moving of the barge by the tug in an emergency without exhaust capture hood retrieval not anticipated<br>• System is designed for extreme tidal wave scenarios. |
| **1.5.10** Tug moves barge before spud was retrieved | | • Damage to spud, barge structure | | Asset | 2 | B | 2B | | |
| **1.5.11** Spud Retrieval Unable to retrieve spud | • Mechanical failure<br>• Spud stuck at bottom | • Unable to move barge<br>• Unable to move vessel | | Asset | 2 | C | 2C | See recommendation # 43, 44 and 45 | • Barge is outside boom containment area<br>Spud retrieval time / procedures<br>• Spud retrieval power requirements to be ascertained. |
| **1.5.12** Loss of power | • Electrical / mechanical faults | • Unable to perform exhaust capture operations<br>• Hood(s) lift away naturally (mechanically) when power is removed<br>• Process blower shuts down | • At least one redundant power source (e.g., genset), each capable to handle entire load.<br>• Monitor and automatically anticipate fuel needs | Asset | 1 | D | 1D | | • The basic barge has two gensets<br>• Stand by genset automatically comes online<br>• Additional power sources are planned (e.g., hydrogen fuel cells) |

| System Level Nodes - Hazard Scenario | Potential Cause | Consequences | Effective Safeguard | Category | Risk Ranking S | L | RR | Recommendations (R#) | Comments |
|---|---|---|---|---|---|---|---|---|---|
| **1.5.13** Barge exhaust gas (both from cleaned vessel exhaust and barge genset) | • Significant distance between exhaust and vessel | • Exhaust gases may trigger alarms in vessel accommodation | • High cleaning efficiency by barge | Human | 2 | B | 2B | See recommendation # 32, 33 and 34 | |
| **1.5.14** Obstruction by vessel mooring lines | • Vessel Mooring lines cause interference with positioning arm | • Unable to install barge due to interference with mooring lines<br>• Arm hitting mooring lines | • Mooring farther astern of vessel | Asset | 2 | D | 2D | 49. Mooring arrangement of vessel and tug to be studied for each berth location to identify restrictions and limitations | Mooring diagram to be provided for barge and vessel |
| Obstruction with spud | • Vessel mooring line obstructing/interface with spud when sped in up position at arrival, departure | • Spud damage<br>• Mooring line damage<br>• Entanglement | • Lower spud<br>• Do not fully raise spud during departure<br>• Proper procedures and training | Asset | 2 | C | 2C | | |
| Tug mooring lines | • Tug mooring line/vessel mooring line over each other, obstructing | • Tug unable to moor<br>• Entanglement of mooring line<br>• Unable to disconnect | • Proper procedure and spacing | Asset | 2 | C | 2C | | |
| Fire on tug | • Fire on tug | • Fire damage to vessel mooring lines | | Asset | 3 | C | 3C | | |
| Mooring line overhead of tug people | • Vessel mooring line break falling | • Human injury/fatality | | Asset | 3 | C | 3C | | |
| **Node # 2 Emergency Situation** | | | | | | | | | |
| **2.1 Emergency Situation** | | | | | | | | 50. Emergency procedures to be developed for all configuration and operational modes of barge. | Aft configuration |
| **2.2 Emergency on other tanker** | | | | | | | | 51. Emergency procedures and plan need be developed and need to consider emergencies on other tankers and at the terminal | |
| **Node # 3 Structure** | | | | | | | | | |
| **3.1.** Structural failure on Barge | • Corrosion, loss of integrity, fatigue/fractures | • Loss of stability, water ingress Unable to perform exhaust cleaning operation | • Regular inspections of barge internal spaces<br>• Standby tug can move the barge away from vessel. | Asset | 3 | C | 3C | 52. Develop inspection and maintenance plan for the barge to prevent corrosion and/or fatigue issues. | • Port water depth = ? |
| **3.2.1** Spud failure | • Fatigue/fractures<br>• Shear forces in horizontal plane<br>• Dropped objects (anchor/ wires / pipelines/debris) | • Loss of spud<br>• Unable to perform exhaust cleaning operation | • Spud designed to Class requirements Spudding procedures<br>• POLB requires that all berths be surveyed for water depths and obstructions every two years | Asset | 3 | B | 3B | 53. Spud design to be review, tested and operational envelope to be developed to identify various parameters such as wind, wave, depth, soil parameter etc.<br>54. Procedure for crane boom to be developed to avoid contact with spuds and explore provision of proximity sensors.<br>55. Be familiar with the depth, soil type and any obstructions prior to operations<br>56. Develop inspection and maintenance plan for the spud system to prevent corrosion and/or fatigue issues. | • Spudded but not jacked-up. Spudding is based on self-weight and barge is floating when spudded.<br>• Possibility of barge tipping over is unlikely. Enough bearing friction area between spud and barge.<br>• Spuds are 100 feet in length. Boom getting into contact with spud is an operational consideration. Boom crane needs to have visibility for operator to avoid spud and provision of proximity sensors needs to be investigated. |

| System Level Nodes - Hazard Scenario | Potential Cause | Consequences | Effective Safeguard | Category | Risk Ranking S | L | RR | Recommendations (R#) | Comments |
|---|---|---|---|---|---|---|---|---|---|
| **3.2.2** Spud failure | | • Spud is stuck to bottom | • Seek assistance from crane barge to remove spud / barge. | Asset | 3 | C | 3C | 57. Develop emergency procedures for stuck-spud retrieval | |
| **3.3** Tanker mooring line failure | | | • Tanker has 12 to 16 mooring lines<br><br>Approved mooring diagrams and procedures. | Asset | 1 | C | 1C | | • Loosing 1 or 2 lines will not cause immediate issues |
| **Node # 4**<br>**Safety System** | | | | | | | | | |
| **4.1** Fire<br><br>**4.1.1** - Fire on barge<br>Fire on Barge | | | | | | | | 58. Safety checklist to be developed by operator and barge. Guidance to be provided by owner consider all applicable rules and regulations. | • |
| | • Fire in machinery spaces, fuel, electrical fire, etc.<br>• Electrical equipment fire<br>• Short circuit | • Fire and smoke<br>• Unable to perform exhaust cleaning operation<br>• Barge shut down<br>• Barge damage | • Barge has PPE and FFA<br>• Evacuation<br>• Separation between the 2 generators<br>• Standby tug can assist in firefighting and move the barge away from vessel if possible<br>• Portable fire extinguishers located at control room, crew rest room, and on deck (4 nos.) near gensets | Asset | 3 | C | 3C | 59. Develop firefighting procedures to meet regulatory requirements<br>60. Firefighting requirements to be studied and proper firefighting equipment to be provided.<br>61. Crew should be trained to fight fires<br>62. Consider fire and smoke detectors for fire detection | • FFA provided as per regulations<br>• Chemicals used in emission capture system is unlikely to be cause of fire.<br>• Sources of ignition - genset, fuel, motors<br>• Generators in containers and can be closed to extinguished<br>• Explore option to have tanker vessel provide support by their FF capability and hydrant on deck |
| | • Fuel oil spill | • Operation Shutdown | | Environment | 2 | C | 2C | | • <See previous node> |
| **4.2.2** Fire on tanker | | | | | | | | 63. Procedures to be developed for barge action when vessel / tanker has fire event and consider tanker procedure also<br>64. Vessel during emergency needs to be moved away in 30 mins and barge needs to develop procedures to align with tanker movement | • <See previous node> |
| **4.3.3** Communication | | | | | | | | 65. Develop communication protocols and procedures for barge engagement, operations and disengagement | • VHF used for communication with vessel / tanker<br>• MBR used for communication with port.<br>• Alternative method is cell phones<br>• barge has 2-person crew - System operator is in charge of the process/operations. |
| **4.4.4** Camera / Video/monitoring<br><br>Not working / partially working | • Electrical, system fault Camera lens not cleaned<br>• Fog, rain | • Potential for Crane boom hitting vessel stack | • Camera / vision system, detectors including wind speed sensors at the tip of the capture arm , | Asset | 1 | C | 1C | 66. Boom system to be verified and validated prior to use for all operating conditions.<br>67. Operational limits to be confirmed/ investigated and developed for initial | • <See previous node> |

| System Level Nodes - Hazard Scenario | Potential Cause | Consequences | Effective Safeguard | Category | Risk Ranking S | L | RR | Recommendations (R#) | Comments |
|---|---|---|---|---|---|---|---|---|---|
| | | | infra-red cameras. Redundancy provided.<br>• Crew assistance to position<br>• Operational procedures | | | | | positioning of boom and continuous operation. | |
| **4.4.5** Electrical system earthing between vessel and barge | | | • Fenders between barge and vessel<br>• Separation between hood and vessel exhaust stack | Asset | 2 | C | 2C | 68. Separation and isolation from electrical continuity between barge and vessel to be evaluated. | • Provision of insulation to be investigated. |
| **4.4.6** Emergency disconnect | | | | | | | | | • There is no need for emergency disconnect type system for operation |
| **4.4.6.1** Mooring | | | | | | | | | • Mooring lines from Barge to Pier disconnected in an emergency situation is a manual process. |
| **4.4.7 Ventilation for barge office space/ release of vapor or H2S from tanker** | • Tanker cargo tank over pressurized and release<br>• Emergency on other tanker | • Hazardous vapor circulated through ventilation system in office space<br>• Hazardous vapor from nearby tanker | • Oil vapor and H2S detectors provided | Asset | 3 | B | 3B | 69. Appropriate oil vapors and H2S monitoring/gas detectors to be provided as required by OSHA and US Coast Guard regulations.<br>70. Consider study and provide appropriate gas and hazard detection equipment<br>71. Develop appropriate safety procedures when alarms are initiated upon detection of oil vapors and H2S. | |
| **Node # 5 Deck System** | | | | | | | | | • Barge has power to operate all deck machinery systems simultaneously |
| **5.1** Spud winch failure | • Mechanical failure | • Unable to drive spud or retract the spud | • Redundant control system | Asset | 2 | C | 2C | | • 4 spud winches<br>• Each spud has a redundant control system |
| **5.2** Mooring winch Failure | • Mechanical failure | • Unable to maintain tension | • Mooring line tension can be maintained manually (by hand) | Asset | 1 | C | 1C | | • 2 mooring winches. 4 mooring lines |
| **5.3** Control capture arm Failure | • Mechanical failure | • Unable to perform emission capture<br>Control arm is stuck in extended position | • Pulling barge way from the vessel | Asset | 2 | C | 2C | 72. Procedures to be developed for safe retraction of control arm and subsequently restore operation<br>73. Develop procedures for moving barge away with control arm failure with boom deployed | • Redundancy in each arm<br>• Does not prevent pulling barge way from the vessel.<br>• Depending on the failure some functionality is still available. |

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