APPENDIX D

Assessment of Ship Impact Frequencies
WHITE ROSE
DEVELOPMENT APPLICATION

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ASSESSMENT OF SHIP IMPACT FREQUENCIES

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1 INTRODUCTION

This Appendix presents the Input Initiating Frequencies (IIFs) for ship-installation collision risks due to authorized and passing vessels, for the White Rose project, using Fault Tree Analysis. These IIFs will be used as inputs to the event trees in the QRA Risk Profile model, in order to estimate risk levels.

1.1 Authorized Vessels

Any offshore installation must be supported by various vessels, providing a variety of specific services. The close proximity of shuttle tankers, supply/standby vessels, and other specialized ocean crafts (e.g., diving operations vessel) are essential to any installation. Therefore, the approach in determining the risks due to authorized vessel collision is similar for all installations, regardless of location. However, the categories of authorized vessels that service a facility will depend on the type of installation utilized. For example, a ship-shaped floating, production, storage and offloading (FPSO) vessel will typically be serviced by supply/standby vessels and shuttle tankers because hydrocarbon production, storage, and offloading operations are carried out at the same location, whereas a semi-submersible is normally serviced by supply/standby vessels only. A semi-submersible is not typically used for storage. The White Rose semi-submersible will be accompanied in the field by a floating storage unit (FSU), to store the crude as it is produced and carry out shuttle tanker offloading operations. Therefore, there is no direct need for shuttle tankers to venture within close proximity of the semi-submersible installation. For the semi-submersible option, there will still be a risk of shuttle tanker/FSU collision, though the FSU has a much smaller manning level.

It should be noted that because the authorized vessels maneuver close to an installation, it has been assumed that the installation is not able to take measures to avoid a collision.

The frequency of collision between a shuttle tanker and an installation, or storage unit, is estimated to be 0.0046/year due to failure of the dynamic positioning system [Ref. 1]. It is assumed that 20 percent (i.e., 0.0009/year) of shuttle tanker collisions occur after loading operations are complete and the fully loaded vessel is leaving the field. This relatively low percentage is due to the fact that the shuttle tanker is holding and maintaining position, in order to achieve loading, and is aware of the installation’s location. In addition, it is usual practice to perform shuttle tanker loading operations at a safe distance from the facility. The remaining 80 percent (i.e., 0.0037/year) of shuttle tanker collisions are assumed to occur while the tanker is empty and on approach to the facility.

The failure of the dynamic positioning system on a maintenance support vessel, causing a collision, is estimated to be 0.0137/year [Ref. 1].
In the event of a collision, the severity of damage that an installation experiences differs, depending on the impact energy of the collision. The following equation is used to determine vessel collision impact energy [Ref. 2]:

\[ E = \frac{1}{2} \left( \frac{M}{1000} \right) kV^2 \]

Where:

- \( E \) = impact energy (MJ)
- \( M \) = vessel mass (tonnes)
- \( V \) = vessel speed (m/s) = 0.514 x (speed in knots)
- \( k \) = hydrodynamic added mass constant
  - \( k = 1.1 \) for head-on (powered) impact
  - \( k = 1.4 \) for broadside (drifting) impact

Note: It is assumed that for supply/standby vessel collisions, ‘\( k \)’ is equal to 1.4, and for shuttle tanker collisions, ‘\( k \)’ is equal to 1.1.

It is presumed that for supply/standby vessel collisions, the vessel is at maximum mass (i.e., Total Displacement = Deadweight Tonnage + Light Ship Weight) since collisions will be more likely during approach to the installation. Table 1 illustrates The mass of the vessels that service current Grand Banks production facilities, which are used as the basis for this assessment, are provided in Table 1.1-1.

**Table 1.1-1 Vessel Displacement**

<table>
<thead>
<tr>
<th>Vessel</th>
<th>Light Ship Weight (t)</th>
<th>Deadweight Tonnage (t)</th>
<th>Total Displacement (t)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Maersk Bonavista/Placentia</td>
<td>2,500</td>
<td>1,800</td>
<td>4,300</td>
</tr>
<tr>
<td>Maersk Norseman/Nascopie</td>
<td>4,654</td>
<td>2,088.2</td>
<td>6,742.2</td>
</tr>
<tr>
<td>MCM Kometik</td>
<td>27,094.5</td>
<td>126,646.6</td>
<td>153,741.1</td>
</tr>
</tbody>
</table>

¹ Maersk data is from Reference 3 and Kometik data is from Reference 4.
² All of the Maersk vessels serve as supply and standby duties. Therefore, in this conservative analysis, the Total Displacement of Maersk vessels is 6,745 t.

It is conservatively assumed that vessel collisions occur during maneuvering. The percentage of incidents, at various speeds, for historically recorded occurrences is presented in Table 1.1-2 [Ref. 2].
Table 1.1-2  Maneuvering Collision Mean Speed and Percentage of Incidents

<table>
<thead>
<tr>
<th>Speed Range (kts)</th>
<th>Mean Speed (m/s)</th>
<th>% of Incidents</th>
</tr>
</thead>
<tbody>
<tr>
<td>0 – 1</td>
<td>0.3</td>
<td>27</td>
</tr>
<tr>
<td>1 – 2</td>
<td>0.8</td>
<td>26</td>
</tr>
<tr>
<td>2 – 3</td>
<td>1.3</td>
<td>13</td>
</tr>
<tr>
<td>3 – 4</td>
<td>1.8</td>
<td>7</td>
</tr>
<tr>
<td>4 – 5</td>
<td>2.3</td>
<td>20</td>
</tr>
<tr>
<td>5 – 6</td>
<td>2.8</td>
<td>7</td>
</tr>
</tbody>
</table>

The following categories of impact energy are chosen on the basis of potential damage to the installation:

- 0 to 30 MJ: minor damage to facility
- 30 to 100 MJ: moderate damage to facility
- 100 to 200 MJ: heavy damage to facility
- 200 MJ: catastrophic loss of facility

Impact frequencies have been estimated for each category to allow the event tree modelling to represent the different consequence levels.

Design rules typically require all offshore installations to be capable of withstanding at least 15MJ impacts, however it is likely that actual capacity will exceed this value by a significant amount. The risk assessment assumes that impacts of energy less than 30MJ will not cause damage to the hull, hence the choice of energy bands in this analysis.

The calculated impact energy, and percentage of incidents are illustrated in Figures 1.1-1 to 1.1-3.
Figure 1.1-1  Probability Distribution of Impact Energy for Supply/Standby Vessels

Figure 1.1-2  Probability Distribution of Impact Energy for Shuttle Tanker (Full)
Figure 1.1-3  Probability Distribution of Impact Energy for Shuttle Tanker (Empty)

The resulting IIFs from the above approach are presented in the Fault Trees illustrated in Figures 1.1-4 to 1.1-6.
Figure 1.1-4  Fault Tree to Estimate Frequency of Collisions by Authorized Vessels (FPSO)

Authorized vessel collision with FPSO

**Impact Energy**
- 0 - 30 MJ 0.016/yr
- 30 - 100 MJ 0.00183/yr
- >100 MJ 0.000477/yr

**Total** 0.0183/yr

**HF**
- 0.016/yr
- 0.00183/yr
- 0.000477/yr

Shuttle tanker loss of position

- 0.0046/yr

Maintenance support vessel loss of position

- 0.0137/yr

Shuttle tanker loss of position while empty

- 0.0037/yr

Shuttle tanker loss of position while full

- 0.0009/yr
Figure 1.1-5  Fault Tree to Estimate Frequency of Collisions by Authorized Vessels (Semi-submersible)

Authorized vessel collision with Semi-Sub

Impact Energy  IIF

0 - 30 MJ  0.0130/yr
30 - 100 MJ  0.00056/yr
>100 MJ  0.00056/yr

Total: 0.0137/yr

Maintenance support vessel loss of position

0.0137/yr
1.2 Passing Vessels

Risks due to passing vessel collisions are highly dependent on the installation location. Installations in areas with heavily travelled shipping lanes (such as the North Sea) would expect greater risks from passing vessel collision than an area with relatively low ocean traffic (such as the Grand Banks). The most common types of non-oil related vessels encountered on the Grand Banks include tankers, container ships, bulk carriers, fishing vessels, and naval vessels. “Naval vessels cause relatively low risks of ship-[installation] collisions due to their high standards of operation, which makes errancy and breakdown relatively unlikely” [Ref. 2]. Therefore, the risks due to naval vessel collisions are excluded.
In considering a passing vessel collision, the vessel has to be on a collision course with the installation. Due to a lack of historical shipping lane information and traffic data for non-oil related vessels on the Grand Banks in relation to oil and gas operations, passing vessel frequencies can only be estimated approximately. A value of 0.00038/year has been recorded for the frequency of passing vessel collisions with fixed installations [Ref. 5]. This value is based on worldwide data, collected over 89,000 installation years, and is conservatively assumed for the White Rose analysis.

One of the main advantages of a floating installation, as opposed to a fixed facility, is the ability to move off-station, as a precautionary measure, in the event that an approaching vessel poses a threat of collision. Riser and mooring systems are designed for controlled and emergency releases. The controlled release includes measures to depressurize risers prior to disconnecting, whereas an emergency release may not.

The disconnection ability for the FPSO will be a highly reliable system, with extensive design effort devoted to ensuring a high level of availability-on-demand. It is assumed, therefore, that for the FPSO, FSU and Semi-Sub, the overall probability of disconnection failure is equal to 1 percent.

Once disconnected the facility must also move out of the path of any approaching ship (or iceberg) and this requires the availability of the thrusters (and power to the thrusters). There will be multiple thrusters, and partial manoeuvrability will be possibility even with only one or two thrusters available. However, even if the facility loses all ability to move under its own power there will still be the option of a support vessel towing the facility clear of any errant ship or iceberg. It can be concluded therefore that provided the facility can disconnect then it will be able to avoid a collision.

As with the analysis for authorized vessels, it is clear that the severity of damage that an installation would experience differs, depending on the impact energy of the collision. Passing vessels are generally larger than authorized vessels, with the possible exception of shuttle tankers, and in the case of powered impacts would generally be travelling at much higher speeds during impact. Sample vessel fleet data obtained from Maersk and Oceanex are illustrated in Table 1.2-1.

Table 1.2-1  Sample Vessel Data

<table>
<thead>
<tr>
<th>Company</th>
<th>Vessel Type</th>
<th>Deadweight Tonnage (DWT)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Maersk</td>
<td>Crude Carrier</td>
<td>308,300</td>
</tr>
<tr>
<td>Maersk</td>
<td>Crude Carrier</td>
<td>299,700</td>
</tr>
<tr>
<td>Maersk</td>
<td>Crude Carrier</td>
<td>277,000</td>
</tr>
<tr>
<td>Maersk</td>
<td>Bulk Carrier</td>
<td>68,166</td>
</tr>
<tr>
<td>Oceanex</td>
<td>Container ship</td>
<td>21,849</td>
</tr>
<tr>
<td>Oceanex</td>
<td>Container ship</td>
<td>10,919</td>
</tr>
<tr>
<td>Oceanex</td>
<td>Container ship</td>
<td>14,597</td>
</tr>
</tbody>
</table>

¹ Maersk data are from Reference 6 and Oceanex data are from Reference 7.
Considering a powered collision between the smallest of the above vessels (i.e., 10,919 DWT), at a speed of 12 kts (this particular vessel is listed with a speed of 18 kts), the calculated impact energy is greater than 200 MJ. Consequently, powered passing vessel collisions will conservatively be assumed to result in catastrophic failure of the installation.

It should be noted that a drifting vessel collision would cause considerably less damage than a powered collision. The Terra Nova Concept Safety Analysis [Ref. 1] demonstrates that drifting vessels contribute 10 percent of the frequency for all passing vessel collisions. Therefore, it is reasonable to assume a similar proportion for White Rose. Because this is such a small portion of the overall frequency, it is not justified to investigate this issue any further. Consequently, it is reasonable, but conservative, to assume that all passing vessel collisions (i.e., both powered and drifting) result in the loss of the installation.

The results of the above approach are presented in the Fault Tree illustrated in Figure 1.2-1.
Figure 1.2-1  Fault Tree to Estimate Frequency of Collisions by Passing Vessels

- Passing vessel collision with facility: $3.8 \times 10^{-6}$ /yr for FPSO, Semi-sub or FSU
- Failure to release mooring and riser systems: 0.01 for FPSO, Semi-sub or FSU
- Passing vessel on collision course with installation: $3.8 \times 10^{-4}$ /yr
2 REFERENCES

1. Terra Nova Concept Safety Analysis, Magellan Engineering Consultants, 1996


3. Personal Communication between David Randell and Captain Bill Morgan (Maersk), March 15\textsuperscript{th}, 2000.

4. MCM Kometik company brochure.


6. Maersk Website: www.mearsk.com

7. Oceanex Website: www.oceanex.com