APPENDIX E
Dynamic simulation of FSRU

TO THE

INDEPENDENT RISK ANALYSIS
(APPENDIX C1)

Marine Innovation & Technology

Cabrillo Port EIS/EIR - Dynamic simulation of FSRU subjected to blast resulting from an ignited LNG spill during cargo transfer with LNG tanker moored side-by-side

Rev 0 – July 2004

Written by: C.A. Cermelli
Reviewed by: D. G. Roddier

Document: 2004-005-002

[redacted]

Cabrillo Port EIS/EIR - Dynamic simulation of FSRU subjected to blast resulting from an ignited LNG spill during cargo transfer with LNG tanker moored side-by-side.

Executive summary

The effect of a blast caused by an ignited spill between FSRU and LNG tanker has been assessed on the global motion response of the FSRU. Results show that the FSRU global ship response due to the blast is small. The structural effects of the blast onto the FSRU hull, containment system, and facility have not been checked due to the limited scope of this work, and the lack of information on the structural characteristics of these elements.

The blast will cause a small roll inclination of about 1 degree, and will increase the separation between the two vessels by approximately 4 feet. The mooring lines connecting the two vessels have a high likelihood of burn damage due to the fire, and their rupture is likely. This event would cause the two vessels to separate.

Introduction

Computational Fluid Dynamic (CFD) was used to perform modeling of a vapor cloud explosion initiated between an FSRU and a Carrier ship while in offloading position: see ref [1] for model details and results. This scenario was selected as a result of the April 2004 workshop held in Long Beach, regarding the Cabrillo Port LNG facility and the related license review. The purpose of this work was to calculate pressure load histories for a vapor cloud at vulnerable locations of the FSRU and storage tanks.

The present work is aimed at modeling the dynamic response of the FSRU subjected to the resulting blast load. Details of the hydrodynamic model are provided below.

Results of the time-domain simulations are provided herein. Due to scope of work limitations, this study only covers the global response of the FSRU. The potential for localized structural damage (hull breach, tank or processing facility damage) has not been assessed, although these are more likely to occur, and could have serious consequences.

Model description

The FSRU hydrodynamic model was built based on the vessel and mooring main characteristics as provided in [2] and [3].

Hydrodynamic properties of the vessels were computed in the frequency domain using WAMIT, a commercial linear diffraction-radiation package. The exact FSRU geometry was not known. However, the hull was modeled using specified main dimensions and a full hull shape, with a parabolic bow. A 220 KCM generic LNG tanker moored along side the FSRU was used in the hydrodynamic model. General dimensions of both vessels are summarized in table 1. General layout arrangement is summarized in table 2. Hydrodynamic quantities, such as added-mass and wave damping included the coupling effects of the LNG tanker on the FSRU.

Time-domain simulations of the ship response were performed by time-marching of the rigid-body equation of motion (Newton's equation). The mooring configuration was computed at each time-step using a finite-difference scheme coupled with a Newton-Raphson algorithm. Convolution of the frequency-dependent hydrodynamic characteristics with the body response was performed to model the impulse response.

Table1: General Dimensions of the FSRU and LNG tanker used for the present computations.

Main Dimension	*Units*	**LNG Tanker**	**FSRU**
Volume Capacity	*KCM*	220	280
Length (Lpp)	*m*	320	312
Beam	*m*	50	47
Draft	*m*	12	15
Weight	*metric ton*	$1.489\ 10^5$	$1.823\ 10^5$
Roll Radius of Gyration (Rx)	*m*	16.9	12.5
Ry & Rz	*m*	80	80
Roll damping	*% critical*	3	4
Vertical Center of Gravity (KG)	*M*	16.4	10

Magnitude of blast impulse

Partial results of CFD computations performed by Analytical & Computational Engineering, Inc [1], are given in Fig. 1 below.

[redacted] [redacted]

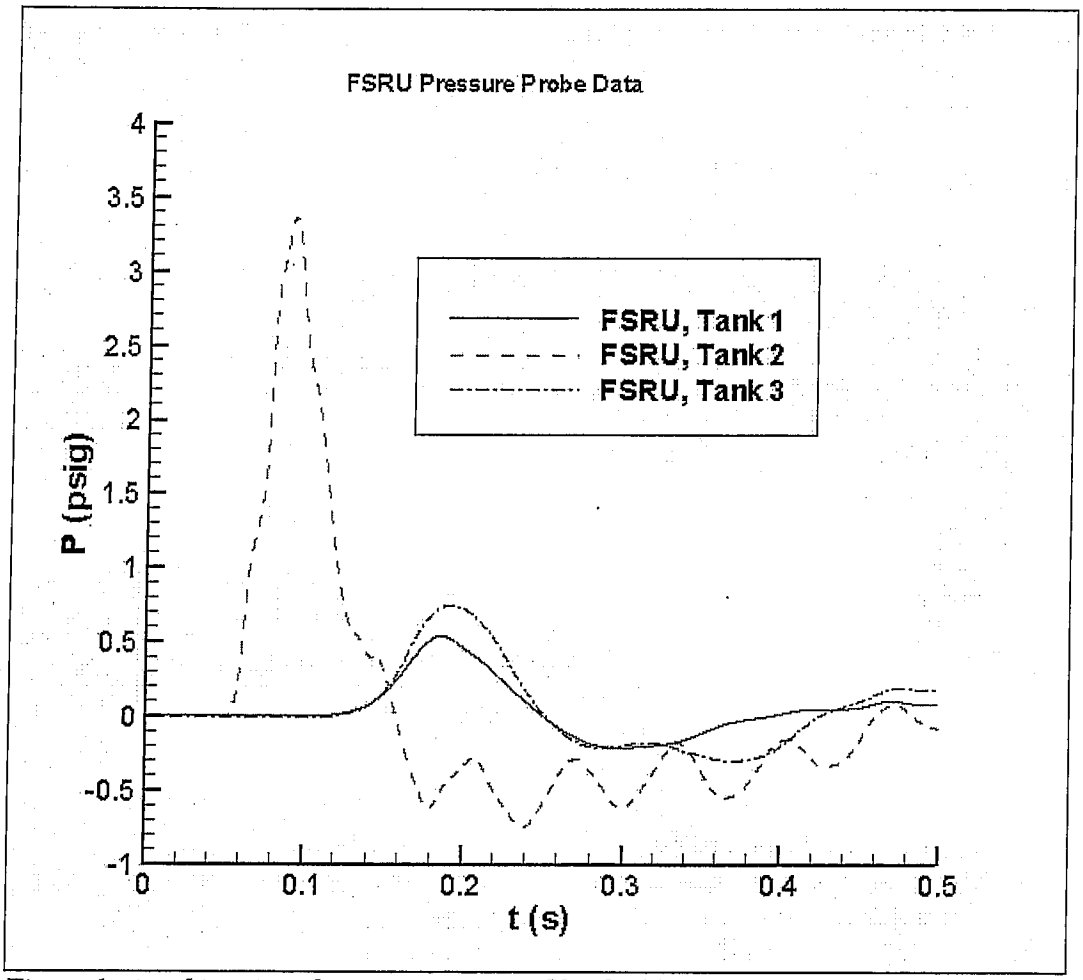

Figure 1: time-histories of pressure generated by the blast at various location on FSRU

The pressure was interpolated and integrated over the FSRU as a function of time to yield the global force impulse (sway force and roll moment) generated by the blast. The resulting force and moment is modeled as the following impulse (Fig. 2).

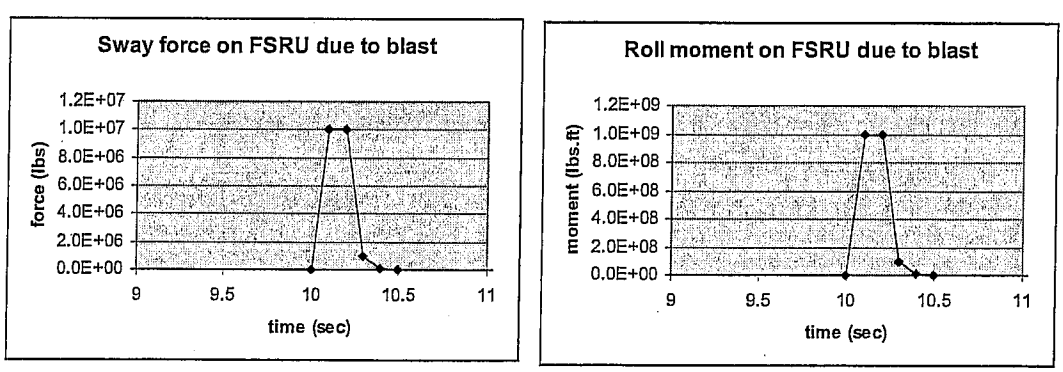

Figure 2: time-histories of blast force and moment on FSRU

Results

The blast is assumed to occur at t=10 sec while the sea-state is very mild (Hs=3ft). Time-histories of the wave environment and blast forces are plotted in Fig. 3. The effects of the blast on the FSRU global response are plotted in Fig. 4.

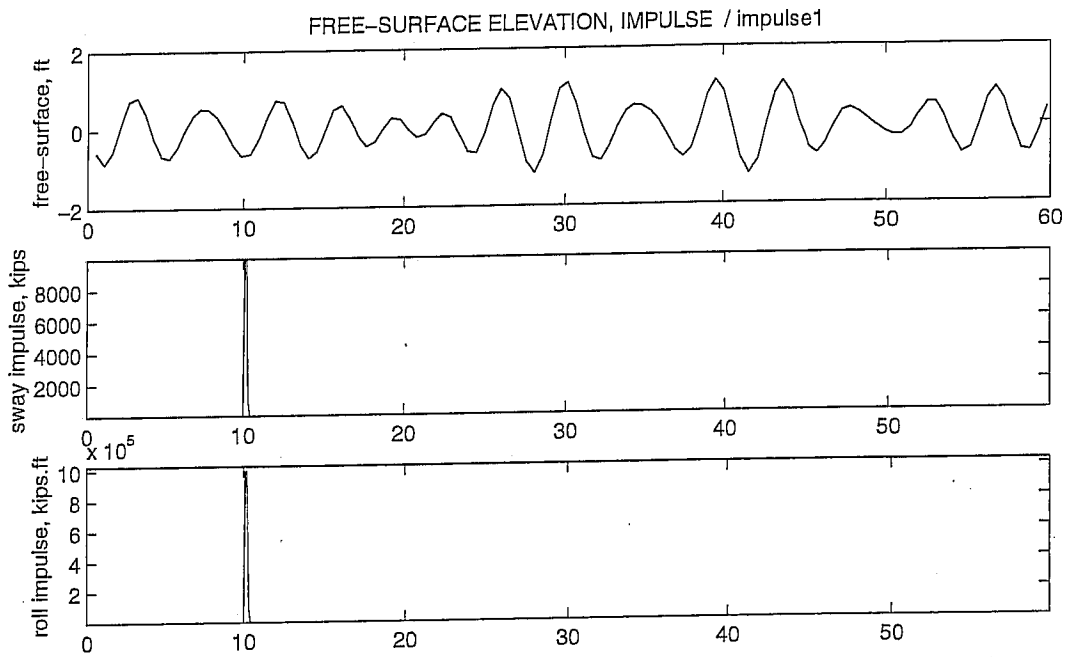

Figure 3: time-histories of wave environment and blast force and moment on FSRU

[redacted] [redacted]

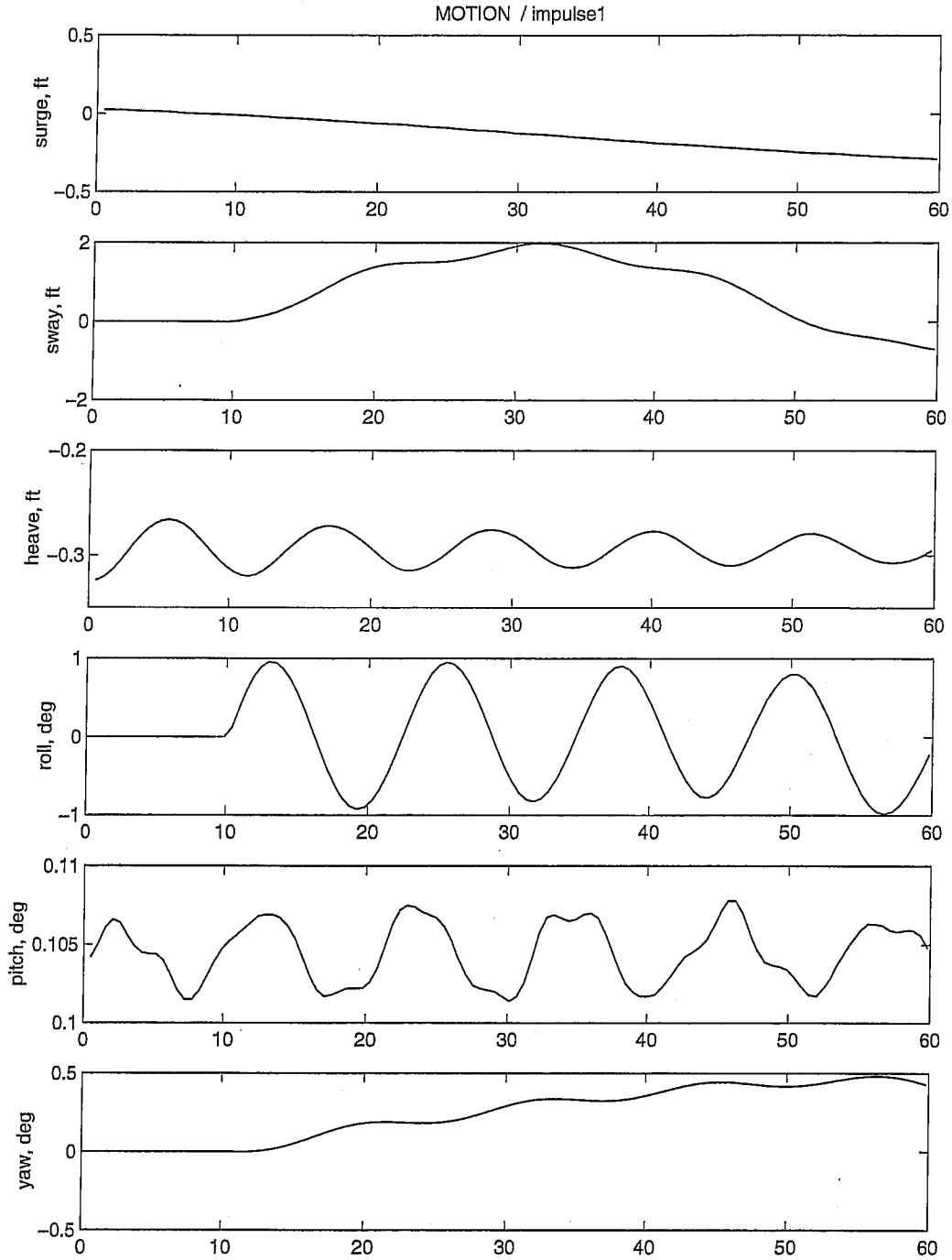

Figure 4: time-histories of FSRU response to blast

The blast force impulse causes a slight roll response of the FSRU (approximately 1 deg). The roll decays slowly since the wave damping and the quadratic viscous damping for small roll oscillations are small. The blast also causes the two vessels to separate (about 2 feet per vessel). Small sway oscillations occur, however the response in sway is uncertain due to the likelihood of significant damage to the mooring line resulting from

the blast. Nylon lines connecting the two vessels are likely to burn, resulting in the disconnection of the LNG tanker from the FSRU. The FSRU will stay on location, since damage to the turret-moored system is unlikely.

Conclusions

The effect of a blast caused by an ignited spill between the FSRU and an LNG tanker has been assessed on the global motion response of the FSRU. Computational Fluid Dynamic (CFD) was used to perform modeling of a vapor cloud explosion initiated between an FSRU and a Carrier ship while in offloading position. The resulting pressure load impulse was applied to the FSRU to investigate its global response.

Results have shown that the FSRU global response due to the blast is almost negligible. However, the potential for localized structural damage (hull breach, tank or processing facility damage) has not been assessed due to the limited scope of this work, and the limited information available on the structural characteristics of these elements.

The blast will cause a small inclination of about 1 degree of roll, and will increase the separation between the two vessels by approximately 4 feet. The mooring lines connecting the two vessels have a high likelihood of burn damage due to the fire, and their rupture is likely. This will, in turn, cause the tanker to separate from the moored FSRU.

References

[1] Analytical & Computational Engineering, Inc. *Scenario No. 4: Vapor Cloud Explosion Between FSRU and Carrier,* Prepared by ACE Project No. 101-03-013, July 7, 2004

[2] MARIN, *LNG Side-by-side offloading study*, Report No. 17964-1-CPO

[3] SOFEC, final study report - Mooring *and risers for an LNG FSRU import terminal offshore ventura* - 1209-PR-00331 rev A