FLNG Safe Tandem Offloading of LNG in Severe Offshore Environments

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FLNG 2009, Seoul, South Korea
September 24, 2009
Outline

- Why Tandem Offloading for FLNG systems?
- Design Requirements
- Development of the SOFEC Yoke Mooring System
- Equipment on the FLNG Vessel & LNG Carrier
- Marine Operations
- Summary
Offloading Oil from an F(P)SO Tandem and Side-by-Side Gulf of Mexico
Typical Offload Operation Criteria

• Tandem offloading using Nylon Hawser from FPSO to Tanker:
  – Maximum Connect Hs = 2.5m
  – Maximum Offload Hs = 3.5m

• Tandem Offloading using DP Shuttle Tankers
  – Maximum Connect Hs = 4.5m
  – Maximum Offload Hs = 5.5m

• Side-by-Side Offloading from FPSOs to Oil Tankers:
  – Maximum Connect Hs ~ 1.5 to 2m
  – Maximum Offload Hs ~ 2.0 to 2.5m
Simulation Response in Hs 5.5m seas (Orcaflex™)
Design Requirements

- Offloading from Floating LNG (FLNG) Vessels
- High Safety and Reliability Requirements
- Use Field Proven Technology
- Severe Operational Environmental Conditions:
  - Offload in $H_s = 5.5m$ seas
  - Connect mooring and LNG transfer system in $H_s = 4.5m$
  - No additional support vessels
- Offload Frequency ~ 2 offloads / week
LNG Tandem Offloading System Development

SOFEC Duplex Yoke
Mooring System Equipment

- **Connection hardware on FLNG**
  - Mooring system
  - Mooring yoke [parked, floating, and connected to LNGC]
  - Hawser winch, constant tension
  - Auxiliary winches
  - Lines
  - Yoke connector cone

- **Connection hardware on LNG Carrier**
  - Connection module
  - Hawser connector
  - Cone Connector assembly
  - Auxiliary deck winch

- **LNG Transfer system options**
  - FMC Loading Systems pantograph pipe & swivels
  - Aerial cryogenic flexible hose when proven & available
Yoke in Parked Position

Two Winches
325mt capacity
Lift yoke
Either will lift yoke in emergency

Hawser winch
300 mt capacity
Render & Recover

Two Auxiliary Winches (225 mt)
Stabilize sway
On port & stbd side
Arrangement of Yoke Mooring System

- Yoke system steel weights
  - Tank 600 mt
  - Yoke 400 mt
  - Links 200 mt
  - Total 1200 mt
  - Water Ballast adds 1410 tons
Yoke Tip Cone

Pivoting cone on two-axis gimbaled joint with internal vertical axis yaw bearing
Mooring Hook-Up
Procedure Summary
Throw-line Zone for LNG Carrier Bow Position

F.P. Position Zone

Throw-line Gun Position
Req’d Range: 52m – 102 m
Lines Required for Hook-Up

- **Hawser** *(Winch on FLNG)*
  - 5” diameter x 400 meters
  - Dyneema SK-75 HMPE
  - 975 metric ton MBS
  - Winch on FLNG

- **Floating Pick-Up Line**
  - 2” Polypropylene
  - 21 mt MBS

- **Throw Line**
  - Coiled in pneumatic throw gun
  - 3/16” Dyneema x 300m
  - 2.2 mt MBS

- **Recovery Line (on LNGC)**
  - 1” diameter x 400m
  - Dyneema SK-75 HMPE
  - 44.5 mt MBS
  - Winch on LNGC
Yoke in Parked Position
Ready for LNGC Arrival in Area

Final inspection of yoke before connection

Slacken Lines on Two Auxiliary Winches Port & Stbd

Throw line gun ready
Release Hook
Pick-up Line
Yoke Connection Procedure
Hawser pull continues
Yoke Connection Procedure
Yoke lifts out of water as hawser is retrieved to FLNG
Yoke Connection Procedure
Cone approaches receptacle
Yoke Connection Procedure

Yoke connected, propulsion stopped

LNG Pantograph Hook-up sequence begins
Connection Simulation (Orcaflex™)
Yoke Connection Procedure
LNG Pantograph connected & offloading
Mooring Yoke Disconnect
Summary
Yoke Disconnection Procedure
Pantograph retracted
Yoke Disconnection Connection Procedure
LNGC begins thrust astern to back away

Cone Connector releases, Yoke lowers on Hawser
Yoke Disconnection Procedure
Hawser retrieved back to LNGC

- Hawser End Fitting returns to Cone tip
- Floating Pick-up Line
- LNGC Departs
Yoke Disconnect Procedure
Yoke in Parked Position, Ready for next LNGC Arrival

Inspect Yoke after disconnection

Unless required by weather, leave snubbing lines slack on Auxiliary Winches Port & Stbd

Inspect Pick-up Line

Throw line gun made ready
Summary & Conclusions

• Robust tandem mooring system developed for FLNG Offloading in severe environments
• Can be used with existing LNG Transfer Systems
• Also suitable for use with cryogenic hoses (under qualification / not yet field proven)
• System has been technically qualified by major oil companies for mooring & LNG transfer
• Marine procedures have been accepted by major oil company mooring and marine operations officials