Floating Offshore LNG Receiving and Regasification Facility
For the Gulf of Mexico

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Floating Offshore LNG Terminal - Gulf of Mexico
With Gas Storage in Salt Caverns

(One of many possible arrangements)

Salt dome

Gas storage caverns

Fixed platform jacket for drilling rig and cavern pumps

Single point anchor leg mooring system

LNG Carrier

Floating weathervaning platform with intermediate LNG storage, heat exchangers, pumps & generators

Gas pipelines
To shore

Gas pipelines
(Not cryogenic)
Operational LNG Offloading Objective for a Floating & Weathervaning LNG Regas Facility

- Safely berth/unberth carriers 99% of time in Gulf of Mexico
- Design Conditions:
  - Berth Carriers in 2.5m Hs (8.2 ft)
  - Offload in up to 3.5m Hs (11.5 ft)
LNG Ship Berthing at a Shore Facility

Gaztransport & Technigaz GT No 96 Membrane Containment
Seagoing Tug Operations

• Limitations of large seagoing tugs:
  [Ref: OCIMF Mooring Equipment Guidelines, p.18, Oil Companies International Marine Forum]
  – Limited to 1.5 m waves in conventional push handling on hull sides of ships due to tug motions, especially with the tug broadside to the waves
  – Excessive power of tugs can result in over compression of fenders and damage to the ship’s side

• Advantages of tug operations with the FMC Floating Offshore Re-Gas Facility
  – Eliminates need for tug pushing on ship sides while rolling in heavy seas, berthing accomplished in 2.5 m waves, use hawsers only
  – Seagoing tugs can safely tow ship in over 3.5 m waves when tugs not broadside to the waves
    (2.5 m = 8.2 ft, 3.5 m = 11.5 ft)
  – Platform moves to the stationary ship while held by tugs fore and aft while berthing
  – Platform moves away from ship when un-berthing
Wave Height Data (Hs) vs Date – Shallow Water Location

Significant Wave Height at Buoy 42035 in GOM (2003)

This wave height data shows the importance of berthing in up to 2.5 m waves, and then remaining moored, offload, and un-berthing in 3.5 m waves:
Very High Operational Productivity

Berthing, Hs ≤ 2.5m

Offload & Un-Berthing, Hs ≤ 3.5m
Wave Height Data (Hs) – Shallow Water Location

Cumulative Probability Distributions of Waves at Buoy 42035 in GoM

Offload & Un-Berthing, $H_s \leq 3.5\text{m}$

Berthing, $H_s \leq 2.5\text{m}$
Hull Structures for Weathervaning Terminals

• Monohull (ship type)
  – Large LNG storage
  – Long shipyard delivery
  – Motions larger
  – Slower to swing around single point mooring (SPM)

• Column stabilized structure
  – LNG storage 25 km³ to 38 km³
  – Fab-yard construction
  – Delivery time faster
  – Vessel motions smaller
  – Faster swing around single point mooring
FMC SOFEC LNG Floating Platform
Column Stabilized Platform for Shallow Water, under 40 m (131 ft)
FMC SOFEC LNG Floating Platform
Column Stabilized Platform for Deep Water, over 40 m (131 ft)
FMC SOFEC LNG Floating Platform
Concept Advantages

• Platform design suitable in any water depth (deep or shallow)
• Ample deck space for space separation of modules = safety
• Achieves minimum relative motions between platform & ship = improved operational availability
• Active position control using thrusters = higher operational safety for carrier mooring
• Construction efficiency, float out completely tested system
• Least introduction of new technologies
• Size scalable as needed for increased gas throughput

Shallow Water
Weights & Dimensions – LNG Storage 25,000 m³
Column Stabilized Platform for Deep Water over 40 m (131 ft)

- Deck Load 10,000 t
- LNG & storage tanks 18,000 t
- Structure 26,000 t
- Displacement 54,000 t
- Dimensions
  - L = 334 m (1096 ft)
  - B = 62.8 m (206 ft)
  - Depth = 26 m (85 ft)
  - Draft = 11 m (36 ft)

• Compare displacement with loaded 250k m³ LNG carrier:
  Carrier displacement approx. 175,000 ton
  Platform weight (displacement) = 31% of LNG carrier wt.
Vaporization Process, Marine Equipment & Components
Many Vaporization Processes Are Suitable for FMC SOFEC Floating Terminal

• Submerged combustion vaporizers (SCV’s)
• Seawater vaporization
  – Shell & tube heat exchangers
  – Closed loop or open loop
• Ambient air vaporization
  – Mustang Smart™ Regasification System
  – Supplementary SCV’s
• The choice of vaporization equipment depends on location site, economics, and circumstances
FMC SOFEC Floating Platform
with Mustang Smart™ Ambient Air Vaporizer System
Tandem FPSO & FSO Oil Offloading to Tankers

The Future for LNG?

LNG Cryogenic Hose

- Floating Hose - Not commercially available yet
- In-Air Cryogenic Hose – Maybe soon

But until then..........
LNG Loading Arms  Tested for SBS (Side by Side) Loading

- Cryogenic hose motion envelope?
- No new LNG manifolds on LNG carrier

- Full scale connect testing of 16” arm in 2003 for Shell Global Solutions by FMC
- Flange **Connection** Motion
  - 4 m vertical motion range @ 0.85 m/s
  - 5 m horizontal motion range @ 1.15 m/s
  - 10 m surge fore-aft (design)

- FMC Targeting system assistance for flange connection in very severe dynamic conditions.
- Simple mechanical system.
- Connects to conventional mid-ship manifolds
FMC Marine Loading Arms for LNG
Shown on Shallow Water Weathervaning Platform
Water Depth 15 to 40m (49 to 130 ft)
Marine Fenders

• Desired Characteristics
  Commercially Available
  Proven Applications / Passive

• Design Basis
  165,000 m³ LNG Carrier / 0.8 knots / 15 deg. Berthing angle
  Berthing, Sway and Yaw Kinetic Energies considered
  Mooring Line Effects

• Marine Fender Selection
  Yokohama Pneumatic Fender 4500x9000 P50 - normal operation

• Catastrophic Event
  Defined as a collision energy of 14,000 kJ by DNV & LRS.
  Further study/definition required based on marine operations, site specifics and risk analysis.
Platform Pelican Hooks for Mooring Lines
Remote Release, Load Monitoring System
Seawater Lift System for 3.9 Bcf/d Vaporization
(7500 m³/hr LNG)
Eight Pumps, 42” 3000 HP each, 33,000 GPM each
Seawater Discharge System 3.9 Bcf/d Vaporization

4 - 58" dia. manifolds with 8 - 18" dia. Nozzles each
Discharge velocity: approx. 10 ft/sec
75000 cubic meters per hour total discharge volumetric flow rate (330,000 gpm)
Discharge Water Temp. : 50F (10C)
Ambient Seawater Temp. : 70F (21C) data from buoy shows this is average temp. for 8 months excluding winter.
Current Speed: 0.25 ft/s

Zone of cool water influence approx. 3 meters from nozzle (defined by a deltaT of 3F or greater)
High Pressure Gas Swivel

900 Lb (2200 Psi) Dry Gas Rating
1.8 Bcf/d @ 1900 Psi & 40F
1.8 Bcf/d @ 1200 Psi & 35 F

Two (2) separate swivels
For two separate flow paths
• 2 ports per swivel
• Each port: 14” (12.12” ID)
• Total of 4 ports, 14”

One spare swivel
• One separate flow path
• 2 ports, 14”

Est. Wt. 131 Ton (289,000 Lb)
Marine Operations
& Ship Docking
Carrier Berthing Operations

Berthing Hs ≤ 2.5 m (8.2 ft)  Offload Hs ≤ 3.5m (11.5 ft)

1.1 SWING PLATFORM AWAY FROM SHIP BERTHING LOCATION
1.2 WITH MOORING MASTER ABOARD, TOW SHIP TO BERTHING POSITION WITH TUGS HEADING INTO SEAS
1.3 USING TUGS, STOP SHIP’S HEADWAY & HOLD AS STATIONARY AS PRACTICAL NEAR BERTH POSITION

165,000 m³ LNG CARRIER

APPROX. 75 METER
BERTHING OFFSET
(1.5 x CARRIER BEAM)

BERTHING LINE

PREVAILING WEATHER CONDITIONS
Carrier Berthing Operations

Berthing Hs ≤ 2.5 m (8.2 ft)  Offload Hs ≤ 3.5m (11.5 ft)

2.1 CONTINUE HOLDING SHIP NEAR BERTH LOCATION WITH TUGS HEADING INTO SEAS
2.2 SWING PLATFORM TOWARD SHIP USING PLATFORM THRUSTERS

T = THRUST
Carrier Berthing Operations

Berthing Hs ≤ 2.5 m (8.2 ft)  Offload Hs ≤ 3.5m (11.5 ft)

3.1 CONTINUE HOLDING SHIP NEAR BERTH LOCATION WITH TUGS HEADING INTO SEAS
3.2 USING PLATFORM THRUSTERS, BRING PLATFORM AFT FENDERS TO BEAR ON SHIP
3.3 COORDINATE THE PLATFORM SWING WITH SHIP YAW MOTION
Carrier Berthing Operations

Berthing Hs ≤ 2.5 m (8.2 ft)  Offload Hs ≤ 3.5m (11.5 ft)

4.1 CONTINUE PLATFORM PUSHING ON SHIP TO BRING SHIP HEADING AROUND TOWARD PLATFORM BERTHING LINE
4.2 TUGS CONTINUE HOLDING SHIP STATIONARY FORE & AFT AS IS PRACTICAL
Carrier Berthing Operations

Berthing Hs ≤ 2.5 m (8.2 ft)   Offload Hs ≤ 3.5m (11.5 ft)

5.1 TRANSFER SHIP'S MOORING LINES TO PLATFORM PELICAN HOOKS
5.2 MAINTAIN SHIP POSITION AGAINST PLATFORM FENDERS USING TUGS FORE & AFT AND BY PLATFORM PUSHING SHIP PARTLY BEAM-ON TO THE WIND
6.1 Using mooring lines and tugs fore & aft, move ship forward to align midship manifold with LNG loading arms.

6.2 Finish all mooring line pretensioning.

6.3 Connect LNG loading arms.
7.1 WITH ALL MOORING LINES SECURE, TUGS CAN MOVE TO STANDBY LOCATION
7.2 STARTUP REGAS PROCESS, BEGIN LNG COOL-DOWN AND OFFLOADING
7.3 PLATFORM AND SHIP CAN FREELY WEATHER-VANE IF SHIP MOTIONS REMAIN SATISFACTORY
7.4 IF NEEDED, USE PLATFORM THRUSTERS TO ADJUST PLATFORM AND SHIP HEADING TO MOST FAVORABLE DIRECTION TO WEATHER DURING LNG OFFLOADING TO MINIMIZE SHIP ROLL MOTION
7.5 MONITOR LOADS IN ALL MOORING LINES CONSTANTLY DURING OFFLOAD, AND ADJUST PRETENSION IF NECESSARY
Carrier Un-Berthing Operations
Offload & Un-Berth in Wave Height Hs ≤ 3.5m (11.5 ft)

8.1 UPON COMPLETION OF OFFLOADING AND SHUTDOWN SEQUENCE, DISCONNECT LNG LOADING ARMS
8.2 RECONNECT TOWING LINES TO TUGS (IF DISCONNECTED)
8.3 POSITION TUGS FORE & AFT FOR SHIP DEPARTURE
9.1 USING THRUSTERS, SWING PLATFORM AND SHIP TO CREATE A LEE ON THE PLATFORM FENDER SIDE
9.2 RELEASE PELICAN HOOKS AND RECOVER MOORING LINES TO SHIP
9.3 AS MOORING LINES ARE RELEASED, BEGIN RAPID PLATFORM SWING AWAY FROM SHIP USING THRUSTERS
9.4 TUGS BEGIN MOVING SHIP ASTERN AND SWINGING BOW AWAY FROM PLATFORM USING WIND DIRECTION TO ASSIST
9.5 TUGS CONTROL SHIP HEADING FOR DEPARTURE AND TOW SHIP TO CLEAR PLATFORM

T = THRUST
Carrier Un-Berthing Operations

Offload & Un-Berth in Wave Height $H_s \leq 3.5\text{m (11.5 ft)}$

10.1 TUGS AND SHIP CONTINUE MOVING AWAY FROM PLATFORM
10.2 WITH SHIP UNDER POWER, RELEASE TOWING LINES
Carrier Un-Berthing Operations

Offload & Un-Berth in Wave Height $H_s \leq 3.5\text{m (11.5 ft)}$

11.1 TUG ESCORTS SHIP UNDERWAY TO SAFE ZONE BOUNDARY
11.2 MOORING MASTER RE-BOARDS TUG FOR TRIP TO NEXT WAITING SHIP
## LNG Terminal Loads & Motions – Shallow Water

Comparison of Tower-Yoke Loads & Motions - 20m Water Depth

<table>
<thead>
<tr>
<th>Parameter</th>
<th>QHD 32-6 FPSO</th>
<th>LNG Terminal</th>
<th>Unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Storm Conditions</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Significant Wave Height, Hs</td>
<td>5.2</td>
<td>9.2</td>
<td>meters</td>
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<tr>
<td>Wind Speed</td>
<td>26.6</td>
<td>41.2</td>
<td>m/s</td>
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<tr>
<td>Current Speed</td>
<td>2.05</td>
<td>1.1</td>
<td>m/s</td>
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<tr>
<td>Vessel Displacement</td>
<td>201,380</td>
<td>39,000</td>
<td>m. tons</td>
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<tr>
<td>Vessel Motions (@ FP)</td>
<td></td>
<td></td>
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<tr>
<td>Surge, Max</td>
<td>5.4</td>
<td>2.1</td>
<td>meters</td>
</tr>
<tr>
<td>Surge, Min</td>
<td>-9.8</td>
<td>-8.8</td>
<td>meters</td>
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<tr>
<td>Sway, Max</td>
<td>10.96</td>
<td>7.8</td>
<td>meters</td>
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<tr>
<td>Sway, Min</td>
<td>-15.42</td>
<td>-3.9</td>
<td>meters</td>
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<tr>
<td>Yaw, Max</td>
<td>38.5</td>
<td>29.1</td>
<td>degrees</td>
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<tr>
<td>Yaw, Min</td>
<td>15.1</td>
<td>20.9</td>
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<td>Tower Forces</td>
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<tr>
<td>Fx- Longitudinal Force</td>
<td>-861</td>
<td>-724</td>
<td>m. tons</td>
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<tr>
<td>Fy - Transverse Force</td>
<td>-320</td>
<td>166</td>
<td>m. tons</td>
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<tr>
<td>Fz - Vertical Force</td>
<td>-367</td>
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<td>Fxy - Resultant Force</td>
<td>871</td>
<td>724</td>
<td>m. tons</td>
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<tr>
<td>Fxyz - Resultant Force</td>
<td>908</td>
<td>750</td>
<td>m. tons</td>
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<tr>
<td>Max Tension</td>
<td>742</td>
<td>695</td>
<td>m. ton</td>
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LNG Terminal Loads & Motions – Shallow Water

Side-by-Side Offloading Loads & Motions - 20m Water Depth

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Offloading</th>
<th>Berthing</th>
<th>Unit</th>
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<tr>
<td><strong>Storm Conditions</strong></td>
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<tr>
<td>Significant Wave Height, Hs</td>
<td>3.5</td>
<td>2.5</td>
<td>meters</td>
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<tr>
<td>Wind Speed</td>
<td>32</td>
<td>28</td>
<td>m/s</td>
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<tr>
<td>Current Speed</td>
<td>0.40</td>
<td>0.35</td>
<td>m/s</td>
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<tr>
<td><strong>LNG Carrier</strong></td>
<td>165,000</td>
<td>165,000</td>
<td>m^3</td>
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<tr>
<td><strong>Relative Motions (@ Loading Arms)</strong></td>
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<tr>
<td>Surge, Max/Allowable</td>
<td>82%</td>
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<tr>
<td>Sway, Max/Allowable</td>
<td>76%</td>
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<tr>
<td>Heave, Max/Allowable</td>
<td>50%</td>
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<tr>
<td><strong>Max Mooring Lines Tension</strong></td>
<td>53</td>
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<td><strong>Safety Factor</strong></td>
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<tr>
<td><strong>Max Pull-in Wire Tension</strong></td>
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<td>71</td>
<td>MT</td>
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Platform Construction & Schedule
Platform Construction Advantages

- Shipyard drydock not required
- Tubular and flat plate construction, fabricate in domestic or foreign fab yards
- Lends itself to modular construction
- Dockside testing of all onboard process & power generation units
- Offshore construction spread is minimal
- Install offshore & commission in a few weeks time
Floating Platform Size

- Column Stabilized Platform
  - 58m W x 26m H x 330m L
  - 26,000 ton steel w/o payload
  - Fab yard: GoM or SE Asia

- Exxon Lena Guyed Tower
  - 36.6m x 36.6m x 328m
  - 24,000 ton trussed tower
  - Brown & Root Harbor Island Yard, 1983
Schedule for Floating Platform Design, Fabrication, Installation

<table>
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<th>ID</th>
<th>Task Name</th>
<th>2005</th>
<th>2006</th>
<th>2007</th>
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<tr>
<td>1</td>
<td>Project Sanction</td>
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<td>2</td>
<td>Preliminary Engineering</td>
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<td>Detailed Engineering</td>
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<td>4</td>
<td>Procurement</td>
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<td>5</td>
<td>Platform Fabrication</td>
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<td>6</td>
<td>Deck Fabrication</td>
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<td>7</td>
<td>Topside Equipment Installation</td>
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<tr>
<td>8</td>
<td>Tower Fabrication</td>
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<tr>
<td>9</td>
<td>Tower Installation</td>
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<tr>
<td>10</td>
<td>Vessel Connection/Commissioning</td>
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Total Elapsed Time: 26 months
Conclusion

• No technology gaps to hinder permitting, design, & construction completion of a floating LNG receiving terminal within 28 months

• FMC Energy Systems can fully support the import facility construction requirements for this project by
  – participating in the port permit application process
  – by supplying hardware systems including:

  ➢ LNG loading arms
  ➢ Platform, gas swivel, risers, & mooring
  ➢ Cavern wellheads, subsea or dry trees
  ➢ Gas metering