



FLNG Safe Tandem Offloading of LNG in Severe Offshore Environments

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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**



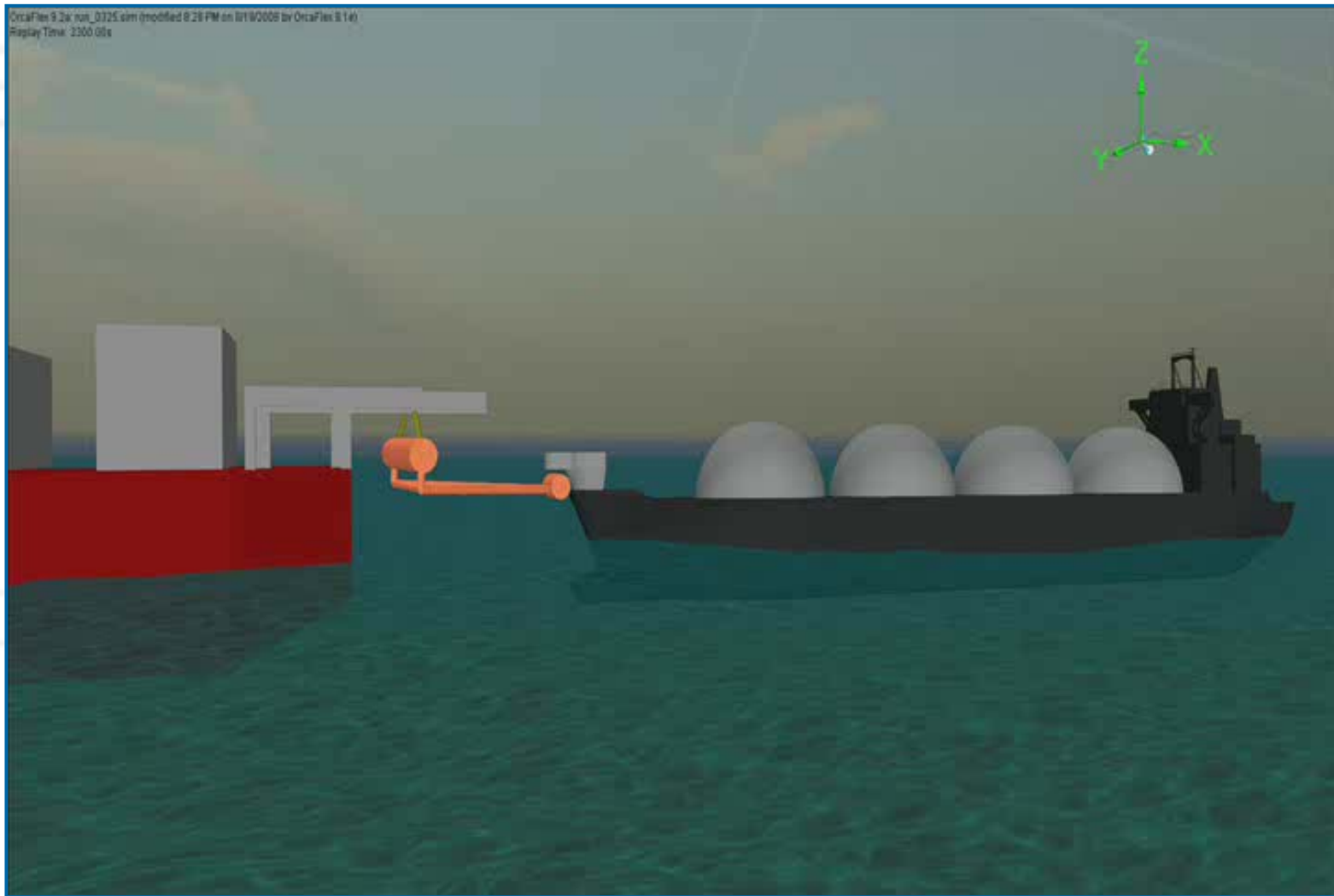
Offloading Oil from an F(P)SO Tandem and Side-by-Side Gulf of Mexico



Typical Offload Operation Criteria

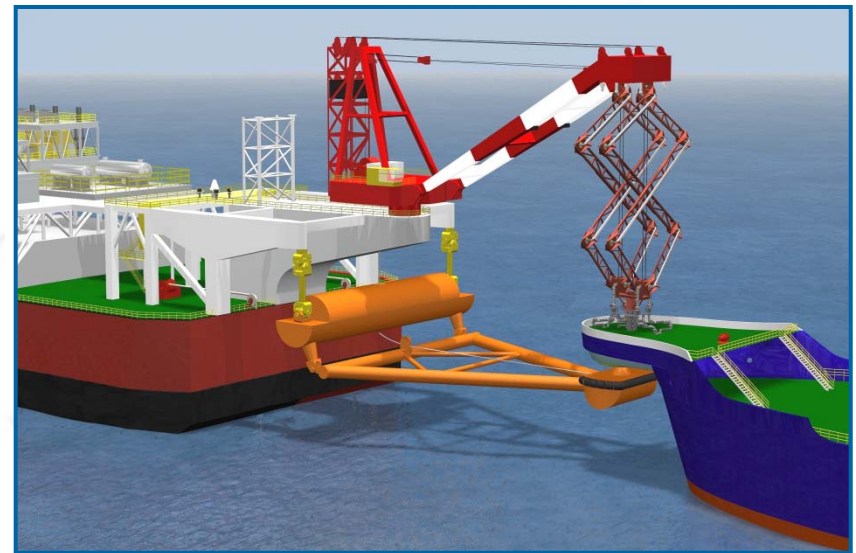
- **Tandem offloading using Nylon Hawser from FPSO to Tanker:**
 - Maximum Connect Hs = 2.5m
 - Maximum Offload Hs = 3.5m
- **Tandem Offloading using DP Shuttle Tankers**
 - Maximum Connect Hs = 4.5m
 - Maximum Offload Hs = 5.5m
- **Side-by-Side Offloading from FPSOs to Oil Tankers:**
 - Maximum Connect Hs ~ 1.5 to 2m
 - Maximum Offload Hs ~ 2.0 to 2.5m

Simulation Response in Hs 5.5m seas (Orcaflex™)

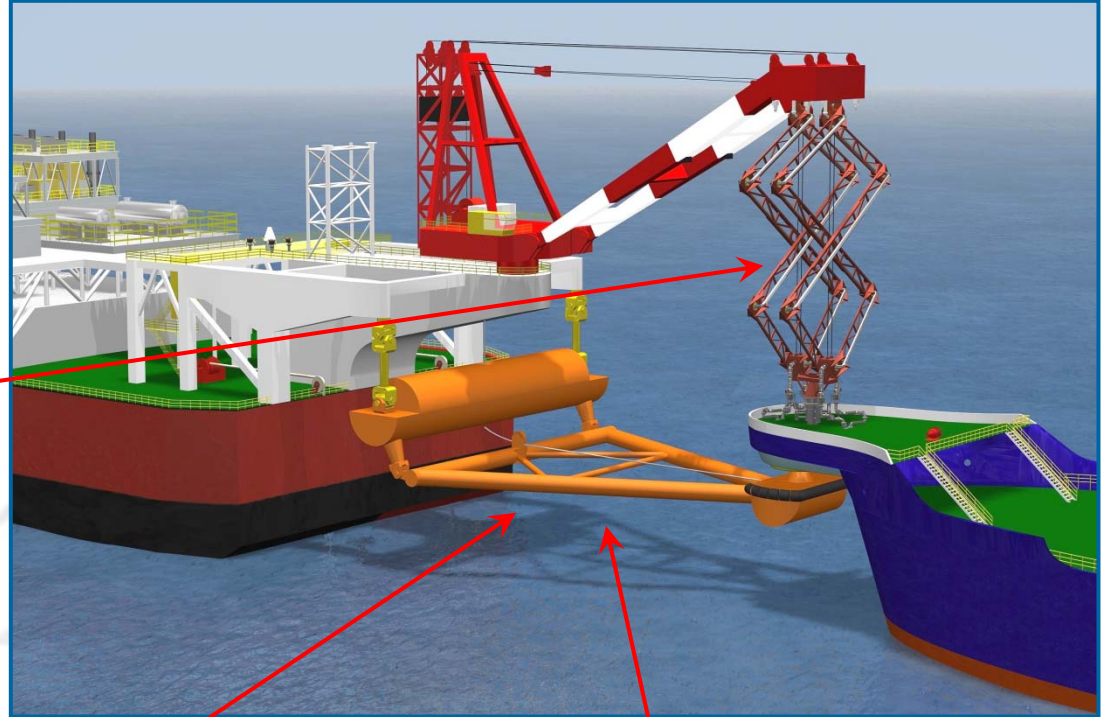


Design Requirements

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



LNG Tandem Offloading System Development



SOFEC Duplex Yoke

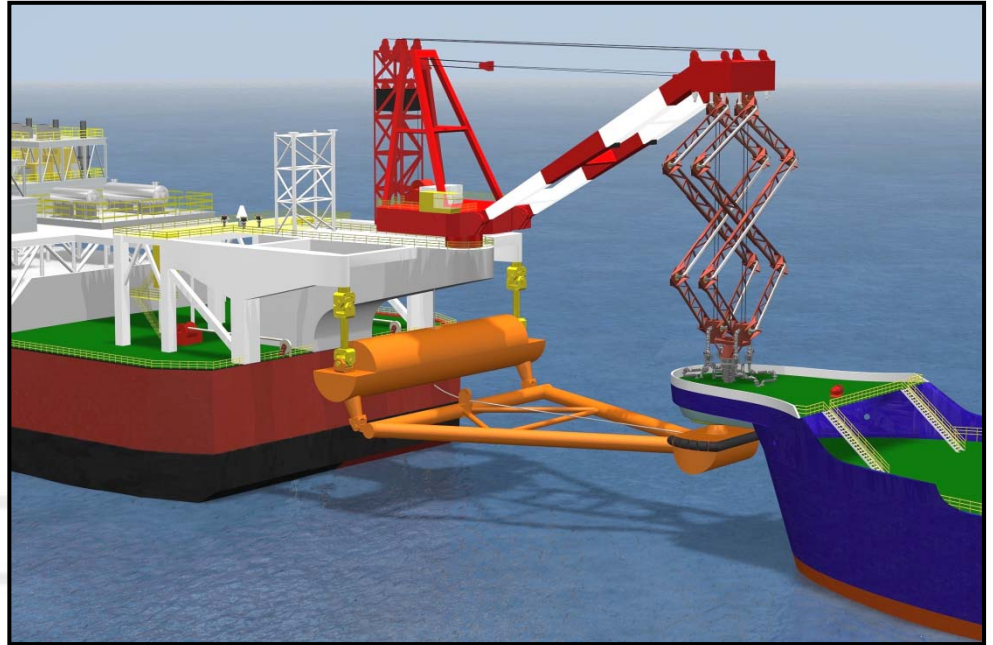
Mooring System Equipment

- **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**

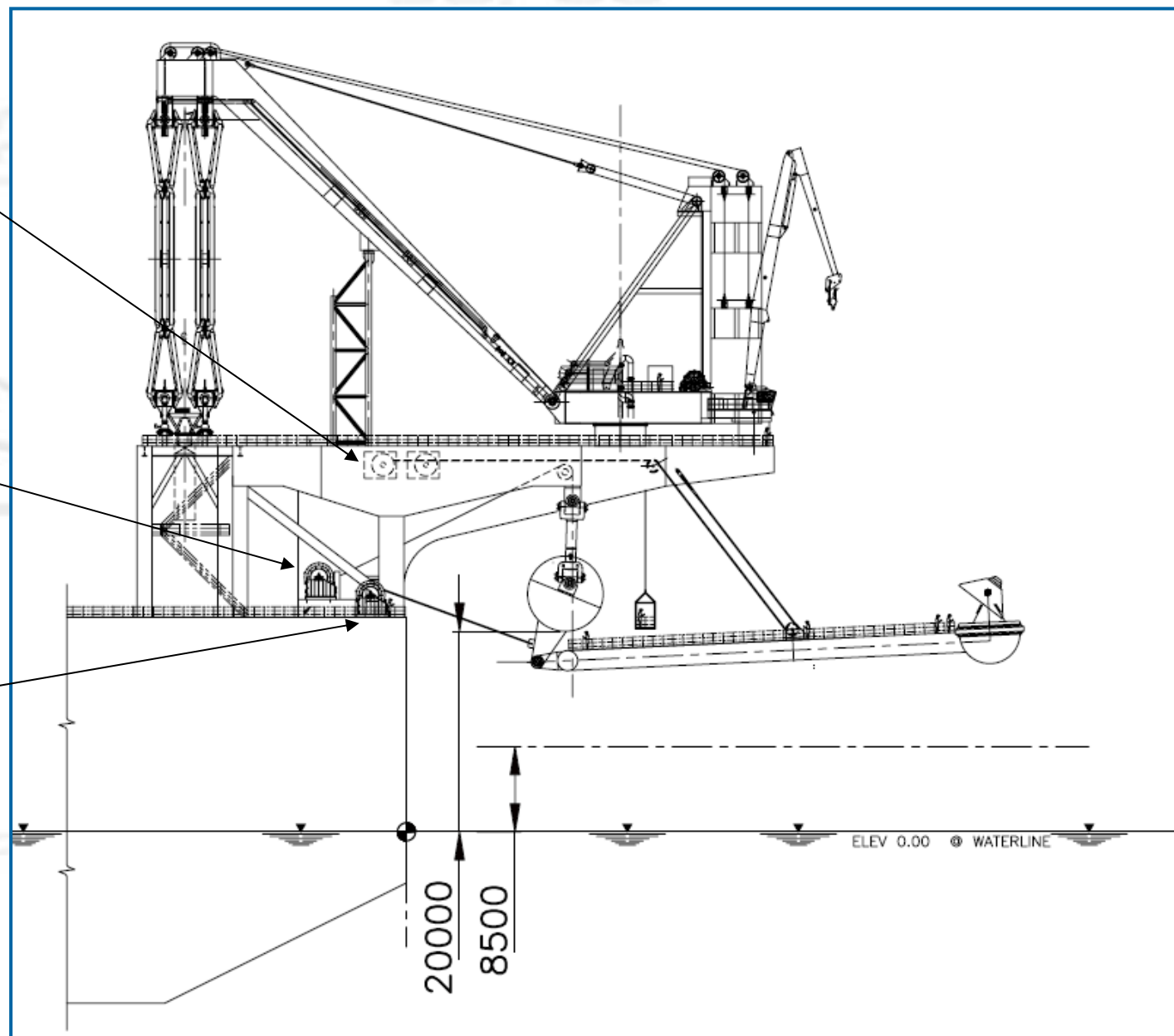
- FMC Loading Systems pantograph pipe & swivels
- Aerial cryogenic flexible hose when proven & available

Yoke in Parked Position

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

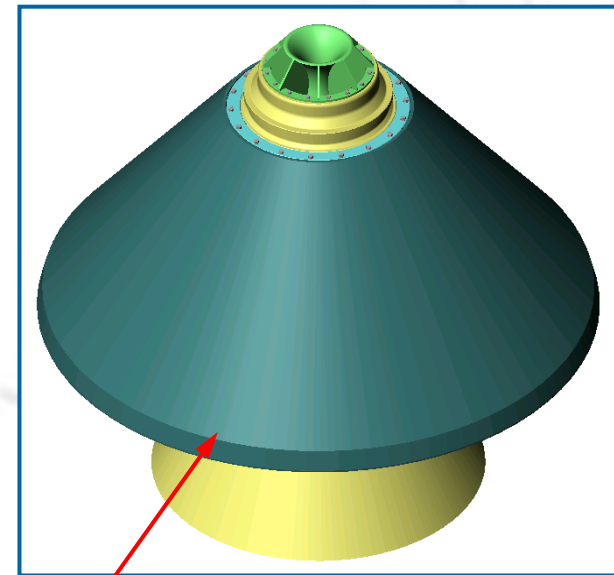
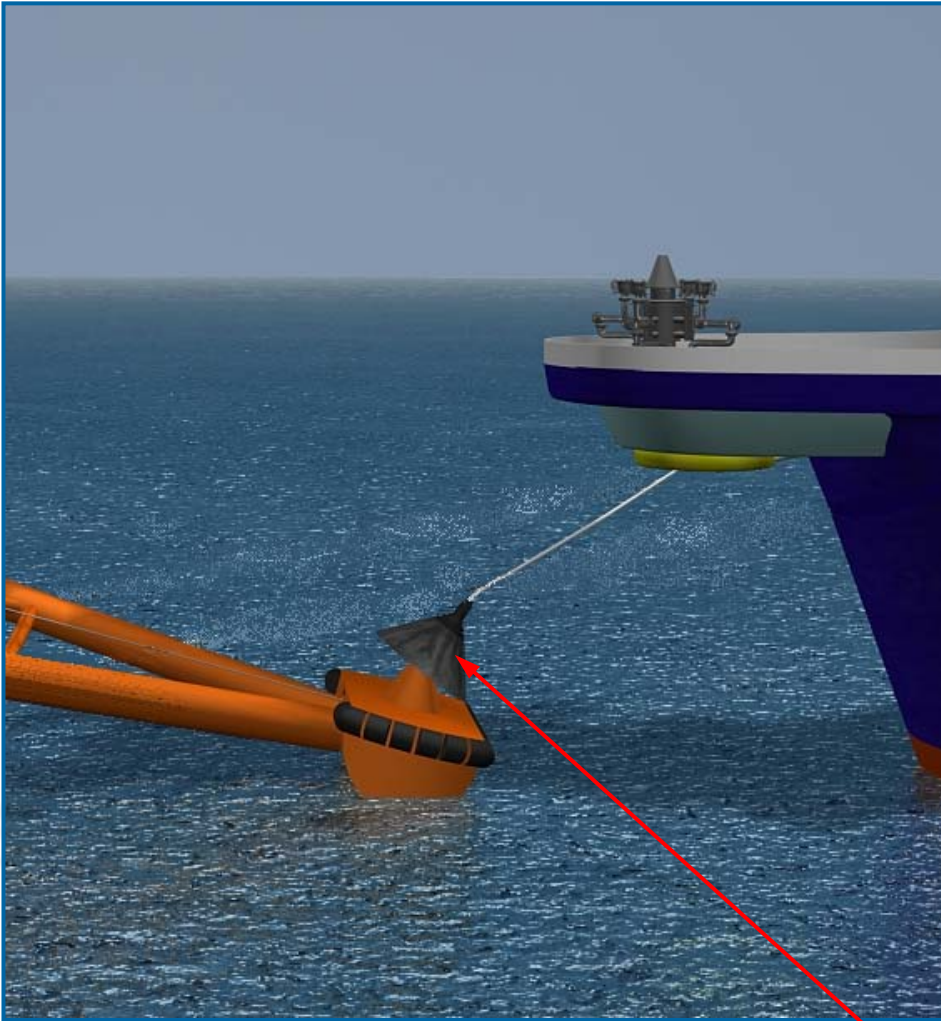
Hawser winch
300 mt capacity
Render & Recover

Two Auxiliary
Winches (225 mt)
Stabilize sway
On port & stbd side





Yoke Tip Cone

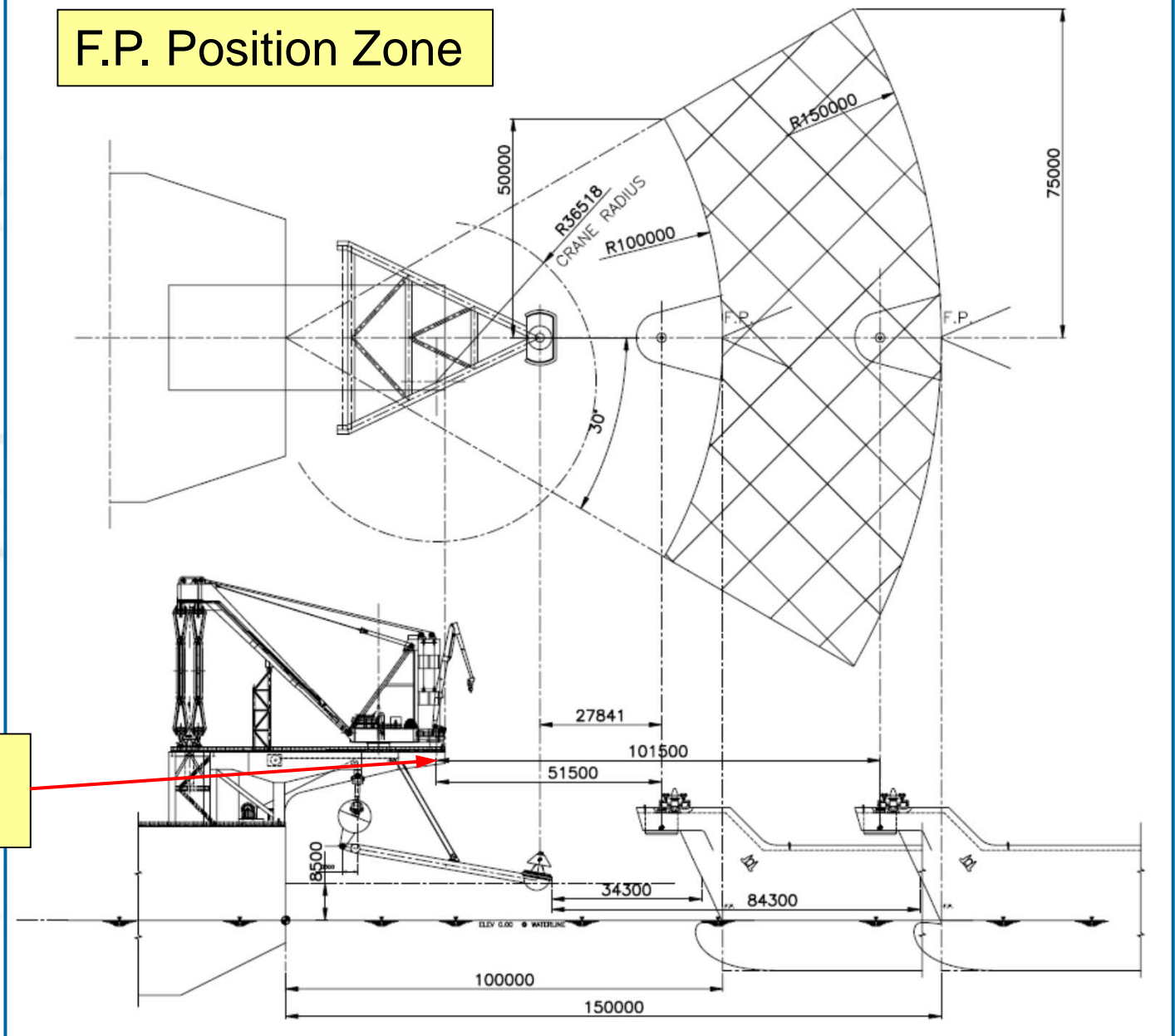


Pivoting cone on two-axis gimbaled joint with internal vertical axis yaw bearing

Mooring Hook-Up Procedure Summary

Throw-line Zone for LNG Carrier Bow Position

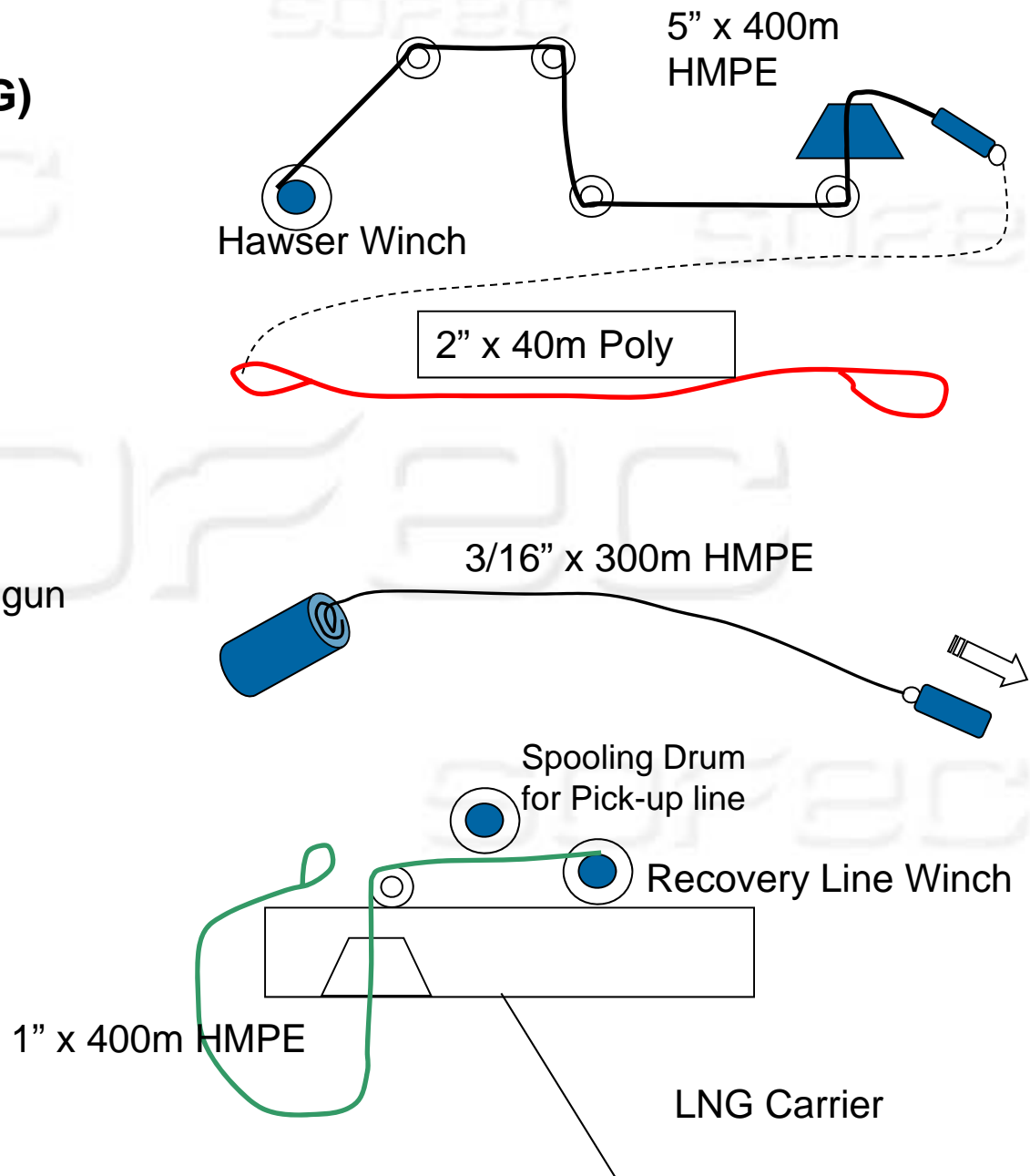
F.P. Position Zone



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

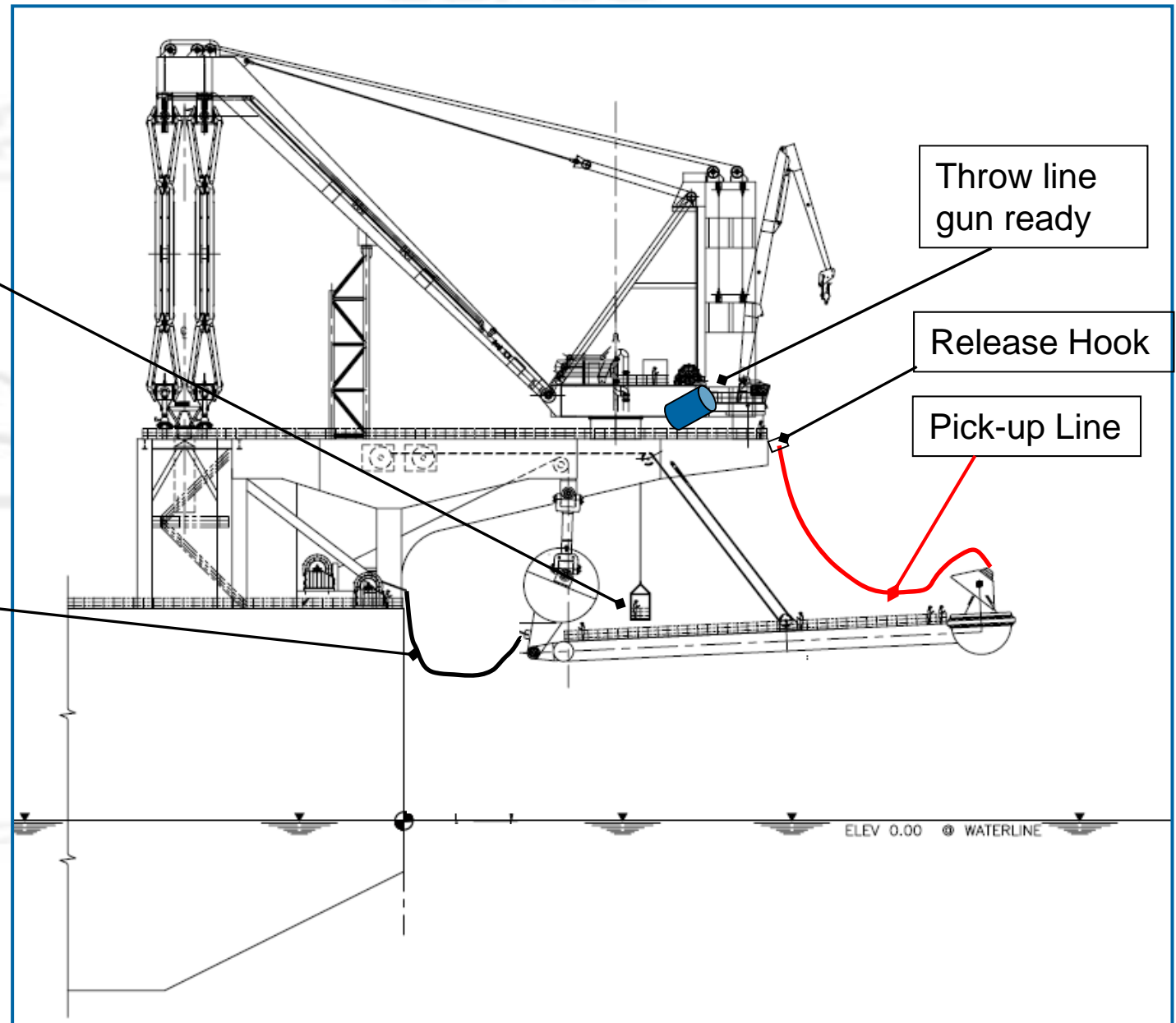
Final inspection of
yoke before
connection

Slacken Lines on
Two Auxiliary
Winches
Port & Stbd

Throw line
gun ready

Release Hook

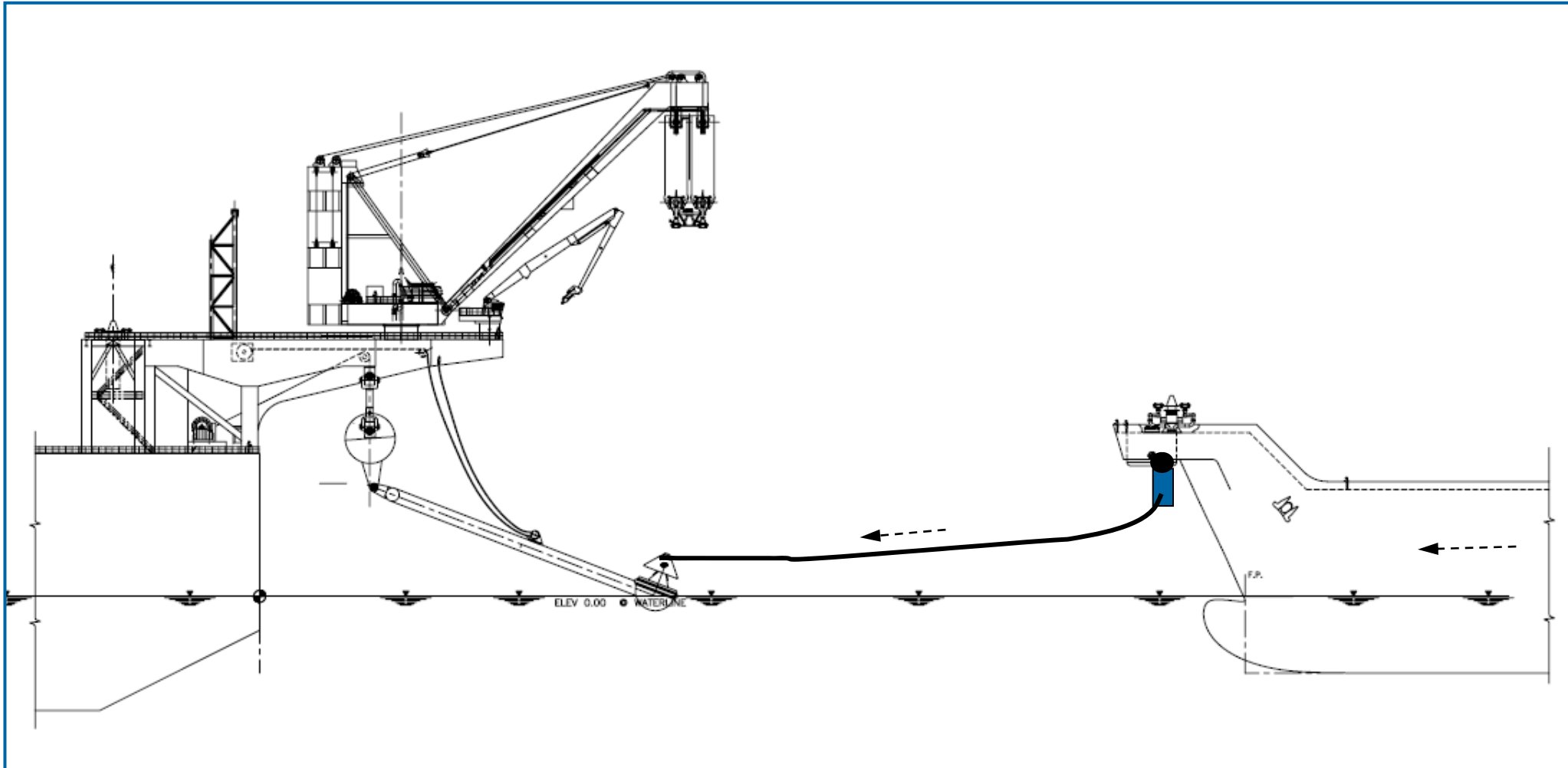
Pick-up Line



Yoke Connection Procedure

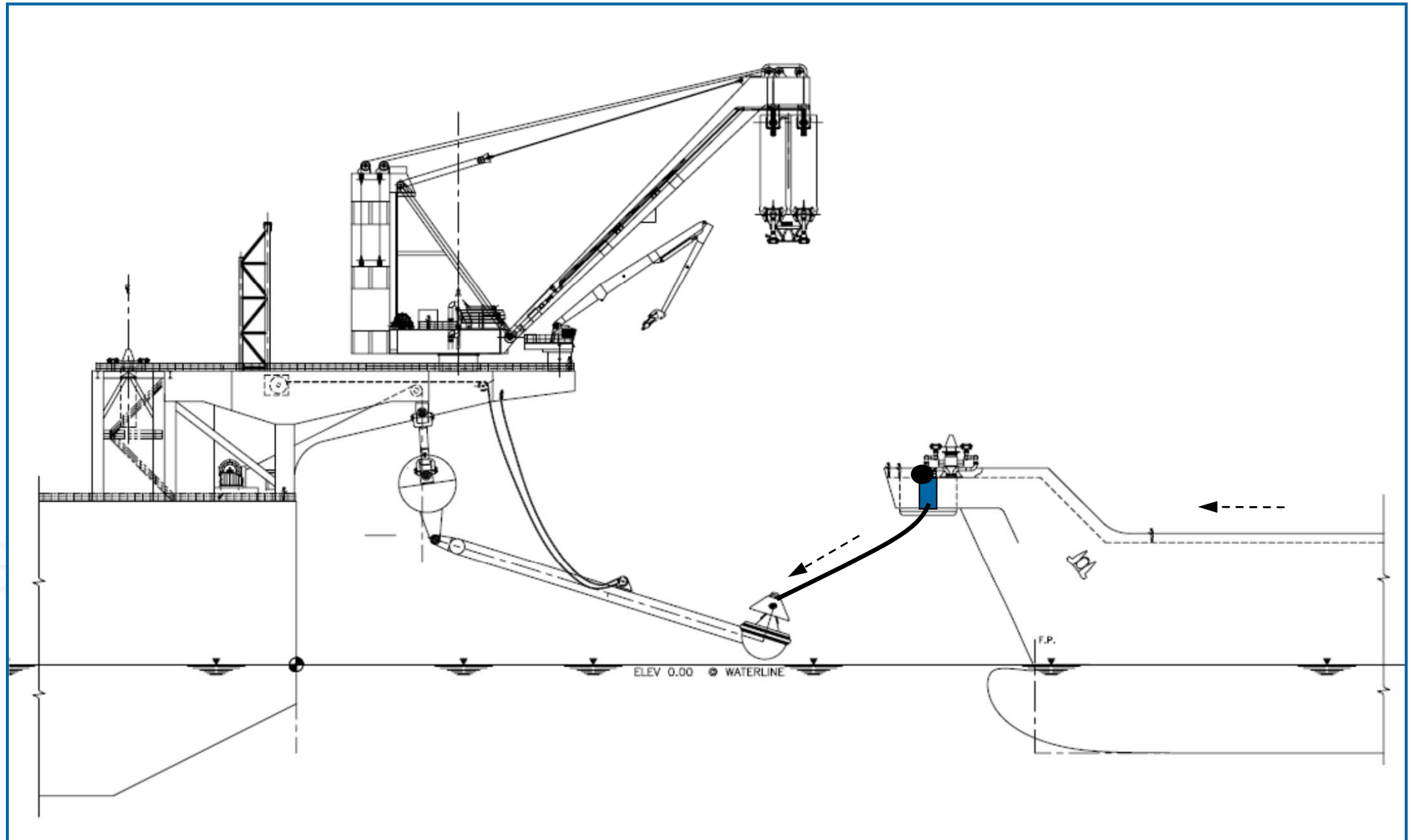
Hawser pull continues

SOFEC



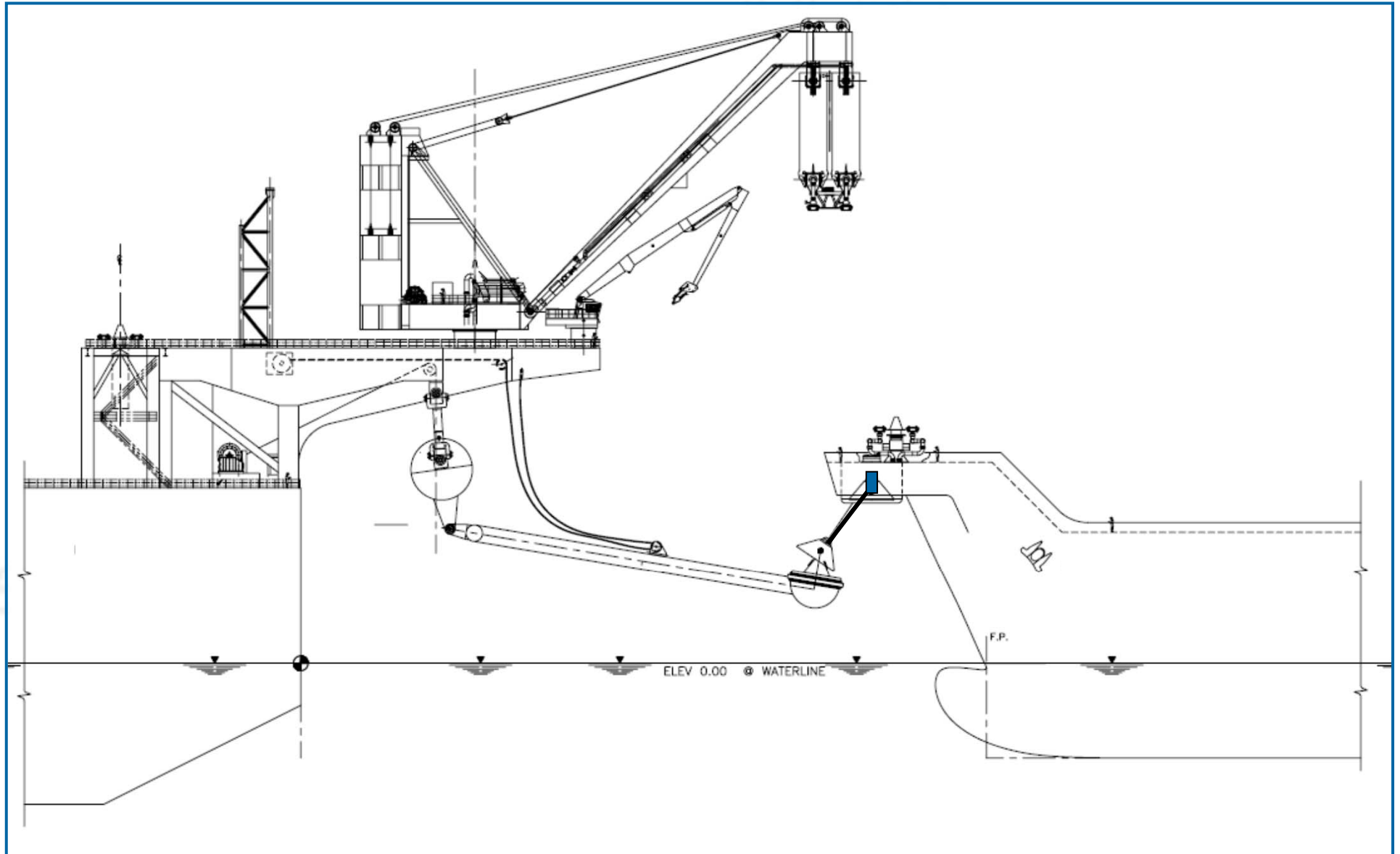
Yoke Connection Procedure

Yoke lifts out of water as hawser is retrieved to FLNG



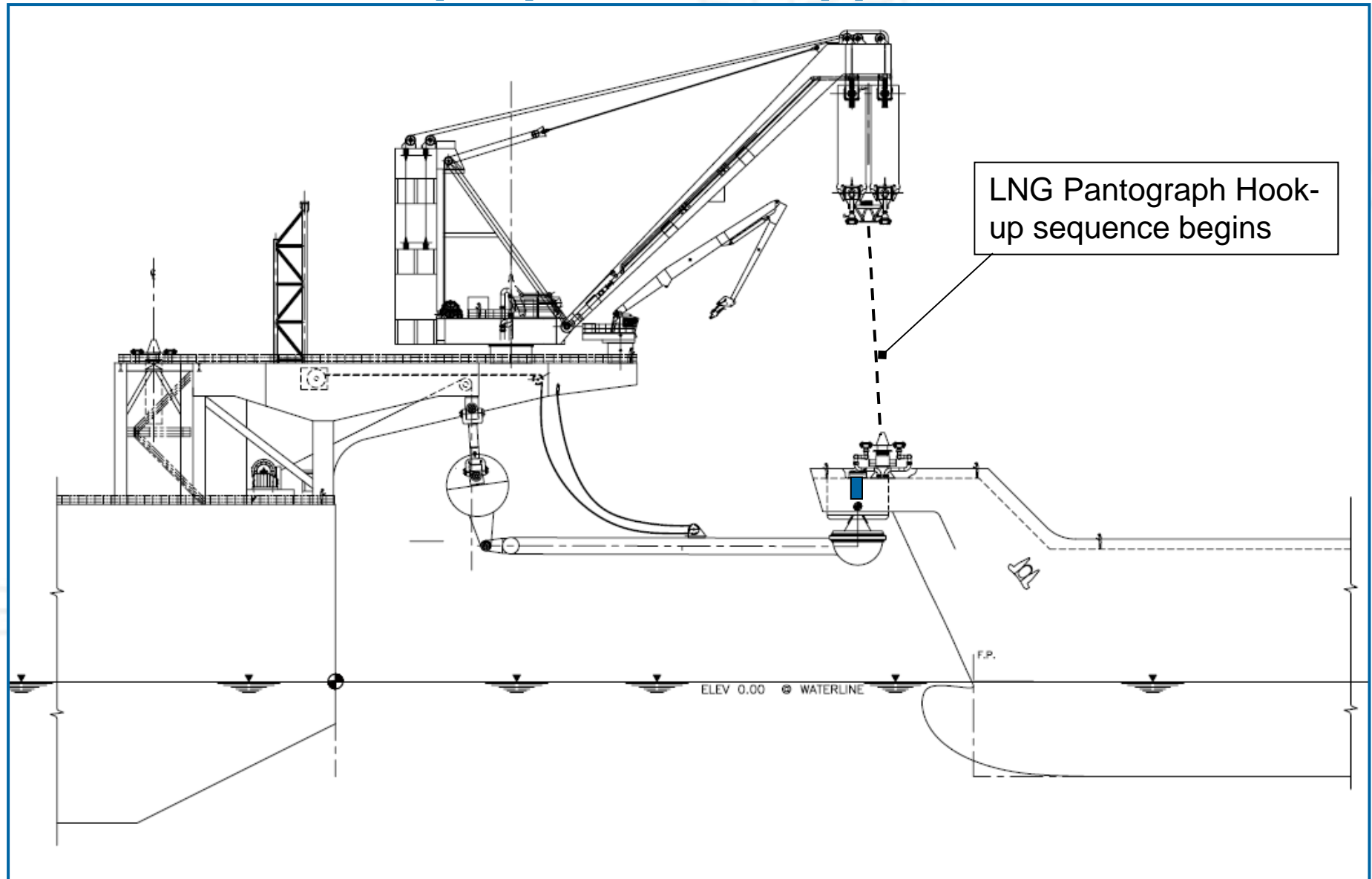
Yoke Connection Procedure

Cone approaches receptacle

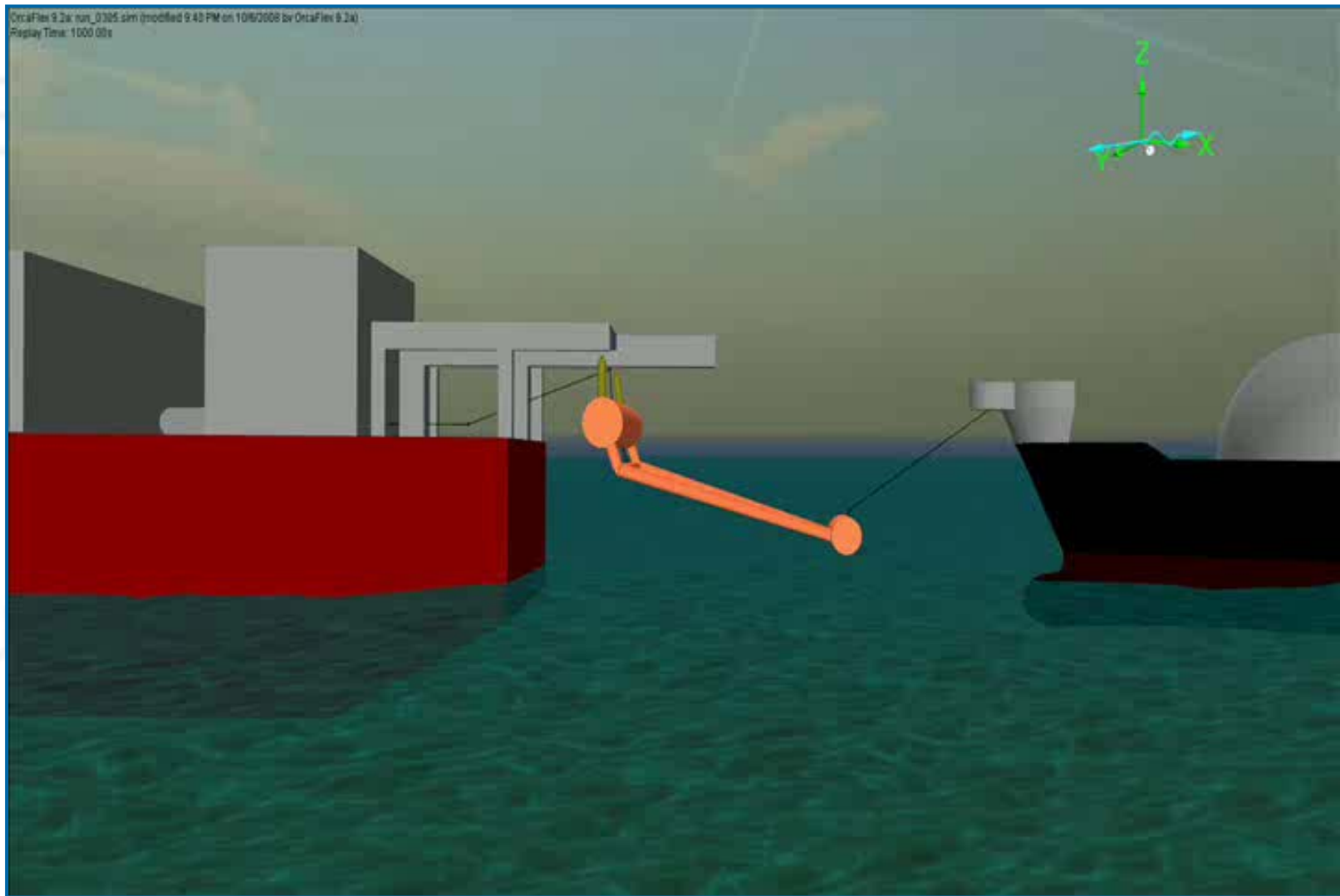


Yoke Connection Procedure

Yoke connected, propulsion stopped

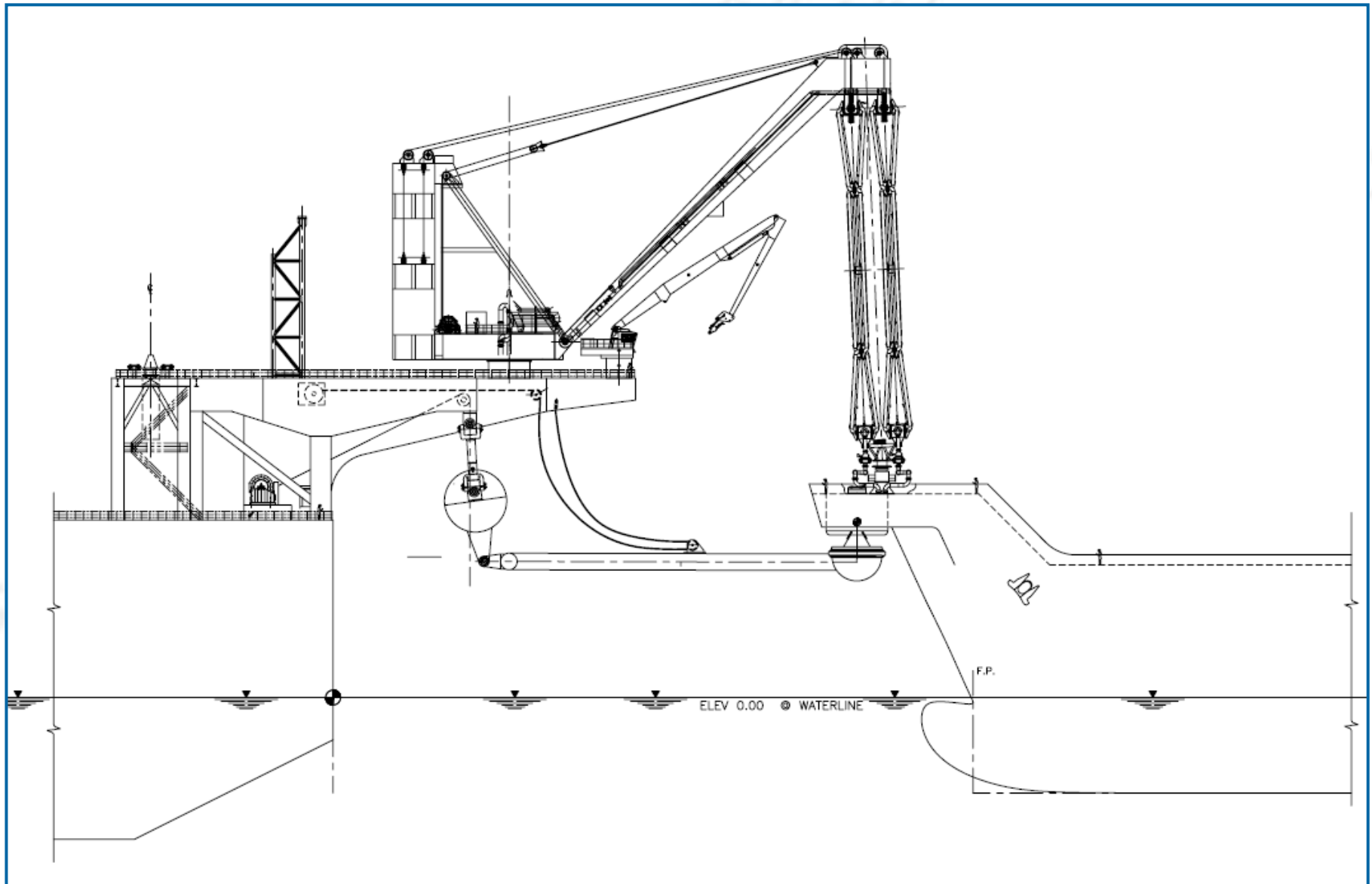


Connection Simulation (Orcaflex™)



Yoke Connection Procedure

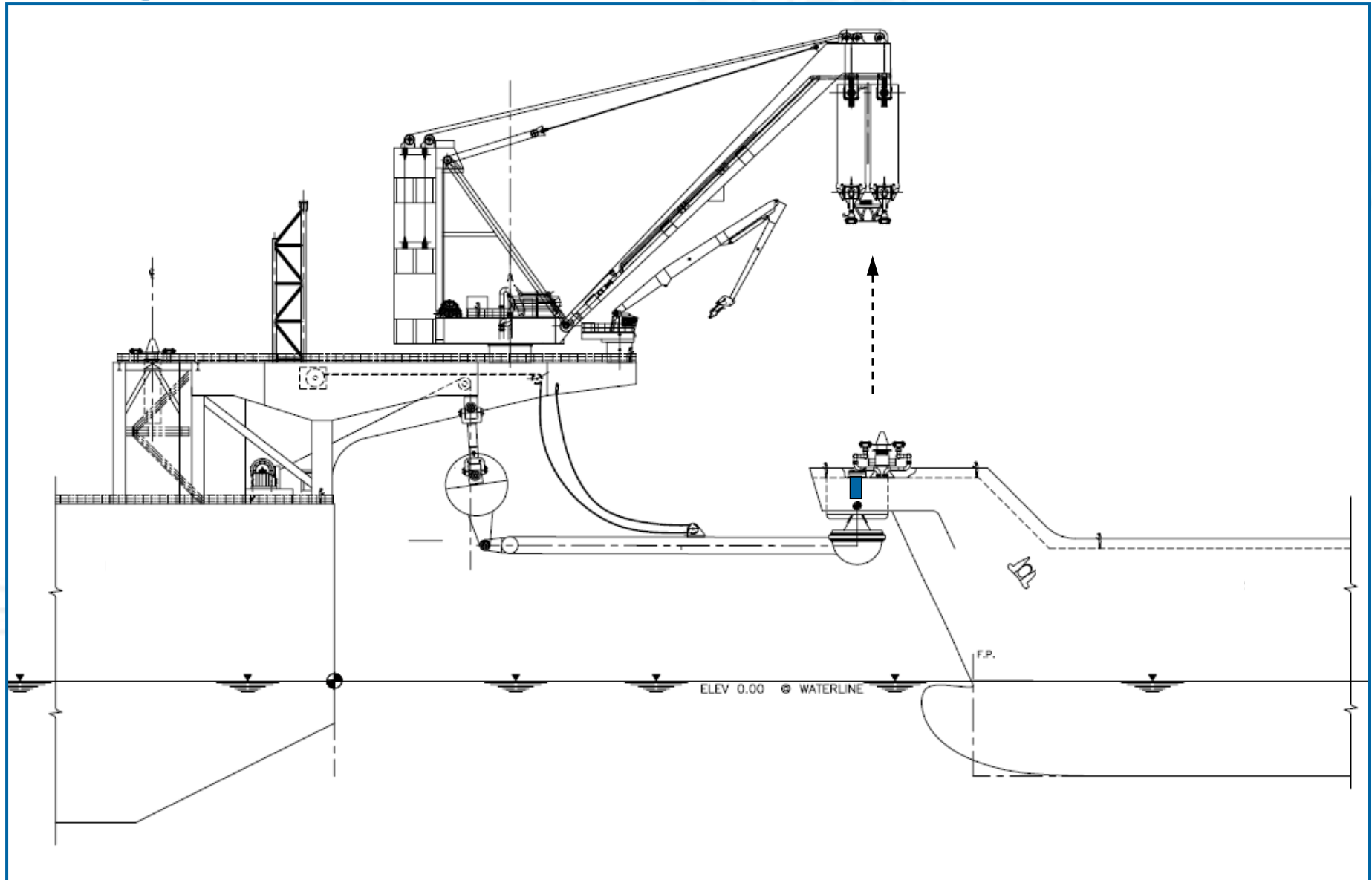
LNG Pantograph connected & offloading



Mooring Yoke Disconnect Summary

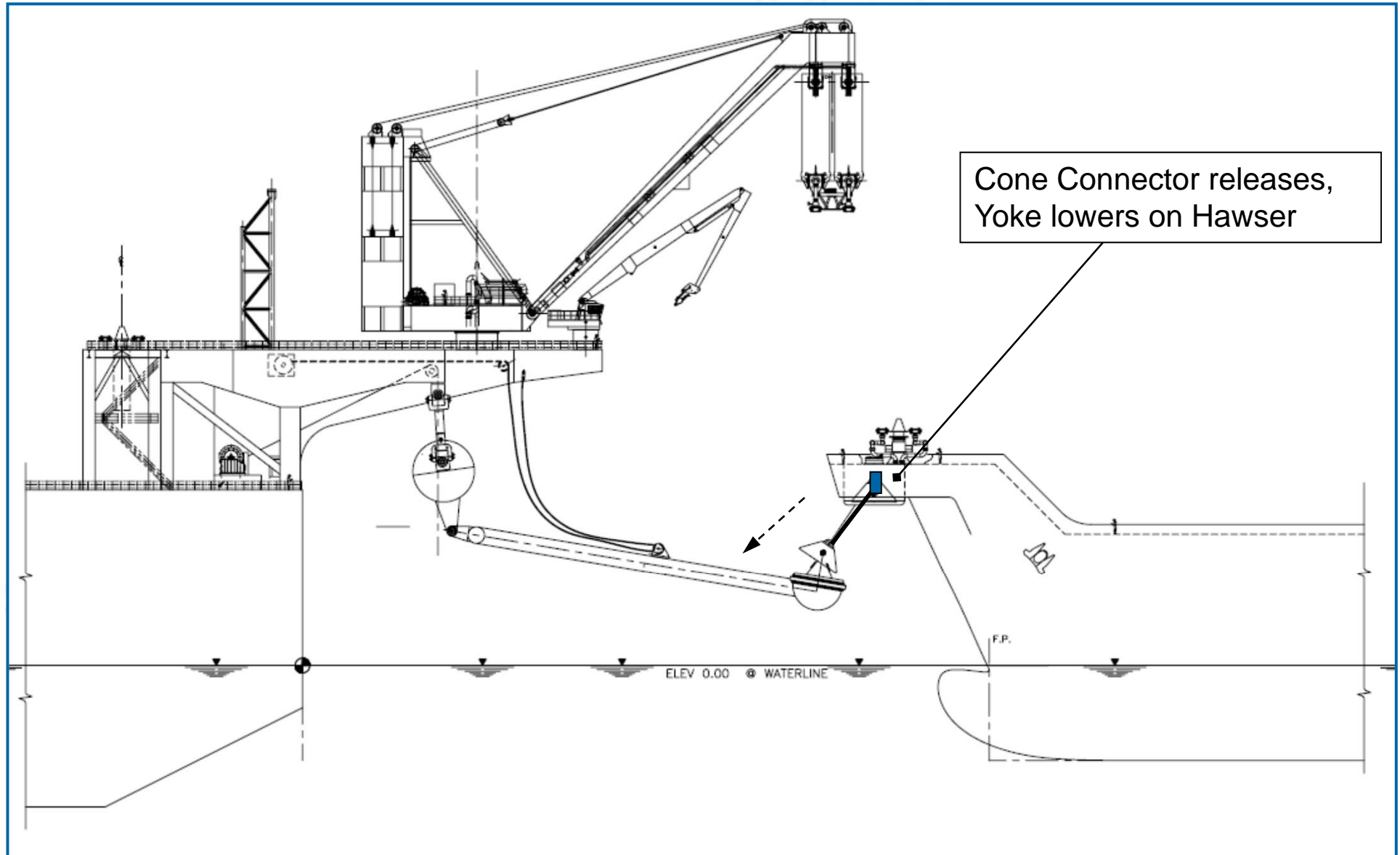
Yoke Disconnection Procedure

Pantograph retracted



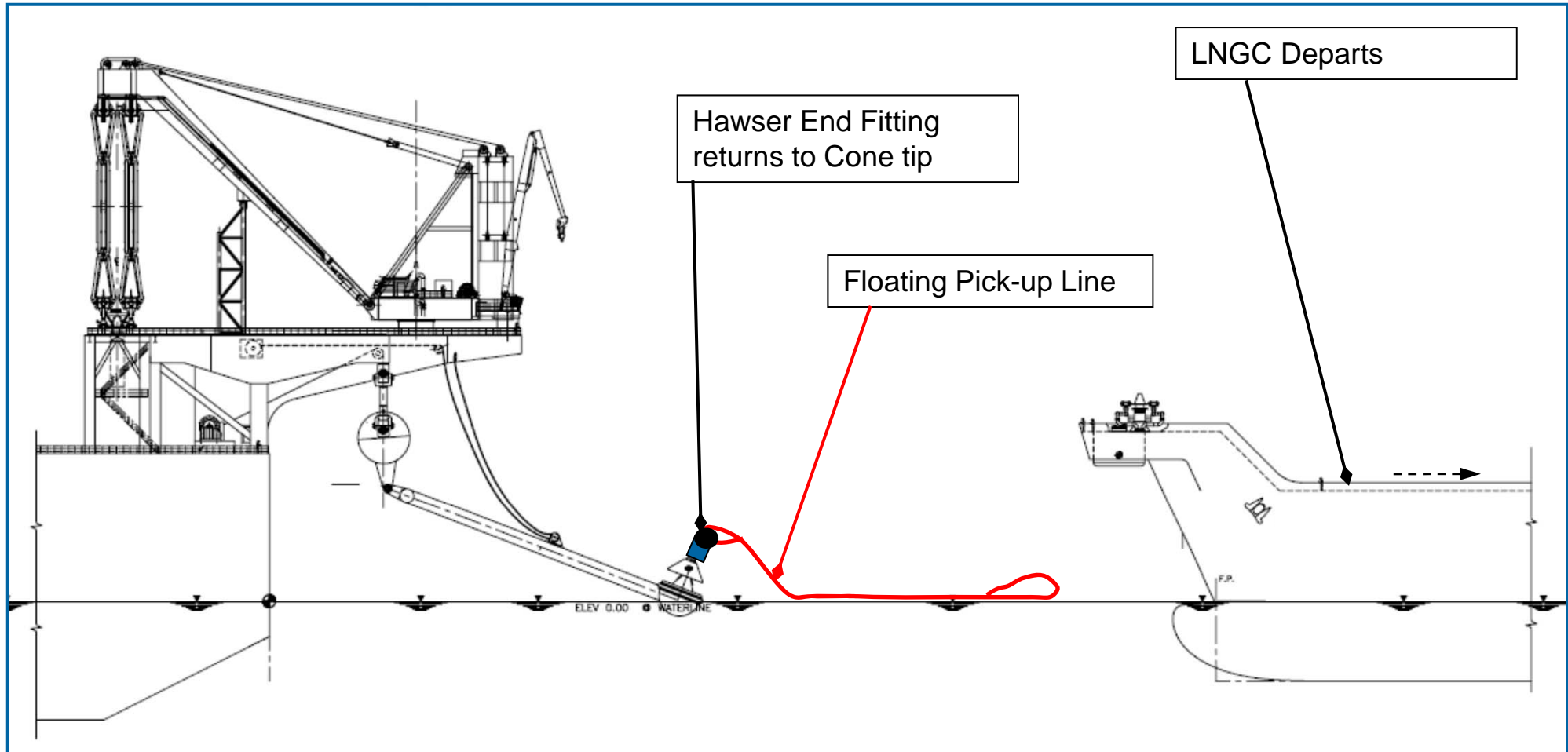
Yoke Disconnection Connection Procedure

LNGC begins thrust astern to back away



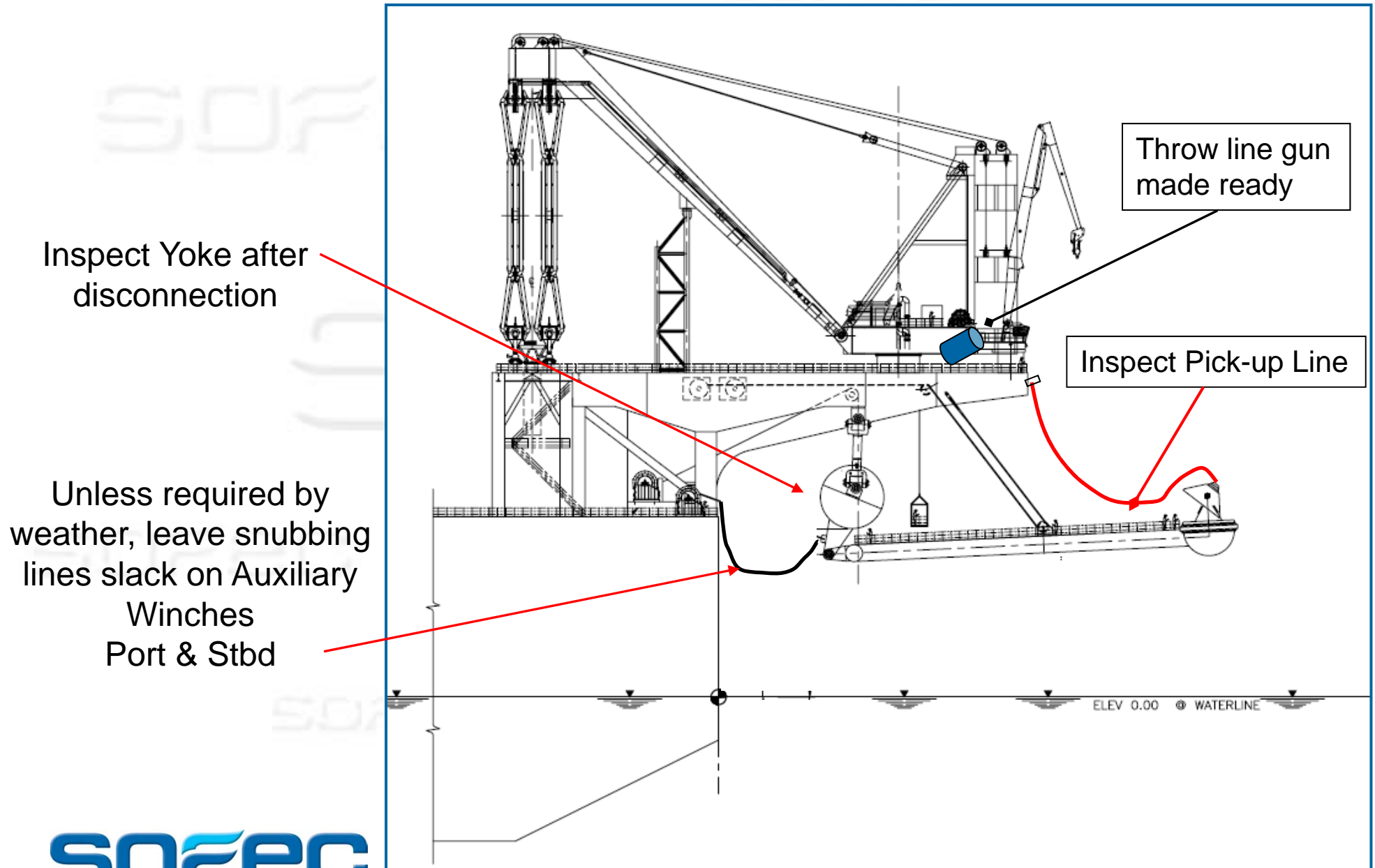
Yoke Disconnection Procedure

Hawser retrieved back to LNGC



Yoke Disconnect Procedure

Yoke in Parked Position, Ready for next LNGC Arrival



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**