Harsh environment mooring solutions for a wide variety of floating wind applications
Content

• NOV-APL
• Mooring System Design
• Mooring Components
• Offshore Installation
APL is a world wide player w.r.t. mooring systems
APL™ at a Glance

- **$105M** ($402M/2015) annual revenue
- **160** employees at HQ
- **140+** engineers
- **200** employees globally
- **R&D Center**
  - Vindholmen Arendal
- **Sales**
  - Arendal, Houston, Singapore, Rio, Lagos
- **NO Headquarters in Arendal**
- Established 1993
- Acquired by NOV 2010
APL™ Technology

Pioneering design for optimized uptime

- Proven solution with 80 turret and spread-moored arrangements, 5 subsea hose loading systems, and more than 100 loading and offloading systems and shipboard equipment packages
- Superior innovation
- Complete life-cycle support
- Customized as per site requirement
- Certified equipment as per project requirements

APL has proven technology that can be adopted to the project requirements
Turret and Spread-Moored Systems

STL – Submerged Turret Loading

STP – Submerged Turret Production

ETP – External Turret Production

BTL – Buoy Turret Loading

SM – Spread Mooring

SIT – Ship Integrated Turret

SAL – Single Anchor Loading

SYS – Submerged Yoke System

SSY – Submerged Swivel and Yoke
Typical Scope

Includes design, analysis, procurement, fabrication, certification / class approval and delivery of a complete system including transport to yard and offshore mobilization site.

System:
• Anchors
• Mooring lines (chain, wire rope, synthetic rope, accessories, connections)
• Riser, umbilical and cable system with associated subsea foundations/accessories
• Buoy and turret
• Fluid and power transfer system
• Shipboard equipment and structures

In addition:
• Offshore installation support
• Service and After Sales
Components vs. System

• Design, engineering, procurement, manufacture and delivery of single components:
  Typically EPC with installation support

• Design, engineering, procurement, fabrication and delivery of complete mooring and riser systems
  Typically EPC with installation support, but can also be full EPCI
Mooring System Design
Mooring System Design

- Design
- Analysis Capability
  - Marine Analysis
    - Vessel Motion Analysis
    - Station-Keeping Analysis (Mooring Analysis)
    - Model Tests (ocean basin tests and wind tunnel tests)
    - Riser and Cable System Analysis
  - Geotechnical Analysis
  - Structural Analysis
  - Flow Assurance Analysis
  - Installation Analysis
  - Stability Analysis
- Specification, Procurement and Fabrication
  - Mooring Components
  - Structural Components
  - Mechanical Components
  - Process Equipment
- Attended and attending several related JIP’s
Spread-Moored FOWT

Typically:
• 3 (non-redundant) to 6 (redundant) mooring lines
• Suction or drag embedment anchors
• Synthetic rope (polyester, nylon, dyneema) and/or chain
• Associated mooring connections/tensioners
  • Fixed/Adjustable mooring lengths

Challenges: Cost of Hardware & Installation, OPB, ....
Turret-Moored FOWT

- Disconnectable for maintenance and repair, but designed as permanent
- Cost and time for disconnection and connection define type of system
- Possible with simple connection and disconnection of cable

Courtesy of Floating Power Plant, Cruse Offshore, Saitec Offshore, Eolink and X1Wind, respectively.
Mooring Components
Traditional Mooring Components

- Mooring Line Buoyancy Element
- Touch Down Preventer
- Connecting Link
- Single Axis Chain Stopper
- Chain Clump Weight
- Anchor
APL and other NOV companies also design and deliver special mooring components associated with diverless connections, tensioning operations, etc.

APL also work with external suppliers if their products is better suited for a given application.
Connecting Links

- Proven components
- Minimize OPB/IPB on chain / wire rope
- Full angular freedom in two directions
- Permanent connection, i.e. non-disconnectable
- First/inner link typically installed between two mooring lugs
- Standardized tension/angle monitoring
- Several applications
  - Spread-moored / FOWT
  - Turret
  - Anchor

With tension monitoring Cables properly fixed

With angle monitoring

Can be adapted to chain, steel wire rope and synthetic rope
Materials and Bushings

• Materials
  • Pins: Typically Duplex or Super Duplex
  • Links: Forged or machined from plates, typically ASTM 182 F22 or DNV NVF36

• Self-lubricated bushings
  • Bushing material and associated friction coefficient important for OPB/IPB
  • Metallic bushings towards structure for electric continuity
    (for CP of connecting links)
  • Composite bushings towards mooring line for electric discontinuity
    (to avoid drainage of CP system by mooring)
Out-of-Plane and In-Plane Bending

**BTL**
1st installed 2006, 4th to be installed 2020
Small Buoy / Large Motions, High Pretension ➔ OPB/IPB Important

**SYS/SSY**
1st installed 2004, 4th to be installed 2019
High Pretension ➔ OPB/IPB Important
APL conducted OPB/IPB tests on chain as early as 2004

Typical approach includes:

• Finite Element Analysis
• BV Guidance Note NI 604 DT R00 E 2014
  • NI 604 is presently the only standard for OPB/IPB
  • ABS is working on their own standard
  • DNVGL has a purpose built test rig for OPB/IPB
• Bearing design
  • APL has long experience with low friction bearings
  • Effect on stick-slip and thus OPB/IPB
Offshore Installation
**Offshore Installation**

- **Small scope:**
  - Develops outline installation procedures
  - Attends offshore installation

- **Large scope:**
  - Full responsibility for offshore installation

Long experience in design, fabrication, procurement and installation of mooring systems with non-adjustable mooring line lengths.