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UpwingEnergy

# Magnetic Drive System (MDS) for Offshore Artificial Lift

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# Top-level Objectives

- Significantly increase **reliability**
  - 10-year run life without a workover
- Maximize **rigless retrievability**
  - Slickline retrievable with a single run
  - Serviceable by all major service companies
- Robust **scalable** system
  - Addresses the market needs of today and tomorrow
- **Engineered** solution
  - Develop a solution to meet the application requirements (i.e. from a clean sheet of paper), not limited to the use of existing equipment
  - Utilize components and latest technologies that are proven in oil and gas or other industries and don't limit performance

# The Solution

- Step change improvement over conventional and existing rigless ESP systems in the market
  - Maximum Reliability
    - Hermetically sealed PM motor stator
    - Flow through motor
      - Optimum cooling
      - Elimination of all dynamic seals
    - Elimination of wet-mate connectors
    - Lubrication free passive magnetic bearings
  - Simplified Retrievability
    - Slickline deployment and intervention
    - Single run operation for 1MW ESP system
  - What an ESP should be
    - Engineered solution that integrates proven technologies
    - Bigger motor in casing instead of through-tubing motor
    - Light weight retrievability
    - Capable of high speeds for a broader operating range

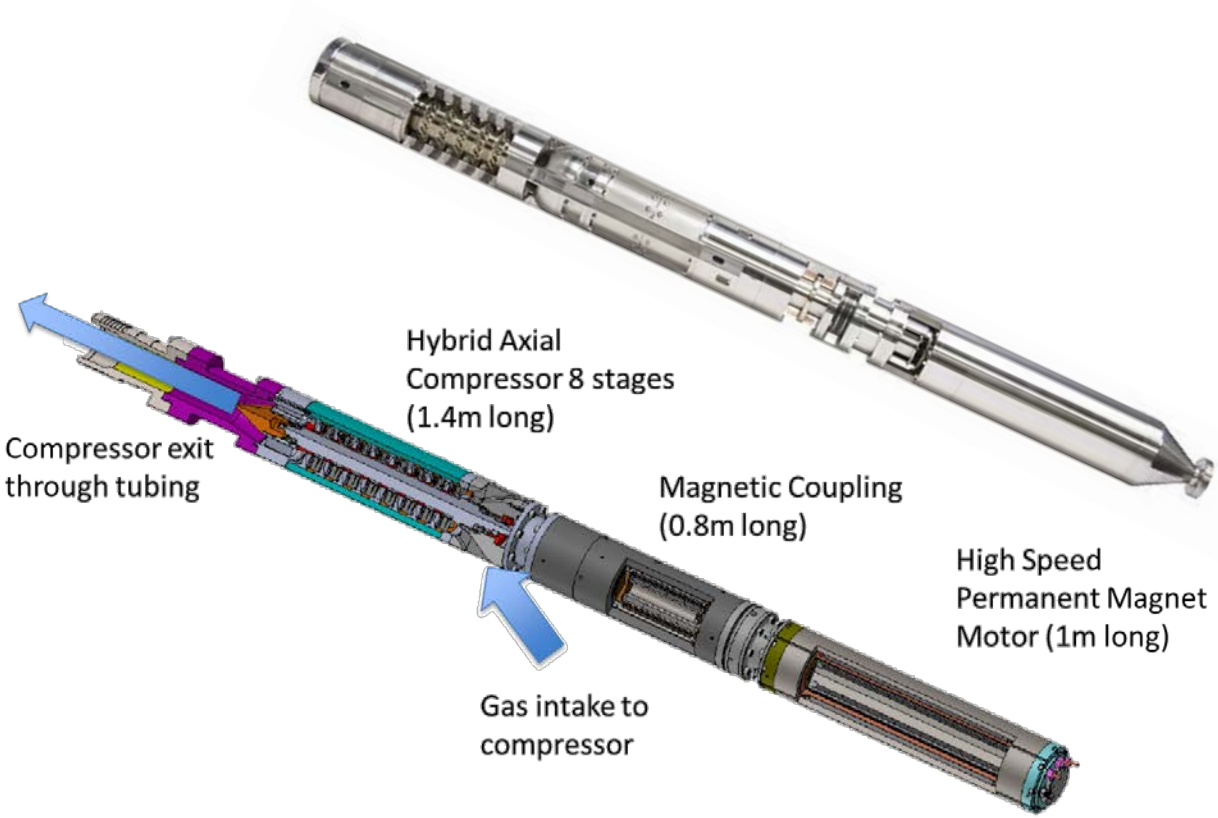
The project is supported and funded through the DeepStar Global Offshore Technology Development Consortium) and executed by Upwing Energy and Mitsubishi Heavy Industries (MHI)

# Specifications (Phase 2)

- Casing size: 9 5/8” (53# ID 8.535”)
- Tubing size: 5.5” (ID of 4.67”)
- Burst/collapse pressure: up to 20,000 psi
- Wellhead pressure: 500 psi (flowing)
- Wellhead pressure: 15,000 psi (shut in)
- Environmental temperature rating: target 250$^{o}$F
- Water depth: 10,000 ft.
- Setting depth from sea floor: up to 15,000 ft.
- Production rate:  Rated 10,000 BPD (surface flow), up to 12,000 BPD
- Water cut: 20%
- GOR: up to 300 scf/stb
- H2S: < 5ppm
- Particle size: 200 um
- Max Effective Viscosity: 100 cP (evaluating pumps up to 500cP)
- Operating speed: up to 8,000 rpm
- Bubble point: 1,200 psi
- Pump inlet pressure: above bubble point
- Produced water salinity: 1.1 sg
- Velocity of the production fluid through motor: preferred below 11ft/s, max 15ft/s
- Operating angle: up to 45 deg

# Upwing Core Technology

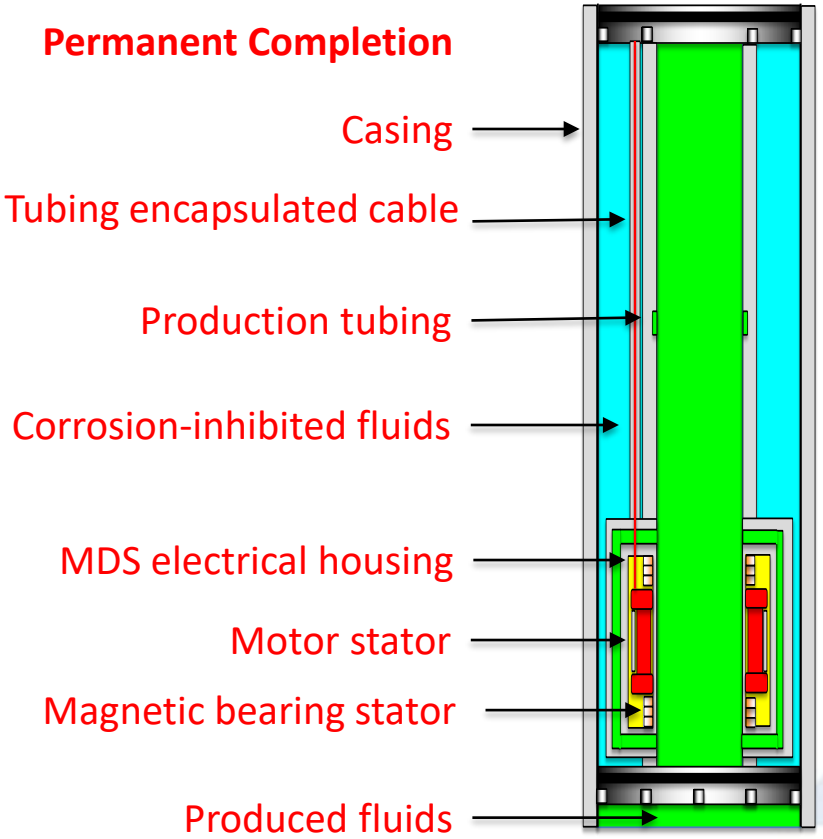
- Subsurface Compressor System (SCS)
  - Hermetically sealed electrical components
  - Torque transmittal via a magnetic coupling
  - High speed operation with magnetic bearings




# Permanent Completion

**Electrical system hermetically sealed in completion for maximum reliability**

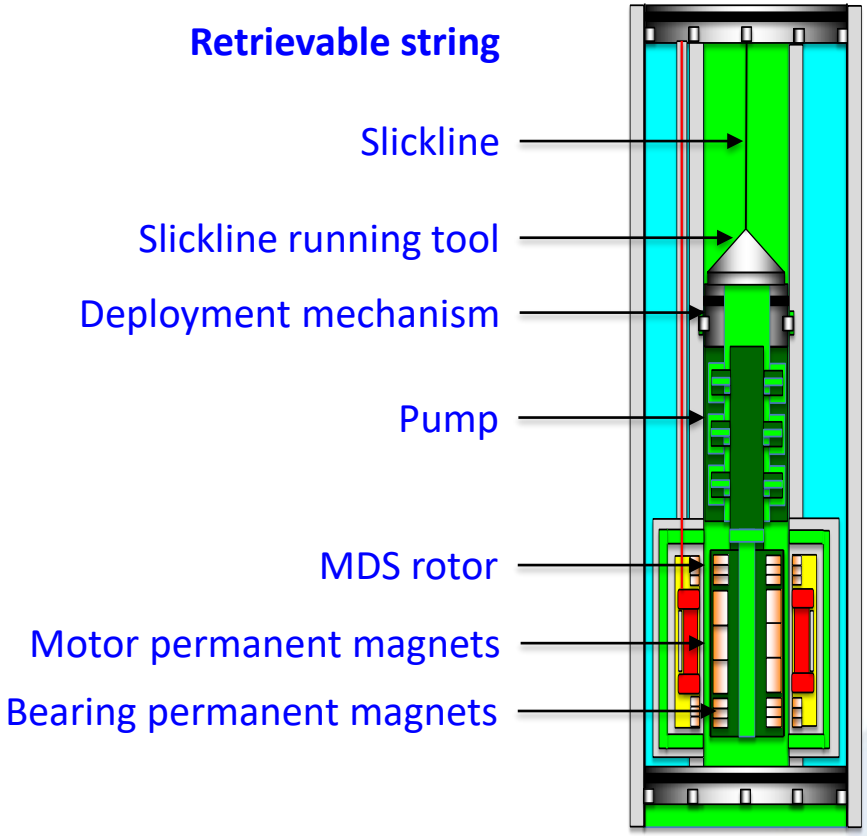
- Complete electrical system is part of permanent completion
- Motor and magnetic bearing stators are hermetically sealed inside the MDS electrical housing
- Cables and connectors are metal encapsulated and metal-to-metal sealed
- No rotary seals or wet-mate connections
- Submerged in corrosion-inhibited fluids for further protection



# Retrievable String

**Mechanical parts are deployed by slickline for high retrievability**

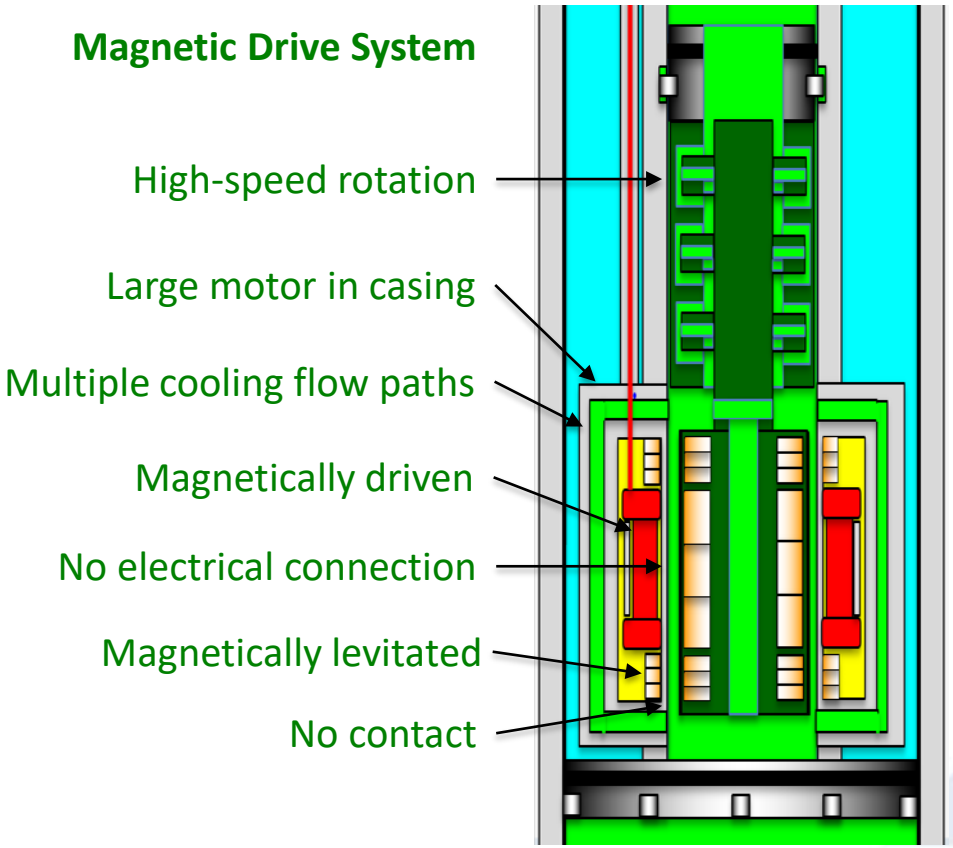
- MDS motor rotor and pump make up retrievable string
- Deployment mechanism anchors to tubing string and prevents the recirculation of the pumped fluids
- An off-the-shelf pump is connected to deployment mechanism and driven by the MDS rotor
- MDS rotor contains permanent magnets for motor and bearings that are encapsulated by Inconel



# Functionality

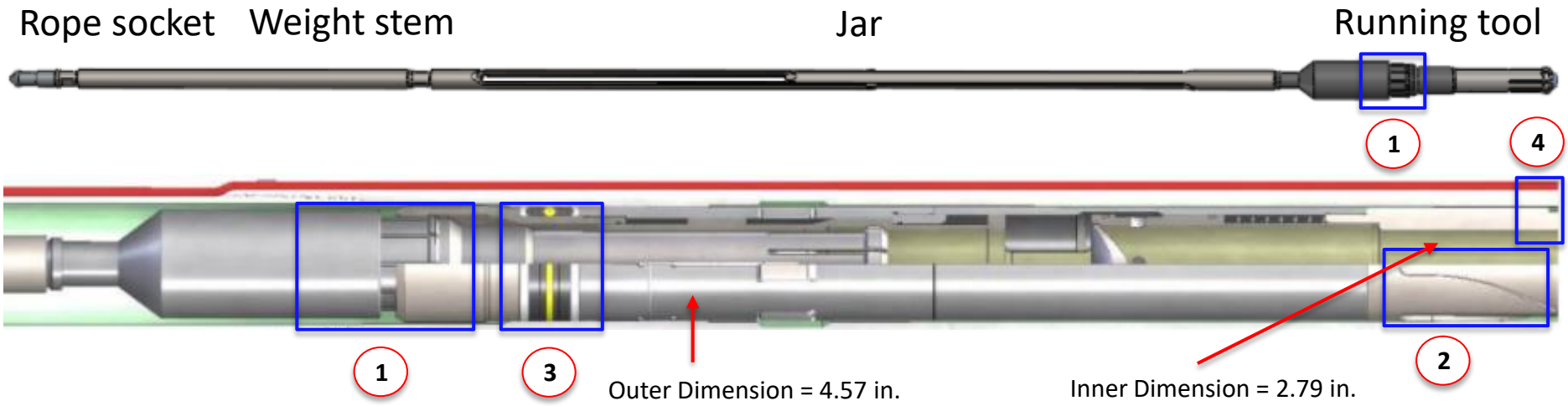
**Magnetic Drive System has both high reliability and high retrievability**

- Magnetic drive without any electrical connection in fluid flow
- Magnetic levitation, no need for any physical-contact bearings in motor
- Flow-through motor, no need for a rotary seal and protector
- Multiple flow paths keep motor cool at high-speed rotation
- High-speed rotation shortens both the motor and the pump
- Utilization of full casing size shortens motor length



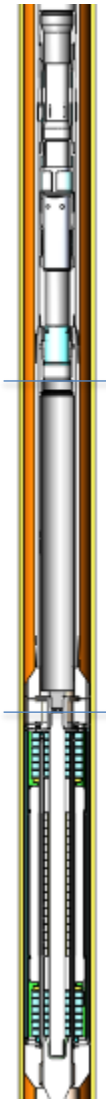

https://www.upwingenergy.com/oil for the functional video

# Deployment Intervention Mechanism (DIM)




1. Running tool locked to the top (fishing neck) of the DIM
2. Spirals on the orientation section of the DIM self-align with the ribs in the torque section of the landing sub (part of completion) to prevent rotation
3. Seals on the DIM engage with polished bore section of the land sub to prevent re-circulation
4. Orientation section of the DIM and torque section of landing sub as no-go

# MDS Layout



Deployment and Intervention Mechanism (DIM)

High-speed pump

MDS motor

## Module, Casing and Tubing Specifications

| | Length | | Weight (Retrievable String) | |
|---|---|---|---|---|
| **Module** | ft. | m. | lbs. | kg. |
| DIM | 3.75 | 1.14 | 120 | 54.43 |
| Pump | 21.5 | 6.55 | 700 | 317.51 |
| Motor | 29.25 | 8.92 | 900 | 408.23 |
| Total | 54.5 | 16.61 | 1720 | 780.18 |

Only requires 1/4 in. light weight slickline for intervention

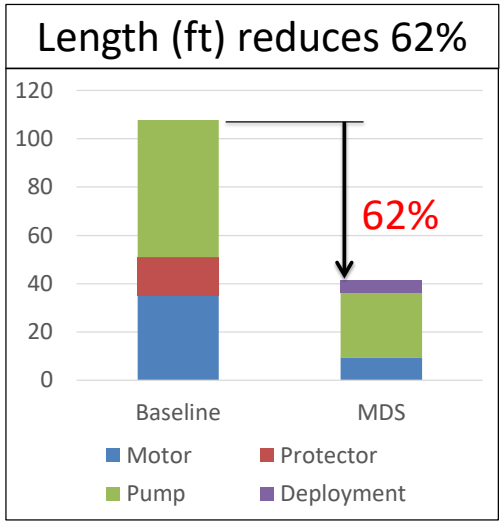
- Casing Size: 9-5/8 in. 53# Drift ID 8.379 in.
- Tubing Size: 5.5 in. 23# Drift ID 4.545 in. with collar OD 6.050 in.
- Tubing Size: 6.0 in. 26# Drift ID 5.007 in. with collar OD 6.625 in.

- Integrates existing technologies
  - Top side VSDs
  - Well head penetrators
  - Metal encapsulated power cable
  - Metal-to-metal connections
  - Existing slick line mechanisms
- All Upwing Energy SCS tool technologies for magnetic bearings and high-speed motor
- Mitsubishi Heavy Industries, Ltd. developed high-speed pump

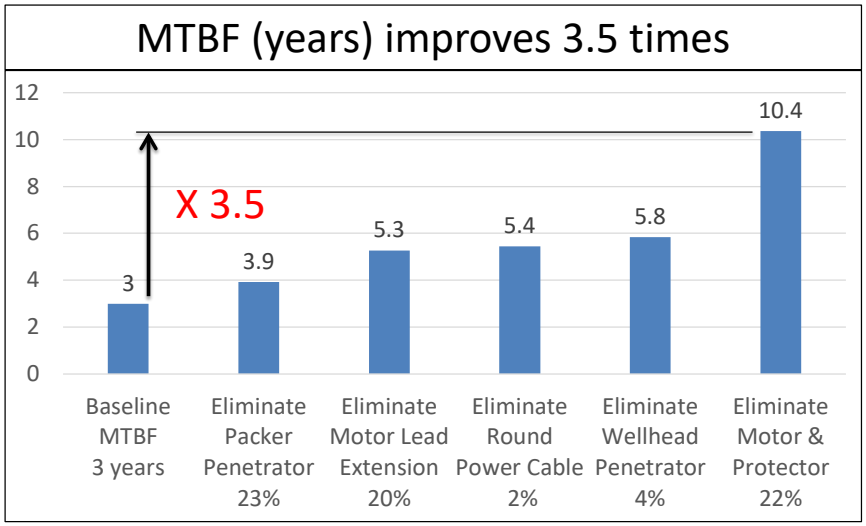
# Overall Value of MDS for Offshore

**MDS improves ESP availability by both higher reliability and retrievability**

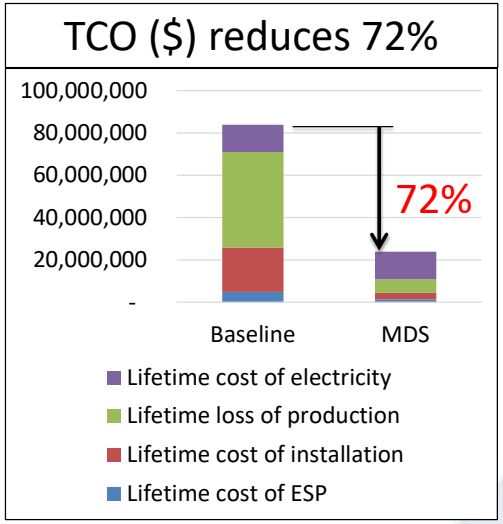
- Higher retrievability of short MDS retrievable string by slickline in a single run
- Higher reliability of MDS with longer Mean Time Between Failure (MTBF)
- Higher availability of ESP reduces Total Cost of Ownership (TCO) significantly




(For 8,000 BPD; 9-5/8" csg; 5-1/2" tbg.)



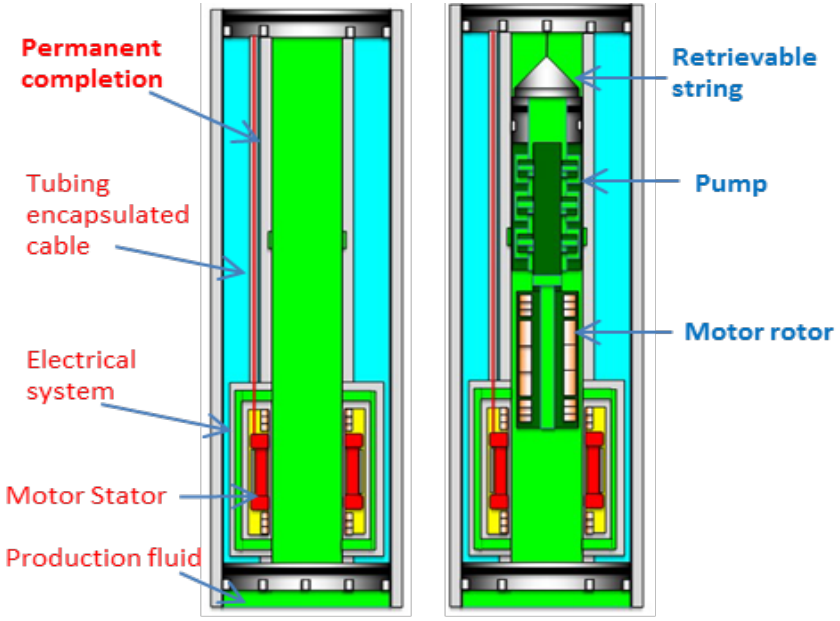

(SPE-182925-MS, SPE-184176-MS)



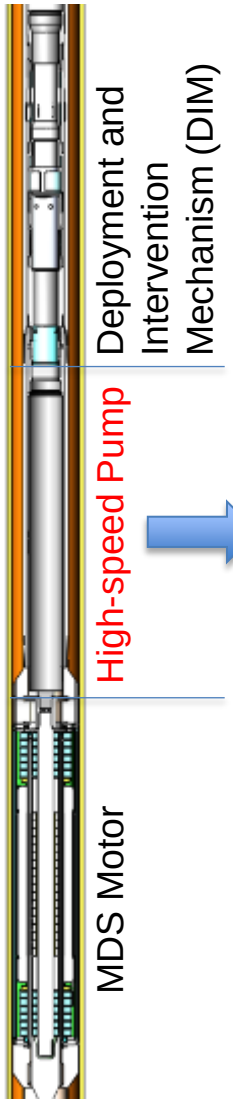

(An average offshore well for 30 years)

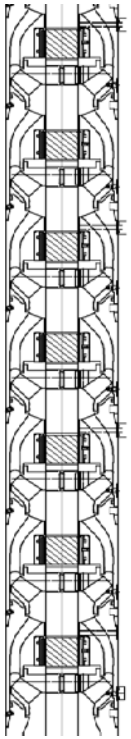
# Demonstration of Enabling Technologies

- DeepStar Committee identified three areas to be demonstrated that enable/improve the complete MDS concept:
  - Radial Passive Magnetic Bearings
  - Magnetic Vibration / Temperature Sensor
  - High-speed pump and affiliated bearings



# High-Speed Pumps

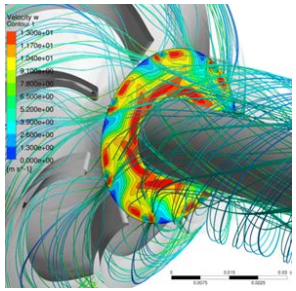


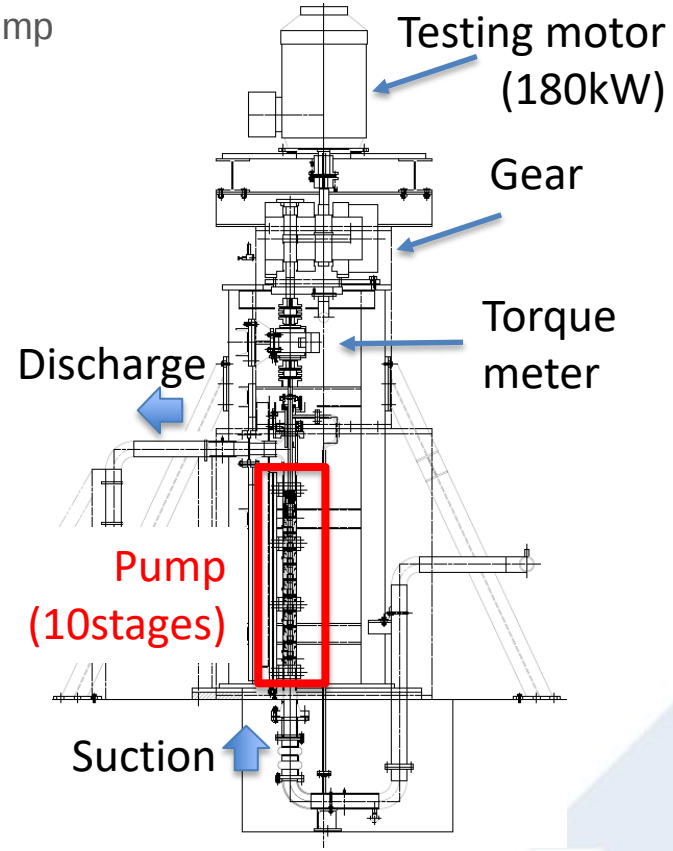
- High-speed pump by Mitsubishi Heavy Industries, Ltd. is specially designed for the MDS.
- The pump enables larger production in compact size with extra abrasion resistance.
- Rotor dynamics and hydraulic performance of the pump be validated experimentally.

| | |
|---|---|
| **Pump flow rate** | 12,000BPD |
| **Operating speed** | Up to 8,000rpm |
| **Particle** | Max 200 μm |
| **Tubing size** | 5.5” |

Pump specification

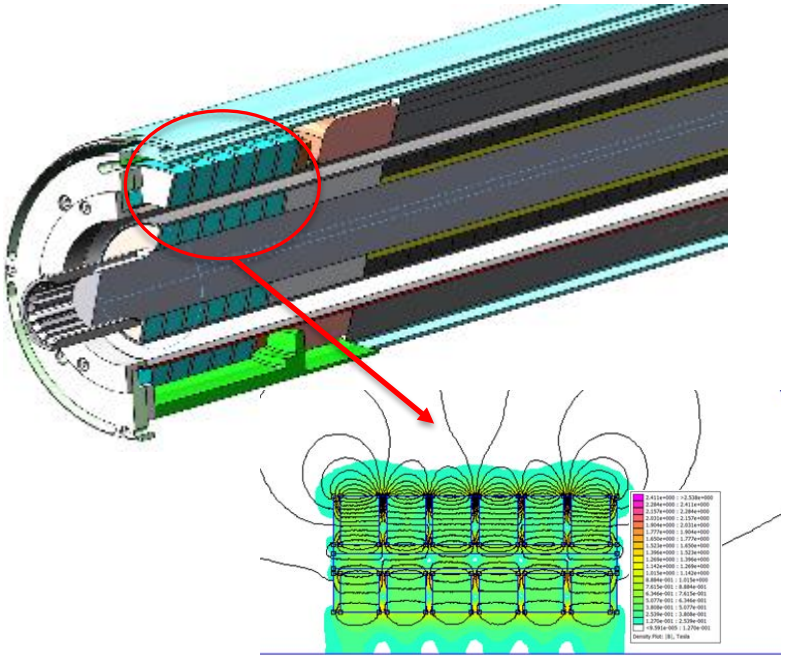


CFD with particle in fluid



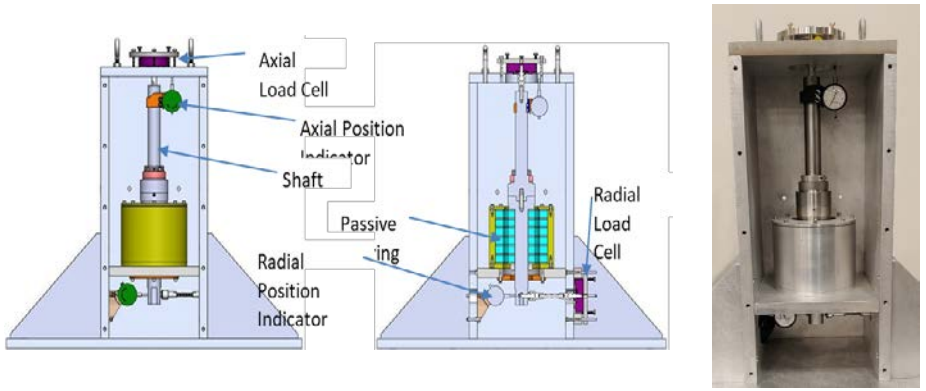

Pump testing stand (up to 8,000 rpm using gear)

# Passive Magnetic Bearings & Magnetic Sensors



- Non-contacting bearings
  - Large gap clearance between rotor and stator
  - Operates with fluid flow in gap
  - Rotor and stator are sealed in Inconel
- Does not require any controls
- Capable of operating over 300°C

- Rotor velocity sensing uses permanent magnet installed on rotor at sensor location
  - Basic concept proven in the SCS
  - Sense coils installed as part of the permanent completion
  - Large radial clearance between the stator and rotor
  - Calibrated for measuring the temperature of permanent magnet, i.e. rotor
- Targeting use in pump, motor and thrust module of MDS or conventional ESP systems




Full Scale Passive Bearing and Magnetic Sensor Test System

# Conclusion

- MDS ESP addresses reliability and retrievability simultaneously, providing 10-year life for maximum availability
- MDS electrical system is higher reliability by being hermetically sealed in the permanent completion
- MDS retrievable string contains only mechanical parts and can be deployed/retrieved by slickline in a single run (light and short)
- MDS high-speed, flow-through motor is magnetically driven and levitated without any contact or connector between the stator and the rotor, eliminating bearing life concerns
- High-speed pump for MDS is developed by Mitsubishi Heavy Industries, Ltd.
- MDS leverages proven technologies from various applications to offer a downhole technology that meets operators' needs

UpwingEnergy

Thank You!

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