Deep Submersible Motors
What’s possible

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Hayward Tyler Ltd
Group Technical Director
Ken Sears
Progressive innovation

1908 First submersible (water filled) electric motor

“Gold Medals awarded
Paris 1878
Calcutta 1884
London 1884”
Technology development...
BCP’s to Subsea

Wet Stator Glandless Motor Pump
1948… Remains industry standard!

Submersible motor SWLP, FWP

Subsea motor
The case for Subsea processing...

- Sea Water Injection
- Crude Oil Boosting
- Produced Water Re-Injection
- Multi Phase Pumping
- Separation
Benefits of subsea pumping

“Installing subsea pumps close to wellheads may increase the total recovery rate for subsea wells by up to 25% when compared with unboosted production” (Aker Solutions)
General Subsea Motor requirements...

- **High Voltage**
  - Up to 11kV
- **Variable speed**
  - Up to 4000 rpm
- **Compact**
- **High casing pressures**
  - Suitable for 3000m
- **Fully compliant to Oil Industry Standards**
  - IEC 60034
  - Norsok
  - Oil Company Standards
  - API 610
- **Ultra high reliability**
  - Proven technology
  - Conservative design
Deep Submersible motors

kW Depth (m)


0 1000 2000 3000 4000 5000 6000 7000 8000

Est. 1815
1992

- Kvaerner boosting station
- 350kW
- 500m
• EniAGIP multiphase pumping
• 2.5MW
• 1000m depth
• 120 bar int.  95 bar ext
• 9kV (operating) 11kV (specification) VSD
• 3m x 1.01m dia 12.8 tonnes
• Superduplex materials
• Subsea mud pump
• 935kW
• 2300m depth
• 6.6kV VSD
• 3m x 1.2m dia 7.15 tonnes
• Superduplex materials
2008

- Subsea water injection pump
- 2.5MW
- 3000m depth
- 6.6kV
- VSD super synchronous
- 2,500 to 4,000 rpm
- 3.3m x 1.2m dia
- 12.4 tonnes
- Superduplex materials
Tyrihans SRSWI Project

SRSWI = Subsea Raw Sea Water Injection

- Increased oil recovery
- Power supplied from Kristin Platform over 30 km away
- Variable Frequency Drive (VSD) system at Kristin
- Subsea step-down transformers adjacent to the modules
- 2 AKS LiquidBooster™ modules
  - AKS 8-stage centrifugal pump
  - Hayward Tyler 2.5 MW motor
Technical risk management

- Performance prediction
- Insulation capability
- Penetrator
- Starting conditions
- Thrust bearing life
- Coolant circulation pump
- Thermal stability
- Material compatibility
Motor functional requirements …

- Rated power (shaft output): 2500 kW
- Max current: 320 A
- Operating speed range: 2500-4000 rpm
- Rated voltage / frequency: 6.6 kV / 60 Hz
- Winding insulation level: 11 kV
- Casing internal design pressure $\Delta P$: 150 bar
- Casing external design pressure $\Delta P$: 30 bar
- Design lifetime: 20 year (minimum)
- Time between intervention: Minimum 5 year
- Maximum total thrust (standstill): 46 kN
- Min seawater temperature: +1 °C
- Max seawater temperature: +10 °C
- Max pit water temp during testing: +25 °C
Multi disciplinary engineering challenges

- Electrical analysis
- Rotor dynamics analysis
  - Electrical losses
  - Internal hydraulic losses
  - Thermal analysis
  - Cooling system analysis
  - Hydraulic Design of cooling pump
  - Shaft deflection analysis
  - Casing Stress analysis
  - Bearing analysis
  - Radial & Axial Thrust analysis
Oil vs Water/Glycol filled Technology

**Oil**
- **High viscosity**
  - High frictional losses particularly at higher speeds
- **High dielectric properties**
  - Standard industrial motor insulation
- **Higher operating temps**
  - Can lead to increased corrosion
- **Seawater ingress leads to immediate catastrophic failure**

**Water / Glycol**
- **Low viscosity**
  - Lower frictional losses
  - Higher speeds possible
- **Good dielectric properties**
  - Fully insulated cables & joints
- **Cooler operation**
  - Corrosion inhibiting
- **Seawater ingress does not cause immediate failure**
- **Water / Glycol is a commonly used control fluid**
- **Environmentally friendly**
Motor description

3.3 m

12400 kg

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Pressure Casing

Machining of Outer casing
Stator shell and windings

XLPE insulated cables and joints
“Stiff” radial bearings
Power supply:
Crossing the pressure boundary
Junction box & compensator
Coolant circulation pump

High efficiency impeller
Cooling Coils

Spiral Heat Exchanger

6 parallel circuits
Design iterations ....

Motor Efficiency

Length L

Diameter d

Unbalanced Magnetic Pull

High shaft deflections & Critical Speed problems

L/d ratio

Motor Efficiency

0 10 20 30 40 50 60 70 80 90 100

0 2 4 6 8 10 12

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Design iterations 

- Diameter $d$
- Length $L$

Pie chart distribution:
- Rotor Gap-friction 46%
- Rotor Iron 0%
- Circulation Pump & Disc 27%
- Stator Iron Electrical Stray 3%
- Stator Copper 9%
- Rotor Copper 11%
- Hydrodynamic Thrust Bearing 1%
Some of the many Qualification Tests...

- Thrust Bearing performance and endurance tests
- Penetrator Vibration Tests
- Coolant pump tests
Conclusions

- Motor Technology is now catching up with the demand for Subsea drives
- Qualified machines
- 2500 kW at speeds up to 4000 rpm a proven reality
- Designs suitable for 11kV voltage spikes
- Designs suitable for 3000m depth water
- Water/glycol filled motors provide proven reliability
- Scaleable designs valid for higher powers and speeds
Customer & Supplier partnerships

Statoil
Operator

AKS
System Integrator & Pump manufacturer

ABB
Inverter & Transformers

Hayward Tyler
Motor manufacturer

Tronic
HV Connectors

Hayward Tyler
Material Suppliers

Hayward Tyler
Material Suppliers

Hayward Tyler

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Deep Submersible motors

$kW$ vs Depth (m)

- Depths and power outputs over time from 1990 to 2020.
- Chart shows an increasing trend in both kW and depth over the years.

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Thank You

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