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Written text was not submitted for this tutorial. The slide presentation is provided here.
**What is Multiphase Flow?**

- Flow consisting of at least:
  - Liquid
  - Gas

(But often high volumes of gas, mixed with oil, water, and solids)

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**GVF for Gas-Oil-Water Mixtures**

Actual BPD of Gas = 
\[(ACFD) (7.481 \text{ gal/cu ft}) (1 \text{ bbl/42 gal}) = (ACFD) (0.178 \text{ bbl/cu ft.})\]

where

\[ACFD = [(SCFD) (14.7 \text{ psia}) (MPP Inlet Temp F+460) (Z)] / [(MPP Inlet Press psia) (520R)]\]

where Z is often 1.0

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**Multiphase Pump Criteria**

- Gas Volume (Void) Fraction [GVF] at Suction Conditions
- measured in %
- Particulate - measured in %
- Maximum Particle Size and Distribution
- Liquid Viscosity
- Temperature
- Gas Composition
- Suction Pressure
- Discharge Pressure
- Flow Rate
- Potential for Slug Flow

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**GVF for Gas-Oil-Water Mixtures**

BPD = (Actual BPD of Gas + BPD of Oil + BPD of Water)

And therefore

GVF = (Actual BPD of Gas)/(BPD)

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**Types of Multiphase Pumps**

- Need: Oil Rate in BPD
- Gas Rate in SCFD
- Water Rate in BPD
- Pump Inlet Pressure in PSIG
- Pump Discharge Pressure in PSIG
Types of Artificial Lift and Multiphase Pumps (MPPs)

- Electric Submersible Pumps (ESP’s) - Centrifugal
- Progressive Cavity Pumps (PCP’s) - Positive Displacement
- Helico-Axial Pumps - Centrifugal
- Twin Screw – Positive Displacement

Progressing Cavity Pumps (PCPs)

Electric Submersible Pumps (ESPs)

Helico-axial

MPP
7-stage helico-axial
125,000 bpd
700 hp motor w/ VFD (3600 rpm)

Progressing Cavity Pumps (PCPs)

Helico-axial Pump

MECHANICAL SEAL
BEARINGS
Helico-Axial Rotor Assembly

Hydraulic Helico-axial
- Special design of helico-axial Pump with a multistage hydraulic turbine fed by a remote high pressure pump
- Turbine and pump integrated on a common shaft in a cartridge barrel casing

Slide 16.

Slide 19.

Buffer Tank

Hydraulic Helico-axial

Slide 17.

Slide 20.

Helico-axial Subsea Pump

Slide 18.

Slide 21.
**Twin Screw - Timing Gears**

**Upstream Applications**
- Eliminate Flaring at Reduced Cost
- Reduce Backpressure at Wellhead and Increase Production at Wellhead
- Pump Gas & Liquid Mixtures up to 100% GVF (usually when designed for specific time periods)
- Reduced Installed Cost vs Traditional Systems

**MPP Drives**
- Usually Motors with VFDs, especially for positive displacement pumps (PCPs and Twin Screws)
- Engines (Natural Gas, Diesel)
- Hydraulic Turbines

**Downstream Applications**
- Flare KO Drums
- Any highly gaseous liquid stream
- Replace centrifugal pumps that have cavitation problems due to excessive gas

**General Applications**

**Advantages and Disadvantages of Different Types of MPPs**
Sample List of Chevron Applications

- Venezuela: Boscan – Surface Twin Screws 40% GVF
- Venezuela: Hamaca – Down-hole PCPs
  - Surface Twin Screws 90% GVF
- California: Midway Sunset – Surface Twin Screws 59 to 90% GVF
- California: Midway Sunset – Surface Twin Screw
  - Charge to heater treater
  - Slugs of 100% Gas

Indonesia Light Oil Steam Flood (LOSF)

- 60,000 BPD
- 250 hp motor, 4 poles
- 480V YFD
- API plan 32 seal flush
- Enlarged bearing housing
- Air-cooling for bearing lube oil cooling, with blower installed at coupling hub
- Boxed screws
- 6 chambers screws
- Stellite 12 over weld liner

Humble’s Twin Screw Pump

Indonesia - Twin Screws and Sand

- Natural sand build-up on inlet section
- No evidence of sand accumulation inside liner
- Stellite Liner: 65 HRC

Indonesia LOSF Multiphase Pumps

MPP Primary Functions:
Collect and boost 95% GVF
Steam to Eliminate Flaring

California - Midway Sunset Twin Screw
Twin Screws in Chad

Twin Screws and Particulate

Multiphase Pump Solution

Current Best Technology
- Screws nitrided or borided to depth of 0.003
- Casing coated with tungsten carbide or stellite
- Pump designed with replaceable liner

Twin Screw - Subsea Pump

Mechanical Seals
- Use correct API flush plan
- Use correct seal faces
  - Hard Particulate: hard face vs. hard face
  - Softer Particulate or none: carbon vs. tungsten or silicon carbide
**Indonesian Experience**

- Multiphase production and the installation costs of the traditional system demands simpler and smaller installation and a more cost effective production system.

- Twin Screw multiphase pumping application in heavy oil steam flood in sandy environment is proven to be feasible.

- To date, operational reliability satisfies if not exceeds acceptable industrial standard.

*Slide 52.*

**MULTIPHASE BOOSTING**

*Slide 55.*

**Sample Economics**

*Slide 53.*

**Typical Production Increases**

*Slide 56.*

**Multiphase Installation Advantages**

*Slide 54.*

**Production Increase Due to Reduced Backpressure on Wells**

*Slide 57.*
**Economics, MPP Case**

- Net Present Value (NPV) = $56.6 MM
- Discounted Profitability Index (DPI) = 1.66
- Internal Rate of Return = 36.0%
- Payback = 5.1 years

**Reasons to Use MPPs Offshore (or Onshore)**
- No need to have separation vessel
- One MPP vs. liquid pump and gas compressor
- Smaller installed footprint (especially for offshore rigs)
- Less weight (especially for offshore rigs)
- One COMBINED liquid/gas line (especially for offshore rigs and Subsea installations)

**Duri Production Increases with MPPs**

**Escravos 3B Project: MPP Process**
- The Team narrowed MPP down to four platforms for investigation...Malu, Opolo, Ewan & Isan
- Sought technical support from Chevron ETC. other SBUs experiences
- Preliminary GVF ranged from Opolo (81%) to Isan (97.2%). Opolo and Malu (95%) were considered positive based on CVX field experience.
- Received technical proposals from Bornemann and Leistritz
- Revised Gas forecast...May 2004 gives GVF above 98%

**Offshore Economics Example**

- Opolo - Potential capex savings would be about $6MM.
Subsea Developments

Summary
- MPPs have been used to:
  - Eliminate Flaring at Reduced Cost
  - Reduce Backpressure at Wellhead
  - Increase Production
  - Pump with Low Shear & Decreased Emulsion Formation
  - Pump with Low NPSHA
  - Reduce Installed Cost and Maintenance Costs vs Traditional Systems

Multi-phase Pumps: Subsea Efforts
- Twin Screw
- Helico-axial
- Hydraulic Turbine Helico-axial

The End

Summary
- MPPs have been used to pump multi-phase fluids that have:
  - Temperatures from ambient to 300°F
  - Suction pressures from 6 psig
  - Discharge pressures to 2000 psig
  - GVF’s to 100% (for designed time periods)
  - Particulate concentrations to 0.5%
  - Almost any viscosity