

MULTIPHASE PUMPING

by

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Mr. Heyl has a B.S. degree (Engineering Science) from Hofstra University and attended Columbia University. He is a Steering Committee member of the API Subcommittee on Mechanical Equipment, and is Chairman of API 674, API 675, and API 676 Task Forces. He has participated on API 682, API 614, and API 682.

Written text was not submitted for this tutorial. The slide presentation is provided here.

Presentation Contents

- Definitions and Criteria: Multiphase Flow, Gas Volume (Void) Fraction (GVF) and Criteria
- Types of Artificial Lift and Multiphase Pumps
- General Applications
- Advantages and Disadvantages of Different Types of Artificial Lift and MPPs
- Specific Applications
- Sample Economics
- Reasons to Use Offshore
- Subsea Developments

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Multiphase Pumping

By: Bob Heyl

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Definitions and Criteria

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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 gal/cu ft)(1 bbl/42 gal) = (ACFD)
 (0.178 bbl/cu ft.)

where

ACFD = [(SCFD) (14.7 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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GVF for Gas-Oil-Water Mixtures

Need: Oil Rate in BPD
 Gas Rate in SCFD
 Water Rate in BPD
 Pump Inlet Pressure in PSIG
 Pump Discharge Pressure in PSIG

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Types of Multiphase Pumps

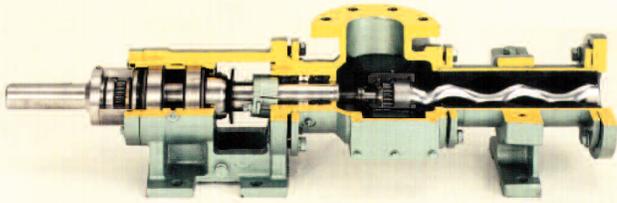
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Types of Artificial Lift and Multiphase Pumps (MPPs)

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

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Progressing Cavity Pumps (PCPs)



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Electric Submersible Pumps (ESPs)



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Helico-axial



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

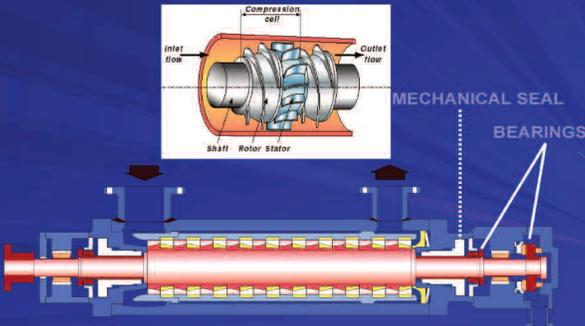
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Progressing Cavity Pumps (PCPs)



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Helico-axial Pump



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Helico-Axial Rotor Assembly



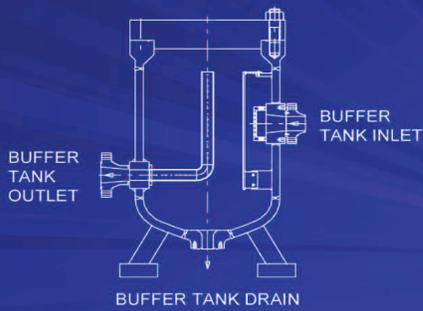
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Hydraulic Helico-axial

- 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

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Buffer Tank



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Hydraulic Helico-axial



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Helico-axial Subsea Pump



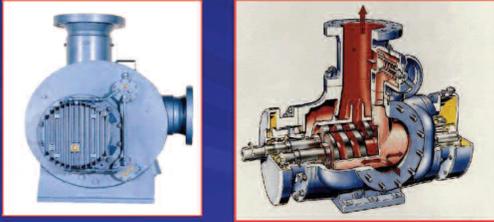
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Helico-axial Subsea Pump



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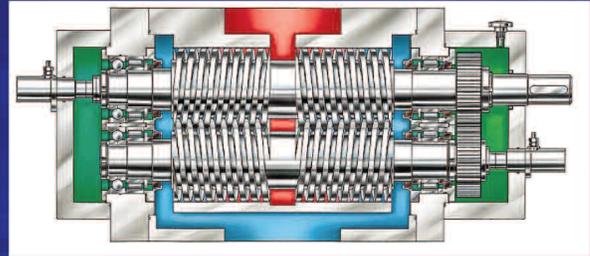
Twin Screw



500 HP
125,000 BPD@1925 RPM
VFD to 2300 RPM

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Twin Screw – Screws in Pump Case



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Twin Screw - Screws



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Twin Screw – Screws in Pump Case



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Twin Screw - Screws



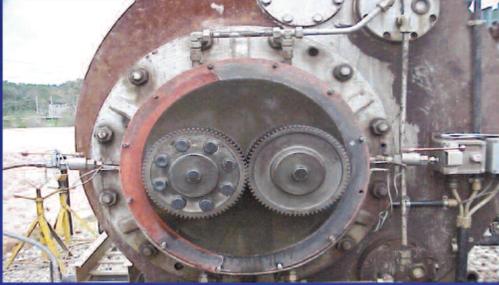
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Twin Screw - Liner in Pump Case



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Twin Screw - Timing Gears



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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

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MPP Drives

Usually Motors with VFDs, especially for positive Displacement Pumps (PCPs and Twin Screws)

Engines (Natural Gas, Diesel)

Hydraulic Turbines

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Downstream Applications

- Flare KO Drums
- Any Highly Gaseous Liquid Stream
- Replace Centrifugal Pumps that Have Cavitation Problems Due to Excessive Gas

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General Applications

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Advantages and Disadvantages of Different Types of MPPs

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ESPs

GENERAL CHARACTERISTICS OF MULTIPHASE PUMPS		
ESPs		
PUMP	ADVANTAGES	DISADVANTAGES
Centrifugal Electric Submersible Pumps (ESPs)	Traditionally down-hole and submersible, but can be used on the surface	If solids, potential erosion
Primarily Upstream Applications	Good for low viscosity liquids	Low gas handling, cavitation
	High speed, high rates	Can't handle high viscosities
	Low cost	No higher than 40% (60%) GVF
	Can handle high temperatures	
	Gas conditioners to 40% (60%) GVF	

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Twin Screws

GENERAL CHARACTERISTICS OF MULTIPHASE PUMPS		
Twin Screws		
PUMP	ADVANTAGES	DISADVANTAGES
Twin Screw PD	Surface, down-hole (in commercialization by one supplier), or submersible (in commercialization)	Surface Pump with 4 mechanical seals
Upstream or Downstream	Low to high speed, rates to 300,000 BPD (surface pumps)	
	Can achieve up to 100% GVF for designed time periods	
	Can run high viscosities	
	Can run high temperatures	
	Low shear	
	Low NPSHr	
	Can run dry, non-contacting rotor and stator	
	1400 psig differentials	
	Particulates to 0.5%	

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PCPs

GENERAL CHARACTERISTICS OF MULTIPHASE PUMPS		
PCPs		
PUMP	ADVANTAGES	DISADVANTAGES
Progressing Cavity PD (PCPs)	Down-hole, submersible or surface	Elastomer problems above 300 F
Upstream or Downstream Applications	Lower speeds, lower volumes	Contacting rotor and stator
	Handles some solids	Can't run dry
	1000 PSI differentials	
	Can run high viscosities	
	Relatively Low shear	

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Specific Applications by Chevron

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Helico-axials

GENERAL CHARACTERISTICS OF MULTIPHASE PUMPS		
Helico-axials		
PUMP	ADVANTAGES	DISADVANTAGES
Centrifugal Helico-axial	Down-hole, surface, or submersible	If solids, potential for erosion
Upstream or Downstream	High speed, High rates	High shear
	Up to 550,000 BPD	
	Up to 1300 psi differential	
	Can achieve up to 100% GVF	

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- ### Sample List of Chevron Applications
- Texas: Humble – Surface Twin Screw
 - Indonesia: Minas and Duri – Surface Twin Screw 30 to 100% GVF
 - Chad: Various Fields – Surface Twin Screws 38% to 56% GVF
 - Great Britain: Captain – Hydraulic Drive Helico-axial

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Sample List of Chevron Applications

- Venezuela: Boscan – Surface Twin Screws
40% GVF
- Venezuela: Hamaca – Down-hole PCPs
- Surface Twin Screws
92% 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

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Indonesia Light Oil Steam Flood (LOSF)



- 60,000 BPD
- 250 hp motor, 4 poles
- 460V VFD
- API plan 32 seal flush
- Enlarged bearing housing
- Air-cooling for bearing lube oil cooling; with blower installed at coupling hub
- Borided screws
- 6 chambers screws
- Stellite 12 over weld liner

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Humble's Twin Screw Pump



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Indonesia - Twin Screws and Sand



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

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Indonesia LOSF Multiphase Pumps



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

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California - Midway Sunset Twin Screw



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Twin Screws in Chad



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Twin Screws and Particulate

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Multiphase Pump Solution



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Current Best Technology

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

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Twin Screw - Subsea Pump



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Mechanical Seals

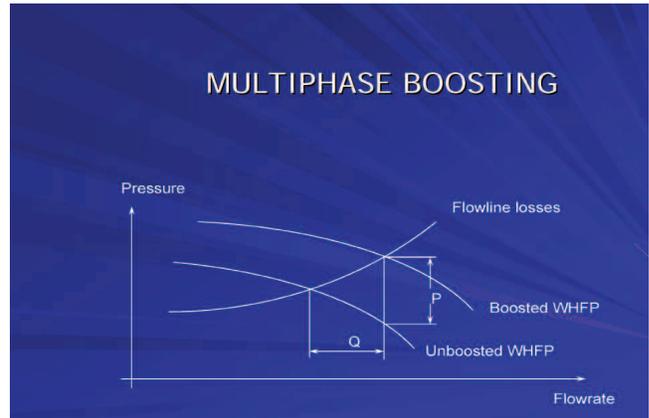
- Use correct API flush plan
- Use correct seal faces
 - Hard Particulate: hard face vs. hard face
 - Softer Particulate or none: carbon vs. tungsten or silicon carbide

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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.

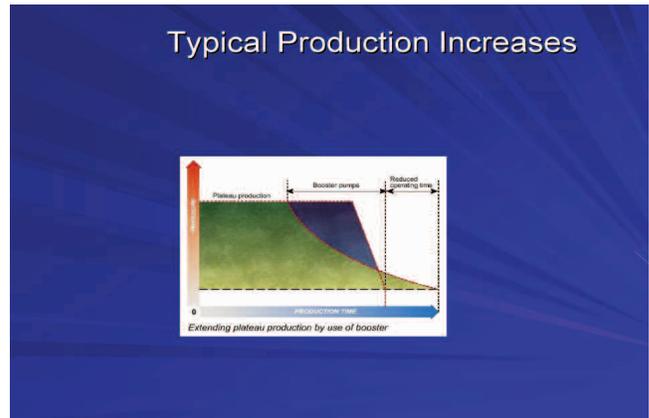
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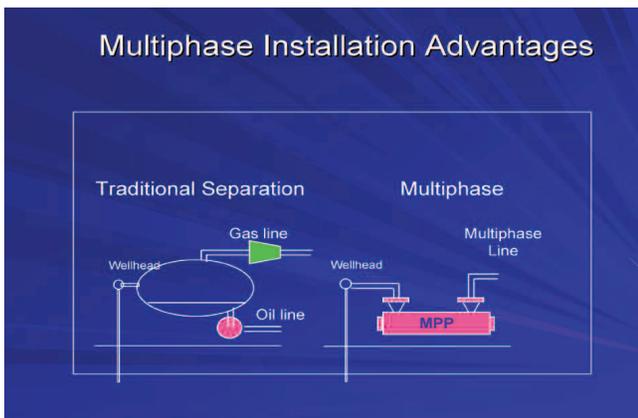
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Sample Economics

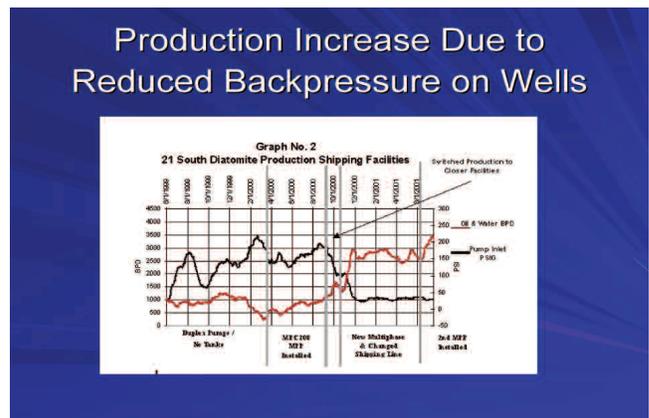
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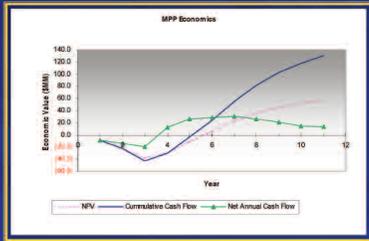


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Economics, MPP Case



Net Present Value (NPV) = \$56.5 MM
 Discounted Profitability Index (DPI) = 1.66
 Internal Rate of Return = 36.0%
 Payback = 5.1 years

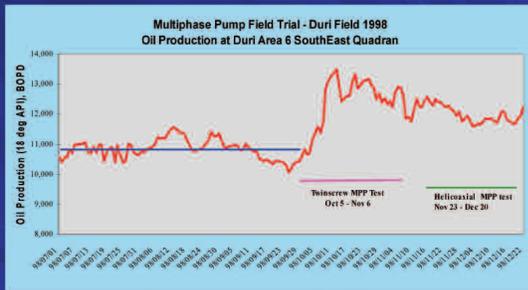
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Reasons to Use MPPs Offshore (or Onshore)

- 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)

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Duri Production Increases with MPPs



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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 SBU 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%

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Offshore Economics Example

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Escravos Economics

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

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Subsea Developments

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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

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Multiphase Pumps: Subsea Efforts

- Twin Screw
- Helico-axial
- Hydraulic Turbine Helico-axial

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The End

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Summary

- MPPs have been used to pump multiphase fluids that have:
 - Temperatures from ambient to 300F
 - 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

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