Finding Petroleum
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Technologies Addressing
The Challenges Today and Tomorrow

Tony J. A. Laing - Regional Manager
tonylaing@framoeng.co.uk
Content

• Introduction

• Market drivers

• Technology Systems that are available

• Life of Field solutions

• Conclusions
Rising to the process challenge – “the ability to manage and enhance recovery”

- Aquifer Support
- Flow Regime
- Hydrate Formation
- Wax Formation
- Scale formation
- Asphaltine formation
- Pressure (15,000 psi)
- Temperature (200 deg C)
Subsea Enhanced Recovery - ‘Framo Systems’ “the ability to manage and enhance recovery”

Water Injection

Multiphase Boosting

Multi-Compressor (Wet Gas) - (handling ‘true’ wet gas)

Separation

Multiphase / Wet Gas Metering

MultiManifold – compact cluster (50% lighter in weight & size)
Global Subsea Capex
*Forecast spending 2011-2016e $73.5bn*

- **US$33.6bn**
- **118% Increase**
- Growth in future driven by Brazil, Africa and Asia.

**Startup Year**
- Africa/Medit.
- Asia Pacific/Middle East
- North Sea
- North America
- South America
Where Do We Find More? | Further, Deeper & Harsher Fields 2000’s

Legend
- 2000's Gas Fields
- 2000's Oil Fields
Company Overview – founded in 1983, owned today by Schlumberger (June 2011)

Main Office
- Located in Bergen
- Project Management, Engineering, & Procurement
- All engineering and technology in-house

Horsøy
- Located just outside Bergen
- New Assembly and Test facility
- 20,000 m²
- Wet test dock

International Locations
- Regional offices in Americas, UK & Asia
- Bases in West Africa, Brazil & Australia
- Plus Schlumberger network (over 80 countries)
Advanced test facilities
Horsøy, 2011 – the future ’today’

Increase Capacity
Enhance Lead Time
Maintain and Improve Quality
Increase Scope and Functionality Offering
Secure our Position as a World Leading System Supplier

- 2 subsea test docks
- Live hydrocarbon test loop
Total System Solution – Flexibility to Field Developments

Pumps Systems
Process Manifolds
Umbilical Systems
Subsea Power & Controls
Swivels and Marine Systems
Multiphase / Wet Gas meters
Intervention tooling
Conditioning Monitoring
Total System Solutions – Subsea to Floater

- Pumps & Subsea Process Systems
- Multiphase Meters & Measurement Systems
- Swivels & Marine Systems
Without costly operational challenges

- not producing while testing
- measuring by difference (re-starting shut-in wells)
PhaseWatcher Vx – ‘Experience ‘counts’

Meter for all process regimes

• The only single meter that can measure 0 to 100% gas.
• Measurement is not effected by emulsions or slugging

Experience

• Over 10 years in Operation (Vx established 1999)
• 1600 meter delivered in Dec 2011

Subsea package ‘HP and HT qualified’

• 205 degrees C (400 F)
• 15K psi (qualified to industry standards – API6A and DNV 203)
Vx Production Optimisation at Marathon West Brae

SPE 124271 Paper; Offshore Europe 2009 – Mike Tharagonnet

17% increase
Cross border measurement and management

PhaseWatcher Vx, the Multiphase and Wet Gas Fiscal “Cash Register” for the North Sea

- **Accuracy**, the main evaluation criteria
- **Marathon Boa Field** – First World wide Multiphase “Cross Boarder” Fiscal Allocation application between UK and Norway, in operation since 2008
- **Dong Trym Field** - First World Wide Wet Gas “Cross Boarder” Fiscal Allocation application between Denmark and Norway, in operation since 2011
Knowing Your Reservoir - Subsea Sampling System and Services

• Representative sample of oil, water and gas
• True PVT quality sampling system
• Compact design for easy integration into the subsea hardware
• Integrated into the Phase Watcher Vx Multiphase Meter
• Field proven components and technology
• In-country Fluids Sampling and Analysis Services throughout the life of the field

Look deeper into your reservoir
Swivels & Marine Systems

- Offshore Cryogenic Transfer
- Swivels and Turret Systems
- Submerged Loading

Framo Offshore Cryogenic Transfer
Framo Swivels and Turret Systems
Framo Submerged Loading
Fluid Transfer - Subsea Wells and FPSO – Swivels - The Heart of the FPSO

UNPROCESSED WELL FLUID FROM WELLS

OFFTAKE

PROCESSING

Fluid Transfer System (Swivel’s)

TO G.I. WELLS

TO W.I. WELLS

FPSO
Reference Projects (by offshore Field name) - 2011
Benefits of Subsea Boosting

### Increased Production and Recovery
- Accelerated and prolonged plateau production
- Increased Recovery

### Production Enabling
- Well kick-off
- Extended reach of remote fields and wells

### Flexibility wrt Subsea Integration
- Applicable for Green-fields as well as retrofit to Brown-fields
- De-bottlenecking in mature fields
- Deepwater applications

### Commercially attractive solutions
- Relative short payback time
- Maintenance by ROV and light intervention vessel
IOR effect of Subsea Boosting

The well will flow at lower pressure

- Weak wells can be produced together with strong wells
- Weak wells can be produced for a longer period before dying
- Weak/dead wells can be started with the pumps
- More efficiently reservoir drainage when wells can flow at higher rate
- More controlled drainage

The liquid production rate will be higher

- Fields can be produced longer before critical low flow is present (slugging and cool-down problems)
- Economical cut-off will be at a higher water-cut
The ambition of the subsea improved oil recovery (SIOR) project in Statoil is to achieve an average recovery factor of 55% from subsea-completed fields.

New technology will be applied to raise the average recovery factor for mature fields while contributing to smart solutions for new projects.

The project cover areas such as:
- Reservoir management
- Cost-effective drainage points
- Light well intervention
- Increased subsea handling of liquids – Subsea Processing
- Reduced subsea wellhead pressure – Subsea Boosting
- Integrated operations
“Everyone involved with the trend agrees that increasing the Lower Tertiary Recovery Factors (RF) is the key to maximizing return. Chevron studies have revealed the following:

With Natural Flow: RF = 1

Production enhancement with seafloor pumps: RF = 1.4 for single phase and 1.6 for multi phase.”
Framo Engineering – ’Experience counts’

GOM
- Jack St Malo

Houston, Texas

Aberdeen, UK

North Sea (typ)
- Tordis
- Gulfaks C
- Columba E
- Brenda
- Liverpool Bay
- Troll Pilot
- Lyell

Bergen, Norway

Southern Europe
- Montanazo / Lubina

Africa
- Clov
- Pazflor
- Azurite
- Ceiba
- Zafiro

Luanda, Angola

Rio de Janeiro, Brazil

Brazilian
- Marlim
- Barracuda
- Albacora

Kuala Lumpur, Malaysia

Austra / Asia
- Lufeng
- Vincent
- Exeter / Mutineer

Karratha, Australia

26 booster pump systems delivered and over 1,600,000 Operating Hours (2011)
Flowing wellhead pressure vs system resistance

- Multiphase pump discharge pressure
- Natural production
- System resistance
- Increased production
Right Technology – to suit the process regime

Designed for handling gas, different flow regimes, viscous fluids, sand and other solids.

Dynamic pump principle
Converts kinetic energy to multiphase head

$$\Delta P = C \cdot \rho_H \cdot \text{Speed}^2$$

Established since the 1980’s
Commitment to a vision

Pioneer within Subsea Boosting!

Track record second to none with more than 1 million operating hours.

1983
Framo Engineering established to develop products for the next decades

1984/5
Screening boosting technologies
First prototypes tested

1987
Selected the Helico-Axial pump principle

1994
Developed the electrical power and control system for subsea pumps

1997
First commercial subsea multiphase pump installed at Lufeng field
Subsea boosting by Framo – Total flexibility

- SPP
- GOM
- HYBRID
- HIGH BOOST
- West Africa
- North Sea
- MPP
- WGC
Modular approach - Seabed Pump Systems
Pump Selection Process

FRAMO

Technology Status
Pump Capabilities
(power, dp, speed etc.)

Pump Selection
• # Pumps
• Multiphase / single phase
• Power / speed / dP / stages etc.
• Recycling, valving etc.

PFD
Power system
Control
Cost

Lift Table
GAP model

OPERATOR

Hydraulic Model of System (steady state)

• Production forecast (rates, wc, gor) per well
  • Reservoir pressure vs. time
  • PI vs time (per well)
• Limitations (oil, water, gas, power, pressure etc.)

Reservoir Simulation

Economical Evaluation
Configurations for the Field Development

- **Parallel Boosting**
- **Separate Line Boosting**
- **Parallel & Serial Boosting**
- **Serial Boosting**
North Sea – Case Study Gas Lifting and Boosting

- 8 WELLS
- 150m – 2200m
- 5 km / 2 x 6"
- 15 km / 2 x 10"
- POWER
Gas volume fraction through system for gas lifted well

Ideal
• High GVF in tubing
• Low GVF in pipeline
• Minimum usage of Gas lift
Lift Alternatives (typical North Sea)
Life of Field Management

FRamo Interactive ENabling Diagnostics

• Increased equipment uptime
• Cost effective remote monitoring
• 24/7 specialized support
From Concept / FEED to Production Optimisation
Conclusions -

- There are many technologies; rising to the challenges (proven and being used)

- Complex process fluids drive technologies

- Complex / sophisticated infrastructure drive technologies

- Environments create new demands and requirements

- Life of Field solutions

- Improving business environment (value / cost / flexibility)
Operational Experience
First commercial subsea electrical pumps
Production Enabler
42 mill barrels of oil pumped

91700 operation hrs of Pump BP009 prior to shut down on 2009, total 430000 hrs accumulated
Framo Subsea Booster Pumps  
CNR’s Columba E Field – UK

First ever subsea seawater injection pumps:  
• Treated Seawater via Framo Filtration System

- 2 x 2400 kW WIP’s
- 2 pumps in series
- 430 bar diff press
- 140 m water depth
- 10 km tie-back

Combined Framo Control System for Pump Module, Manifold & Trees

SPE 109090 Paper; Offshore Europe 2007 – Neil Rogerson
Framo Subsea Booster Pumps
Premier Oil (Oilexco) Brenda Field – North Sea

Improved Reservoir Management
Increased Production
Increased Flexibility
Increased Control Capacity

Framo Production & Boosting System
OTC – 17899 Paper; OTC 2006 - Mike Coulthard

• 1100 kW MPP
• 150 m water depth
• 10 / 20 km tie-back
• Main Pump has been in operation more than 50,000 hours since 2000
• 1 pump covers today's required flow rates
• Lifetime expectancy of up to 5 years (ref EM, Oct 2010)
Framo Subsea Booster Pumps
Amerada Hess’ Ceiba FFD – Equatorial Guinea

Characteristics:
- Deep Water
- Medium tie-back
- Shallow reservoir
- No gas cap
- Medium GOR
- + 45000 hrs ops

Water depth 750 to 900 m
Perf. depth ~ 5700 ft
Hydrostatic pressure 3500 psia
Tie-Back 7 to 11 km
Framo Subsea Booster Pumps
Woodside Vincent development - Australia

- Pumps installed & run May 2008
- Significant production increase reported
- FRIEND System connected

Example of Pump system supplied as EPC Independent of production system contract
Framo Subsea Booster Pumps
Murphy Oil Azurite Project – Congo

- Pump station installed mid 2009
- 1400 m WD
- Start-up late 2010
- FRIEND connected
• FSS boosting one well
• Water Depth: 1040 m
• Tieback: 15.5 km
• Total flow: ~150 Am3/h
• DP: 60-80 bar (High Boost)
THANK YOU

CONFIDENCE THROUGH EXPERIENCE

Framo Dual Pump Station

Framo MultiManifold

Framo Raw Seawater Injection System

Framo Multiphase Pumps

Framo Wet Gas Compressor

Framo Multiport Selector Manifold

Framo Subsea Multiphase Flow Meter

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