Subsea Processing – Ready for the Mainstream?

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SubseaUK Europe & Africa Focus 2013, London
· Introduction & Scene-setting
· What’s meant by “Subsea Processing” technologies?
· Why apply Subsea Processing technologies?
· Where does it typically add most value?
· Technology status & application Overview
· Is it ready for the mainstream?
· Are we asking the right questions?
· Conclusions
INTECSEA

Hull and Moorings for TLPs, Spars and Semisubmersibles

WorleyParsons

Topsides, Jackets and overall PM services

INTECSEA:

Marine Pipelines, Risers, Subsea, Flow Assurance and FPSOs in Deep Waters with integrated reservoir/production system modelling
The term “Subsea Processing”?

Adding energy to wellstream fluids subsea, eg:

- Pumping – liquids & multiphase
- Compression – dry gas & multiphase
- Separation – 2-phase & 3-phase + sand
- Local Produced Water & Seawater Injection
- Electrically Heated Flowlines
- Plus associated Electrical Power Systems

INTECSEA uses the collective term

“SAPT”

“Subsea Active Production Technologies”
INTECSEA’s annual Offshore Mag Poster published every March
Drivers for **Subsea** Processing

- **Separation**
  - Minimize topside water handling requirements
  - Separate liquid & gas streams, remove water from wellstream
  - *Increase well and field overall recovery*
  - Decrease pressure/flow boosting power requirements

- **Pumping**
  - Increase & accelerate production by lowering flowing WH pressure
  - *Increase overall recovery by reducing abandonment pressure*
  - Enable recovery from lower pressure reservoirs
  - Reduce effects of hydrostatic head in deep-water
  - Enhanced transportation of separated liquids

- **Compression**
  - *Increase recovery & enable longer subsea gas tiebacks*
  - Eliminate need for surface structures in difficult environments

- **Water Injection**
  - Reduce weight, space & power loading on host facility

- **Electrically Heated Flowlines**
  - Manage production chemistry issues
Boosting Potential

Flowing wellhead pressure (Pwh)

Natural Production

Increased production

System resistance

Multiphase pump discharge pressure

Boosted Production

MPP diff. pressure

Pressure

Production Rate

Courtesy Offshore Magazine, BHP and contributors to Annual March Poster
Brown Field Subsea Boosting
Later Life Boosting - Constrained

Plateau (Peak Production)

Facility Limitation

Boosted Production & Additional Recovery

Reduced LOF & OPEX

Boosting Time

Conventional Production Time

Time (Years)

Production Rate (MBOPD)

Courtesy Offshore Magazine, BHP and contributors to annual March Poster
Green Field Subsea Boosting
Life of Field (LOF) Boosting - Unconstrained

- Boosted Production
- Conventional Production

Production Rate (MBOPD)

Boosting Time

Conventional Production Time

Time (Years)

Reduced LOF & OPEX

Courtesy Offshore Magazine, BHP and contributors to annual March Poster
Managing Total System Complexity

- Full life-of-field system modelling from reservoir to host at the field development stage is vital
  - Enabled by the new generation of analysis tools (MAXIMUS™) for accurate and rapid evaluation of various subsea processing options
Industry Response to the Compelling Drivers

Regrettable under-investment for several decades (ca 1970 – 2000)

- Impressive pockets of technology development by Vendors
- Isolated forays into offshore piloting by a few Operators
- Relatively little visionary leadership, technology investment, challenge or practical encouragement pre-2000

Zakum Pilot 1972

Kvaerner Booster Station 1993
Seabed processing piloting history

- **ZAKUM** (1969 - 1972) operational pilot
- **Exxon SPS** (1969 - 1974) operational pilot
- **BOET** (1986 - 1989) operational pilot
- **VASPS** (2000) operational pilot
- **Kvaerner Booster Station** (Mid 90’s prototype tested)
- **GASP** (1986 - 1990 prototype tested)
- **AESOP** (1999 - 2000) prototype tested
- **SUBSIS** (2000 - operational pilot)
Brent Crude Spot Price – Market driven

Europe Brent Spot Price FOB

Dollars per Barrel

- Intecsea
- Worley Parsons Group
- Thomson Reuters
The New Subsea Era finally dawns – 30 years on

- **Norway provides vision, challenge and orchestration**
  - DEMO 2000 open R&D initiative for Vendors and Operators
  - Norsk Hydro and Statoil commit to serious offshore pilot projects
  - Vendors provide the vision and resources to evolve the technology

- **Petrobras also provides leadership and challenge**
  - PROCAP 3000 R&D initiative, in partnership with Vendors

- **Deepwater fields start to dominate the near-term prospects**
  - Conventional (passive) subsea technologies no longer adequate
  - Heavy oil reservoirs compound the problem

Then suddenly:
Several Operators finally realize they can’t actually develop some deepwater discoveries without applying enabling subsea processing technology!
Low take-up but broad global spread

WORLDWIDE LOCATIONS FOR SUBSEA PUMPING, COMPRESSION, AND SEPARATION SYSTEMS (As of Feb., 2013)

- Barents Sea
  - Shtokman (Compression)
  - Snohvit (Compression)
- Norwegian Sea
  - Tordis (Separation, Boosting, WI)
  - Troll C. Pilot (Separation, WI)
  - Tyrihans (WI)
  - Draugen (Boosting)
  - Draugen - Expansion (Boosting)
  - Aasgard (Compression)
  - Gullfaks (Compression)
  - DEMO 2000 (Compression)
  - Ormen Lange (Compression)
  - Troll (Compression)
- West of Shetlands
  - Schiehallion (Boosting)
- North Sea
  - Columba E. (WI)
  - Brenda & Nicol (Boosting)
  - Machar/ETAP (Boosting)
  - Lyell (Boosting)
- Mediterranean
  - Montanazo & Lubina (Boosting)
  - Prezioso (Boosting)
- South China Sea
  - Lufeng (Boosting)
- GOM
  - Perdido (Separation, Boosting)
  - Navajo (Boosting)
  - King (Boosting)
  - Cascade & Chinook (Boosting)
  - Jack and St. Malo (Boosting)
  - Julia (Boosting)
- Equatorial Guinea
  - Topacio (Boosting)
  - Ceiba FFD (Boosting)
  - Ceiba 3 & 4 (Boosting)
- Congo
  - Azurite (Boosting)
  - Phase 1 BIS (Boosting)
- Espirito Santo Basin
  - Jubarte - Phase 2 (Boosting)
  - Golfinho (Boosting)
  - Jubarte - Phase 1 (Boosting)
  - Jubarte EWT (Boosting)
  - Canapu (Separation)
  - Atlanta (Boosting)
- Campos Basin
  - BC-10 - Phase 1 (Separation, Boosting)
  - Espadarte (Boosting)
  - Barracuda (Boosting)
  - Marimba (Separation, Boosting)
  - Marlim SSAO - Pilot (Separation)
  - Alborada L’Este (WI)
  - Marlim (Boosting)
  - Congro (Separation, Boosting)
  - Corvina (Separation, Boosting)
  - BC-10 - Phase 2 (Separation, Boosting)
  - Malhado (Separation, Boosting)

Legend:
- Conceptual Project
- Qualified/Testing
- Awarded and in Manufacturing or Delivered
- Installed & Currently Operating
- Installed & Not Currently Operating or Inactive
- Abandoned, Removed
### Subsea Boosting

<table>
<thead>
<tr>
<th>Project Details</th>
<th>Installation Type</th>
<th>Description</th>
<th>Operator 1</th>
<th>Location 1</th>
<th>Operator 2</th>
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<td>MPP at Base of Platform</td>
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<td>Macker Field (ETAP Project)</td>
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<td>Navajo (17)</td>
<td>ESP in Flowline Riser</td>
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<td>King (7) (13)</td>
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<td>GOM, MC Blocks</td>
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<td>Shell</td>
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1995 - 2013

EcoNomics
## Subsea Separation

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<td>Marimba Field (24)</td>
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<td>Tordis</td>
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<td>Pazflor</td>
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- **Troll Pilot – 2000**
- Courtesy of Statoil/ GE
Subsea Water Injection Applications

<table>
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<tr>
<th>Subsea Water Injection Applications</th>
<th>Tordis 2007</th>
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<tr>
<td>Troll C Pilot (15)</td>
<td>See OTC paper 20619, page 16</td>
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<tr>
<td>Columba E.</td>
<td>Awaiting installation, Frame ex-works Sept 09</td>
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<td>Tordis (WI) (12)</td>
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<td>Albacora L’Este Field</td>
<td>Installed in May 2010</td>
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<tr>
<td>Tyrhans</td>
<td>Installed in May 2010</td>
</tr>
</tbody>
</table>

Courtesy of Statoil/FMC
Europe & Africa Application Status

Seabed Pumping:
- Topacio, ExxonMobil, Eq Guinea
- Ceiba, Hess, Eq Guinea
- Azurite, Murphy, Congo
- Draugen, Shell, Norway
- Brenda/Nicol, Premier, UKNS

Subsea Separation/ Pumping:
- Troll-C, NorskHydro, Norway
- Tordis, Statoil, Norway
- Pazflor, TOTAL, Angola
Why are active subsea technologies not yet the norm?

- Lack of awareness of value available?
  - Specialist consultancy advice readily available
- Perception of reliability problems?
  - Hang-over from previous era. No longer a reality.
- Fearful of complexity?
  - Has typically been readily managed for decades already
- Lacking the staff with experience or expertise?
  - Short-term supplementary experienced resources are accessible
- Insufficient interest in maximising value of deepwater discoveries?
  - “Achieving economic thresholds is sufficient – no need for more”
None of these are valid reasons to avoid evaluation
- Systematically remove barriers to accessing value achievable
- Identify what your particular hurdles are and apply the solution

Will not add value in some deepwater fields – but not many!
- At least evaluate the potential gains for any new development
- Seek short-term assistance in developing Business Case
- Make sure that assistance is solution-neutral and objective
Understanding Subsea Evolution: Origins of risk mis-perceptions

- Hydraulic controls initially adequate (1960’s/’70’s)
- Then struggled with electrical connections in seawater
  - One atmosphere chambers to house seabed equipment
  - Allowed hands-on repair by specialists rather than divers
- Inductive electrical couplers replaced pin connectors
  - Allowed surface insulation potting to keep seawater out
  - Downside was high electrical losses requiring high power input
- Oil-filled wet-make electrical connectors
  - Enabled return to efficient and reliable pin connectors
  - This was the single most important technical breakthrough
  - Gave confidence for planning major subsea frontier development
- Industry has traditionally been heavily risk-averse
  - Ignore the upside potential because downside risk needs managing
Cormorant UMC: 1970’s technology
Producing oil subsea for 30 years!

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Subsea Processing State of the Art

- Multiphase Pumping
- Subsea Separation
- Gas Compression
- Raw Seawater Injection
- Electrical Power Supply/Distribution
Framo Subsea Booster Pumps
Statoil’s Lufeng Field – South China Sea

First commercial subsea electrical pumps
Production Enabler
42 million barrels of oil pumped

91,700 operation hours of Pump BP009 prior to shut down on 2009, total 430,000 hours accumulated
Subsea Booster Pumps – Water Depth

- 1993, Draugen -275 m
- 1997, Lufeng -330 m
- 1998, Troll -350 m
- 1999, Topacio -550 m
- 2003, Ceiba -960 m
- 2008, Azurite -1400 m
- 2013, Jack St Malo -2400 m
Subsea Booster Pumps – Design Pressure

- 1993, Draugen, 3000 psi
- 1997, Lufeng, 3000 psi
- 2003, Ceiba, 5000 psi
- 2006, Columba E, 5800 psi
- 2013, JSM, 13000 psi
Subsea Booster Pumps – Power

- 1997, Lufeng, 400 kW
- 1999, Topacio, 850 kW
- 1998, Troll, 1800 kW
- 2006, Columba E, 2300 kW
- 2007, Tordis, 2300 kW
- 2009, Pazflor, 2300 kW
- 2010, WGC, 2500 kW
- 2013, JSM, 3000 kW
Subsea Processing State of the Art

- Multiphase Pumping
- **Subsea Separation**
- Gas Compression
- Raw Seawater Injection
- Electrical Power Supply/Distribution
Marimbá VASPS System

- VASPS – Vertical Annular Separation and Pumping System
- Dummy well with gas-liquid separator and a ESP
- Installed in Marimbá Field in year 2000, and operated with good performance

Courtesy of Petrobras
BC-10 Caisson ESP Application

- Declared commercial in 2005
- 5000 ft water depth
- Production from three fields; Ostra (24 API); Argonauta -BW (17 API); Abalone (42 API)
  - 9 subsea production wells, one gas injection well
- Phase II Argonauta-ON development
  - 7 subsea production wells, 4 water injection wells.
- Production ties back to the Espirito Santo FPSO
- 100,000 bbl/day 15 API oil; 50 MMSCFD Gas
- Seabed boost ESP systems near wellheads
- Step-Out: 5 mi (9.0 km)
- Design Pressure: 5,000 psi
- Pump Capacity: 30,000 bopd heavy oil
- Gas Tolerant ESP: ESP to 50% GVF
  1.2MW 1800 psid (125 bar.d)
- Gas: Free flows through 6” flowline

Courtesy of Shell
Perdido Caisson ESP Application

- Discovered in 2002, production from three fields: Great White; Silvertip; Tobago
- Water depths ranging from 2,300 to 3,000 meters
- Fluid Properties from 17° to 40° API
- GOR from 350 to 2600 scf/bbl
- Low temperature & Low pressure reservoirs
- Fields tied back to the Perdido regional host spar.
- Deepest Spar in the world today.
- Capacity 100,000 bpd oil; 200 MMscf/day gas
- 5 x 30,000 bpd Seabed Boost Gas tolerant Pumps
- Direct vertical Access to Seabed boost systems below spar
TOTAL’s latest success: 
Pazflor Operational Experience

- Successful start-up of new vertical separation solution Aug11
- Separator performance satisfactory & close to predicted
- Liquids boosting reliable & efficient with the reduced GVF
- Operating outside hydrate region but inject MeOH for cold start-up
- Slugging reduced, process stabilised
- Anti-foaming agent mandatory
- Highlights benefits of next generation compact separators

Courtesy of Total
Subsea Processing State of the Art

- Multiphase Pumping
- Subsea Separation
- **Gas Compression**
- Raw Seawater Injection
- Electrical Power Supply/Distribution
A Glimpse of the Future!

Åsgard

Subsea Compressor
*Courtesy of MAN Diesel & Turbo*

Gullfaks South

WGC4000
*Courtesy of Framo*

Subsea Compression Station
*Courtesy of Aker Solutions*

Wet Gas Compressor Station
*Courtesy of Framo*
Åsgard Compression Station size
Åsgard compression in perspective
The Åsgard SS Compression Prize

Åsgard additional production ~ 280 mboe
...potentially $28 billion
Subsea Processing State of the Art

- Multiphase Pumping
- Subsea Separation
- Gas Compression
- Raw Seawater Injection
- **Electrical Power Supply/Distribution**
The Next Big Technical Stretch

• **Subsea Processing’s weak link:**
  • Historically – subsea wet-mate connectors
  • Now – high power, long distance transmission

• **Power delivery solutions:**
  • Equipment size
  • HVAC
  • Reduced frequency HVAC
  • HVDC
So, Where Are We Now?

- **Pumping**
  - Proven production & reserves boost
  - Increasing power and water depth capability
  - Enabling technology for separation systems
  - Increasing reliability and simplified intervention

- **Separation**
  - Mixed history over 40 years – elements now mature
  - Troll separator with water injection still running after 12 years
  - Recent success of Total’s Pazflor system – West Africa

- **Compression**
  - No installations on seafloor yet
  - Statoil’s Åsgard and Gullfaks fields will set the bar
The Development Agenda is changing:
- Subsea technology has long been essential enabler for deepwater
- Energy adding technologies now emerging as gamechangers
- Often essential for deepwater development feasibility
- Inflated Oil price has also created a major investment driver
- Huge potential for recovery enhancement & production acceleration

But are we all aboard the change train?
- Business Case often not even considered
- Vague risk perceptions allowed to over-ride analysis
- Reluctance to share meaningful operational experience
- End-user Investment in the technology still woefully low
So, can we act smarter to capture opportunities?

- Better collaboration across discipline silos
- Better experience sharing between Operators and Vendors
- Better collaboration & visibility on technology qualification
- Better transparency by Vendors on performance data & costs
- Better use of integrated production modelling tools
- Better use of objective solution-neutral specialist resources

Recognise potential applications & select right systems

Collaboration across all industry sectors is the key!

But where is that key??
Collaboration means working together!

- Which main participant stakeholders need to collaborate?
- Recognise that Opcos are dominant beneficiaries of the SSP technology
- Only largest Opcos have resources to engineer SSP solutions inhouse
- Vendors gain good margins by selling Opcos hardware, not engineering
- Engineering houses gain modest returns by selling Opcos systems eng
  - Vendor-neutral front-end/conceptual optimisation with Opcos
- Opcos benefit from use of specialist resources to engage with vendors
  - to specify, qualify, select and integrate new SSP hardware
  - to overcome Opco wariness of vendors’ rose-coloured specs
- Vendors benefit from “free marketing” of best technologies to Opcos
  - Engineering consultancies can represent verified vendor capabilities to Opcos
  - They can also provide systems eng resources to Vendors for peak loads
- Hence no reason for significant misalignment of interests – is there??
- Well, why is it still not happening then??

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So, to answer the title question posed…

► Is Subsea Processing ready for mainstream?
  • I believe strongly that much of it now is

► But, I have a rather more relevant question:
  • Is the mainstream ready for it?
  • If so, why not routinely seek to capture its value?
  • If not, why not, and how can we help?

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Thanks for your attention 😊

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