Subsea Processing

Presented by:
Tim Lowry

Prepared by
Multiple SUT-US Volunteers

Contents

- Introduction and Background
- Subsea Separation
- Subsea Boosting
- Subsea Water Treatment and Injection
- Subsea Electrical Power Supply
- Enabling Technologies
- US Regulatory Requirements

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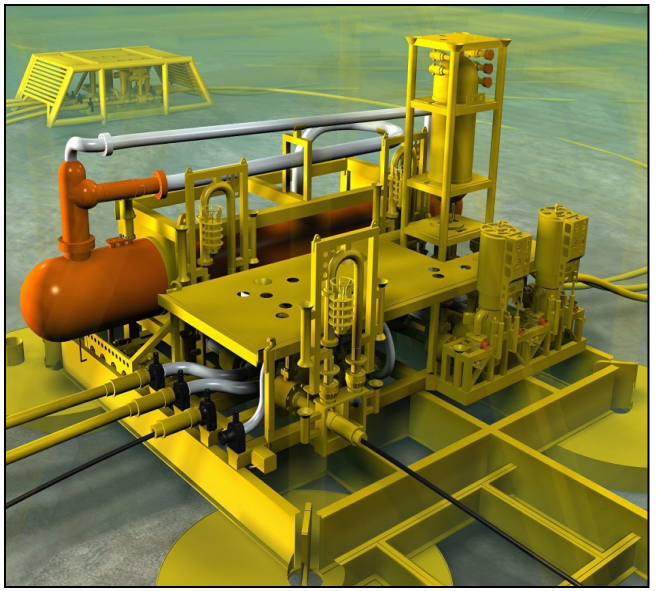
What is Subsea Processing?

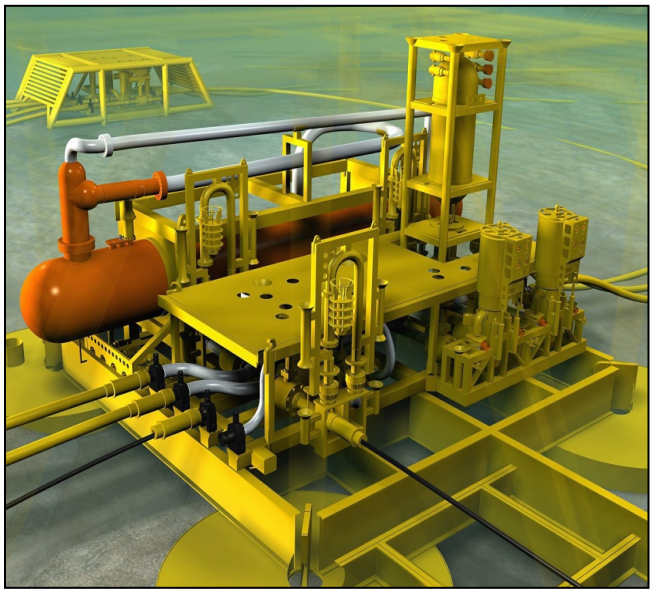


What is Subsea Processing?

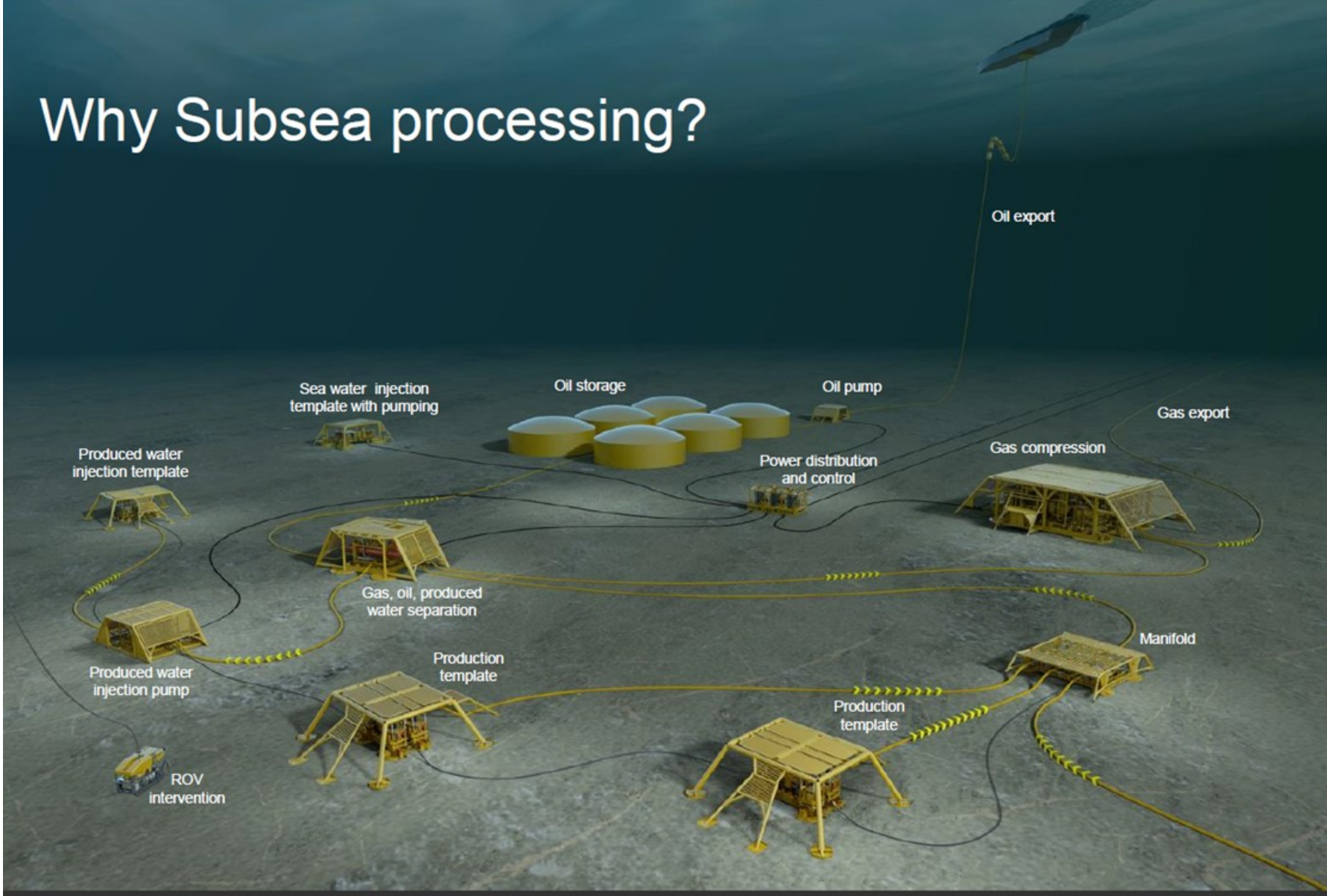
SSP encompasses all separation and pressure-boosting operations that are performed subsea:

- Separation
- Single Phase Pumps
- Multiphase Pumps
- Gas Compression
- Water Treatment and Injection

from API 17TR13



Why Subsea processing?



Statoil

Why Use Subsea Processing?

Why Use Subsea Processing?

- Frees up processing capacity at the host
- Accelerate production and / or prolong plateau
- Increase recovery factor
- Enable tieback of new reservoirs to existing facilities

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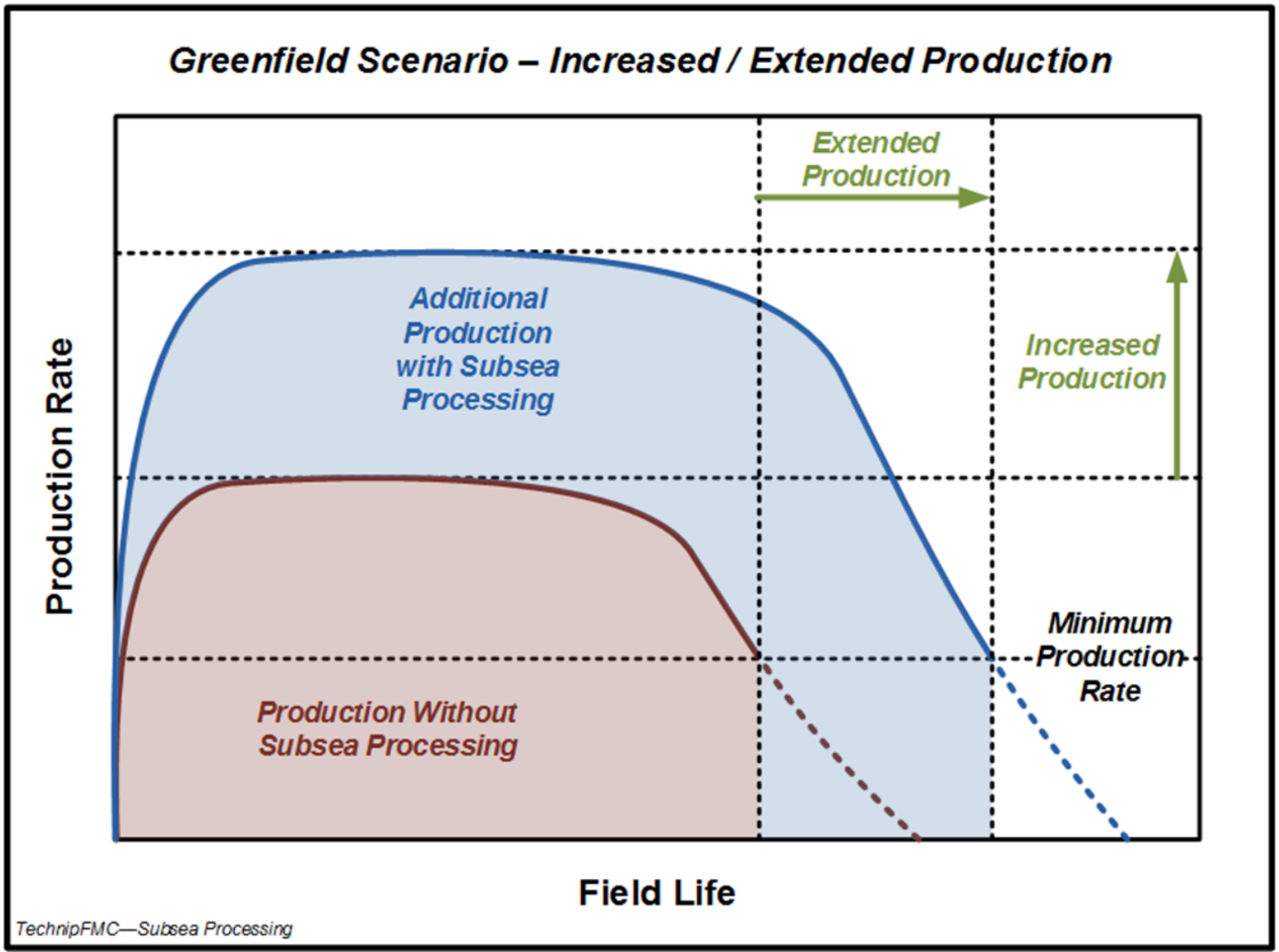

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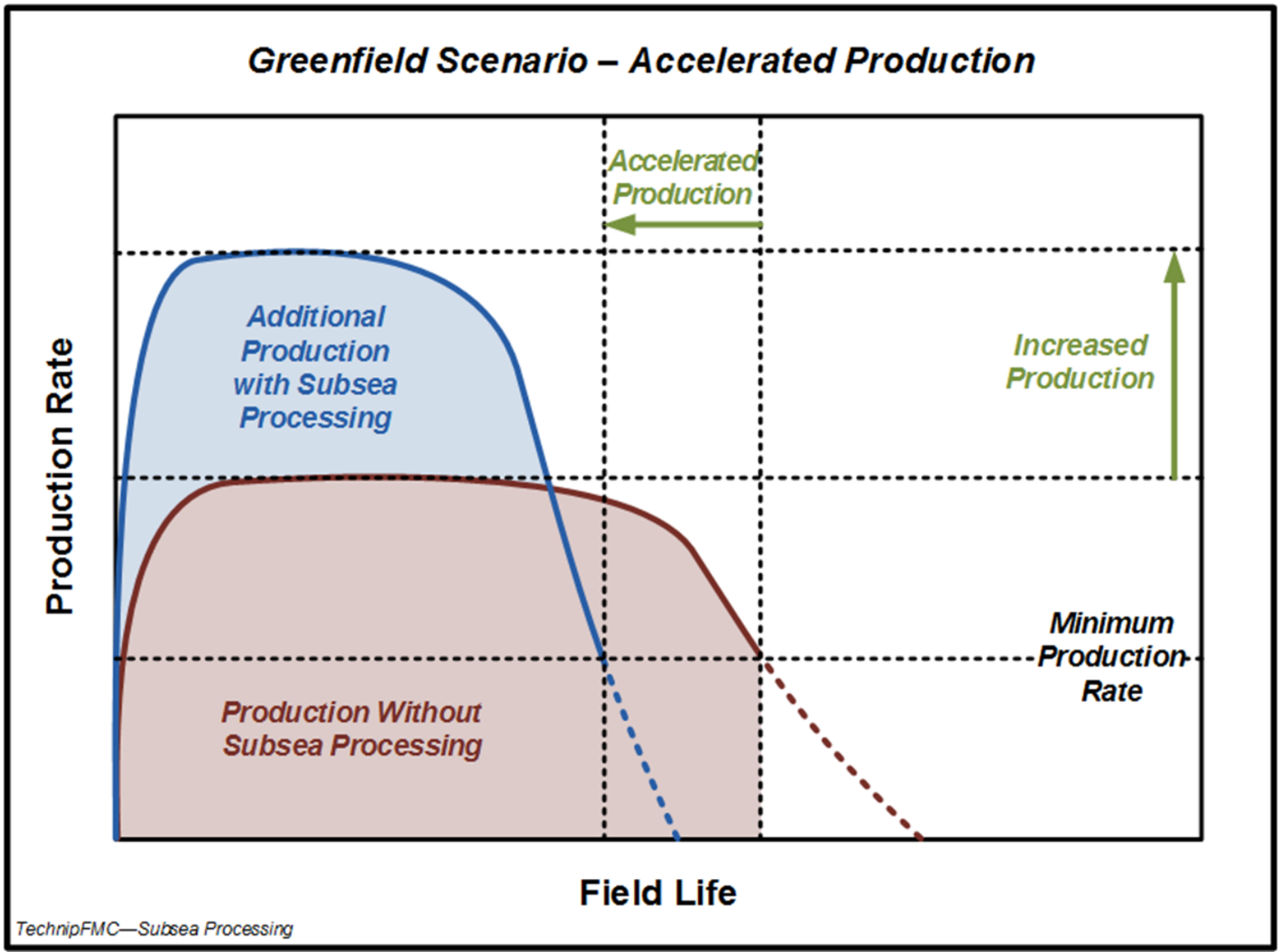

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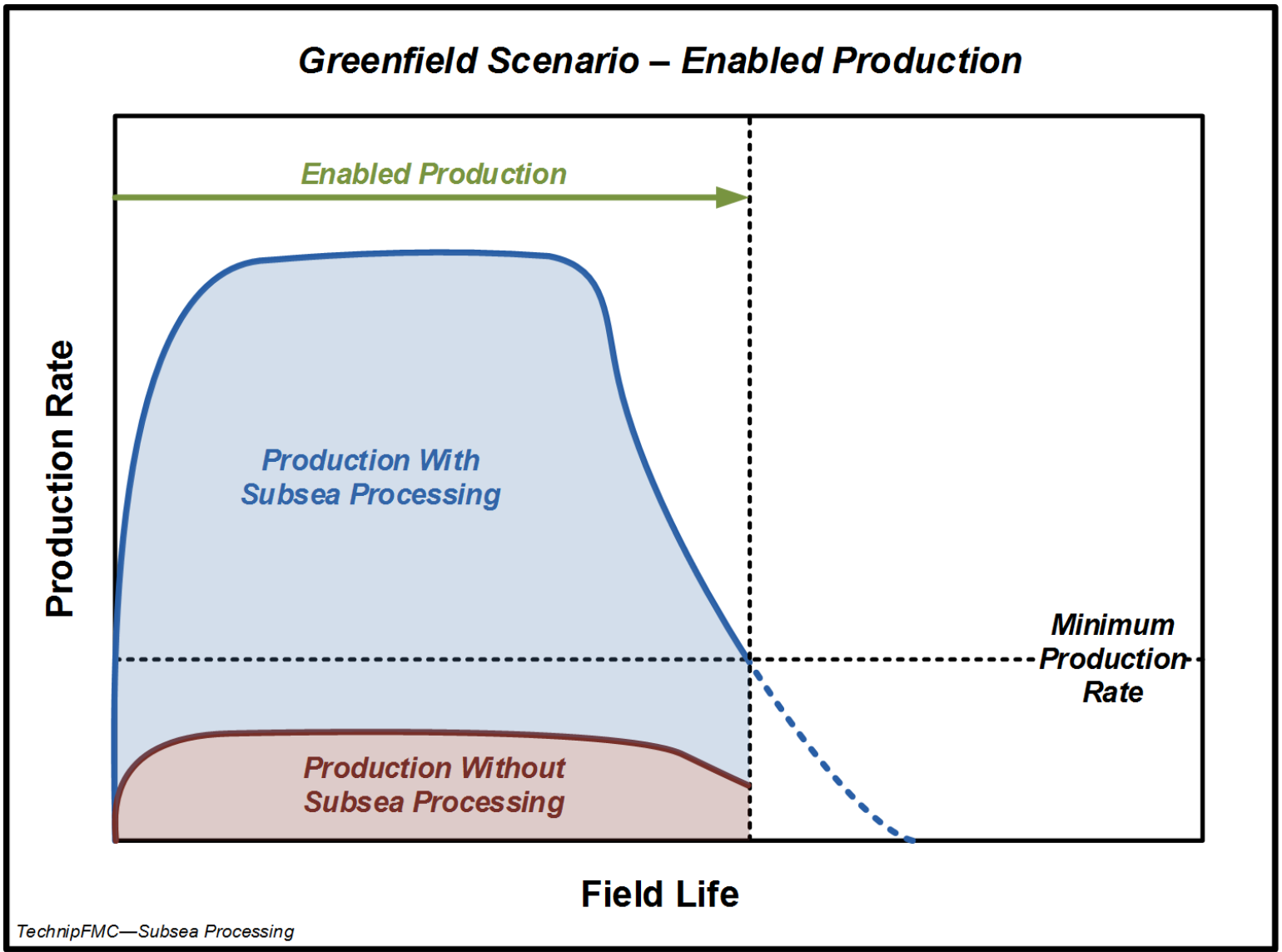

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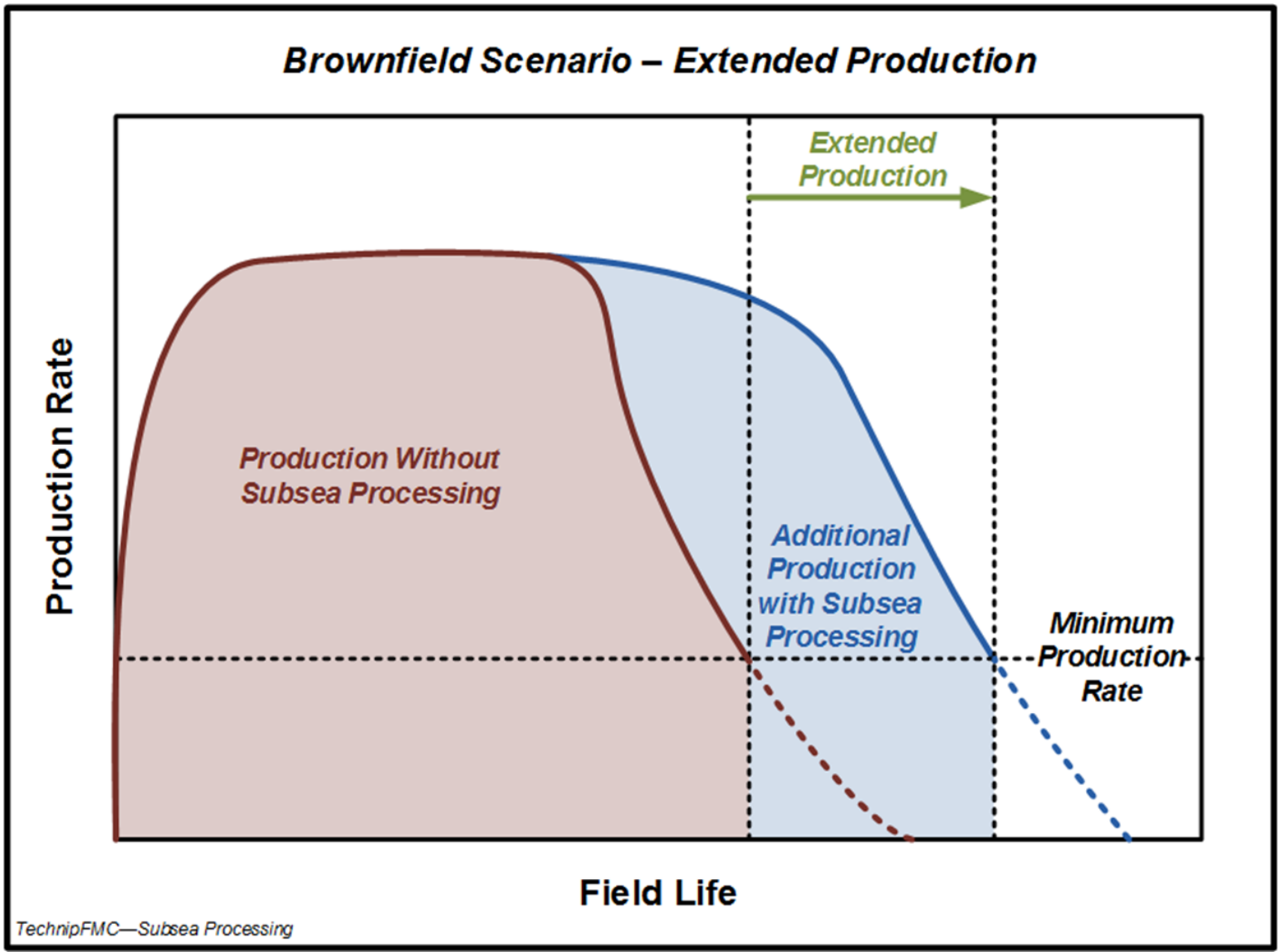

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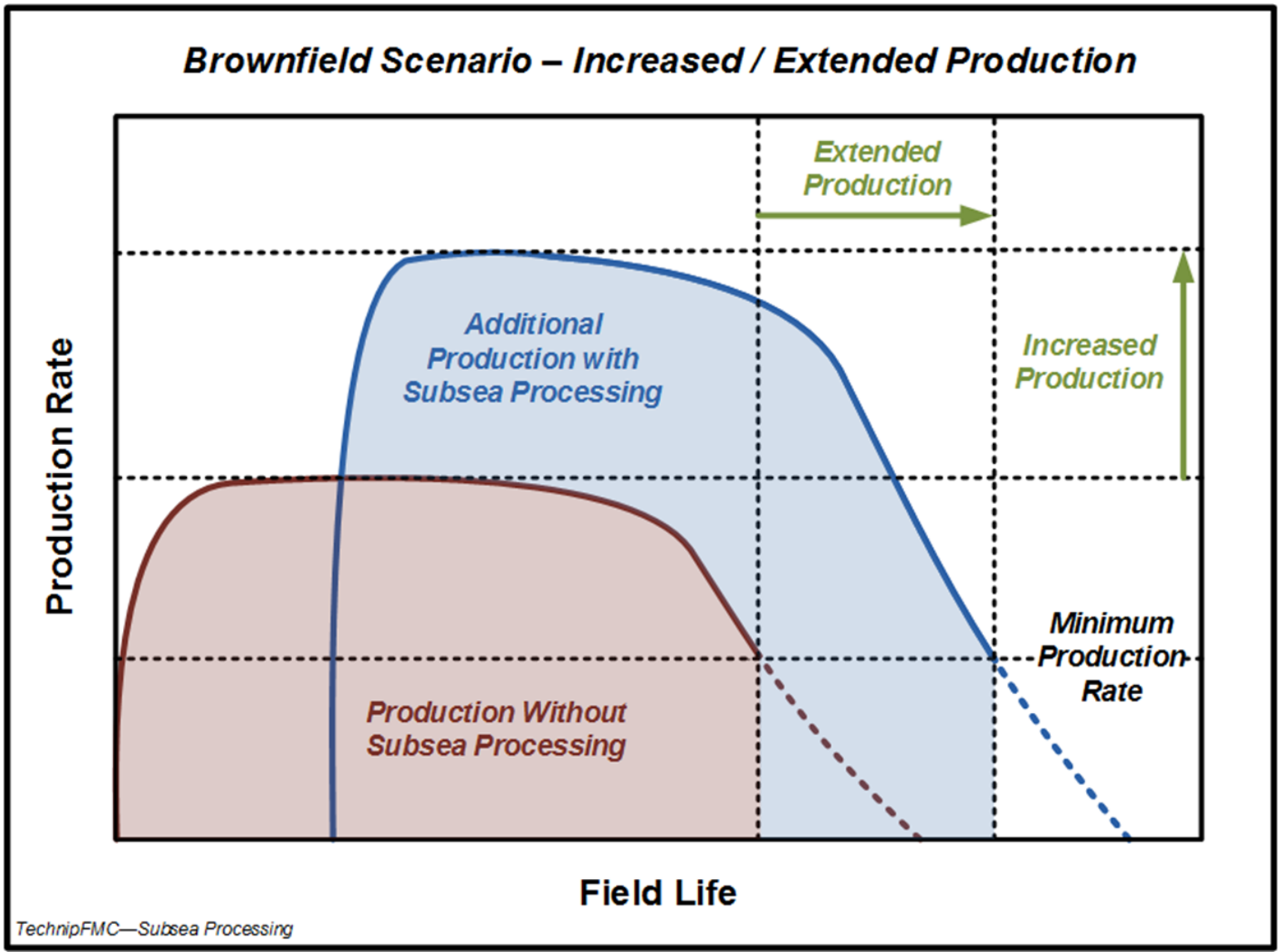
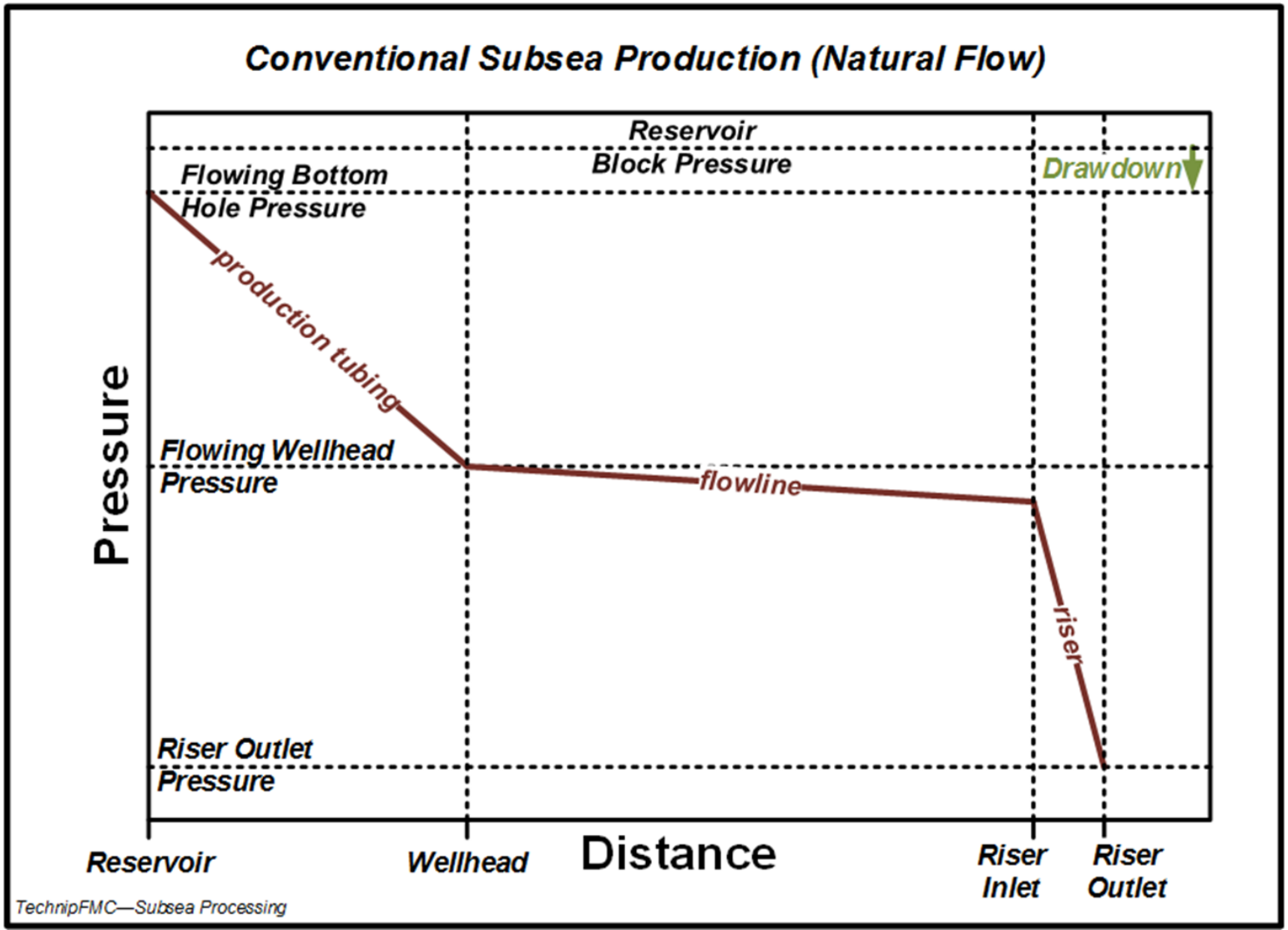


How Subsea Processing Helps



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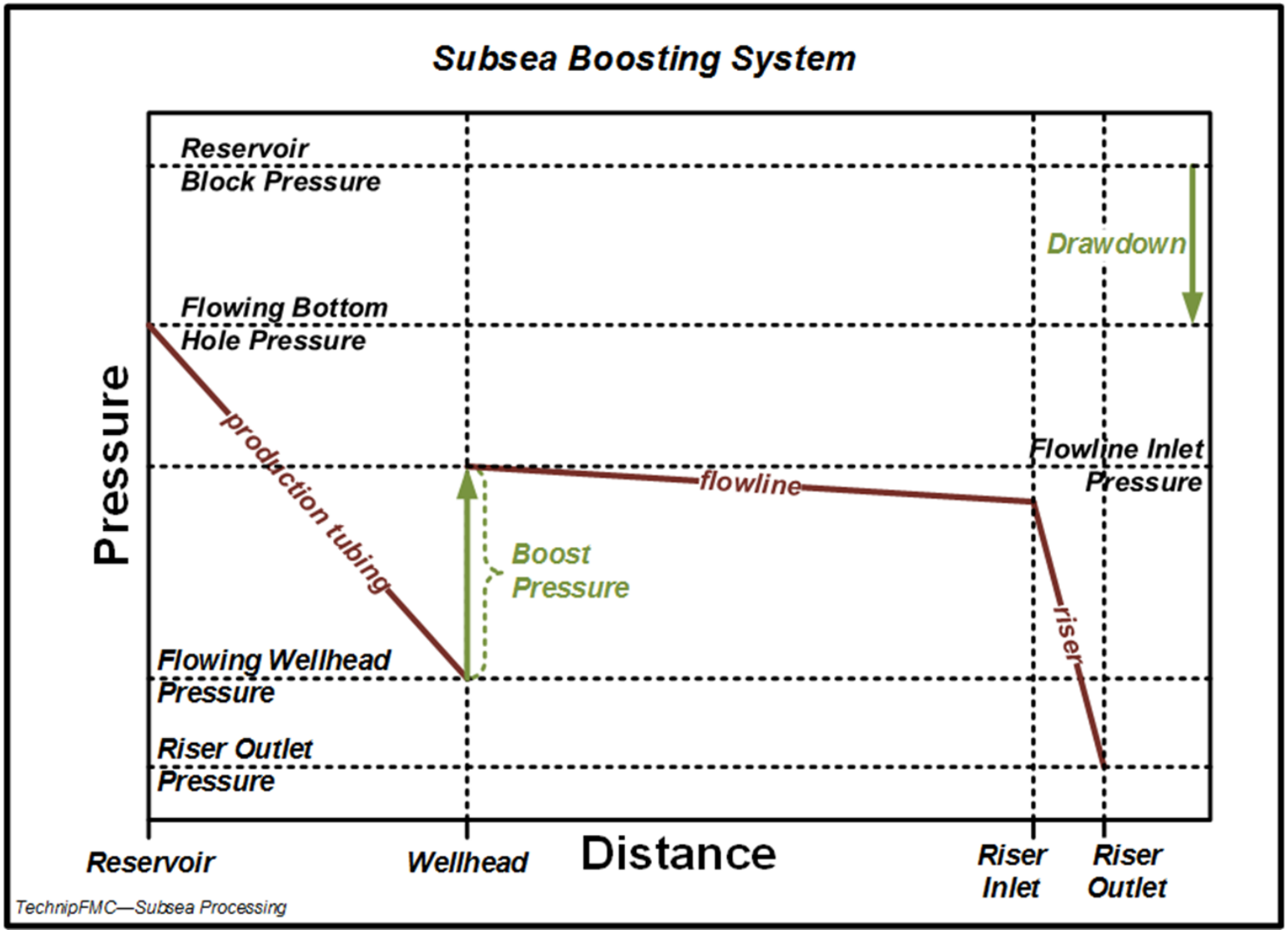

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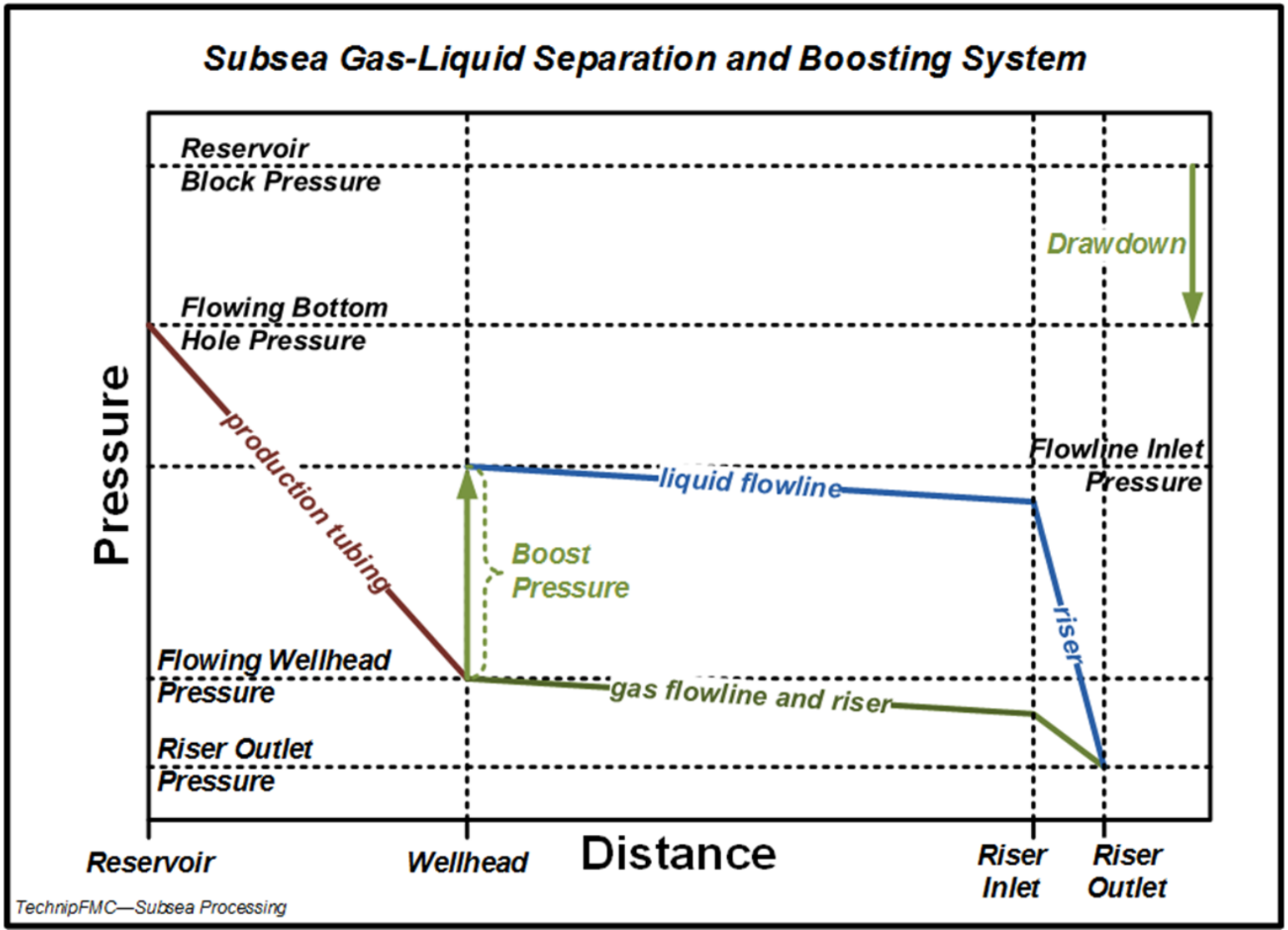

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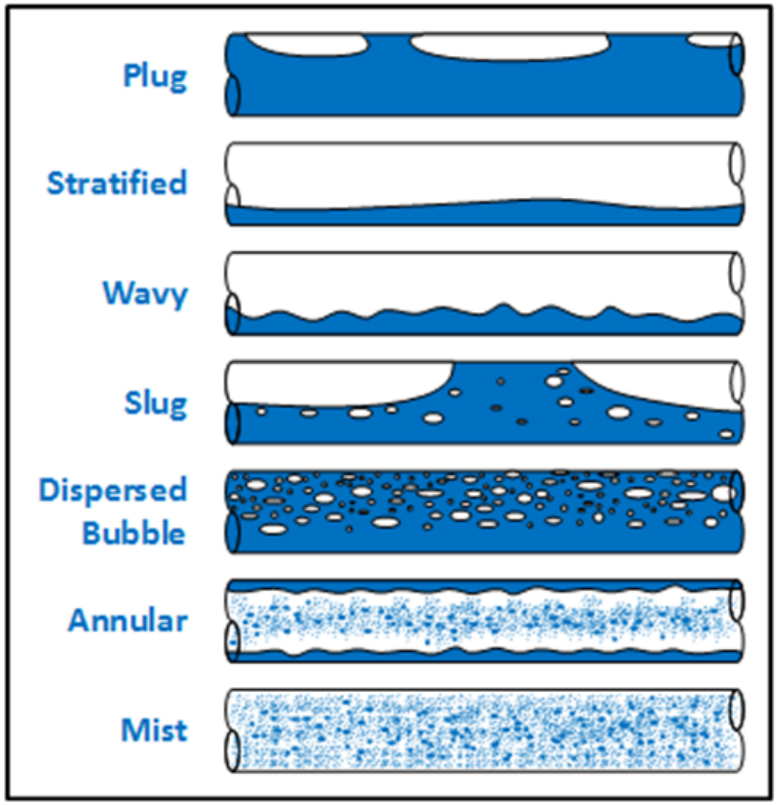
Separation Basics

Remove one (or more) phases from a multiphase production stream

Primary Applications

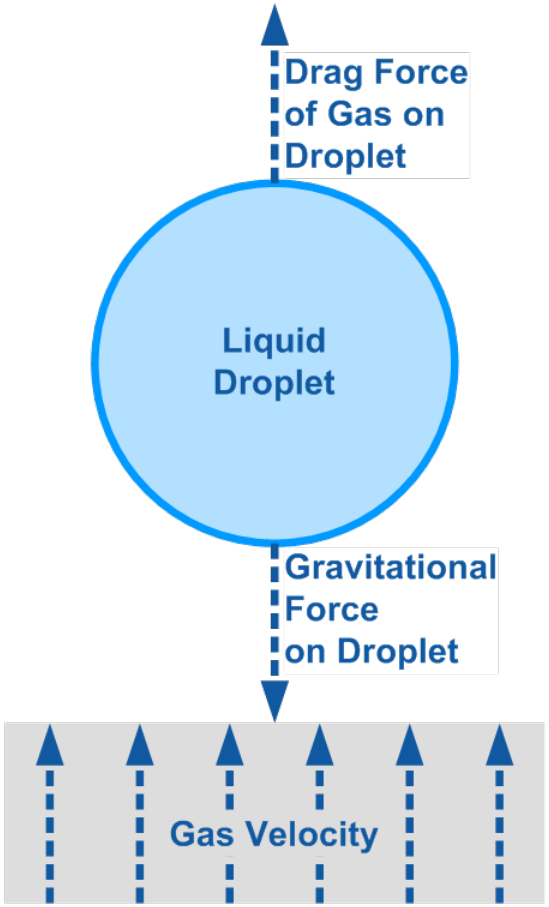
- Gas-Liquid
- Liquid-Liquid
- Gas-Liquid-Liquid



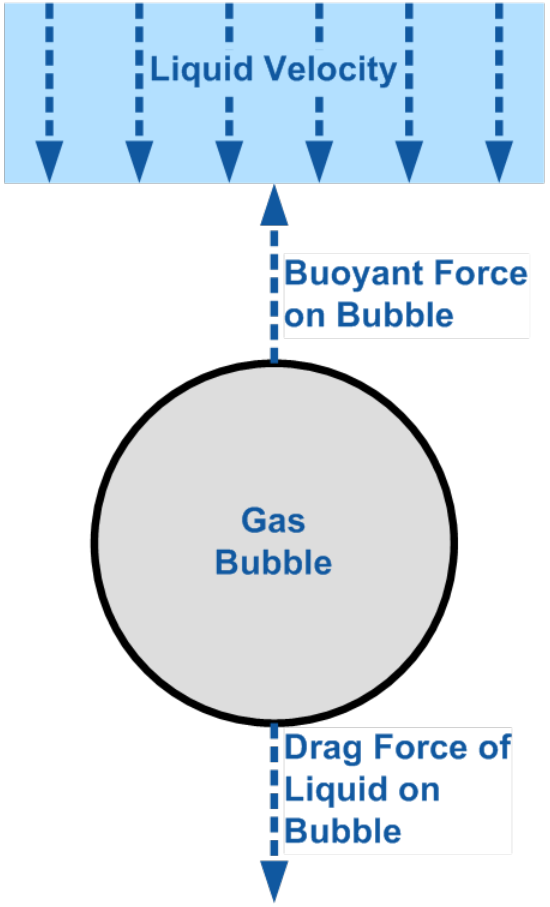
Horizontal Flow Regimes

Separation Basics

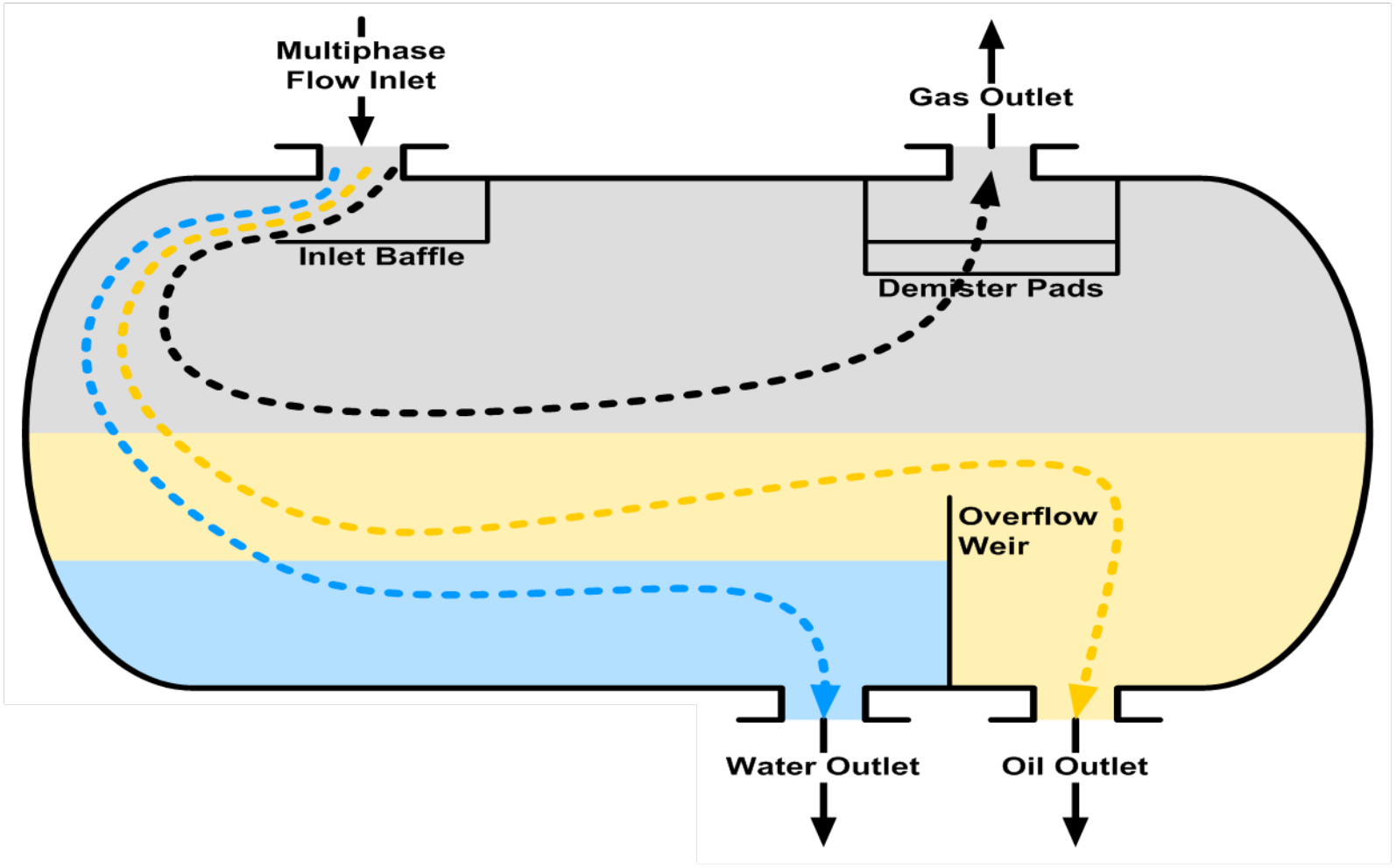
Liquid Droplet Falling in Upward Gas Flow



Gas Bubble Rising in Downward Liquid Flow



Gas-Liquid-Liquid Separation



Conventional Separators

- Vertical
- Horizontal
- Slug Catchers

Conventional Separators

When are these typically used?

- Vertical
- Horizontal
- Slug Catchers

Conventional Separators

When are these typically used?

- Vertical — Gas-Liquid separation
- Horizontal — Liquid-Liquid separation
- Slug Catchers — Slugging

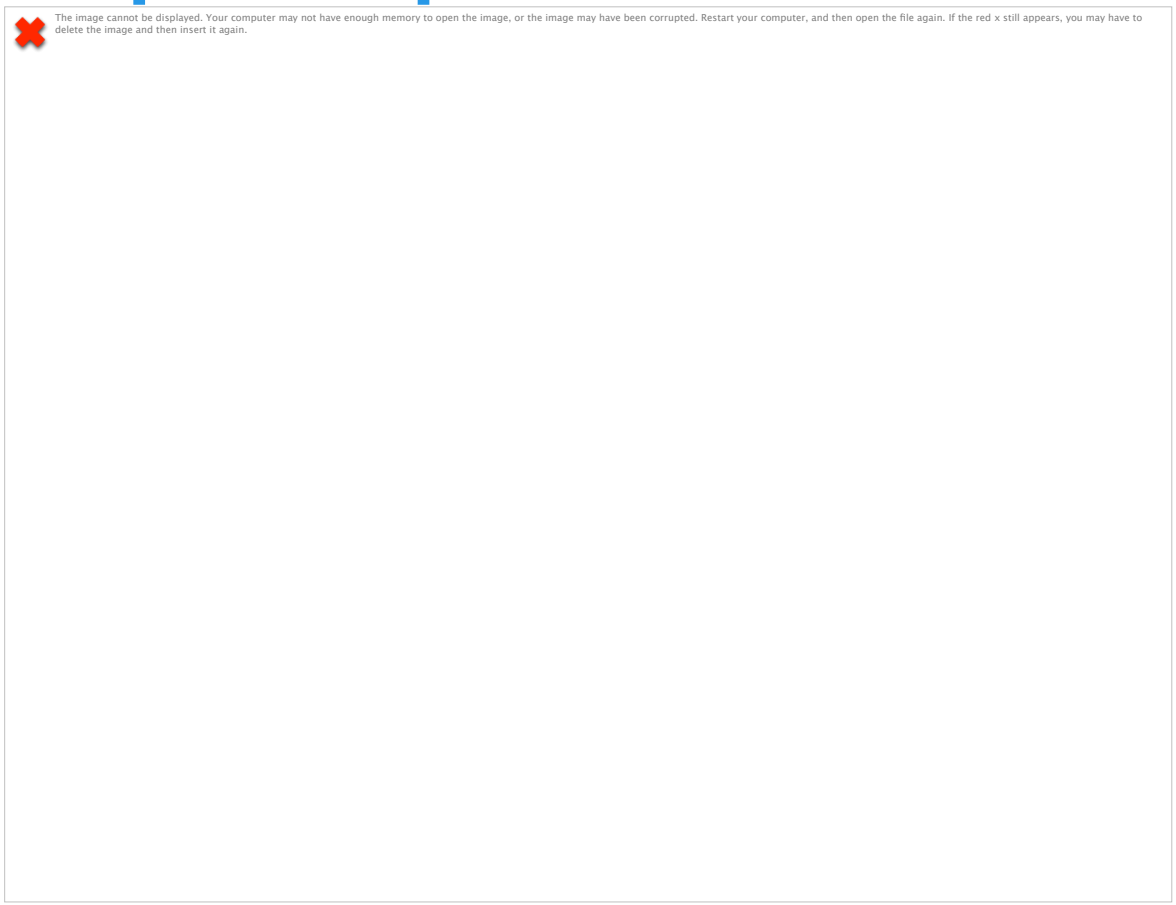
Conventional Separators

Vertical: Gas-Liquid

Pazflor (Total)

Conventional Separators

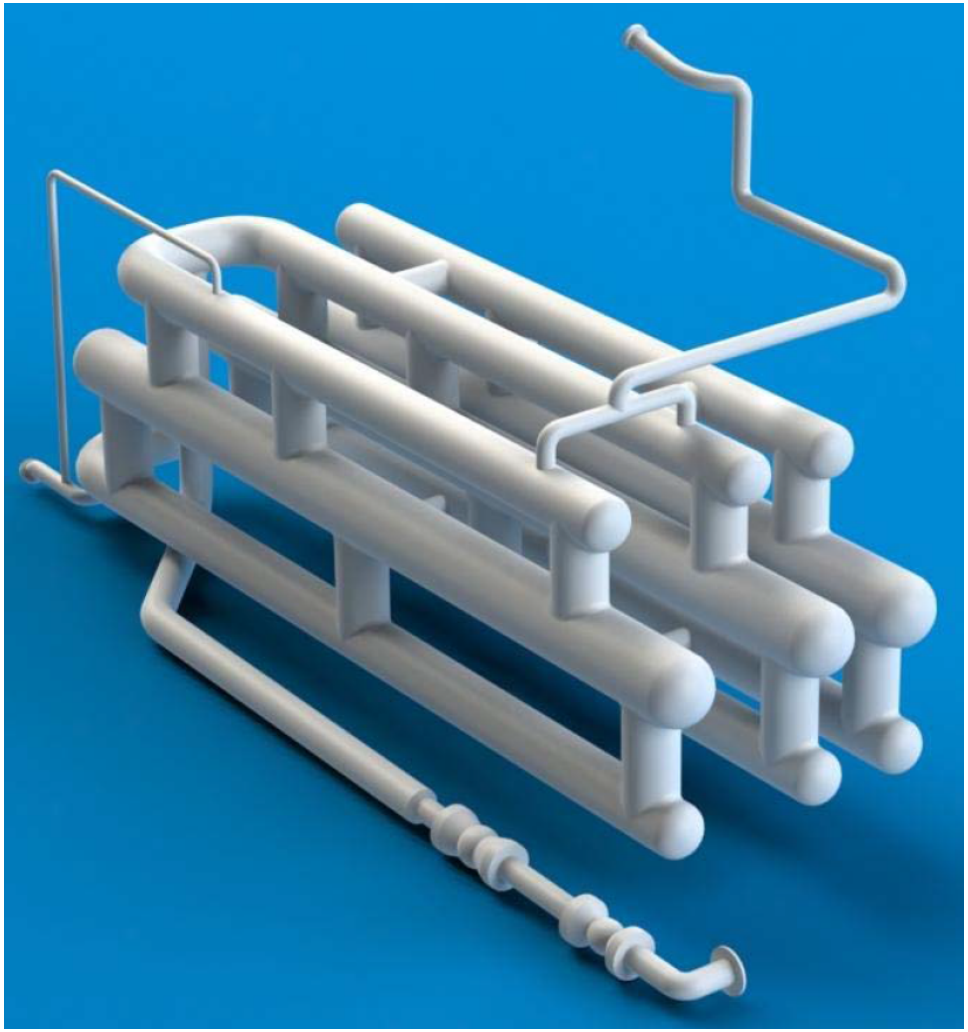
Horizontal: Liquid-Liquid



Tordis (Statoil)

Conventional Separators

Slug Catcher



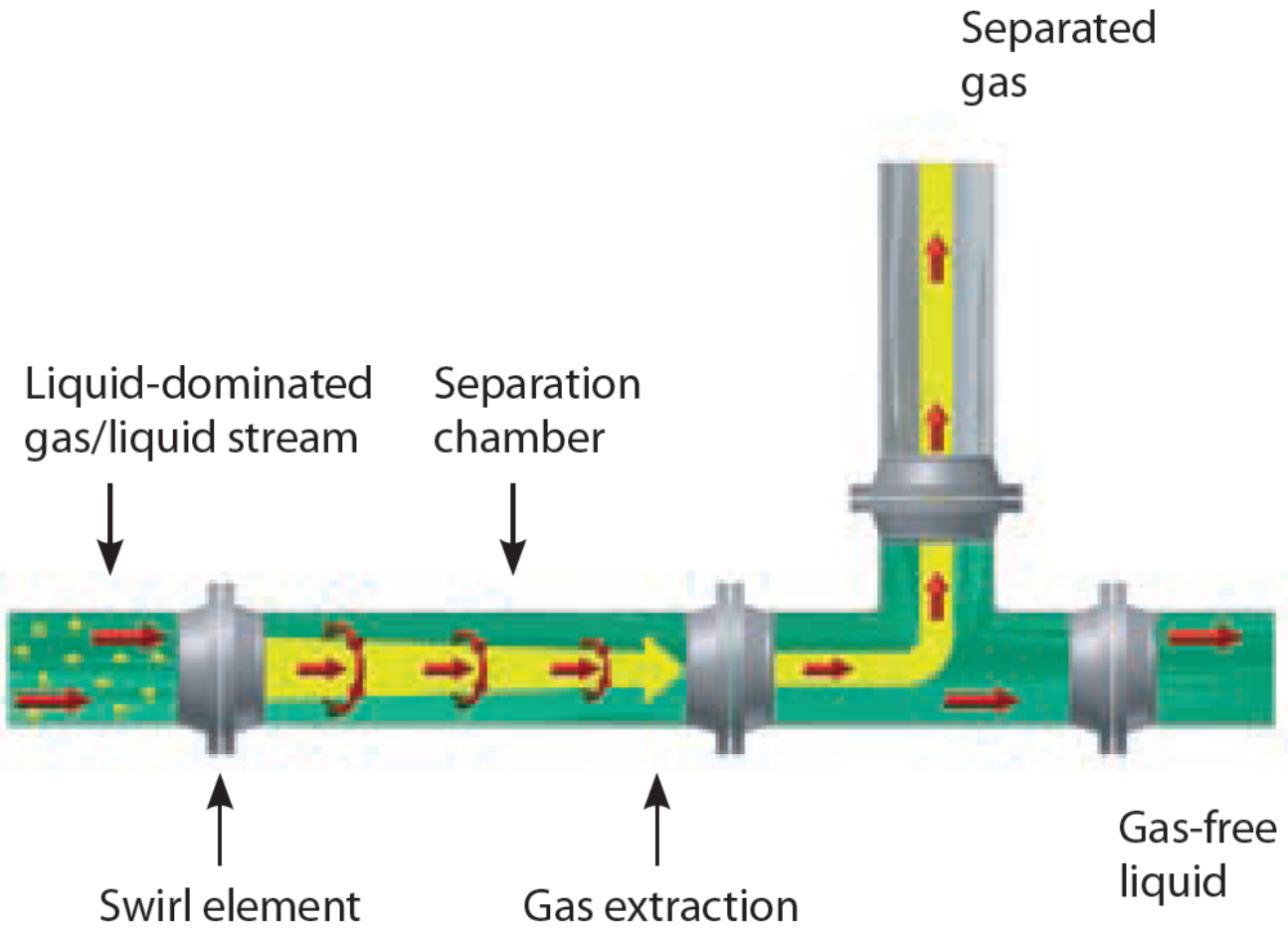
Highlander (Texaco)

Compact Separators

- Degassing
- Deliquidizing
- Desanding
- Deoiling (Hydrocyclone)
- GLCC – Gas Liquid Cylindrical Cyclone
- Pipe Separator

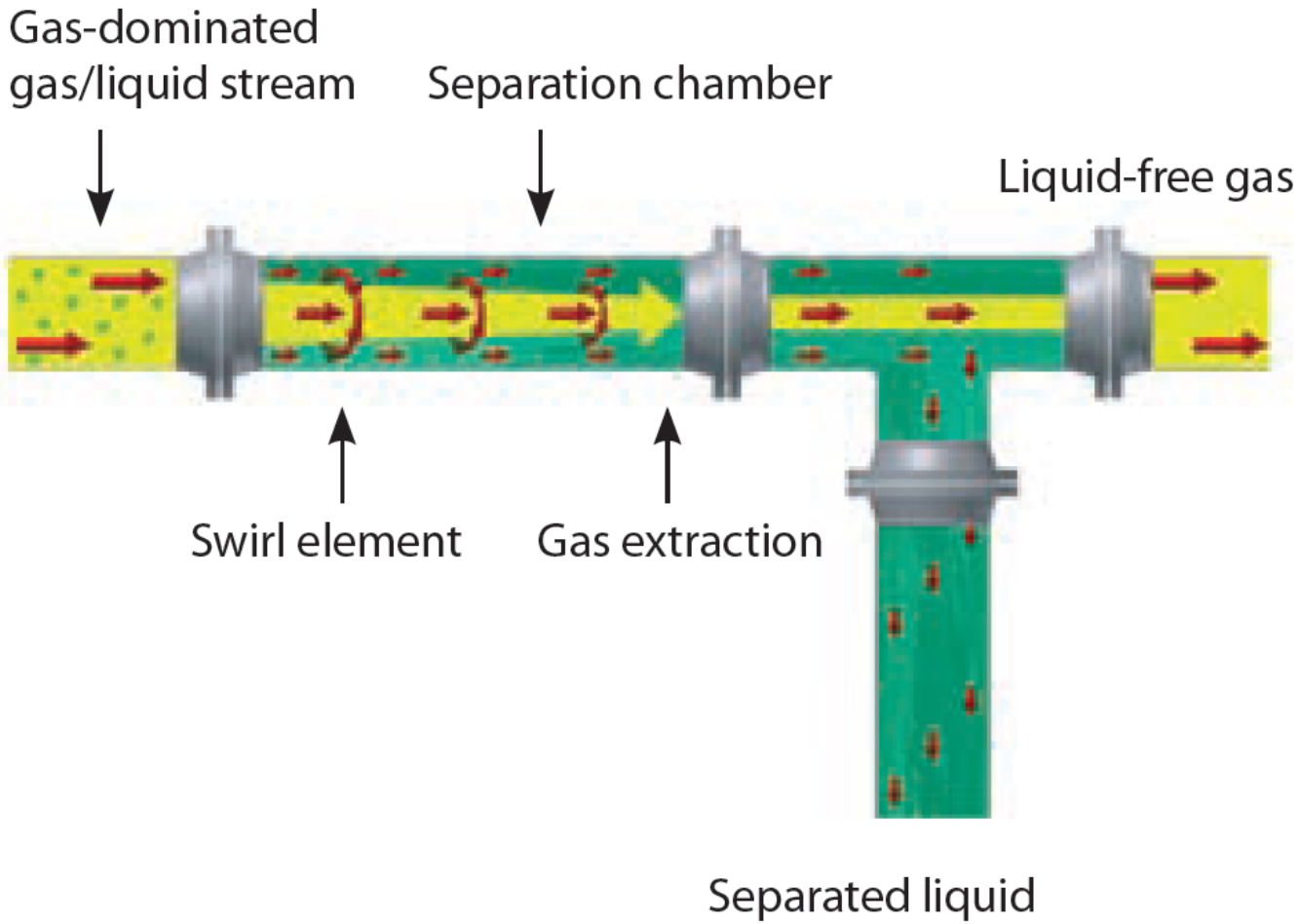
Compact Separators

Degassing



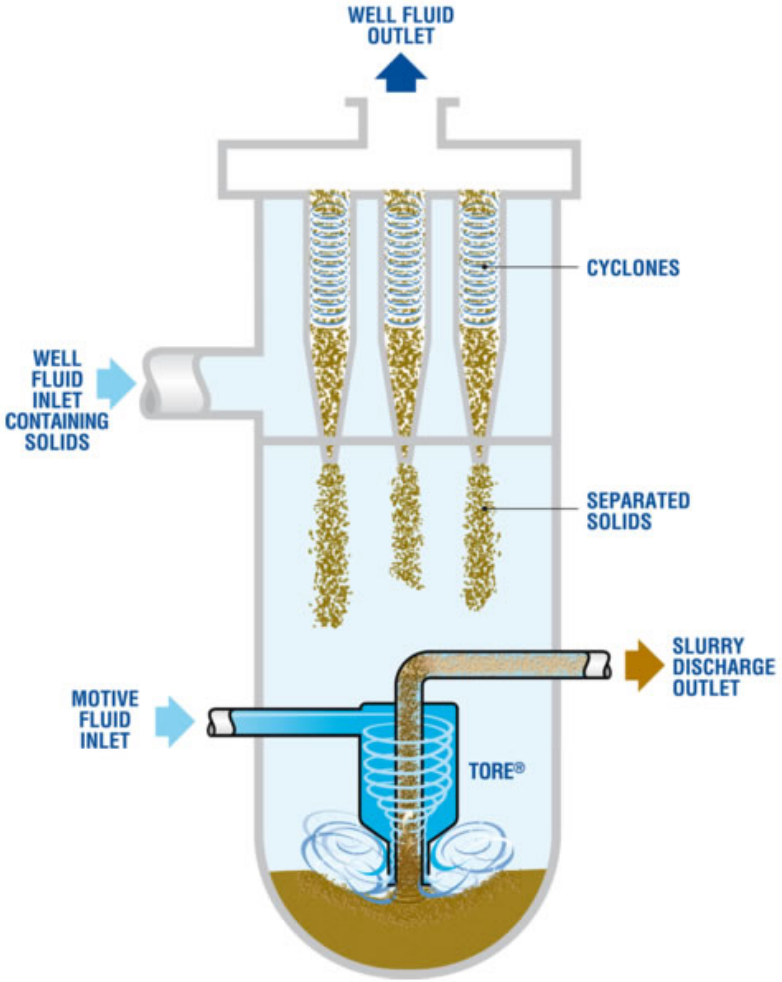
Compact Separators

Deliquidizing



Compact Separators

Desanding

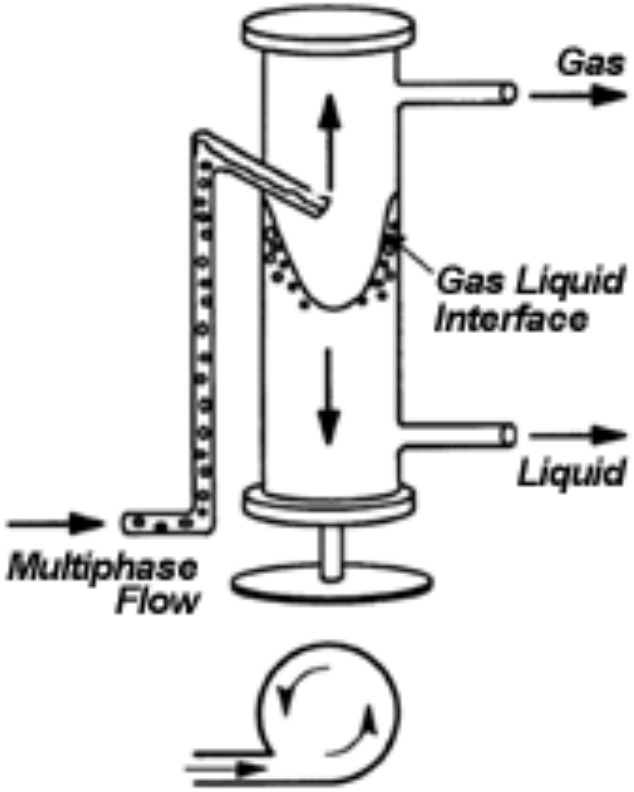


Compact Separators

Deoiling Hydrocyclones

Compact Separators

GLCC – Gas Liquid Cylindrical Cyclone



Compact Separators

Caisson Separator: Gas Removal

Perdido (Shell)

Compact Separators

Pipe Separator: Water Removal

Marlim (Petrobras)

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Subsea Boosting

Pumps

- Centrifugal
- Hybrid
- Helico-Axial
- Twin Screw
- Electrical Submersible Pump (ESP)
- Hydraulic Submersible Pump (HSP)

Compressors

- Centrifugal (dry gas)
- Contra-rotating (wet gas)

Subsea Boosting

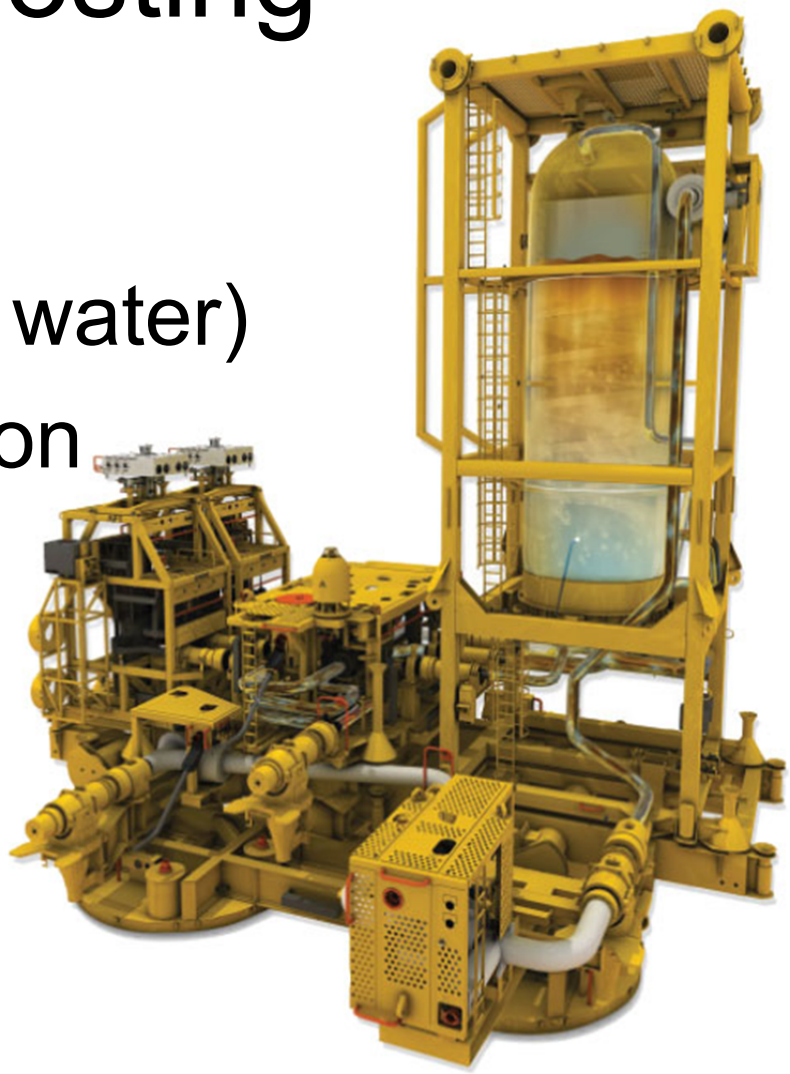
Centrifugal: Full Wellstream Boosting

Jack & St. Malo (Chevron)

Subsea Boosting

Hybrid:

- Liquid Boosting (oil and water)
- Low Gas Volume Fraction



Pazflor (Total)

Subsea Boosting

Helico-Axial: Full Wellstream Boosting

GirRI (Total)

Subsea Boosting

Twin Screw: Full Wellstream Boosting

King (BP)

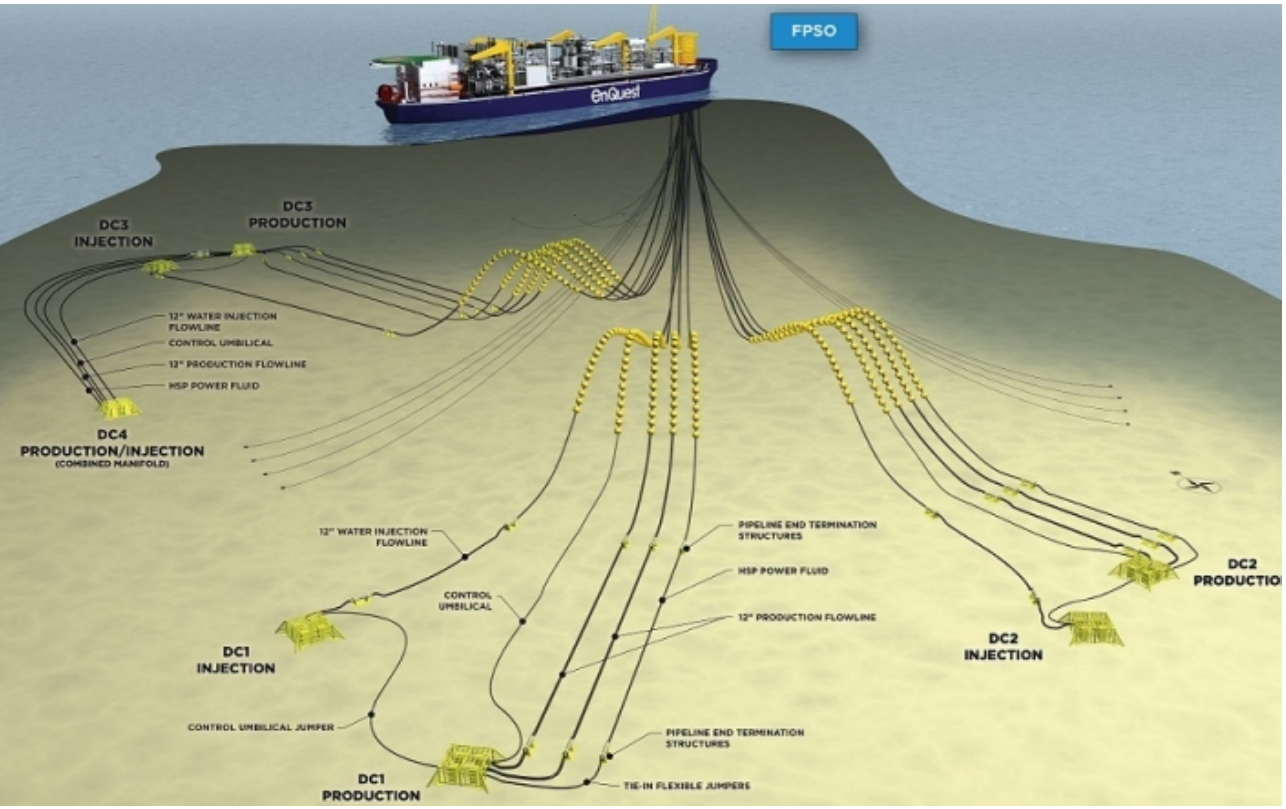
Subsea Boosting

ESP: Full Wellstream Boosting

Cascade & Chinook (Petrobras)

Subsea Boosting

HSP: Downhole Boosting



Kraken (EnQuest)

Subsea Boosting

Centrifugal Compressor: Dry Gas

Statoil (Åsgard)

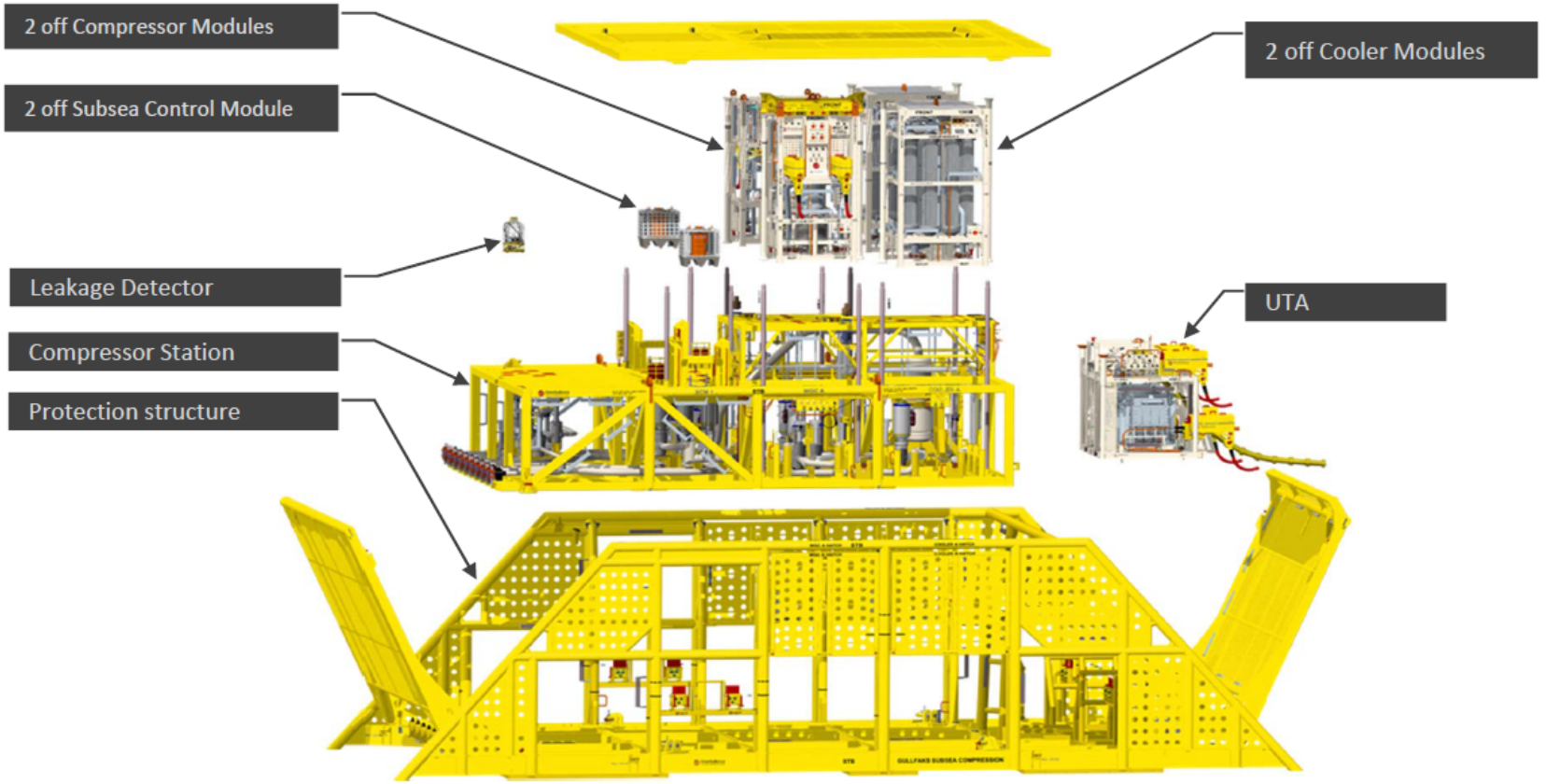
Subsea Boosting

Contra-Rotating Compressor: Wet Gas

Statoil (Gullfaks)

Subsea Boosting

Contra-Rotating Compressor: Wet Gas



Statoil (Gullfaks)

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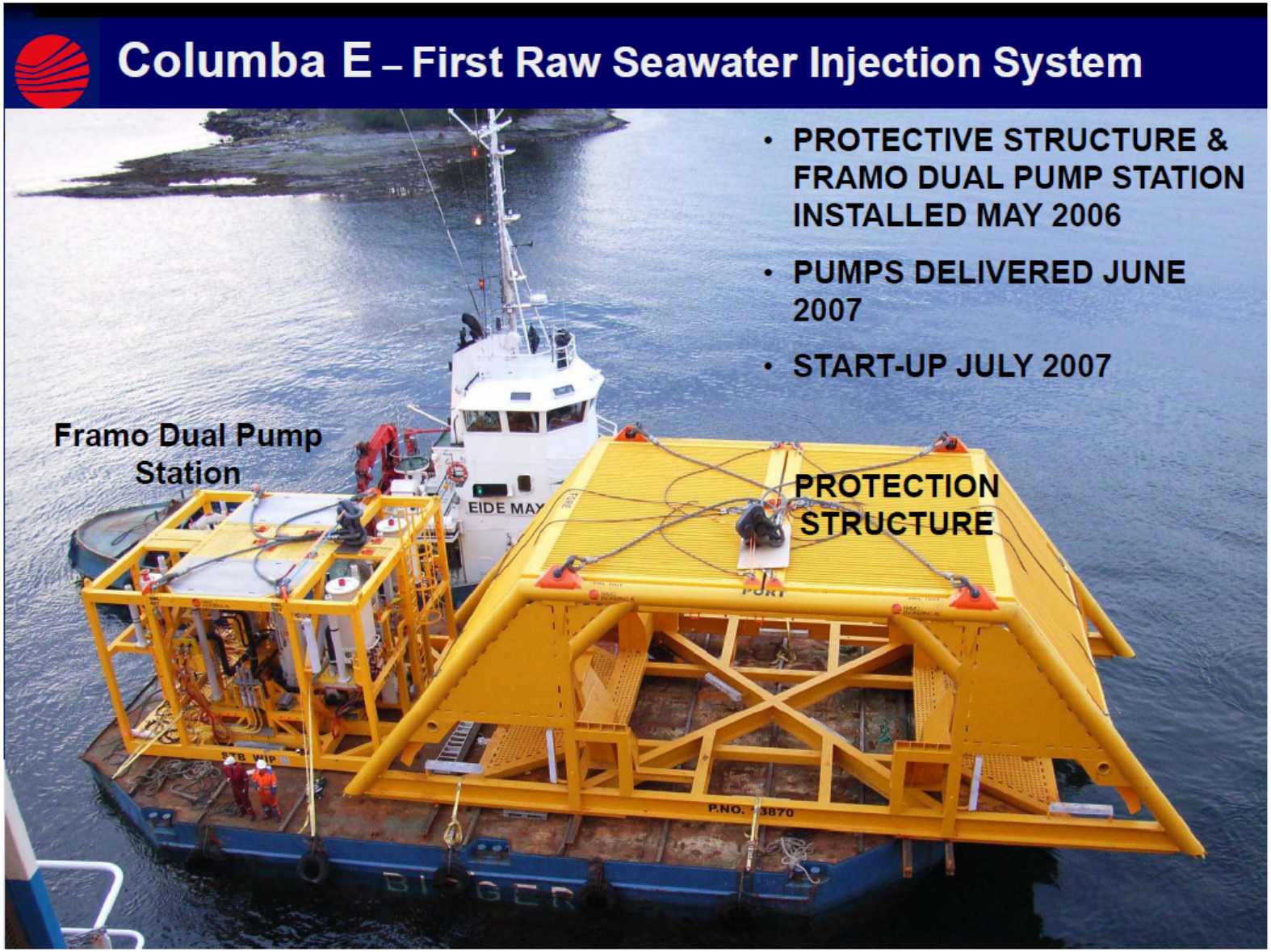
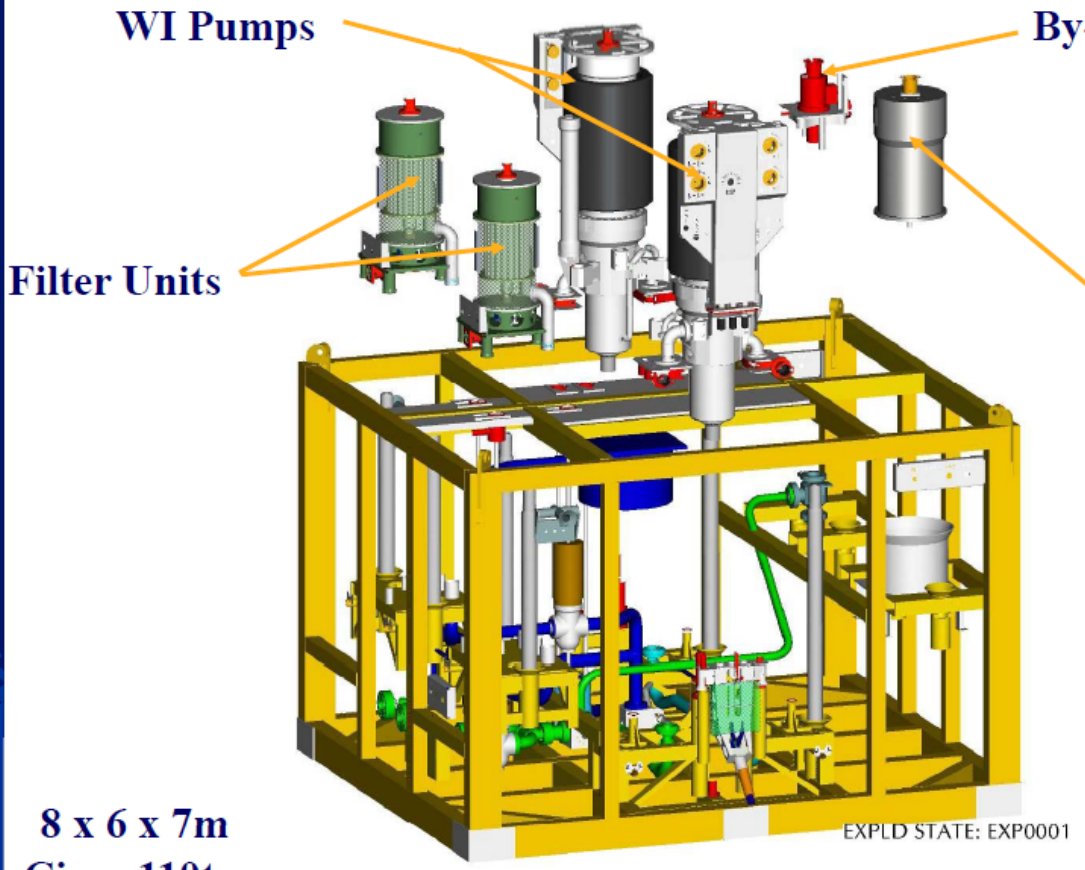
Raw Seawater Injection



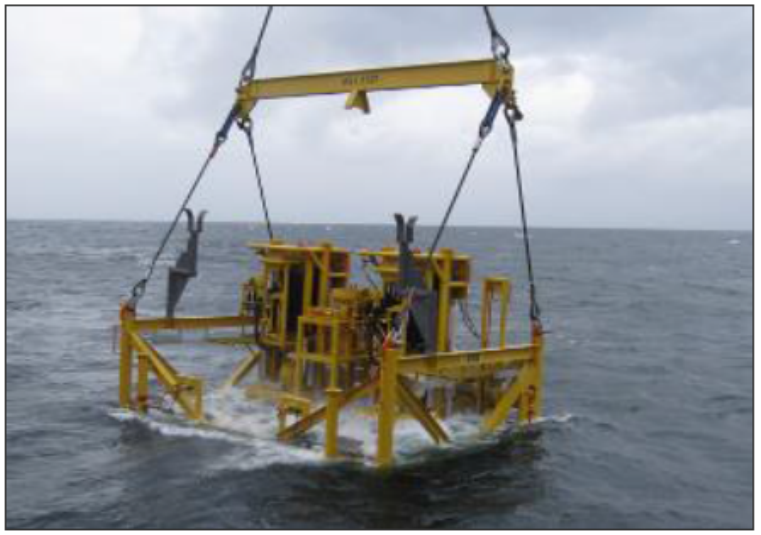
Raw Seawater Injection

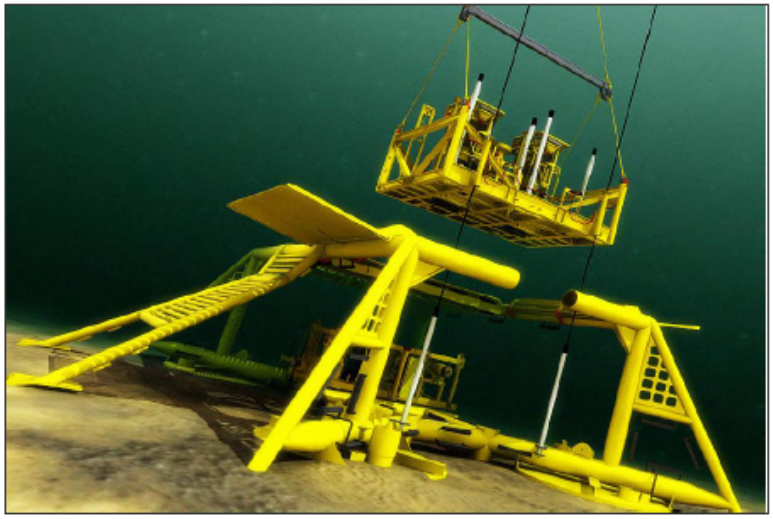
FDS Components



8 x 6 x 7m
Circa 110te.

Raw Seawater Injection





Tyrihans (Statoil)

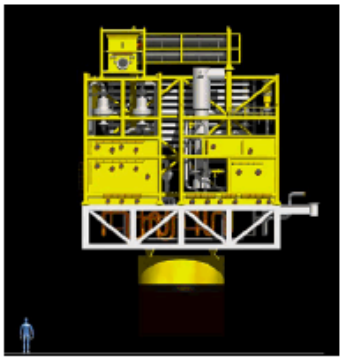
Produced Water Separation, Treatment, and Reinjection

Marlim (Petrobras)

Seawater Treatment and Injection

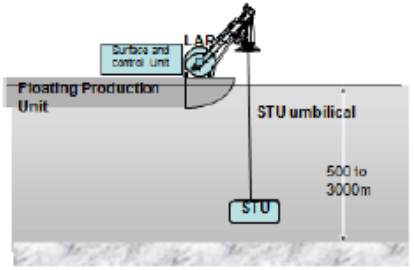
Collaboration Project with SAIPEM/Veolia started in 2007

Conceptual Study



Subsea Test Unit

Construction & Test (6 months)



2008-2009

2010-2011

2012-2014

2017

Lab tests of membranes @ 300 bars / 4 °C

First Industrial Application In Operation

SPRINGS™ is the first unit that allows seawater sulfate removal in the subsea context.

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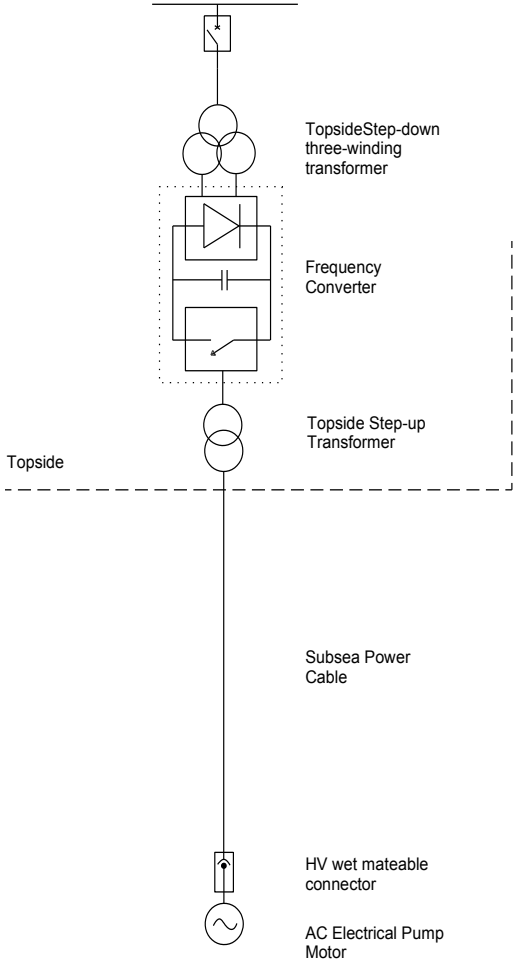
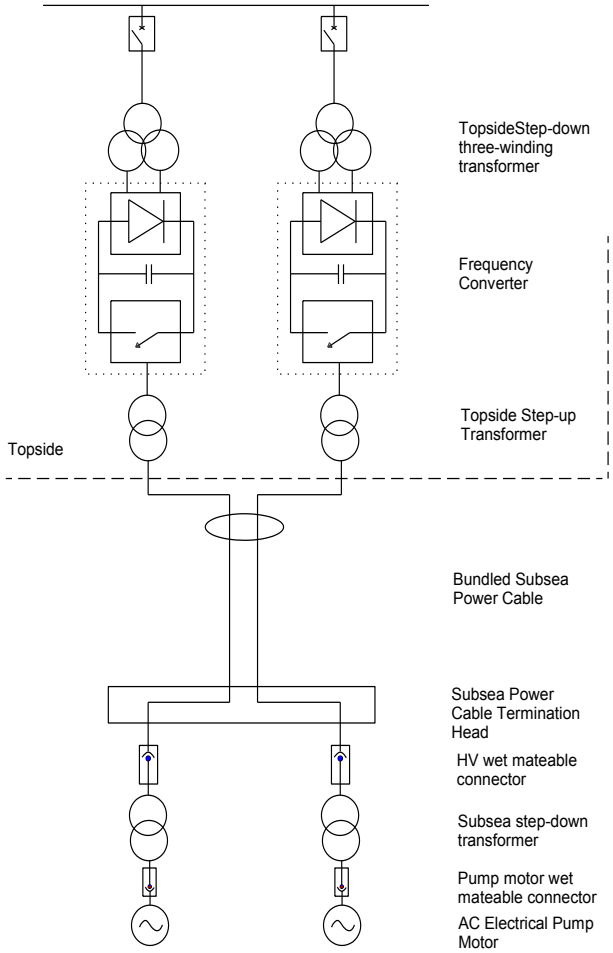
Subsea Electrical Power Supply

Topside Based – Single Consumer



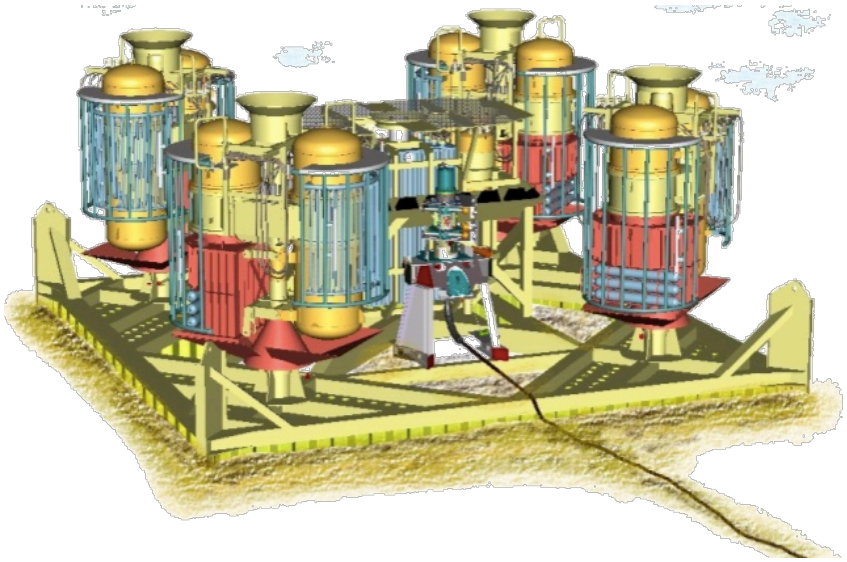
Subsea Electrical Power Supply

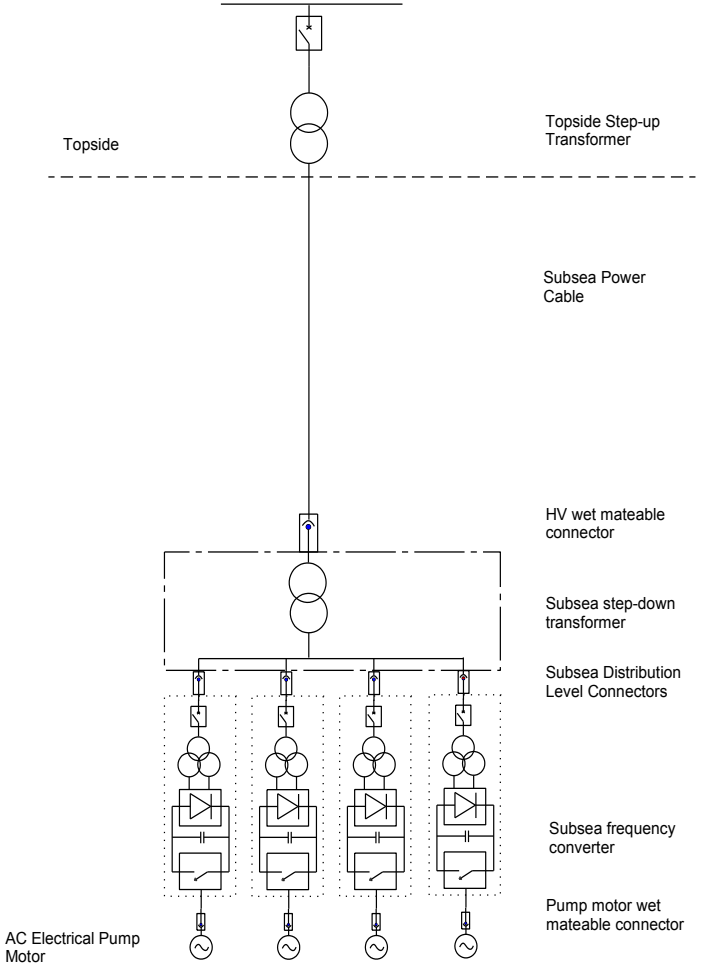
Topside Based – Long Step-Out



Subsea Electrical Power Supply

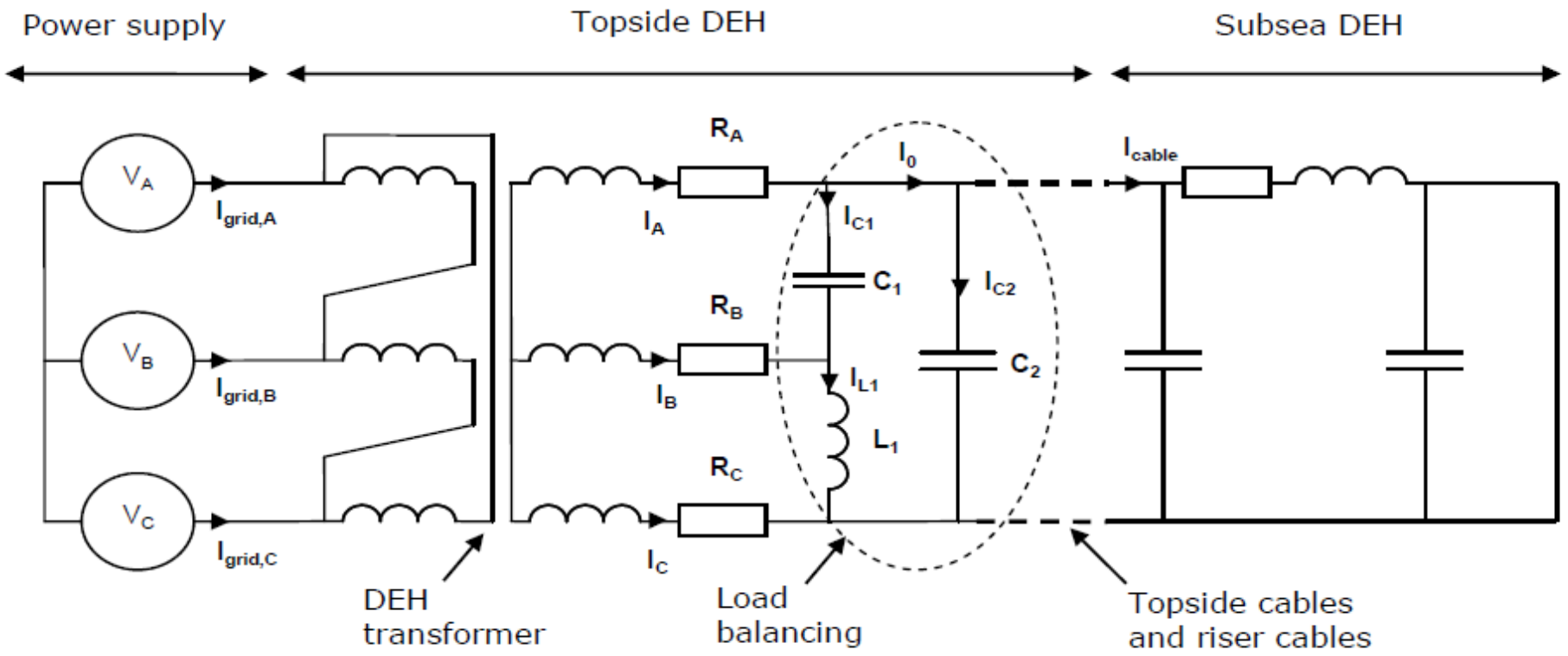
Subsea Electrical Power Distribution System





Subsea Electrical Power Supply

Direct Electric Heating Power Supply



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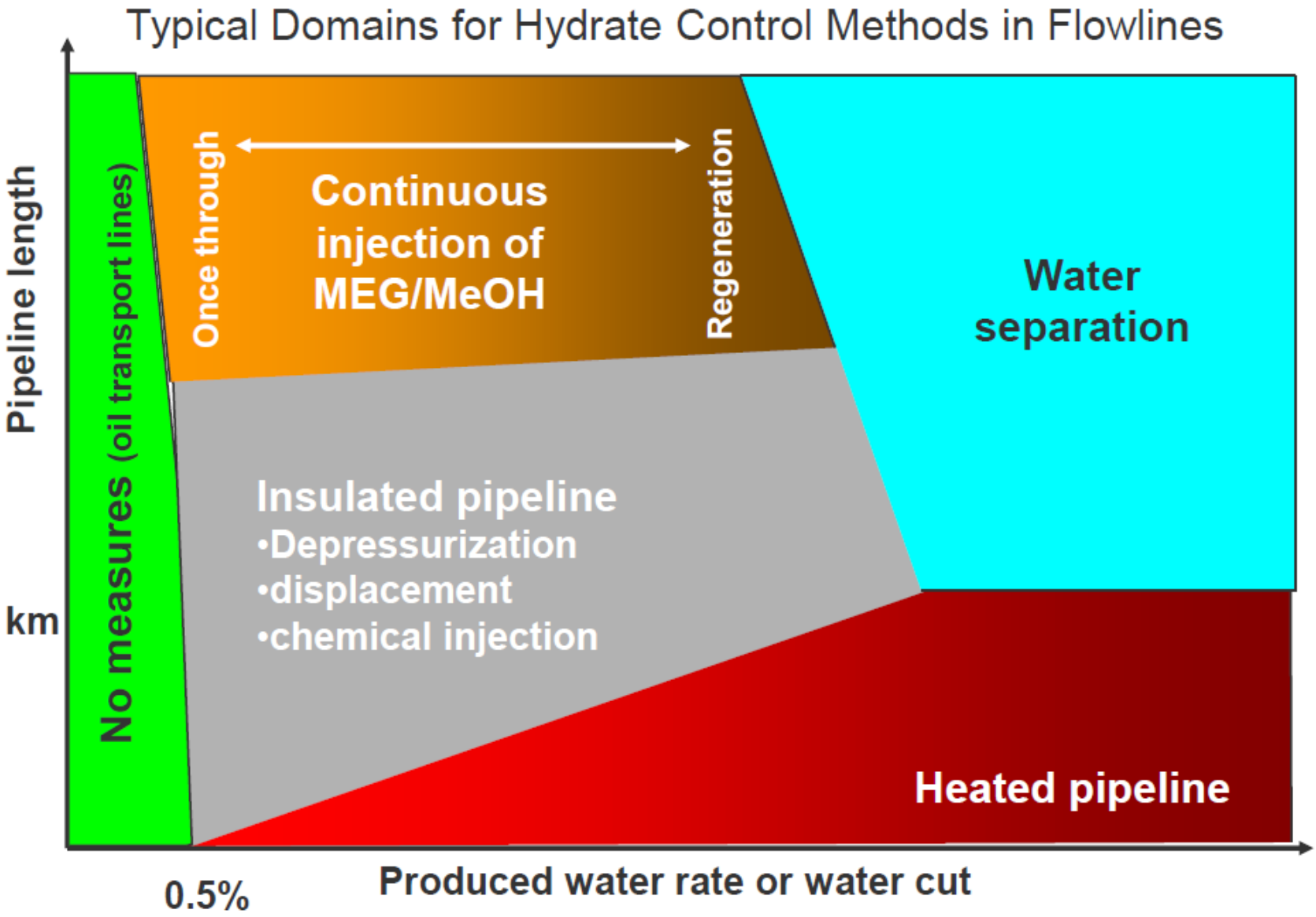
Enabling Technologies

- Flowline Heating
- Multiphase Metering
- Subsea Sampling
- Seabed Storage
- Subsea Chemical Distribution
- Electric Valves
- High Integrity Pressure Protection Systems (HIPPs)

Flowline Heating

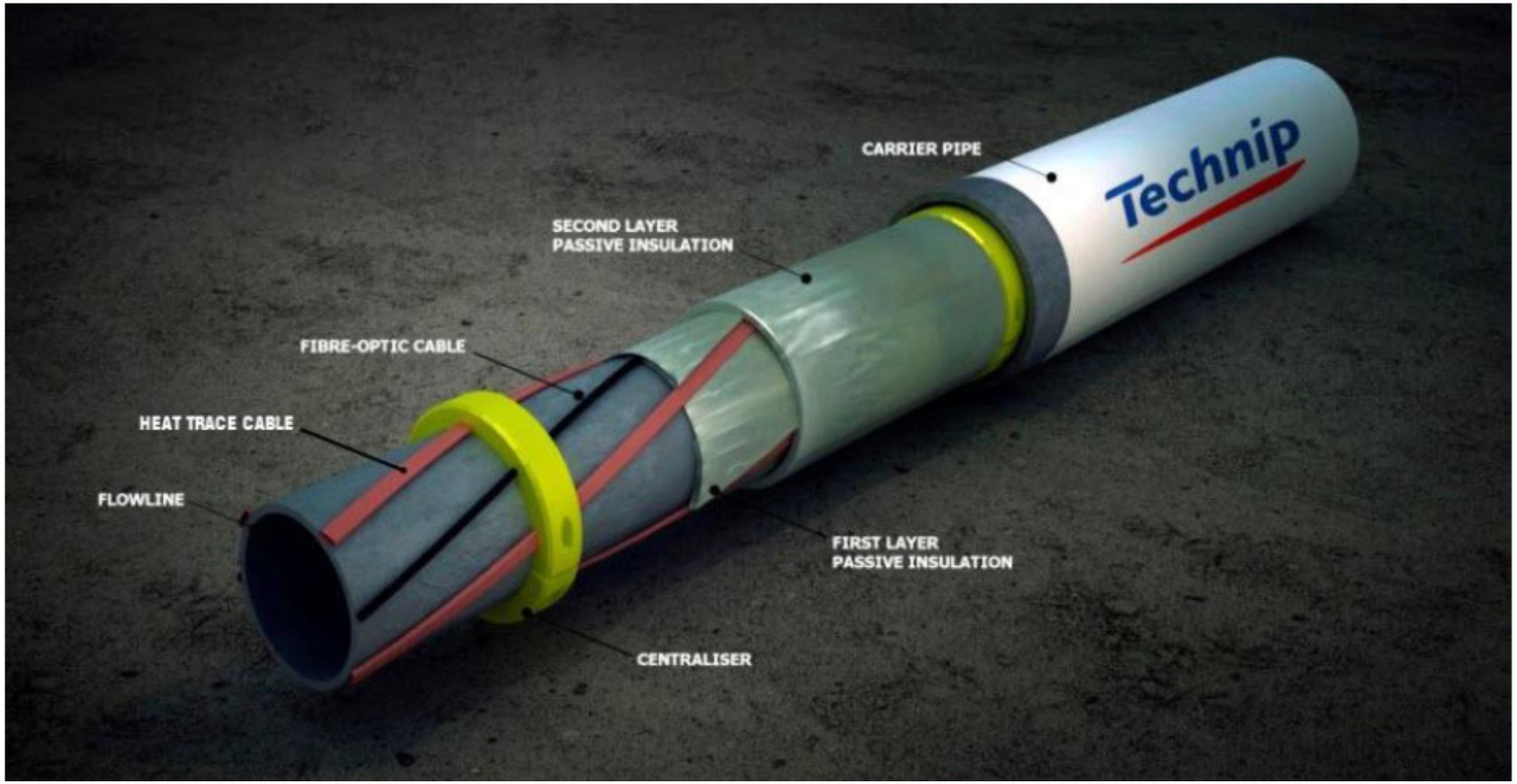
- Heat Traced Pipe-in-Pipe
- Direct Electric Heating
- Integrated Production Bundle
- Pipe-in-Pipe with Hot Water

Flowline Heating



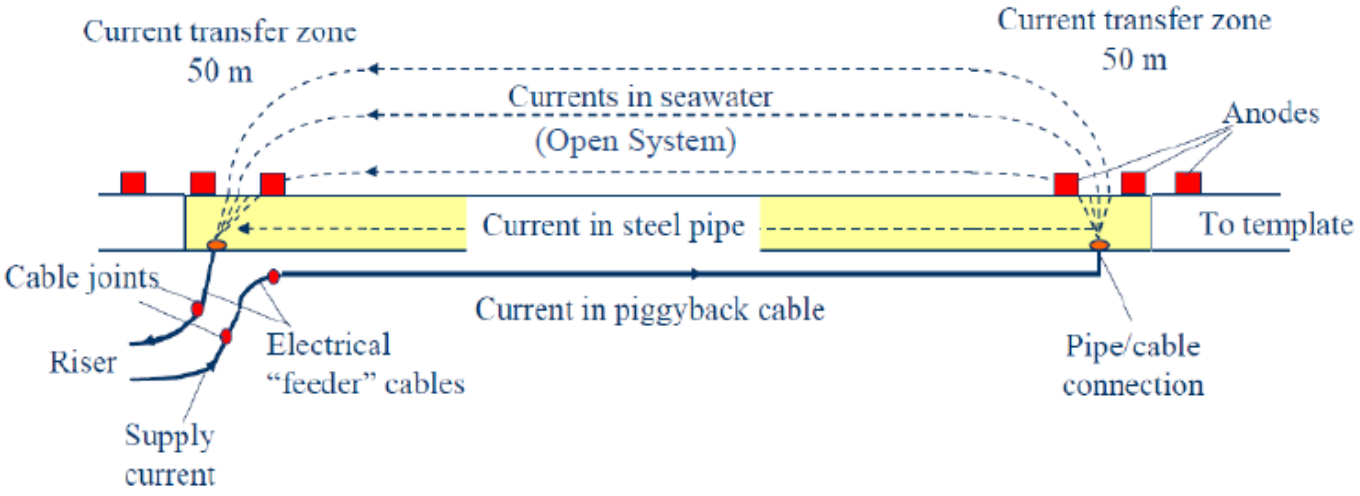
Flowline Heating

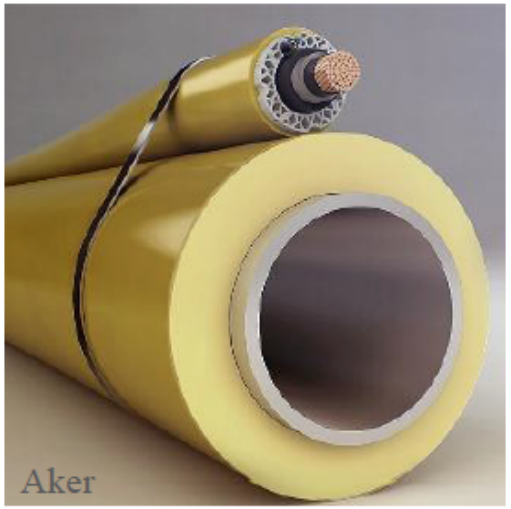
Heat Traced Pipe-in-Pipe



Flowline Heating

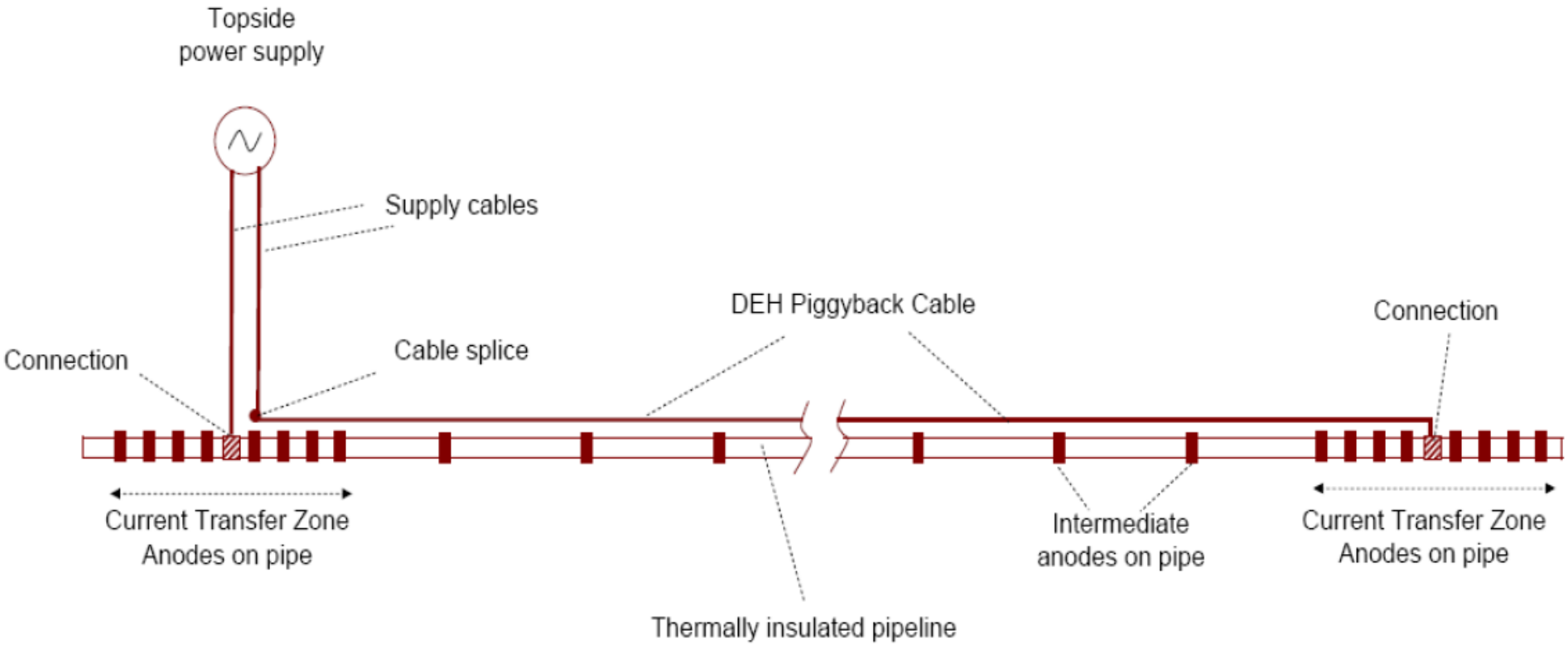
Direct Electric Heating





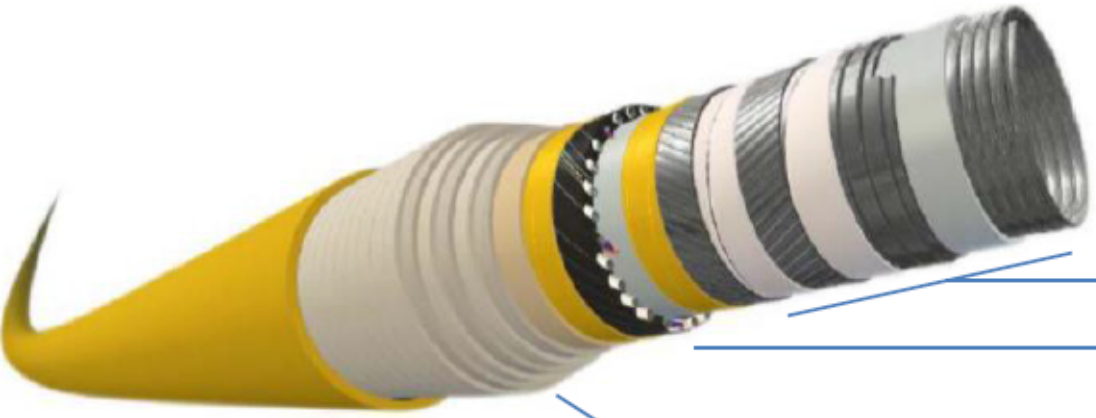
Flowline Heating

Direct Electric Heating



Flowline Heating

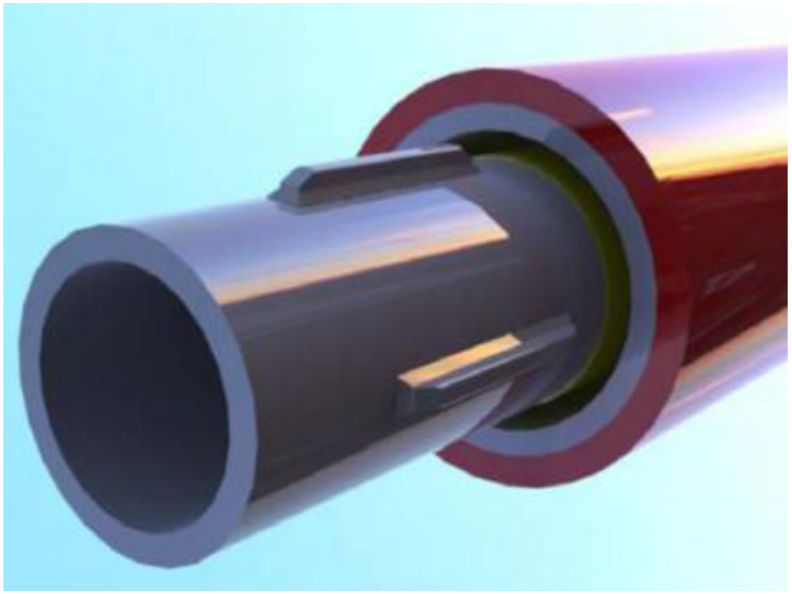
Integrated Production Bundle



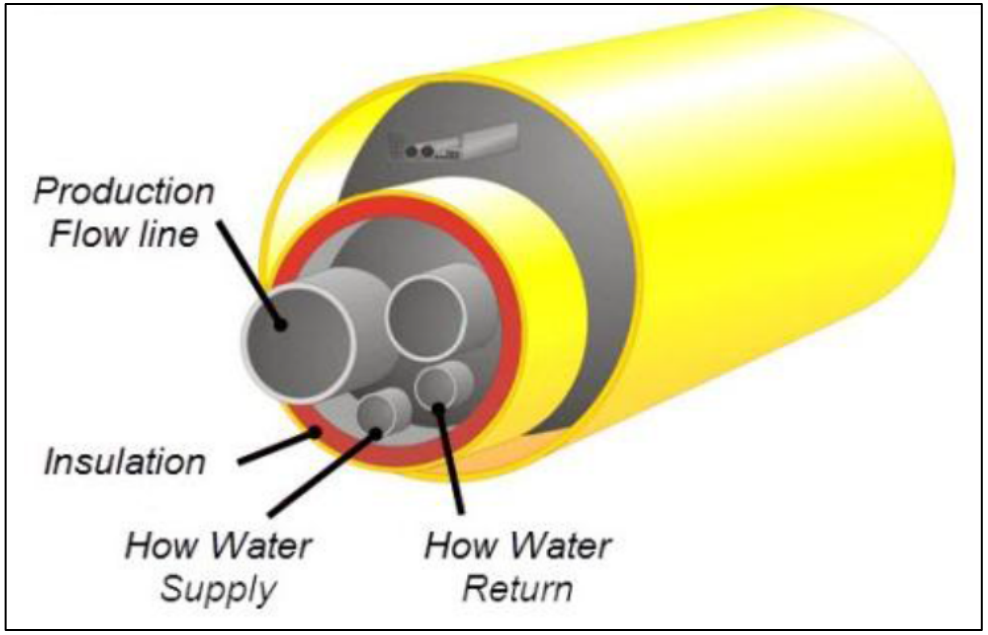
(1) Flexible Internal Flexible Structure
(2) Bundle: Electrical Tracing Cables
Gas Lift Tubes
Optical Fiber
(3) External Insulation and Protection

Flowline Heating

Pipe-in-Pipe with Hot Water



Hot Water Pipe-in-Pipe



Hot Water Bundle

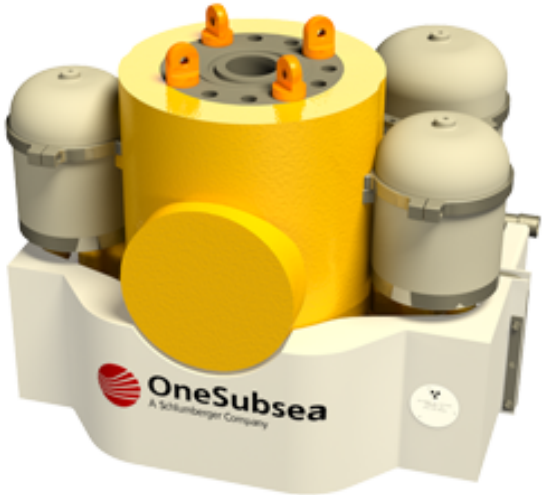
Flowline Heating

Limitations

- Subsea Manifolds
- Jumpers
- Trees

Multiphase Metering

- Allocation
- Well Testing
- Reservoir Management
- Condition Monitoring

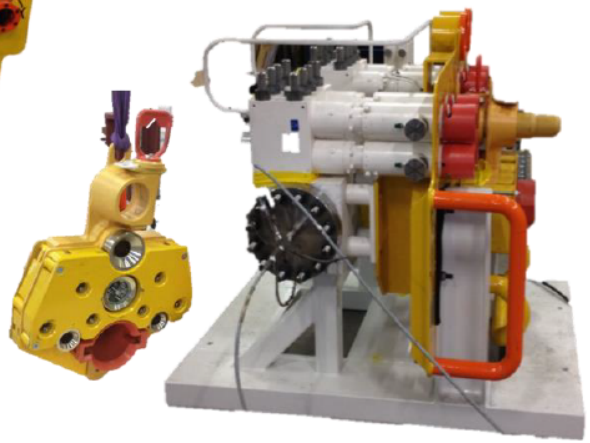


Subsea Sampling

Proserv

- 4m x 2m footprint
- < 5000 kg weight in water
- 10k psi / 250 °F
- 2500 m depth
- 2 x 12 liters

Subsea Sampling

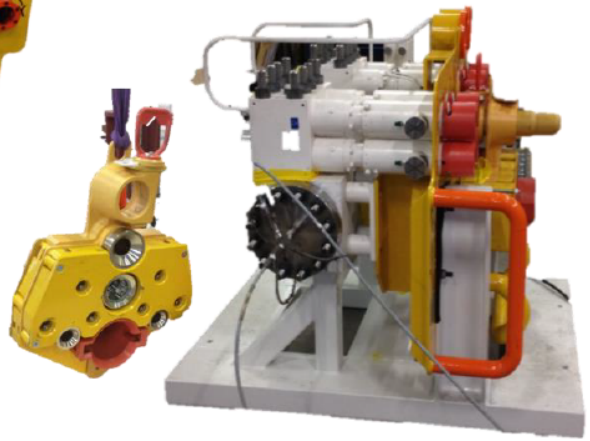


Schlumberger

Subsea Sampling

Schlumberger

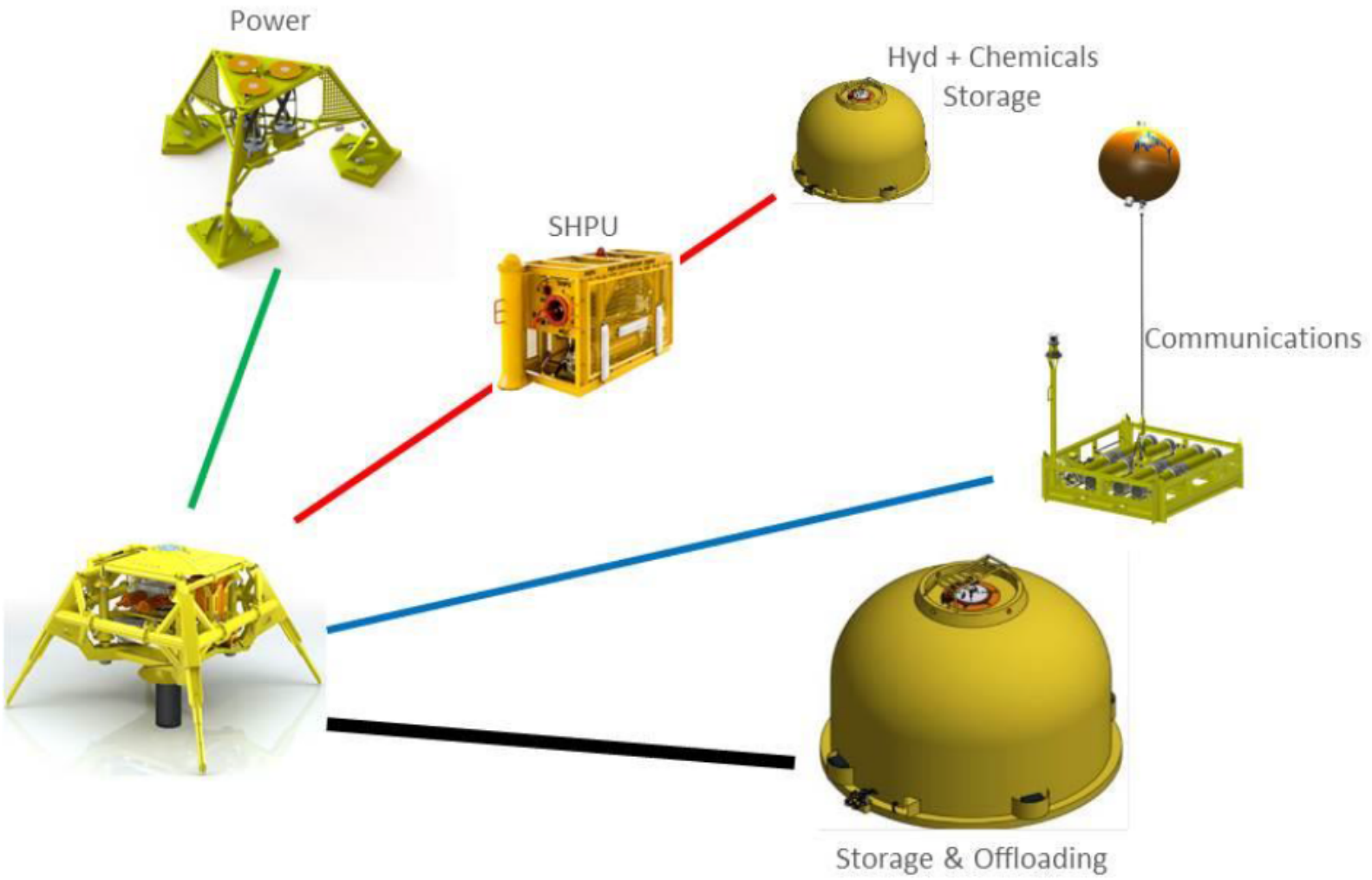
Subsea Sampling



Schlumberger

Seabed Storage

Autonomous Subsea Well (ASW)



Seabed Storage

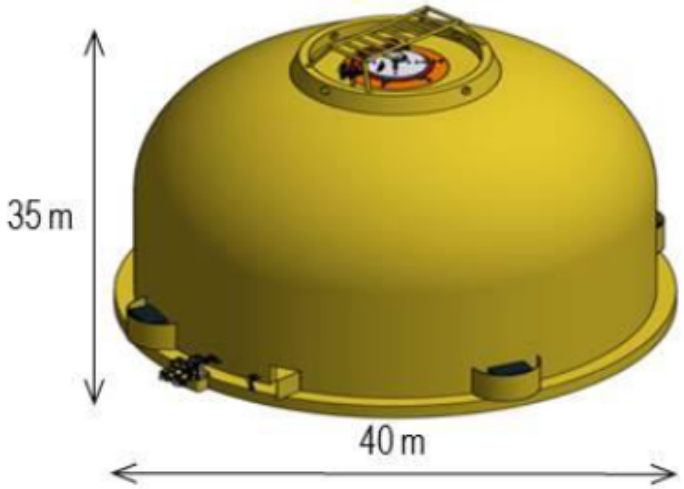
KONGSBERG SUBSEA STORAGE UNIT

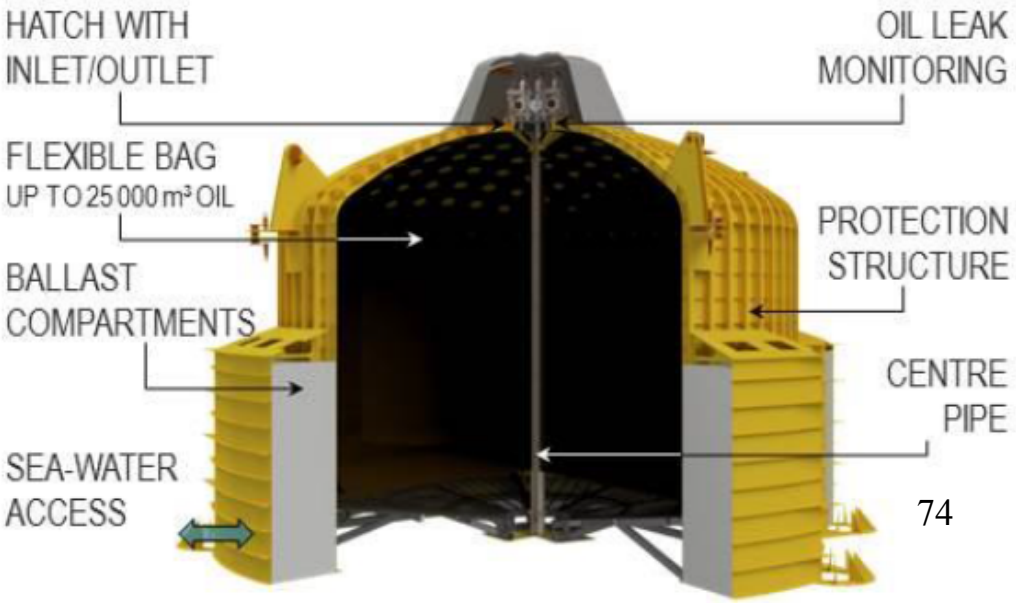
KONGSBERG

Subsea Storage Unit (SSU) is patented technology.

Kongsberg is currently evaluating using the same technology for subsea storage of chemicals and as a settling tank for produced water.

SUBSEA STORAGE UNIT, 25 000 m^3 / ~157 000 BBL ILLUSTRATION





Seabed Storage

HYDROCARBON STORAGE TANK

BIBBY OFFSHORE
because we love this business

Design Considerations

Operational
- Production constraints & contingencies
- Production rate
- Frequency of offloading
- Single vs multiple tanks
- Service life & reusability
- Fishing friendly?

Modular cells in the gravity base foundation

Fabrication & installation
- Ease of manufacture & transportation
- Installation
- Diver access/ROV interfaces
- Modular approach
- Decommissioning

Subsea Storage Tank

Seabed Storage

SOLAN SOST IN LERWICK

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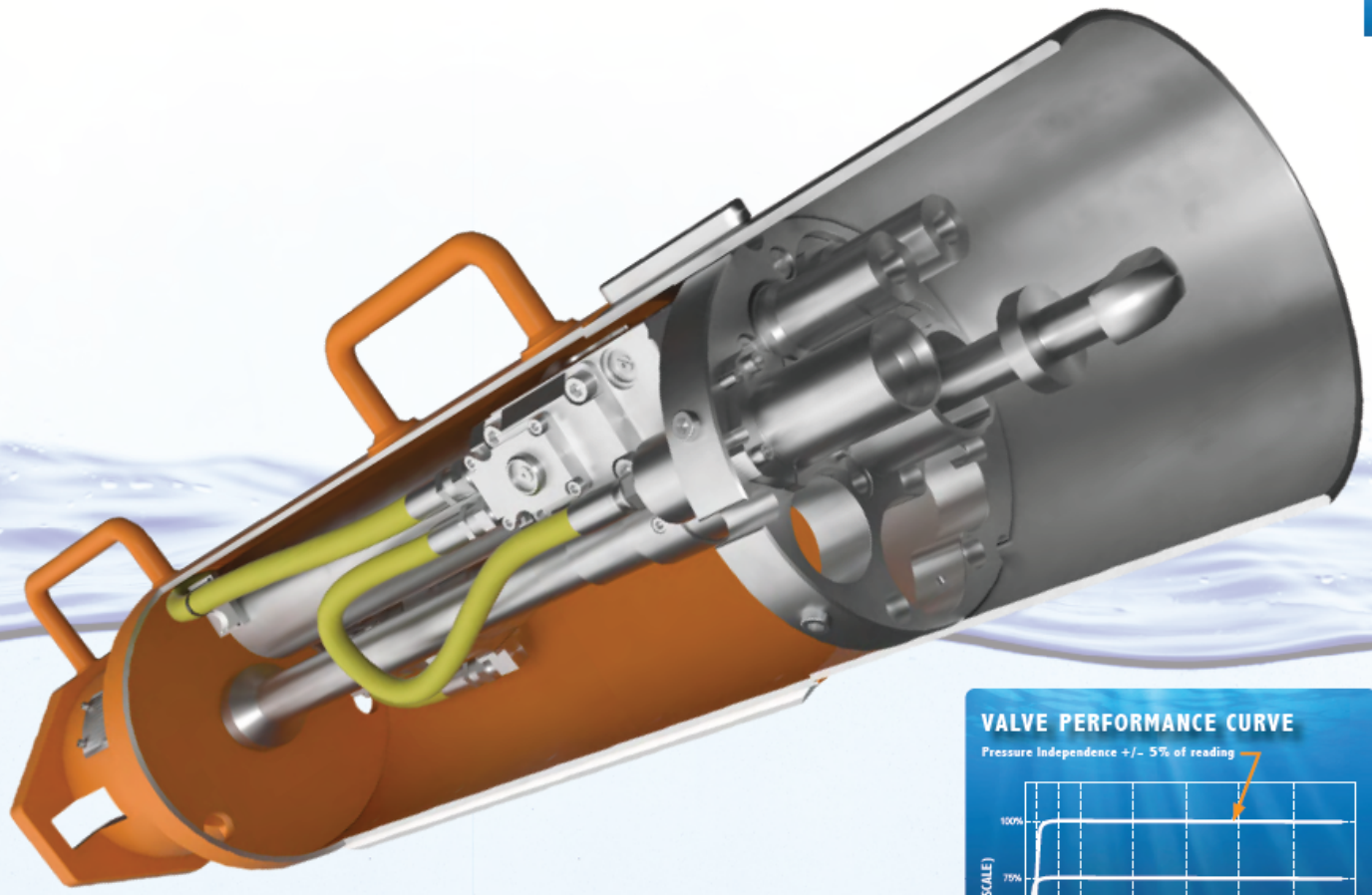
because we love this business

Subsea Chemical Distribution

skoflo
LOW FLOW CIMV

Overview



Low Flow CIMV

Chemical Injection Metering Valves

L200-R, L200-S, L201-R, L201-S

SkoFlo L200 series are the industry leading subsea chemical injection metering valves. CIMVs are used to inject low dosage chemicals such as wax, scale, corrosion, and asphaltene inhibitors and demulsifiers.

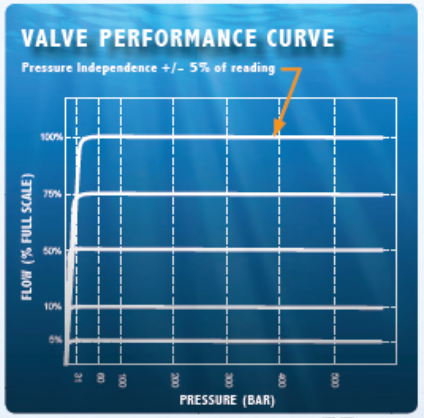
The L series CIMVs bring together the following advantages:

- Pressure independence: Flow delivery rates are unaffected by fluctuations in supply or well pressure.
- SkoFlo's proprietary pressure-balanced piston maintains constant flow while using no electric power.
- Advanced ceramics eliminate filming.
- SkoFlo's highly accurate Positive Displacement Flow Meter (PDFM) with accurate volumetric flow measurement.
- Self-calibrating: The capability to change chemicals easily as project requirements change.
- Three methods of flow measurement for built-in redundancy.

Model No.	Connection	Min Flow (GPD)	Min Flow (LPH)	Max Flow (GPD)	Max Flow (LPH)	Turn Down Ratio
L200-R	ROV Mate	2	.32	500	78.9	250
L200-S	Stab Mate	2	.32	500	78.9	250
L201-R	ROV Mate	10	1.6	1,200	189.0	119
L201-S	Stab Mate	10	1.6	1,200	189.0	119

For Receptacles see page 34

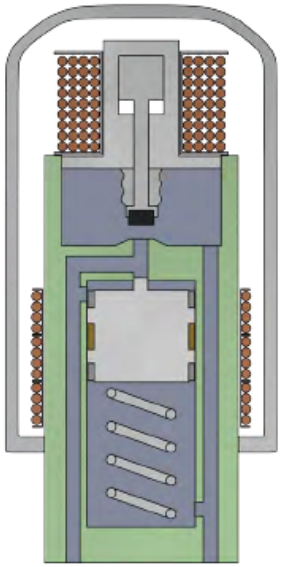
SkoFlo CIMV technology delivers precise and stable flow, regardless of fluctuations in supply or well pressure.



Subsea Chemical Distribution

skoflo
LOW FLOW CIMV

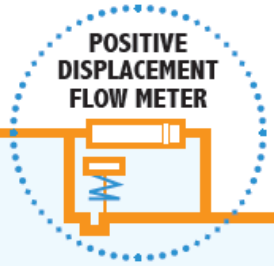
Key Features

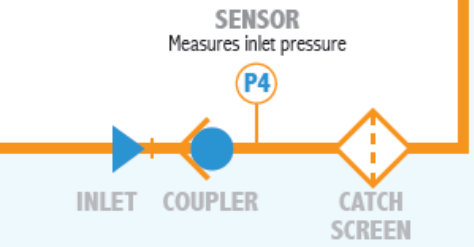


Highly Engineered Technology to Maximize Your Control

Positive Displacement Flow Meter

Positive Displacement Flow Meter (PDFM) is a device used to measure chemical flow rates that provides accurate volumetric flow measurements.
See Benefits on page 14

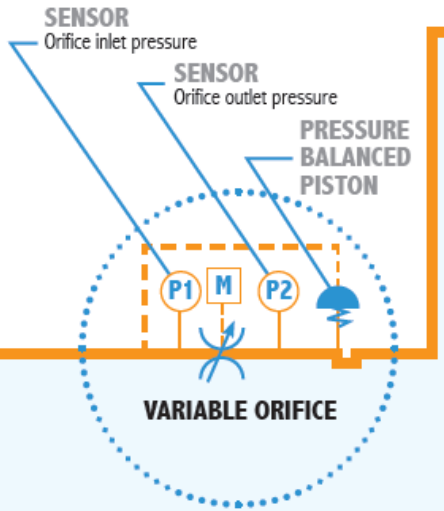




Pressure Sensors

P1 P2 P3 P4

Four pressure sensors calculate flow rate and are used for diagnostic purposes.
See Benefits on page 15

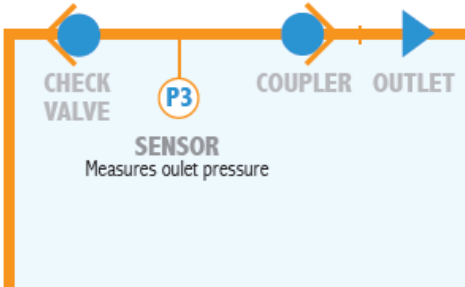


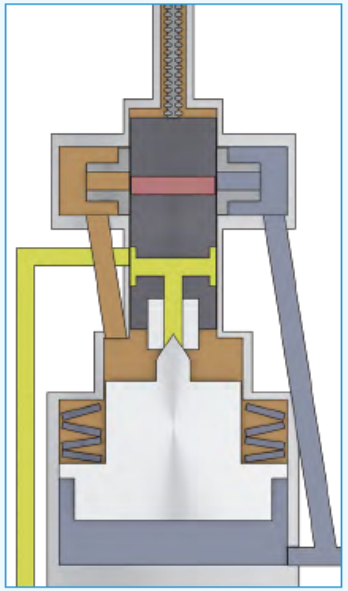
Variable Orifice

SkoFlo patented variable orifice ensures a higher turndown ratio with maximum debris tolerance.
See Benefits on page 15

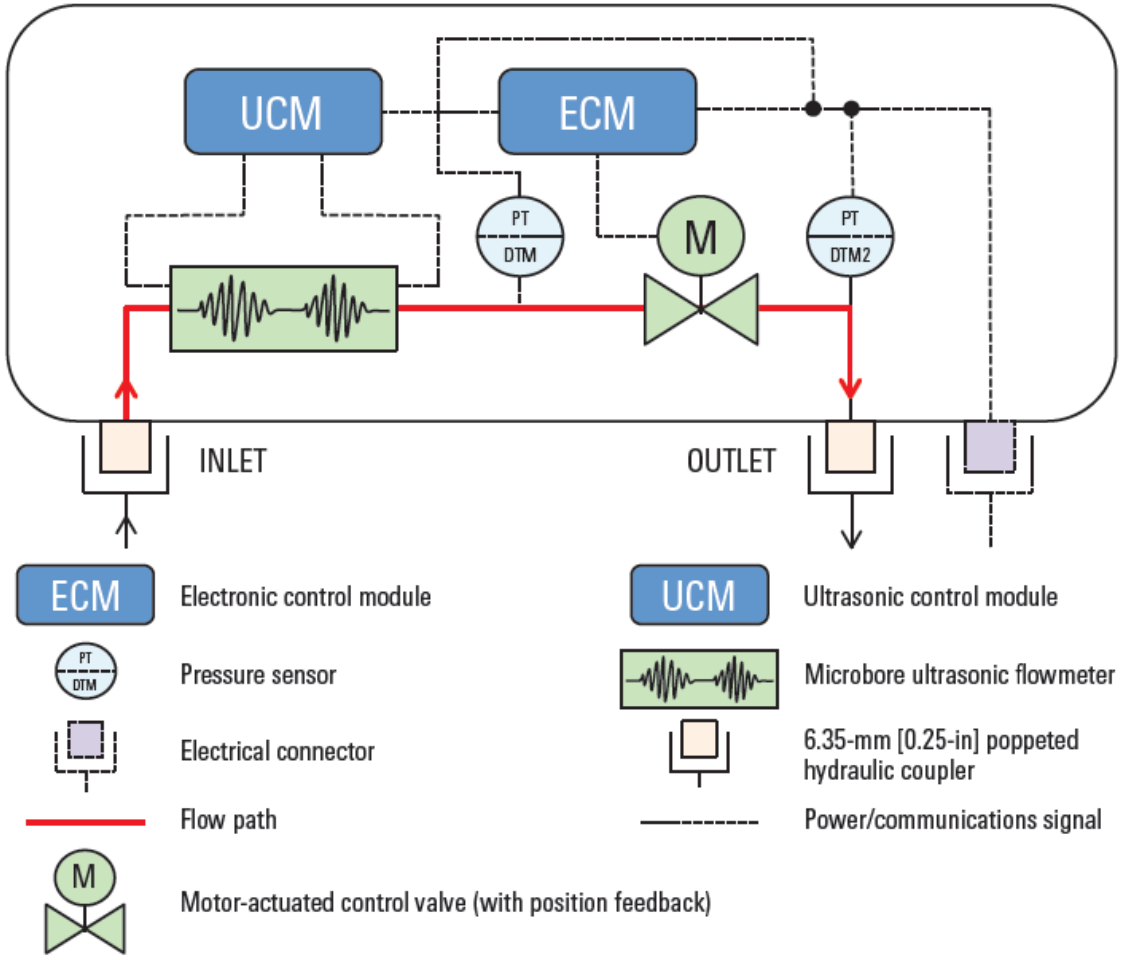
Pressure-Balanced Piston

SkoFlo patented Pressure-Balanced Piston ensures constant flow regardless of any pressure changes. It effectively allows debris to pass through the system. The pressure-balanced piston device is fail as-is without drift.
See Benefits on page 15





Subsea Chemical Distribution



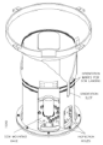
PULSE LF CIMV insert and receptacle.

Cameron Pulse metering valves

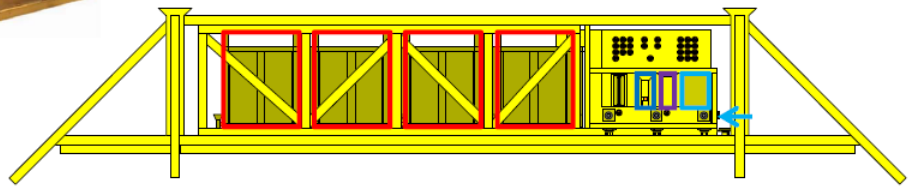
Subsea Chemical Distribution

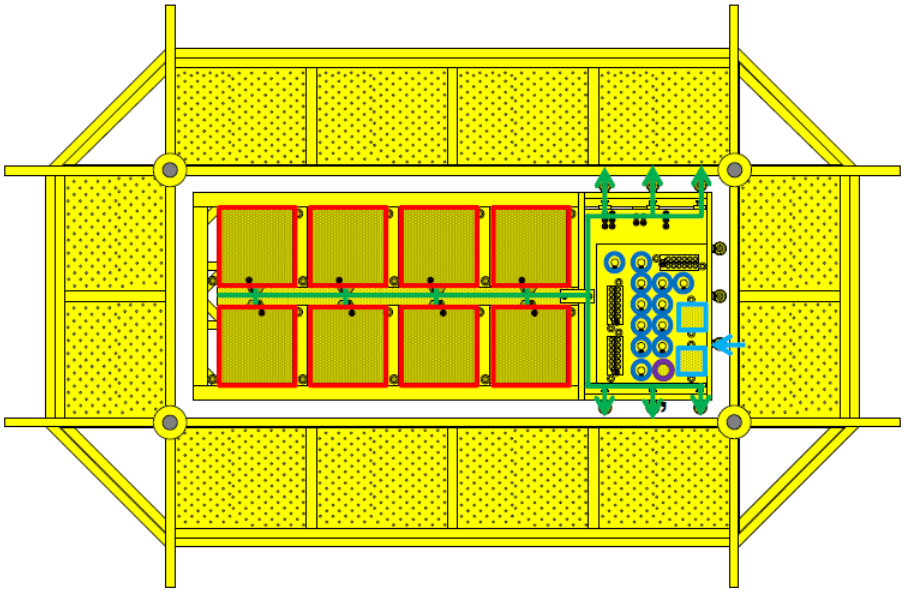
- Subsea storage tanks

- Chemical injection pumps



- Piping for chemical distribution



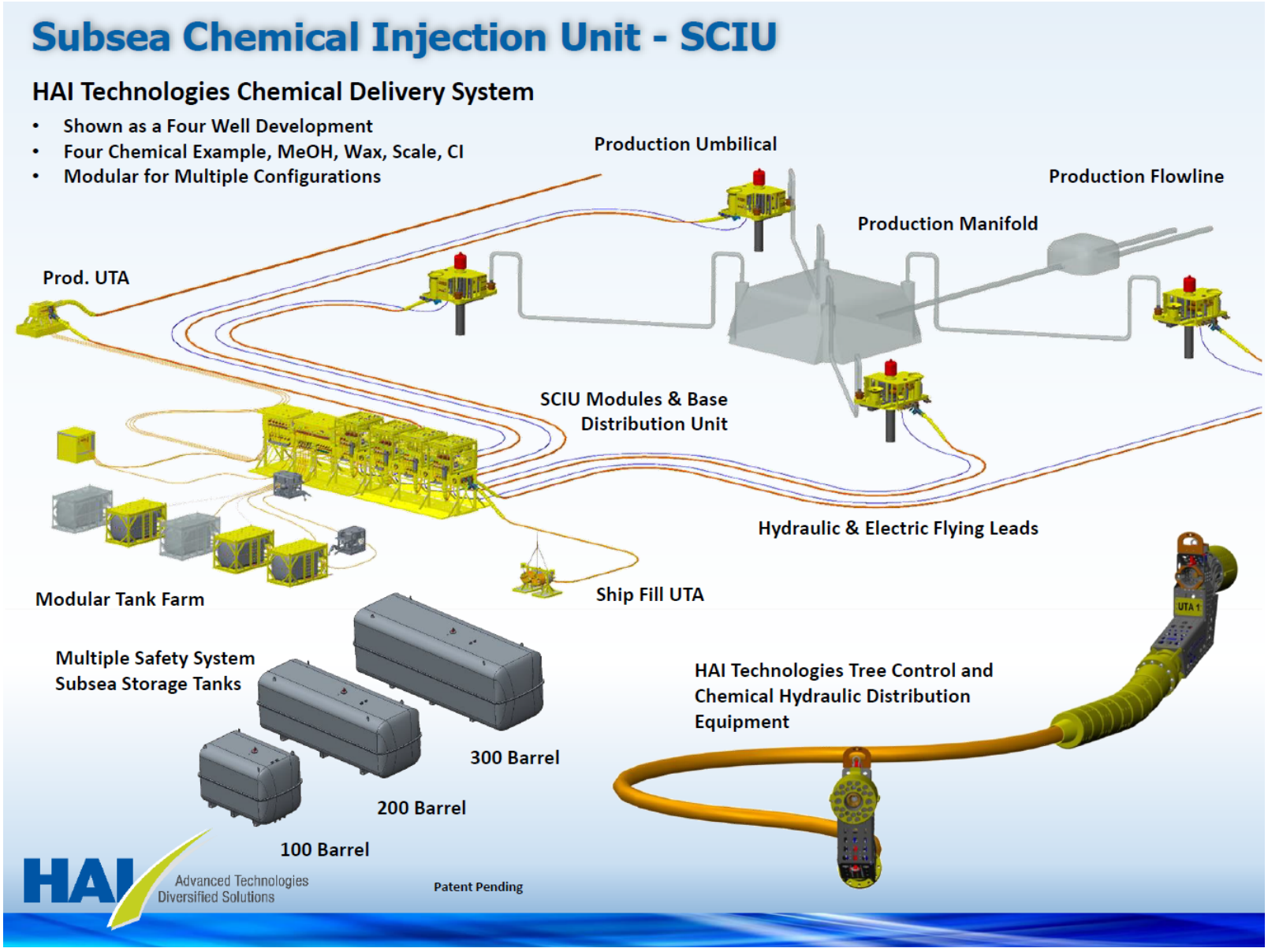


- Subsea control module (SCM)

- Electrical distribution

- Structure

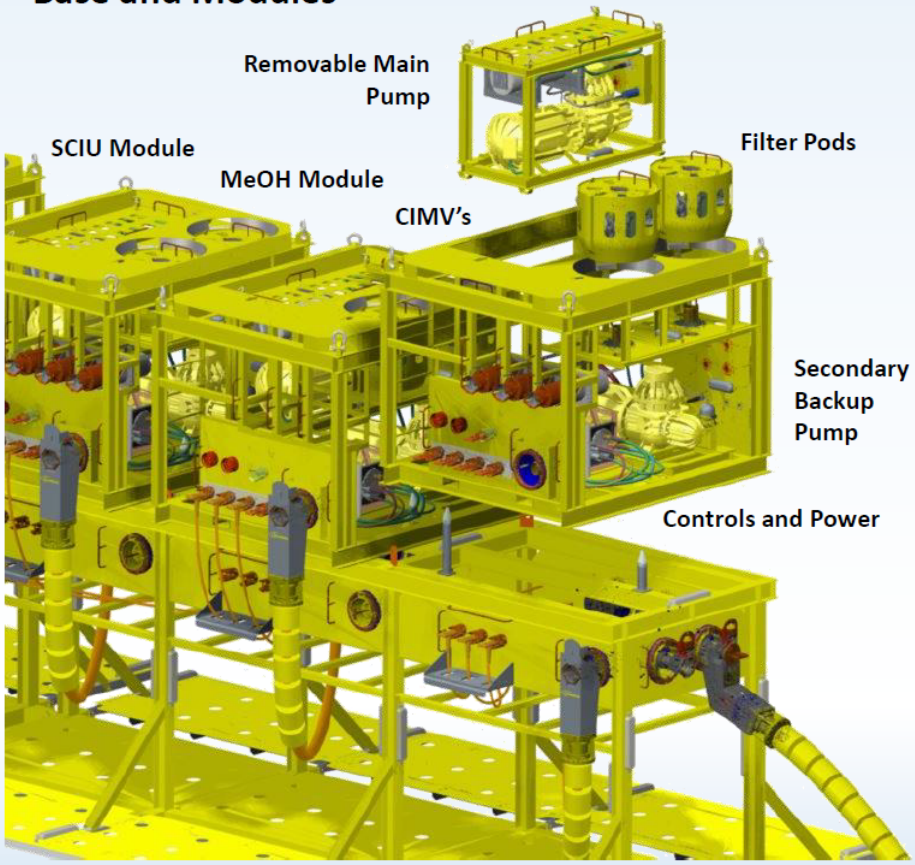
Subsea Chemical Distribution



Subsea Chemical Distribution

Subsea Chemical Injection Unit SCIU

Base and Modules



SCIU Base Module

System Overview – SCIU Module Features

SCIU Base Module

- One Control Can and one Power Can
- Power A&B inputs with auto-switchover
- Control A&B inputs with auto-switchover
- Integrated Reserve Battery System
- Includes Backup Pump
- Three CIMV for up to 6 Injection Points
- May be replaced with minimal Downtime

Removable Main Pump Pod

- Integrated Motor Controller/Soft start
- Sub-Module Removable Main Pump
- Newly serviced pump can be deployed while backup pump operates. No production downtime

Removable Filter Pods

- Filter elements ROV removable

Module Dimensions (all approx.)	Weight in Air	Weight in Sea Water
9' x 9' x 8.5'	19,000 lbs	17,000 lbs
3.2 x 3.2 x 2.8 m	8,620 kg	7,700 kg

HAI Advanced Technologies Diversified Solutions

Electric Valves

K5F All Electric Xtree

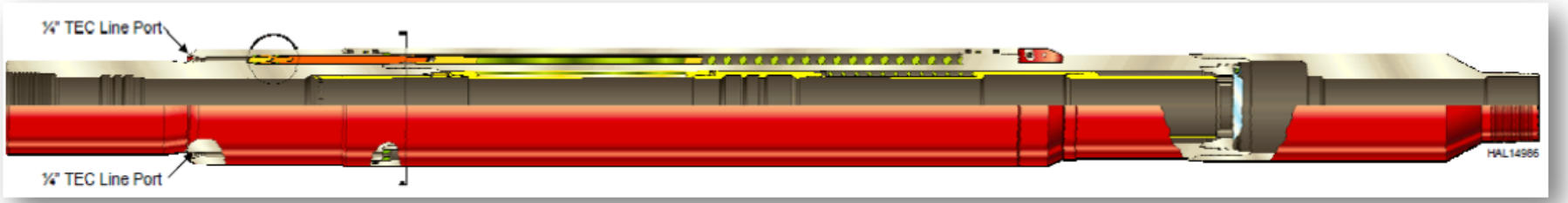
CameronDC Subsea Production System

1. Electric Subsea Control Modules
2. Electrically Actuated Chemical Injection Valves
3. Electrically Actuated Subsea Retrievable Choke
4. Electrically Actuated Production Valves
5. Electrically Actuated Annulus Valves

Electric Power Regulation and Communication Modules
(not shown, mounted on template/manifold)

Electric Valves

Halliburton electrical SCSSV (eDHSV)

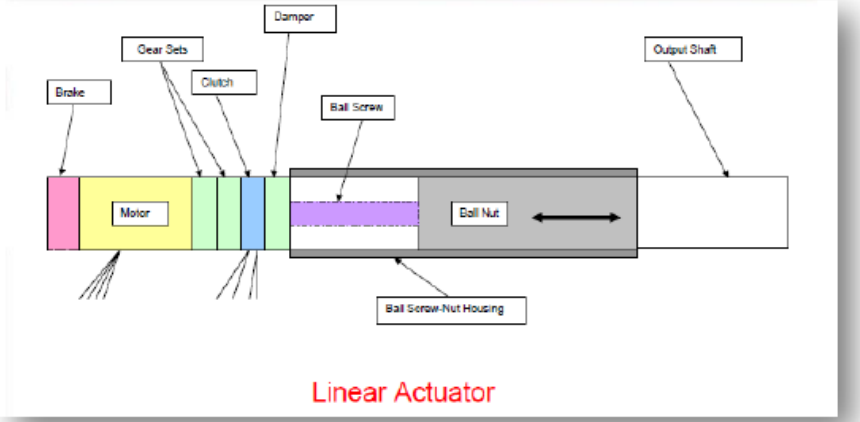


Based on DepthstarTM technology

- Field proven (in operation since 2006) – no operational issues
- Magnetically coupled SCSSV – tubing integrity maintained
- 100 % MTM – no moving seals within the tubing wellbore
- eDHSV Fully Qualified to ISO/API and extended HALT/ALT testing

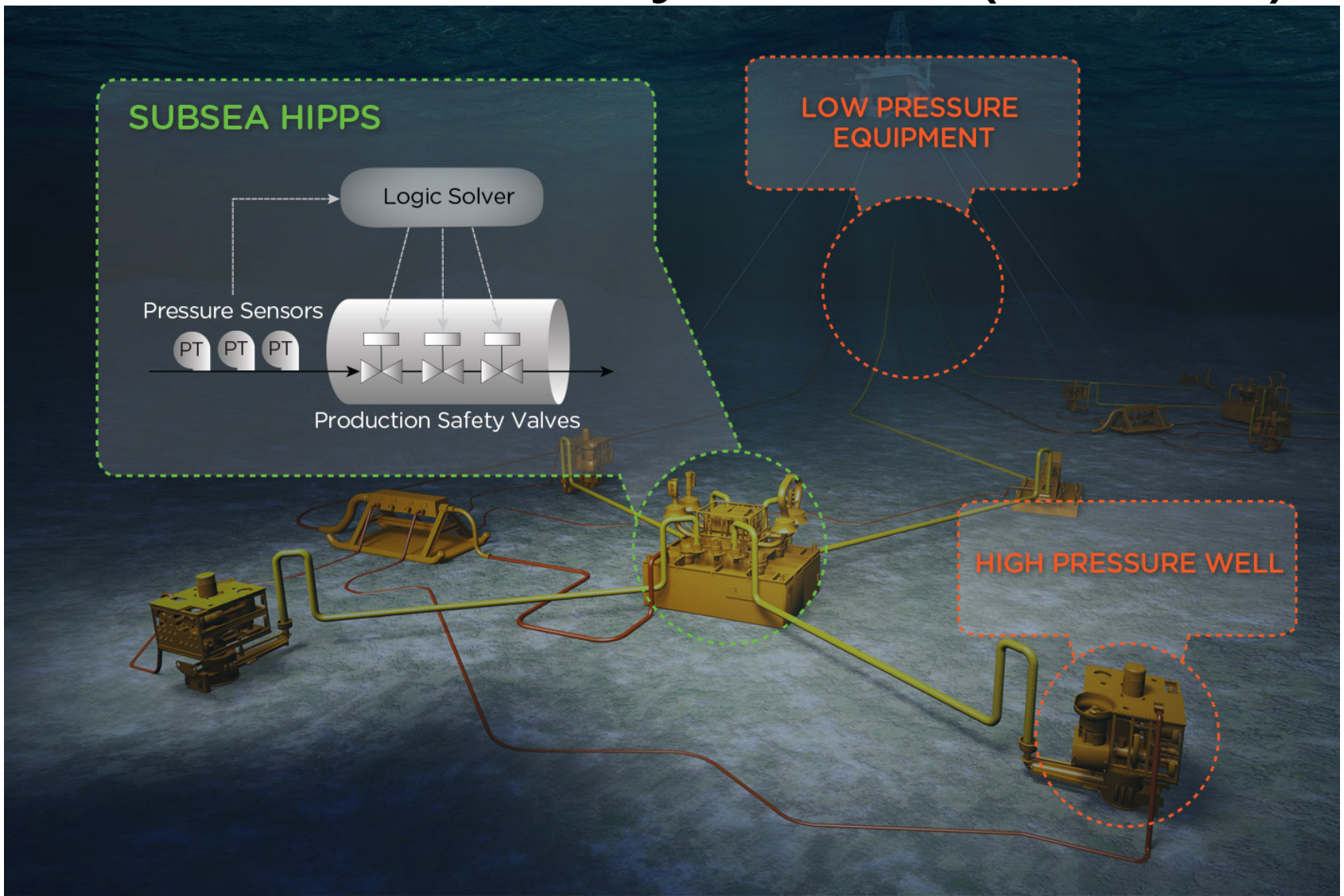
Features

- Dual electric linear actuators
- Electronics isolated from well fluids and pressure
- Position sensor – real time status
- Full redundancy in actuation and controls



Linear Actuator

High Integrity Pressure Protection Systems (HIPPs)



Contents

- Introduction and Background
- Subsea Separation
- Subsea Boosting
- Subsea Water Treatment and Injection
- Subsea Electrical Power Supply
- Enabling Technologies
- US Regulatory Requirements

US Regulatory Requirements

Additional Requirements for Subsea Pump Systems:

- NTL 2011 N-11
- 30 CFR § 250.875

US Regulatory Requirements

Key Considerations:

- Pump Dead Head Operating Pressure (maximum boost)
- System Maximum Allowable Operating Pressure (MAOP)

SUT - US

QUESTIONS?