SUBSEA SYSTEMS

Baker Hughes™

CONTENTS

01

THE FUTURE OF SUBSEA IS HERE

SUBSEA CONNECT is our vision for the future of subsea. It is focused on fundamentally improving the economics of subsea fields to unlock real value for our customers. We have aligned our interests with yours; our unique approach drives early engagement and integration across our portfolio to deliver outcomes that are fully aligned with our customers' priorities. Our portfolio influences 80% of the project cost drivers and Subsea Connect can reduce the economical development point by an average of 30% for the entire project – not just the subsea scope.

02

PROJECT CONNECT

At concept stage, we work directly with our customers to develop targeted project outcomes, and flexible project assessment. This independent planning and risk management, which integrates subsurface, seabed, surface and EPCI capabilities, radically optimizes project execution. It allows us to help customers push the technical limits on process, project schedules and delivery certainty.

03

RESERVOIR TO TOPSIDES TECHNOLOGY SOLUTIONS

Subsea Connect brings our entire portfolio solutions, products and technologies together to deliver real value in the form of outcomes. Our Aptara™ TOTEX-lite subsea system is designed for the life of field and uses standard, modular and compact components that can be configured to suit customer requirements. This approach brings shorter lead times and better value.

04

FLEXIBLE PARTNERSHIPS & COMMERCIAL MODELS

Our flexible partnership model ensures that we work with the partner best suited to our customers' specific needs – based on geography, capabilities and a range of other factors. This allows us to further meet customers' needs and improve project economics. From assessment and project design to drilling, SPS-SURF and Intervention, these partnerships reduce complexity and accelerate speed-to-market across the sub-surface, wells and subsea.

05

DIGITAL ENABLEMENT

We are layering critical technologies with next-generation digital solutions to drive greater uptime and enhance productivity.

06

SUBSEA CONNECT SOLUTIONS

Subsea Connect Solutions are outcome-based solutions that we have created to address specific customer needs and problems. These solutions provide a seamless approach that brings together the entire Baker Hughes portfolio from the reservoir to the top side. This minimizes interfaces and the associated inefficiencies delivering real value. Our ground-breaking vision for the future of subsea was driven by one of the industry's key imperatives: bringing new and disruptive thinking to the table. Read about how we've brought value to our customers through this innovative approach.

07

SUBSEA 101

Selecting the optimal products for your system needs is complex. We have frameworks to guide your subsea design.

08

DETAILED SPECIFICATIONS AND DATA SHEETS

We have structured our product portfolio with well-defined specifications that meet customer demand for vendor-led solutions, which slash capital expenditure, reduce cycle time and increase availability, thereby reducing your OPEX requirements. Our data sheets provide clear information about our product families and the available models and options to meet your needs.

01

THE FUTURE OF SUBSEA IS HERE

Baker Hughes has unparalleled capability and expertise across the upstream value chain. Subsea Connect is our new approach to connect the entire subsea development process and reduce life-of-field development costs by 30%. Through Subsea Connect, we connect the entire subsea development process from the concept phase and support customers in optimizing the initial CAPEX spend and the life-of-field, offering an improvement of up to 80% of project development costs.

WHO WE ARE

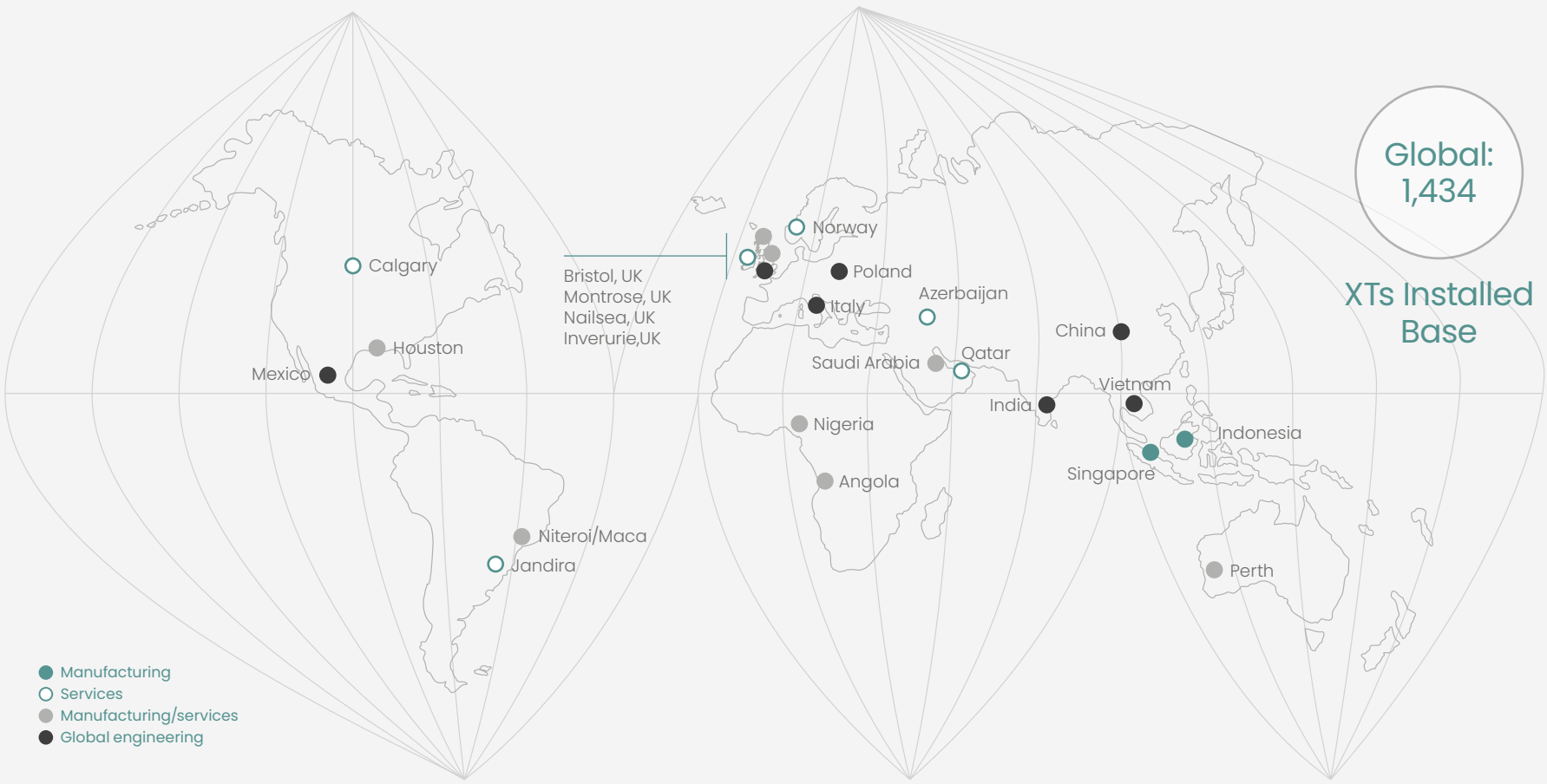
Our capability at a glance

9,000+ Employees

1,000+ Eng Capability

400 Field service engineers (FSEs)

8,000 Rental Assets



You can rely on us

As a world-class subsea life-of-field equipment and services provider we deliver optimal solutions for our customers by using smarter technology, integrated capabilities and digital innovation. We have been inventing solutions that have defined the upstream oil and gas industry for the past 114 years. Our commitment to innovation ensures we will continue to do so in the future.

Our people

Our project teams have delivered projects successfully all around the world.

Together, we have pioneered innovative approaches to solve many of the problems you face. In fact, we have invented several of the solutions in use across the industry today. That's why we are ideally placed to ensure you continue to overcome these challenges.

We have more than 1,000 engineers focused on project execution as well as inventing new products that will make our industry more efficient and productive.

“We have more than 1,000 engineers focused on project execution as well as inventing new products that will make our industry more efficient and productive.

OUR VISION FOR THE SUBSEA INDUSTRY IS BUILT ON COLLABORATION & INNOVATION

At Baker Hughes, our overriding mission is to develop and deliver competitive and innovative subsea solutions that meet the economic and technical requirements of our customers while simultaneously addressing low-carbon imperatives.

INTRODUCTION
By Neil Saunders
Executive Vice-President
Oilfield Equipment

> While using standard "make-to-order" products, we have designed our outcome-based solutions to be configured to suit individual customer priorities across the volatility of the upstream cycle.

Subsea Connect embodies our vision of a collaborative approach with our partners and customers to deliver outcome-based solutions that leverage our wide portfolio of innovative technologies and solutions.

We are committed to delivering projects that maximize efficiencies, mitigate risks and reduce uncertainties across all our subsea operations. Our target is an average 30% reduction in development costs which we aim to achieve via innovative solutions that combine technological advances, early client engagement, tailored contracting strategies and a collaborative approach that maximizes the value of our wide portfolio across Baker Hughes.

We believe disruption will continue to change the energy industry for the foreseeable future; so, while using standard "make-to-order" products, we have designed our outcome-based solutions to be configured to suit individual customer priorities across the volatility of the upstream cycle. We believe enhanced productivity can be achieved by reducing non-productive time, lowering development costs per barrel and improving recovery rates on an ongoing basis. We have also developed a suite of seamless integrated solutions that are designed to maximize recovery and extend the life of existing fields. In addition to maximising financial returns this approach has the added benefit of reducing the carbon intensity of the produced hydrocarbons (as compared to drilling additional wells).

The Baker Hughes subsea toolkit has been brought together here in this catalogue and includes the pioneering Aptara™ TOTEX-lite subsea system, Subsea Connect Intervention Solutions, Subsea Connect Seamless Tiebacks, as well as technological solutions like subsea power and processing. We also pride ourselves on embracing new business models that match today's economic realities: innovative financing, flexibile payment models, advanced project management, dedicated software applications, and integrated data analytics.

Proof through action

As always, actions speak louder than words. And one of the many landmark achievements that has been influenced by our Subsea Connect vision is the Greater Tortue Ahmeyim gas field off West Africa – see page 20 – where Baker Hughes collaborated on the front-end engineering and execution-readiness phase to define the technology and equipment scope for an initial four-well development.

This BP field some 120km off Mauritania and Senegal is in 2,850 metres of water, holds 15 tcf of gas and is expected to produce 2.5 million tonnes of LNG per year. In addition to spearheading a large-bore, high-pressure subsea system, our digital condition monitoring and asset performance management technologies will deliver reliability through the life of the field.

The project is the first in the basin to reach FID and represents the opening of a new deepwater gas value chain to monetise LNG reserves in Africa and beyond. Influenced by our Subsea Connect vision, all involved signed an integration agreement to support collaboration, drive project synergies and reduce time to delivery.

Meeting our climate responsibilities

At Baker Hughes, we believe that leadership in the ongoing transition to low-carbon solutions is both the right thing to do for the planet and will open new opportunities for business.

We are investing in smarter technologies and solutions to cut our own operational emissions by 50% by 2030 and to achieve net zero carbon emissions by 2050. We are committed to rolling annual and three to five-year targets to ensure we remain on track with a range of emission reduction initiatives across manufacturing, supply chain, logistics, energy sourcing and generation.

In addition, we continue to invest in a portfolio of technology solutions that will help our customers to reduce the carbon footprint of their operations. Technology is a core differentiator for us, and our disciplined approach to product development allows us to maintain our leadership and drive returns from our investments in this area. Teams across Baker Hughes have long adopted an agile approach to develop, test and commercialize new technologies – such as our Aptara™ TOTEX-lite subsea system that has innovative reusable subsea tree caps – so that we can bring new reusable solutions to the market faster. The results are real. The Aptara™ tree has about half the CO_2 footprint compared to the previous Baker Hughes standard vertical subsea tree.

> We continue to invest in a portfolio of technology solutions that will help our customers to reduce the carbon footprint of their operations.

Shaping the future

Under the Subsea Connect vision, Baker Hughes is focused on fundamentally improving project economics by aligning our interests with our customers. The Subsea Connect concept drives early engagement to connect all the dots from day one, from the reservoir to topsides, and through the life of the field.

Indeed, everything we do is defined by this core philosophy: help customers develop, transport and refine hydrocarbons more efficiently, productively and safely with a smaller environmental footprint and at a lower cost per barrel. We deploy minds, machines and the cloud to break down silos, reduce waste and risk, and apply breakthroughs from other industries to advance our own.

We want to work more effectively alongside our customers as our industry moves into a new era in which solutions must not only be more efficient and cost-effective, but must also meet the needs of the low-carbon imperative that is now fundamental to all our thinking.

We want to be your partner rather than just your contractor; talk to us about how our unrivalled mix of technology, people and experience can help deliver your project via a shared win-win mindset on risk and reward that results in lower risks, an optimized schedule, and the lowest possible costs.

Neil Saunders
Executive Vice-President
Oilfield Equipment

> Our Subsea Connect vision is helping to shape the future through radically optimized, outcome-engineered, life-of-field solutions

SUBSEA CONNECT

The global E&P market and the subsea sector are both recovering steadily since the downturn. FIDs are increasing and approaching pre-downturn levels, while the industry has displayed exemplary proficiency and discipline to bring down breakeven prices of projects by an average of 30%. This has been achieved through a combination of project design optimization (including well placement and reservoir drainage), simplification, deeper collaboration with the supply chain and price deflation. It is tempting to think that the job is done. Baker Hughes believes there is more to do.

SUBSEA CONNECT

Our analysis indicates that reducing the breakeven price of unsanctioned projects by 30% unlocks an additional 16 billion barrels of hydrocarbons. We need a new way of doing business – to add value to planned developments and to transform marginal, uneconomic assets into cash generating opportunities.

Subsea Connect is our approach for fundamentally improving the economics of subsea – using a uniquely integrated and collaborative approach. First, we start as early as the Opportunity and Concept Evaluation phases to develop a uniquely comprehensive and integrated approach to configure projects to suit the underlying economics. We are making better connections across the development process with technology solutions from the reservoir to topsides.

The supply chain is used to thinking only about its individual siloes, while our customers consider the complete project and its economics across the entire development when making investment decisions. We have listened to our customers, we understand and appreciate your priorities and have aligned our interests with yours. We look beyond CAPEX and consider the Total Cost of Ownership. We go beyond installation and commissioning and design for the life of field. We look beyond cost and focus on a real and measurable "TOTEX-lite" approach which is the cornerstone of Subsea Connect. It's the manifestation of the deliberate and conscious alignment of our priorities with those of our customers.

Baker Hughes is the only company in the world that can connect the entire subsea development process. From concept selection through the entire life of field. We can influence 80% of project development costs and value drivers across the entire project – not just the subsea scope. We can lower the breakeven price of the entire project by 30%, unlocking more reserves and marginal assets – making subsea projects competitive with other projects. We deliver this holistic value through the four key strategic pillars of Subsea Connect – and will continue to build capabilities in these areas:

- Project Connect
- Reservoir to Topsides Technology Solutions
- Flexible Partnerships and Commercial Models
- Digital Enablement

This is profoundly different to what's been previously available on the market. Nobody else has the breadth and depth of capabilities that we do. Second, we are taking the technology further. Lastly, this is a partnership with our customers. We are aligning our interests with yours – flexible solutions that don't lock you in. A project that has been delivered through Subsea Connect has three characteristics:

- **Radically optimized** – across the entire project and not just the subsea scope.
- **Outcome engineered** – we take the time to understand customer priorities and then adapt the approach accordingly. This is not a rigid cookie cutter approach. As an example, customer priorities could be lowest cost of development or maximum recovery or fastest first oil. Depending on the priorities there may be trade-offs and the approach may need to be adapted. Lowest cost of development may mean a lower recovery factor. We do not sacrifice standardization for this – instead, we deploy the standard solutions or systems in a different way.
- **Life-of-field solutions** – Most suppliers see their responsibilities ending at commissioning and installation whereas for our customers, that's when life begins and carries on for the next few decades. When we design our solutions, systems and products, we have taken that into account and the life-of-field factors are a big influence on our solutions, systems and products as demonstrated by our Aptara™ TOTEX-lite subsea system.

THIS IS SUBSEA CONNECT

It's about deploying the very potent arsenal of Baker Hughes wide technological solutions through the central framework of Project Connect to drive real value. We have aligned our interests with yours and Subsea Connect is the vehicle that makes it real.

While the most value from Subsea Connect comes from early engagement we also recognize and appreciate that different operators have different preferences. Some may and do indeed prefer to do some of these activities inhouse. That does not stop us from applying Subsea Connect or our technologies to the project. Our flexible approach allows us to adapt to suit the scope of work and to deliver solutions that are: radically optimized outcome engineered life-of-field solutions.

Subsea Connect: The four pillars

1 PROJECT CONNECT

The **Project Connect** pillar offers an integrated, streamlined approach to contracting from the earliest stages – see page 12.

2 RESERVOIR TO TOPSIDES TECHNOLOGY SOLUTIONS

The **Reservoir to Topsides Technology Solutions** pillar aims to transform the economic development point, productivity and lifetime yield through reservoir optimization, field design, lean well construction, topside optimization, and production enhancement – see page 46.

3 FLEXIBLE PARTNERSHIPS AND COMMERCIAL MODELS

The **Flexible Partnerships** pillar represents a shared risk and reward philosophy starting with assessment and project design to SPS-SURF solutions; partnerships provide a comprehensive solution that reduce complexity, offer integrated solutions and accelerate speed to market – across subsurface, wells and subsea and spanning the fullstream – see page 128.

4 DIGITAL ENABLEMENT

The **Digital Enablement** pillar seeks to provide better recovery, more uptime and lower risks via advanced analytics that inform field planning, production optimization, and asset performance management – see page 146.

02

PROJECT CONNECT

Project Connect is our independent assessment and project delivery process; it integrates subsurface, subsea, surface, and EPCI capabilities.

Project Connect provides the framework and approach to connect early engagement, our wide and deep capabilities and our ability to provide the optimal solutions from Concept to Commissioning and over the Life of Field.

It drives the focus towards understanding required project outcomes and then deriving the optimum associated value proposition around these. Early engagement is part of our core capability – we have invested even more in building up this capability internally. Additionally, through GCA (Gaffney, Cline & Associates) and io Oil & Gas Consulting – we can draw on unparalleled expertise in adjacent disciplines as well.

Project Connect is an integrated approach – starting at concept evaluation involving design from the reservoir up. It connects each system element, reduces and removes interface. It unlocks value and accelerates schedule by eliminating project recycle (revisiting previous steps) and reducing cost overruns. This ultimately:

- Promotes integrated end-to-end solutions
- Manages risk and limits contingency
- Provides efficiency and most importantly, certainty.

Project Connect delivers a new level of execution certainty – one that is aligned with your priorities. Working with the right partners, we can fundamentally change the realities of a given project. We believe that we are the only company that can do this.

EARLY ENGAGEMENT

For operators and the supply chain alike, the demands on our sector have intensified over the past few years. Together with the growing need for hydrocarbons is an unflinching desire to improve performance and increase shareholder value.

Early engagement, together with collaboration and commercial innovation, are key components of our Subsea Connect strategy; designed to drive outcomes across the total life of field. Project Connect, one of the four pillars of our strategy - complemented by Flexible Partnerships and Commercial models – is about engaging earlier than ever before, in an integrated manner, to maximize value through the project lifecycle. The earlier we engage, the easier it is for us to effect change.

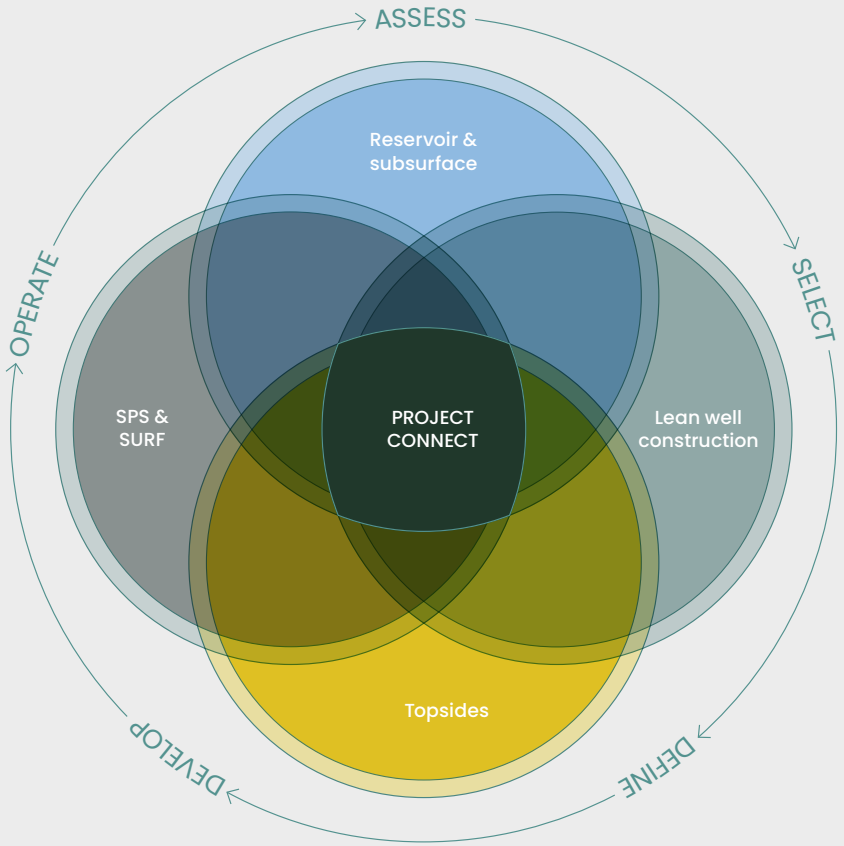
Project Connect is founded on bringing the customer on the journey from the earliest point in the project lifecycle by offering our standard, fit for purpose solutions that are focused on delivering the entire project outcome needs. This pillar is the backbone of Subsea Connect, drawing in partnerships and technologies as required.

Project Connect changes the project development process, dramatically shifting project economics by harnessing the breadth of the Baker Hughes portfolio along with the right partners, the right technology and the right commercial models. We apply an independent and flexible assessment, configuring a project to the economics and leveraging technology solutions from the reservoir to topside. The breadth of our portfolio means we are the only company in the world that connects the entire subsea development process from the concept phase, supporting our customers in optimizing not just the initial CAPEX spend but expenditure across the total life of field (TOTEX).

To further enhance the value in project delivery, we have a network of preferred partners that help us to reduce process inefficiencies and streamline communications; supported by commercial models that have been designed to reduce uncertainty, remove layers of cost and align participants to the project goals. There is no one size fits all. The key is having the flexibility to work together to find the right model and solution that best fits the project. In the end it is all about driving breakthrough outcomes... the type of outcomes that can completely reshape project economics or turn a non-viable project into an economic success.

Baker Hughes' early engagement team is comprised of industry experts who work in partnership with you from the initial stages of your project. The purpose of this team and their Project Connect approach is to achieve an alignment between your strategic targets and the project execution plans. We support you through front-end engineering and design (FEED) studies, to technology development and delivery through to life-of-field support.

> Early engagement is all about starting with the outcome in mind, to reduce risk



Project Connect

Key features

- Economic outcome assessment
- Parallel tracks to compress 'assess' phase
- 'All hands' dedicated project teams
- Independent project management ability
- Technology system configuration and project integration
- Flexible partners and solutions for the project's needs

Benefits

- Execution certainty embedded
- Collaborative and common purpose
- Speed – get FID faster
- Improved schedule

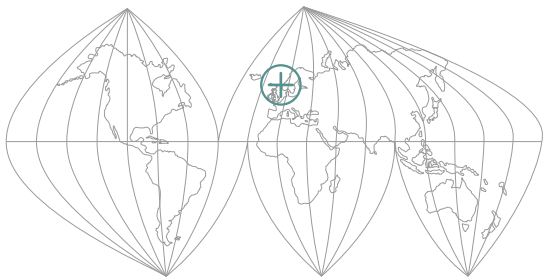
Baker Hughes credentials

- Early engagement starting at concept evaluation
- Built-in capability: Gaffney Cline & Associates, io oil and gas consulting
- Unparalleled expertise in reservoir modelling, planning, project feasibility, conceptual design, environmental advisory, and asset late opportunities
- Fullstream technology capability

CASE STUDY

TEAMWORK ADDRESSES HARSH REALITIES WEST OF SHETLAND

Baker Hughes' subsea team pursued an innovative and groundbreaking approach to partnering and outcome-based contracting to push down costs and increase certainty at Siccar Point Energy's harsh-environment Cambo field, West of Shetland.



The Challenge

The Cambo field lies in 1,050 metres of water, West of Shetland, in what is one of the harshest environments in the global oil and gas sector. Operator Siccar Point Energy is seeking to push the boundaries of development in this region, which is initially expected to feature around 10 gas-lifted production wells, supported by up to four dedicated water-injection wells tied back to an FPSO.

Key to realisation at Cambo is breaking with convention through committed early engagement with an approach in which Baker Hughes designs and integrates the wells, SPS and SURF scopes in a collaborative partnership with Siccar Point Energy.

Better harnessing of the skills and experience in the supply chain is allowing Siccar Point Energy to remain lean and agile with reduced interfaces; strong relationships result in a development that is more efficient, quicker to launch, with lower execution risks and at the lowest possible cost.

Commercial drivers dictate an approach featuring more flexibility and trust over pricing structures as well as an increased onus on performance which links financial rewards for all parties to a successful project outcome.

1,050m (3,445 ft)

Cambo's water depth, 125km West of Shetland.

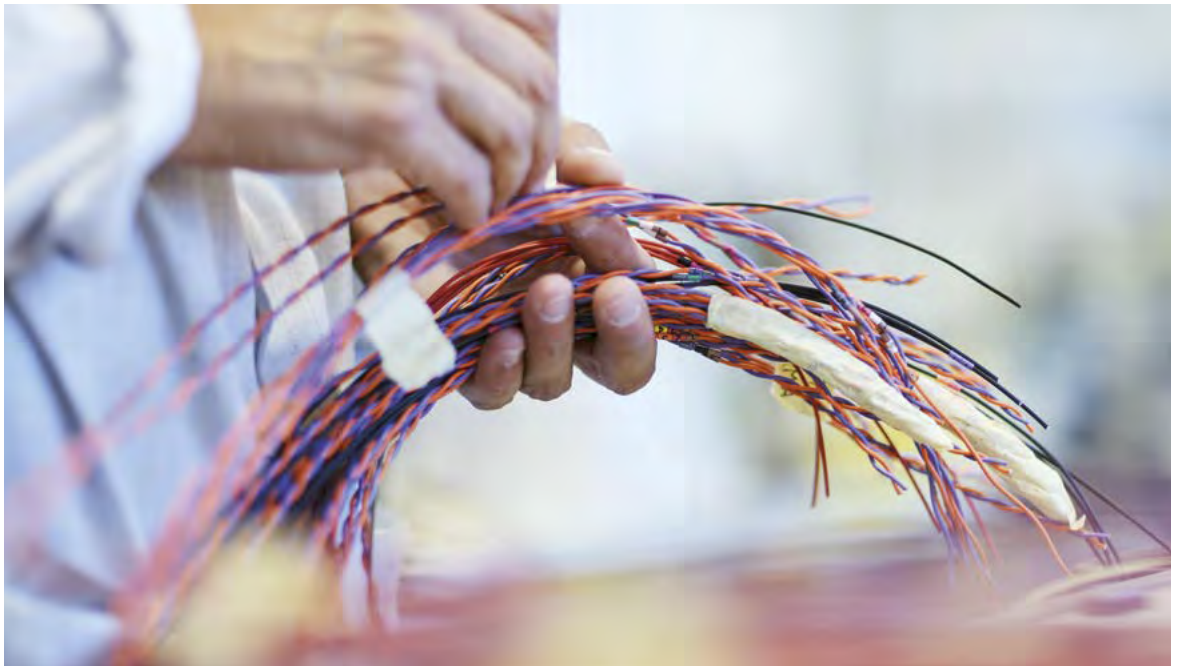
The Solution

Baker Hughes took an innovative approach, analyzing the field development from the reservoir to the FPSO and designing a solution comprising well design, drilling services, SPS equipment, flexible flowlines and a collaborative partnership for installation and commissioning services.

Early engagement with the customer allowed solutions to be tailored to their needs while leveraging Baker Hughes' innovative product catalogue, optimizing the subsea architecture with standardized solutions, emerging Aptara™ technologies and extending across traditional supply boundaries. This flexible approach also facilitated ongoing improvements based on evolving input data as subsurface and FPSO solutions continued to progress. Our willingness to challenge the traditional operator-supplier norms will result in savings across CAPEX and TOTEX – delivering a true TOTEX-lite solution designed for the life of field.

We are working closely with Siccar Point Energy to explore the potential benefits of deploying the Baker Hughes Aptara™ TOTEX-lite subsea system, including lightweight, compact vertical trees, manifolds and horizontal connections. Baker Hughes will also provide completions, wellheads, flexible flowlines and risers and industry-leading control systems.

> It is all about being a part of the project's success as partners and collaborators rather than simply suppliers.



The Benefits

Siccar Point Energy has increased certainty and reduced costs through its partnership with Baker Hughes, which allowed for a much smaller and leaner project team that could access technical guidance and robust prices, schedules and interfaces at a much earlier stage of project development.

We were able to offer continuity and cooperation from initial concept through to execution. We developed a relationship based on trust from the earliest stages, leveraging Baker Hughes' extensive experience of the field development strategy and our understanding of the client's need.

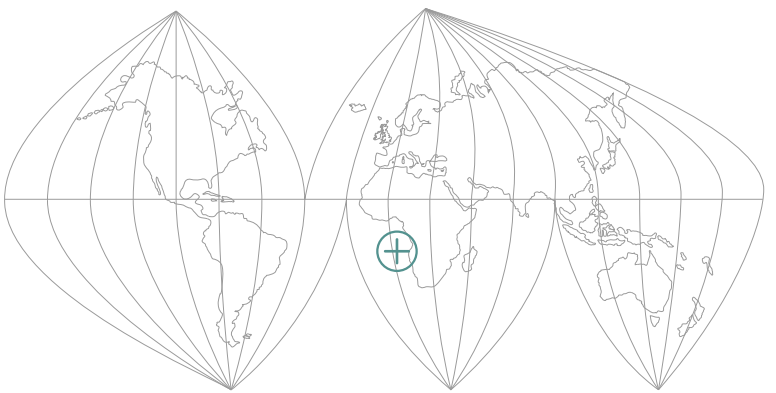
All parties committed to a win-win philosophy based on fairer models and featuring the ability to integrate subsurface and subsea scopes from initial studies through to final decommissioning, the creativity to adapt equipment and service models, and the leadership commitment to prove a new way of working.

Enabling technology
Deepwater Lightweight Vertical Trees
Aptara™ HCCS-L Connection System
Deepwater Harsh Environment Flexible Risers

CASE STUDY

EARLY ENGAGEMENT PAYS DIVIDENDS OFF WEST AFRICA

Baker Hughes spearheaded a fresh approach to FEED work to reduce costs and optimize project delivery for BP's Tortue/Ahmeyim field on the maritime border of Mauritania and Senegal, where resources are estimated at 15 tcf of gas.



The Challenge

The Tortue/Ahmeyim gas field off West Africa posed a three-pronged challenge to developer BP, starting with prolific production wells that demanded a large-bore offtake system. Complicating the flows were water depths of nearly 3,000 meters, among the deepest anywhere in the world, and a long offset to control facilities some 80km away.

Collaborative, early engagement was required ahead of the FEED studies from Baker Hughes and subsea partner McDermott to meet the demands for project optimization and integrated solutions that would reduce costs and streamline delivery. Baker Hughes focused on the subsea production system while McDermott defined the scope for subsea umbilicals, risers and flowlines (SURF) with installation enabled through its differentiated Amazon pipelay and construction vessel.

Tortue/Ahmeyim Phase 1a will initially feature four wells, some 100km offshore, connected through production pipelines to an FPSO closer to shore. The expansion of Phase 1 is expected to require around eight further wells with future phases 2 and 3 likely to take the well count to 40 to 50 in total.

15 tcf

Estimated resources at Tortue/Ahmeyim.

The Solution

We adopted a collaborative approach during the FEED process that combined the expertise, equipment and installation services of the contractors as proven in projects in Asia-Pacific, India and elsewhere in Africa. Together with the client BP, a team approach was adopted that delivered throughout the FEED process as a single unit. This proven approach was subsequently carried forward into full EPC contracts ahead of first gas in 2021.

On this project, we are deploying large-bore 7" Deepwater Horizontal Production Trees and Manifolds rated to 10,000psi working pressure – which have previously been qualified as part of a system on a separate project also in 3,000 meters water depth.

In addition, we are providing Remote Operated Pig Launcher (ROPL) technologies and are leveraging digital tools including RealTrack for more efficient project management and execution. The McDermott vessel Amazon supplied deepwater J'Lay pipeline capability.

The Benefits

Early engagement between Baker Hughes and BP led to reduced costs and optimized project delivery at Tortue/Ahmeyim, where the initial contract has since transitioned into a full EPC contract.

Workscopes were optimized across the project team, including on the supply side, with efficiencies adopted on a project-wide basis rather than confining those benefits in the more traditional fashion to individual contractors.

The development is a further proof point of Baker Hughes' extensive knowledge of deep-water, large-bore gas systems.

Enabling technology
Large bore 7" Deepwater Horizontal Production Trees and Manifolds 10,000psi working pressure; system qualified to 3,000m water depth on another project
Remote Operated Pig Launcher (ROPL)
Digital tools including RealTrak Equipment Integrity Management, Flow Assurance Management
10km of 8" production and 10km of 2.5" gas lift flexible flowline jumpers including terminations and bend restrictors

“This further cements Baker Hughes’ role as a FEED contractor with capabilities that extend to the entire subsea scope.

EXECUTION CAPABILITY

Project execution is the core of our Project Connect offering to our customers.

No two projects or customers are alike, so at Baker Hughes we listen and adapt. Every project has a unique set of challenges, like location, infrastructure, water depth, reservoir conditions or field economics. Similarly, every customer has a unique set of requirements formed from their size, ambitions, resources, finances, culture, portfolio and past experiences. We use this product catalog to support rapid execution and faster mobilization.

The first step for Baker Hughes on any subsea project is therefore to work in close collaboration with our customers and partners to understand the key drivers for project success and explore how best to tailor our approach to maximize the value we can offer. We co-locate with our customers and partners to enable optimum communication, Integrated project controls and active risk management.

Working with Baker Hughes on subsea projects provides more than just a capable supplier - it provides a committed and trusted partner. We prioritize the long-term benefits of the collective project success over any opportunities for short-term individual gains. Baker Hughes has the breadth of technical capabilities, portfolio of industry-leading technologies and appetite for commercial innovation to unlock the potential of the most challenging subsea stranded assets and harsh environments.

We bring industry-leading, robust and reliable technologies, the best in engineering and project execution experience, and combine them with commercial innovation to unlock the full potential of every subsea project we undertake. We proactively engage with customers, partners and suppliers at every stage and forge long-term partnerships built on respect, collaboration and trust. We believe in aligning ourselves with shared vision and commitment to successful project outcomes and continue to seek opportunities to reduce risk and increase value to all stakeholders through the life-of-field cycle from early engagement and design through to decommissioning.

9,000+
employees

1,000+
engineers

Product structuring

We have carried out a structured transformation of our subsea products and services to enable project configuration directly from this catalogue:

- Make To Order Products (MTO)
- Configure To Order Products (CTO)
- Engineer To Order products (ETO)

Our structured products are pre-engineered with a configurable modular design. All products have a defined procurement and stocking strategy and come with optimized manufacturing and testing processes and tools as well as standard test and installation tooling and procedures.

The structured approach provides certainty to our customers in project delivery and quality, as well as:

- Accuracy of tendered price and delivery
- Certainty of delivery time and product quality
- Minimized project risk
- Optimal operational performance
- Standard installation and commissioning methodology
- Lifetime reliability of products and systems

Sourcing

Our sourcing function manages a broad, resilient supply chain that underpins our project execution. We have established long-term partnerships with vendors across the globe to support our manufacturing sites and customer requirements. The transition to structured, repeatable products enables us to deepen our focus on fewer parts, and value engineer these with our supply chain partners to provide further cost and reliability improvements.

Each EPC project we perform for our customers is allocated a project sourcing manager and executed through our supply chain partners. These high-caliber functional experts provide a dedicated interface between the customer requirements and our supply chain. They are well positioned with both vendor and internal contacts to ensure delivery schedules are executed on time with the quality right first time. Further support is provided by our dedicated teams of buyers and experienced sourcing managers in each product line.

Manufacturing capability

Baker Hughes operates Centers of Excellence (CoE) globally; world-leading, high-tech manufacturing campuses which deliver greater efficiency to our customers by delivering new products that lower development costs and increase productivity.

Our subsea manufacturing capability is centred around our Centers of Excellence in Montrose and Nailsea in the UK. They are supplemented with regional capability in Asia (Singapore and Batam) , SSA (Luanda and Angola) and South America (Jandira and Brazil).

The Centers of Excellence in the UK have dedicated capability encompassing machining, welding, cladding, assembly, testing and controls, supplemented with R&D, technology development and dedicated training capability.

The regional execution hubs represents the “extended” factory covering selected machining and full testing and assembly capability to serve regional project execution.

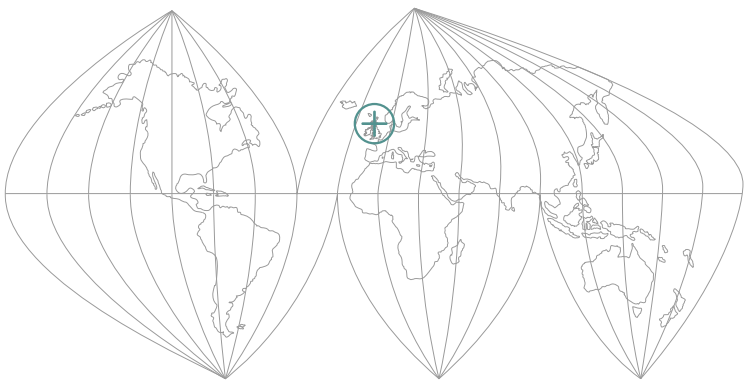
8,000

rental assets

CASE STUDY

CENTER OF EXCELLENCE

Baker Hughes officially unveiled its new Center of Excellence (CoE) in Montrose, Scotland, in June 2019. A world-leading high-tech manufacturing campus, the CoE will deliver greater efficiency for our customers by delivering new products that lower development costs and increase productivity.



From innovation to delivery

We deliver design, engineering, manufacturing, test and assembly services to advance deepwater technology for our customers worldwide. We're committed to bringing the most innovative subsea solutions to market to help customers improve productivity through the life of field. Today, our $43 million Center of Excellence enables Baker Hughes to offer world-leading product innovation from design through to delivery – all from one location to customers globally.

One of the most advanced facilities of its kind, the 35-acre campus brings together our expertise in the engineering, design, manufacturing and testing of subsea equipment with state-of-the-art training and R&D facilities. The campus underlines our international reputation for oil and gas innovation, developing the products and services that our industry needs for the future, while continuously meeting and exceeding the expectations of our customers.

Reliable fulfillment

At Baker Hughes, we work every detail and use our experience to take the integrated view we need to make continuous improvements to the way we bring our products to market.

$43m

This $43m investment underlines our international reputation for oil and gas innovation

Advanced manufacturing

Baker Hughes' Subsea Connect vision is all about manufacturing innovative products that deliver lower costs, increased productivity and a simpler approach to subsea development for our customers. The CoE represents an important step forward in this vision.

Underpinning this is our Aptara™ Global Design Center, which is an integral part of the CoE. Our Aptara™ Totex-Lite subsea system (see page 50) is designed to make installation, production and intervention more efficient and is exclusively manufactured and tested on the campus.

With facilities on site capable of handling X-tree systems up to 100 tonnes, plus a 16 meter high covered controlled environment for trial assembly, the campus has the resources needed for manufacturing both, the smallest complex components and full subsea production systems.

Brilliant Factories

At Baker Hughes we are looking holistically at how we can improve the way we bring our products to market. Manufacturing is at the heart of what we do, so we are investing in several areas where we can take advantage of new technologies – from sensor enablement, additive manufacturing, and digital design, to factory and supply chain optimization, including our digital production scheduling capability. We call this our 'Brilliant Factories' initiative and our objective is to create a new manufacturing paradigm with the ultimate aim of ensuring consistently reliable fulfilment.

35 acres

The 35-acre Center of Excellence in Montrose is one of the most advanced facilities of its kind.

FROM INNOVATION TO DELIVERY

- INNOVATION
- RESEARCH AND DEVELOPMENT
- CLASSROOM AND TECHNICAL TRAINING
- ADVANCED MANUFACTURING ENGINEERING
- MACHINING
- CLADDING AND COLD METAL TRANSFER
- SUB-ASSEMBLY
- TEST AND ASSEMBLY
- SITE, INTEGRATION AND TEST
- CUSTOMER DELIVERY

> The Center of Excellence is helping our customers to boost offshore and deepwater productivity globally.

Advanced tools and processes

The CoE benefits from advanced manufacturing tools and processes that are designed to improve efficiency and productivity. These include:

- Virtual reality tools and training opportunities to help technicians assemble equipment digitally and troubleshoot issues before construction begins
- Automation to boost efficiency on activities like welding, testing and material-handling
- Sensor-equipped machines that allow customers to view manufacturing updates and equipment test results in real-time. Once deployed, the sensors also enable Baker Hughes to analyse critical data to improve operations and increase productivity
- 3D printers to help quickly develop fully-functional prototypes of components and highly complex structures, as well as actual production parts
- Advanced digital metrology testing equipment to improve build accuracy

Emerging technologies

The CoE is Baker Hughes' center for innovation. This is where much of our R&D into new technologies takes place – whether it's new materials or new products.

Our EMT (Engineering, Manufacturing, Technology) teams are focused on identifying and understanding emerging technologies long before they have any commercial application. We're continuously looking for the next generation of innovative and cost-effective technologies that will make our industry more sustainable – and rigorously testing these in our dedicated labs.

With our R&D and EMT teams embedded alongside the engineering and design teams there are opportunities for informal collaboration and the sharing of ideas that help to identify both the challenges our customers face and the solutions they require.

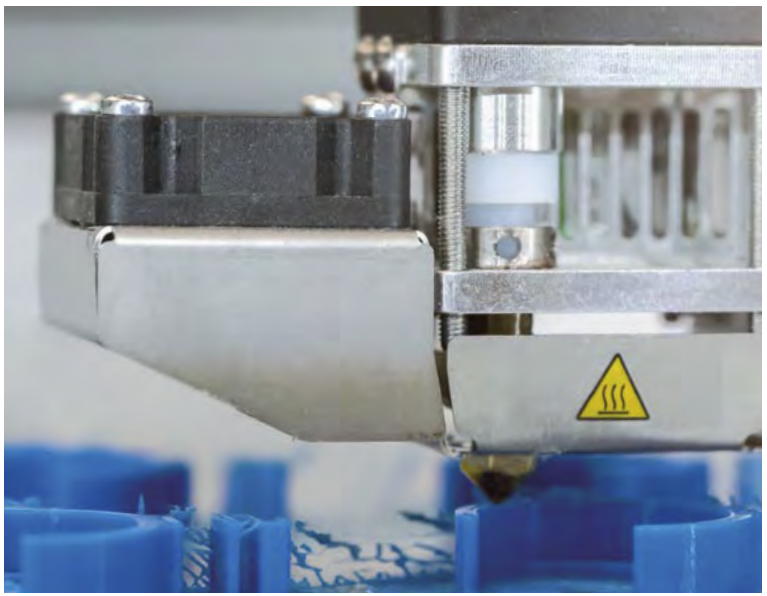
ADDITIVE MANUFACTURING CAPABILITIES

Additive manufacturing, otherwise known as 3D printing, is a growing area of Baker Hughes' manufacturing portfolio. Our additive manufacturing initiative began in 2014 with the mission to develop previously inconceivable products, while supplying parts on demand with no inventory. Baker Hughes has been recognized as a leader in both technology and talent in this field.

Several global teams are dedicated to expanding our capabilities by deploying cutting edge processes that support a wide range of metal and plastic product development. Baker Hughes leverages a large direct asset pool and dozens of industry and academic partnerships to access all seven additive "modalities", or unique additive processes.

Internally, investment has been prioritized on powder bed fusion, laser-powder directed energy deposition, and filament extrusion. Product footprint can range from the micron scale to several feet, and from a diverse range of materials including stainless steels, nickel alloys, to a wide variety of polymers. Baker Hughes' core services include access to a multidisciplinary, global team. Our material scientists develop innovative processes to continually expand the materials supported. Product engineers and technology experts work closely with clients to customize designs while optimizing existing asset performance.

Production is vertically integrated, and employs the latest digital inspection and quality assurance techniques. With the depth of both technology and personnel, Baker Hughes' additive manufacturing practice is firmly dedicated to bringing this new technology to the industry.

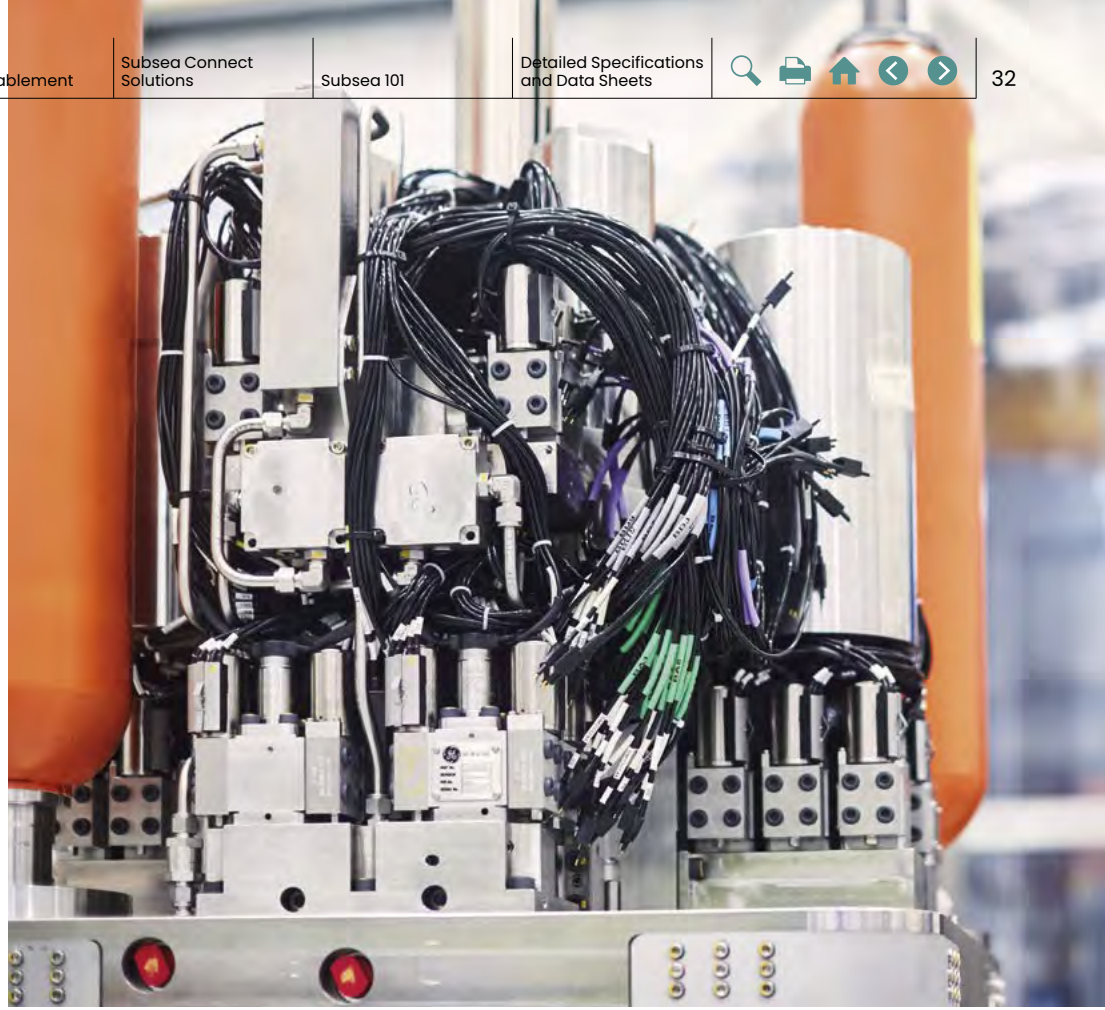


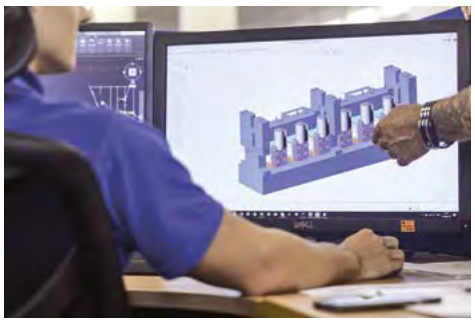
> Our material scientists develop innovative processes to continually expand the materials supported.

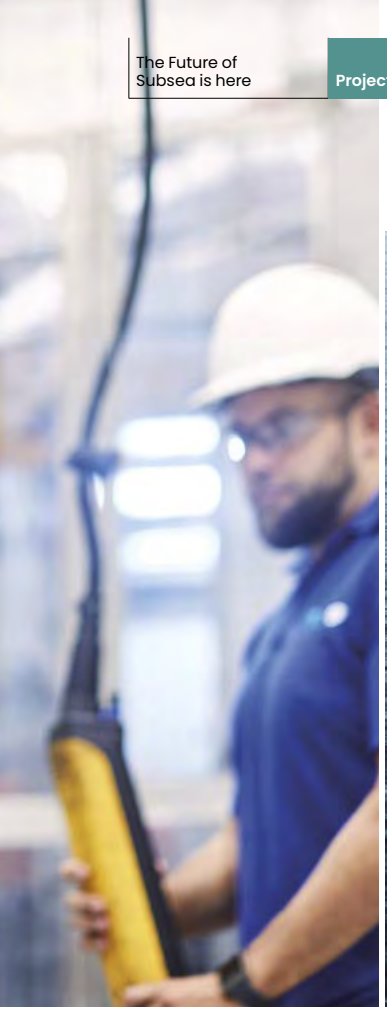
LIFE OF FIELD SERVICES

With more than 100 years' experience in the oil and gas industry, we design innovative and effective solutions that support key industry drivers; uptime, availability, production fluid recovery, safety and efficiency around the globe, leading the industry in installation services, asset integrity management and digitisation.

Throughout our history we have proven capable of executing technically complex solutions, pushing the boundaries of operation, extending the life of your field and working pressure-fuelled scenarios. We are a reliable partner, capable of supporting you through any challenge that presents.







OUR GLOBAL SERVICES FOOTPRINT

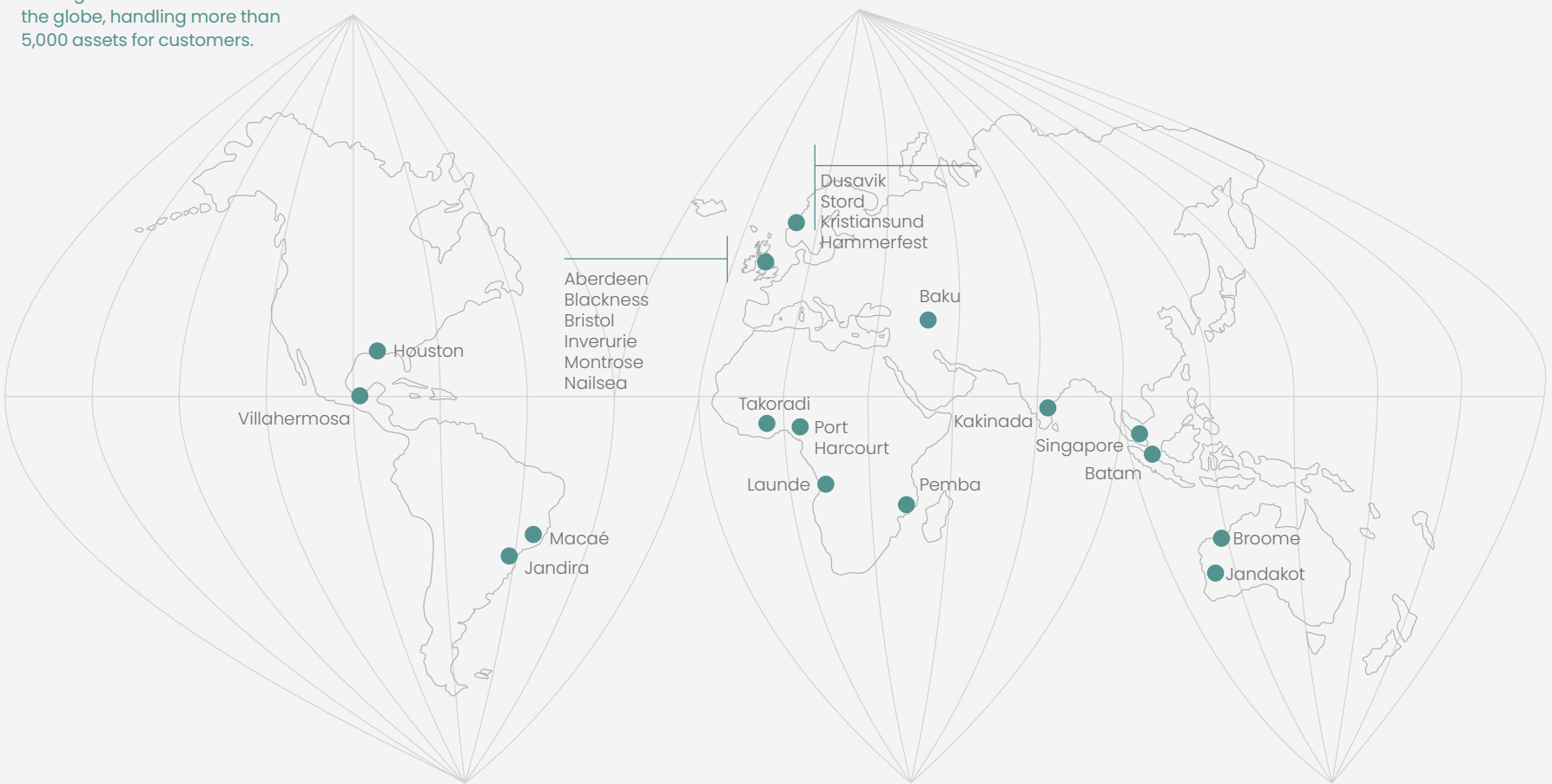
We deliver value through our global scale and local capabilities.

24 global locations, servicing more than 350 customers, with 45 active asset integrity management contracts across the globe, handling more than 5,000 assets for customers.

75 Stadiums equivalent of workshops

400+ Field service engineers

8,000+ Rental Assets



INSTALLATION & COMMISSIONING

Harnessing the experience of an OEM to offer integrated packages and meet your deadlines.

Our core offering:

FIELD SERVICES

400+ highly trained, certified and experienced field service engineers (FSEs) with 24/7 technical support where and when you need it.

RENTAL TOOLING

Our rental fleet includes in excess of 200 sets of wellhead and tree installations, work over and commissioning tooling, ROV, shallow, medium and deep water IWOCS systems and light well intervention stacks.

TRAINING

We have a long history of manufacturing and supplying equipment and supporting operations throughout the project lifecycle. The OEM experience ensures training programs are technically accurate, comprehensive and a key driver in the delivery of EHS, financial and operational performance to you.

The benefits to you:

- 20% average reduction in crew size through our use of multiskilled technicians
- Reduced deck space through integrated well access solutions (IWOCS/LS)
- 80% reduction in cost v CAPEX over three well (Wellhead & XT) campaign using our rental equipment
- 33% reduction in NPT by utilising maintenance and repair teams experienced in tooling management
- Capability to support in excess of 200 wellhead and tree installations every year

INTEGRATED OPERATIONS ACHIEVING SUCCESS UNDER SCHEDULE PRESSURE

Baker Hughes was awarded a large second phase project in the Mediterranean in 2017 with installation activities commencing in 2019. The customer had an aggressive schedule for first gas with minimal margin for unforeseen events.

We successfully installed the first batch of DHXTs with no non-productive time incidents achieved using our completions, controls, and IWOCS FSEs and rental equipment for all operations. We also carried out onboard pre-deployment testing on secondary deployment equipment ahead of the deployment date.

Onshore, at the customer base, our team worked with their project team to bring forward site receival testing on the second batch of equipment to achieve readiness ahead of sailaway dates.

- Zero NPT
- 40% of FSE team local to region
- First gas was achieved on time
- Seamless transition for customer from competitor equipment on first phase to Baker Hughes on current phase
- Owned interfaces with third party equipment to ensure no delay to schedule

ASSET INTEGRITY MANAGEMENT

Many field lives are now projected to continue producing well beyond their original design life. We create flexible partnerships that benefit all to increase uptime, minimize OPEX, cut unnecessary inventory, proactively manage obsolescence and ultimately improve and extend field performance across the entire lifespan of your project.

GLOBAL STORAGE FOOTPRINT

24 global regional hubs providing capability for

- Rapid deployment of equipment
- Localized maintenance, refurbishment and overhaul
- Testing, troubleshooting and fault finding
- Preservation and storage

INTEGRATED EQUIPMENT MANAGEMENT

Our real time, flexible equipment management programs coupled with repeatable maintenance significantly reduce contingency and mobilization spend. We can track usage data to optimize and prioritize inventory globally.

BESPOKE, FAST TRACK REPAIRS, MODIFICATIONS, CONVERSIONS & UPGRADES

We have an unrivalled track record of delivering solutions that offer a cost-efficient alternative to purchasing new. Each year we carry out around 20 XT refurbishments and maintain and/or upgrade more than 400 pieces of controls equipment for our customers. We monitor the worldwide installed base regularly to offer modified equipment to meet our customers' urgent needs.

LONG-TERM PARTNERSHIP

Our Onne facility, in Nigeria, has carried out services since drilling of a customer's first well in 2002 including completion, commissioning, operation, production, health care and intervention and workover on the field.

18 Christmas trees that were no longer producing optimally have been recovered and then refurbished. A further six trees are in progress and another four are planned.

We have a majority Nigerian workforce and they support the blasting, painting and insulation of the trees which are stripped back to individual components and then rebuilt and tested in the country.

These refurbished trees are then rerun on new wells on the customer's project, enabling the FPSO to carry on producing in excess of 200,000bbls/ day.

NORTH AMERICA XT REFURBISHMENT

In 2019, we successfully delivered a 10k deep water Christmas tree system in the Gulf of Mexico, refurbishing, delivering and installing subsea in under eight months with no non-productive time (NPT).

The XT was purchased from an operator and converted from a direct-hydraulic XT to a subsea control module (SCM) controlled XT with metering valves and a flow line isolation valve.

The tubing hangers, crown plugs and internal XT cap were also refurbished.

Assembly and testing of the whole system was completed in our local facility in Houston.

OBSOLESCENCE

Our obsolescence solutions enable significant improvements in production efficiency and operating costs including control system enhancements that co-exist with legacy infrastructure, regardless of the OEM, to both extend functionality and life of older assets.

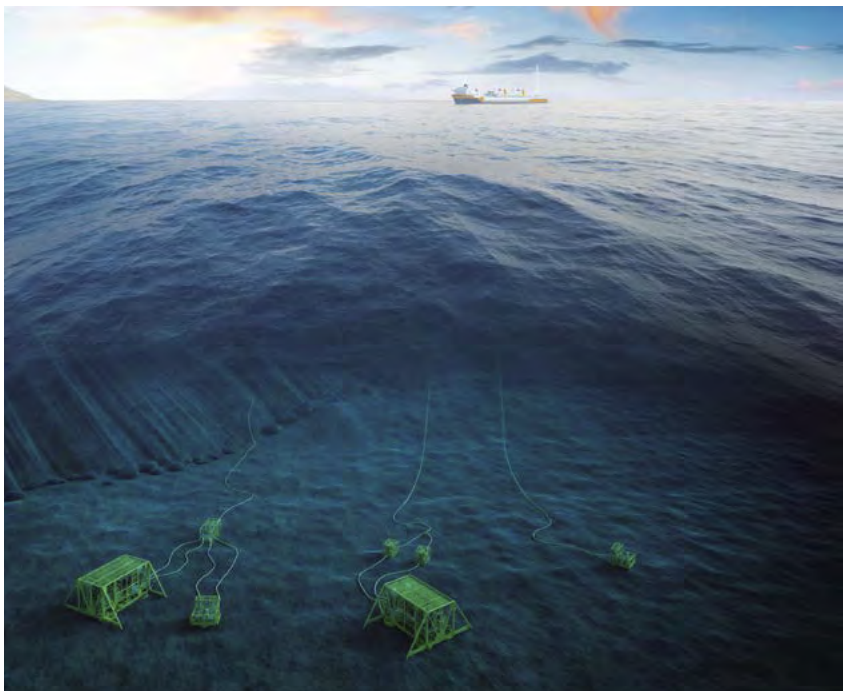
We're committed to keeping our legacy installed base current with a structured and cost-effective approach to obsolescence management and system sustainability, and have a strong record for upgrading subsea controls to our best-in-class, highly reliable, SemStar5 system — with zero failures recorded since it was introduced in 2011 — so fields with older equipment can continue operating efficiently and safely.

The benefits to you:

- 30% reduction in lead time purchasing refurbished equipment versus new
- 60% of work carried out locally
- Experience of managing more than 8,000 assets globally
- 20% reduction in inventory through optimization
- 10% lower mobilization time versus industry
- Typically £1MM production loss being avoided per incidence of an obsolete sub-system failure

PLUG AND ABANDONMENT SERVICES

When a well no longer produces enough hydrocarbons to remain economically viable, it becomes a liability instead of an asset. Our comprehensive integrated portfolio allows us to tailor our approach to each customer and asset, helping meet objectives and adhere to all relevant and local regulations. From sealing the cap rock to final wellhead removal, we help minimize costs, improve reliability, and reduce non-productive time.



PLUG AND ABANDONMENT ACROSS OEMS

We were contracted to provide the well access equipment and supporting project management, engineering, logistics and field service engineers to support a decommissioning project in the UK North Sea. With limited information available and having to control multiple vendors and mechanical interfaces we successfully accessed and abandoned 30 subsea wells consisting of 12 Baker Hughes XTs and 18 from other OEMs. The campaign was delivered within budget, five months ahead of schedule and with zero lost time incidents.

TVCM OBSOLESCENCE SOLUTIONS

We were challenged to extend the life of two fields in the Norwegian Continental Shelf, which had significant obsolescence issues. To complicate the issue further, the fields had subsea control modules (SCM) from multiple vendors.

Following the completion of a FEED we were awarded a contract for the provision of our brand new SemStar5 based controls system with new communications router and single SCM/xadapter plate solution which allowed us to install our products onto the 28 wells from multiple vendors, supporting them all until 2030.

CASE STUDY

RETRIEVABLE HIPPS PROVIDE LIFE OF FIELD ADAPTABILITY

Baker Hughes deployed a retrievable High Integrity Pipeline Protection System (HIPPS) on the Burullus West Delta Deep Marine (WDDM) asset, in the Nile Delta region, offshore Egypt. The modular set of HIPPS units has enabled the operator to further expand the field – and deliver more gas to the onshore LNG plant.

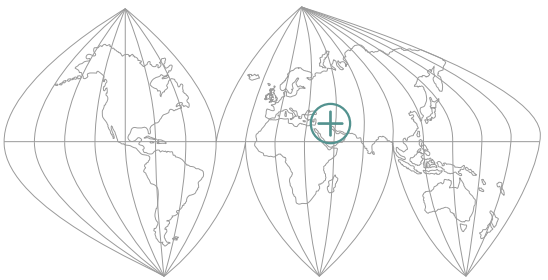
1,100 m

Water depth up to

The Challenge

The WDDM concession was discovered in 1997 and sits 120km off the coast of Egypt. Production started in 2003 and the first seven phases of development delivered 60 subsea wells in water depths between 200m and 1,100m.

More recently, during phases eight and nine of the development, the operator has seen an increase in the rated pressure for the process lines. The rating of the process lines in earliest phases was 228 bar, but with further development, it became necessary to protect the earlier field infrastructure from the relatively high (up to 289 bar) wellhead shut-in pressure (WHSP) in the new wells. In particular, a solution was required to protect the export pipeline to the onshore LNG plant, as there was then a potential risk of over-pressurising this critical system.



The Solution

The deployment of a set of retrievable HIPPS modules made sense logistically and economically. The use of the HIPPS modules allowed for the new, high-pressure wells to be tied into existing manifold and pipeline infrastructure so they can be retrieved and replaced by a passive spool as the shut-in pressures naturally decline. The integration of HIPPS components from several sources required skilful project management of specialist OEM vendors on our part.

Installation methodology and sequence was a key design consideration along with the integration of HIPPS controls with the existing control system. As part of a pressure-containing process line, the HIPPS modules need to provide a high level of risk reduction and had to be certified by a third party independent certification body to achieve the designated safety integrity level (SIL) rating.

Most importantly, in terms of long-term flexibility, the Baker Hughes integrated, compact HIPPS module can easily be retrieved from the seabed when the initially high WHSP has declined after the initial stages of gas production. The flow-line connector mechanisms are specifically designed to allow for vertical installation and retrieval of the HIPPS, without disturbing the flow line or tree hardware. And, once retrieved, and replaced with a passive pipeline spool piece, the HIPPS module can then be reused.

> All six of the HIPPS modules have been installed, tested subsea, and are currently operational.

The Benefits

The cost implications of providing new infrastructure rated at the WHSP of the new wells – described as a 'fully rated' system – is such that the operator was able to make considerable CAPEX savings by being able to continue to operate with their existing lower pressure rated facilities.

An important part of the design and deployment of HIPPS technologies is to achieve this goal, while maintaining safety integrity level (SIL) certification in a cost effective way. The adaptability over life-of-field offered by a recoverable HIPPS unit that can be removed as the reservoir pressure reduces, means this solution offers reduced capital outlay in the future when the HIPPS is reused.

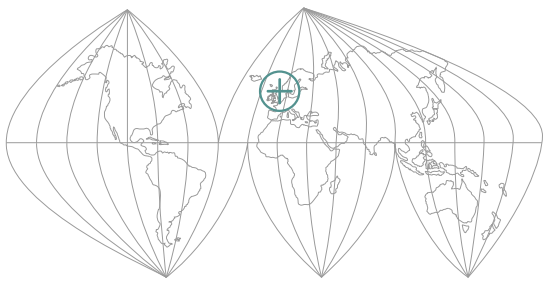
Enabling technology
Standalone HIPPS module
HIPPS module mounting base
Seabed mono suction pile
Retrievable HIPPS module
Passive spool piece (dummy module installed once WHSIP reduced)
Horizontal connection system (to ease recovery of HIPPS module)
MCS functionality to remove HIPPS from HMI following decommissioning

Note: Suction Pile & HIPPS Module Mounting Base are only permanently installed items.

CASE STUDY

UPGRADING AND EXPANDING A MATURE ASSET

Baker Hughes was engaged in 2010 to collaborate on the planned expansion of a major Norwegian North Sea asset – first developed in 1999. We delivered an integrated portfolio of services from concept engineering and equipment upgrades to the supply of new build trees, controls and flexible pipelines.



The Challenge

Phase I of this field was completed in 1999 with Phase II following in 2001. Subsea consisted of four field sites with 17 wells tied back to a FPSO. Phase III proposed adding five new wells – the first since 2001. A life-of-field expansion was granted to 2025 and a substantial scope of work was developed with the customer which identified the following key issues:

- Tree design with a desire to reuse stock trees from 2000
- Controls capacity and obsolescence (Baker Hughes SEM3 variant), no new umbilical planned
- Topsides master control station upgrade, HPU capacity, turret space constraints
- Intervention equipment (WOR/WOCS/IWOCS) refurbishment and recertification
- Legacy equipment versus current company specification compliance

> The subsea control module adaptor plate enabled the ModPod SCM to be fitted to the new trees and also retrofitted to the legacy trees subsea.

New design emergency disconnect package incorporating latest ISO 13628 specification including retainer valves to prevent pollution in the event of an emergency disconnect.

Subsea control module adaptor plate provided the ability to retrofit the ModPod SCM to legacy trees still subsea and to the new trees being built.

The Solution

Baker Hughes rose to this challenge and mobilized teams across the UK and Norway, project managed by a core team in Dusavik, Norway. We drew upon a wide range of expertise and execution skills from across the Baker Hughes subsea portfolio. In addition, multiple sub-vendors were screened and selected to support the team in the refurbishment phases including a major recertification of the riser joints.

Phase III was initiated following early engagement with the customer which saw budgets, financial and commercial terms maturing over several months through small, but highly collaborative teams culminating in the award of the full project scope.

Reuse, refurbishment, conversion and recertification were the customer's initial requests – all to keep project costs to a minimum and meet a tight budget and schedule. FEED gap analyses were used to identify the mandatory specification changes to legacy equipment. In addition the customer was required to seek concessions from their global engineering specifications to adapt legacy equipment certified under the original project development licence.

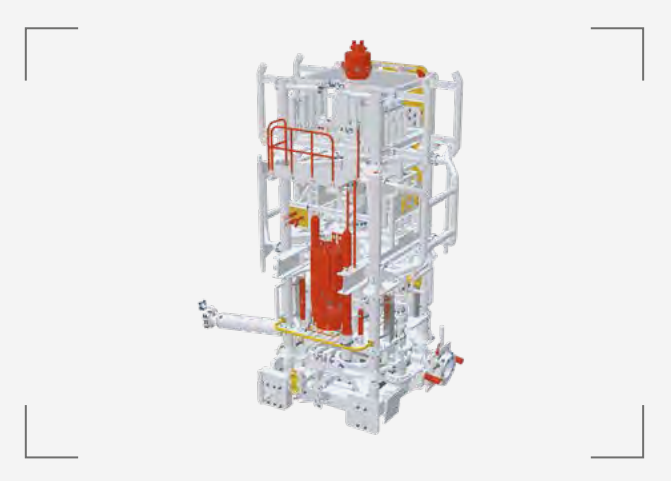
To supplement the reuse of equipment, the project also identified the need for new build equipment to replace obsolete parts or to meet the needs of the planned drilling campaign.

The new build equipment supplied included two trees, work over riser (WOR); running tools; and legacy control modules (SEM3), installation and work over control system (IWOCS); and new ModPod subsea control modules with a virtualised software package and adaptor plates to be fully interchangeable with the installed subsea and new build trees. New build components were, where practicable, designed in accordance with ISO 13628 and Norsok U-001 standards, (valves to ISO 10423 / API 6A).

Hierarchy of applied requirements

Enabling technology

2 x vertical subsea trees including chokes, tubing hangers, controls mounting bases, sensors and harnesses
5 x flowbases including ROV installed flowline hub connection systems
6 x MS700 wellhead systems, conductors and connectors
5 x subsea control modules (SCM) complete with the award-winning SemStar5 subsea electronics module
IWOCS system complete with umbilical, landing string and associated tools and connections
10km of 8" production and 10km of 2.5" gas lift flexible flowline jumpers including terminations and bend restrictors
MCS functionality to remove HIPPS from HMI following decommissioning



Stack-up sketches of the EDP, LRP, XT, flowbase with flowline connector, tree mounted UTA. Tree is shown with the Modpod SCM installed on an adaptor plate to provide full interchangeability with legacy equipment subsea.

The Benefits

Delivering a substantial subsea expansion project like this required the combined efforts and skills of the entire Baker Hughes product portfolio. We rose to the challenges presented by the customer to interface legacy equipment alongside the latest technologies – thereby maximizing their assets while minimizing the need for any significant subsea equipment recovery and upgrades

The upgraded system was not only fit-for-purpose, but ensured that any legacy equipment that fails in the future can be replaced on a simple plug-and-play basis. The client now has the framework in place to deliver any future upgrades at a low engineering cost.

ENABLING TECHNOLOGIES

Subsea control module (SCM) adaptor plate provided the ability to retrofit the ModPod SCM to legacy trees still subsea and to the new trees being built. The solution in this application was used to fit our standard square module onto a legacy round mounting base.

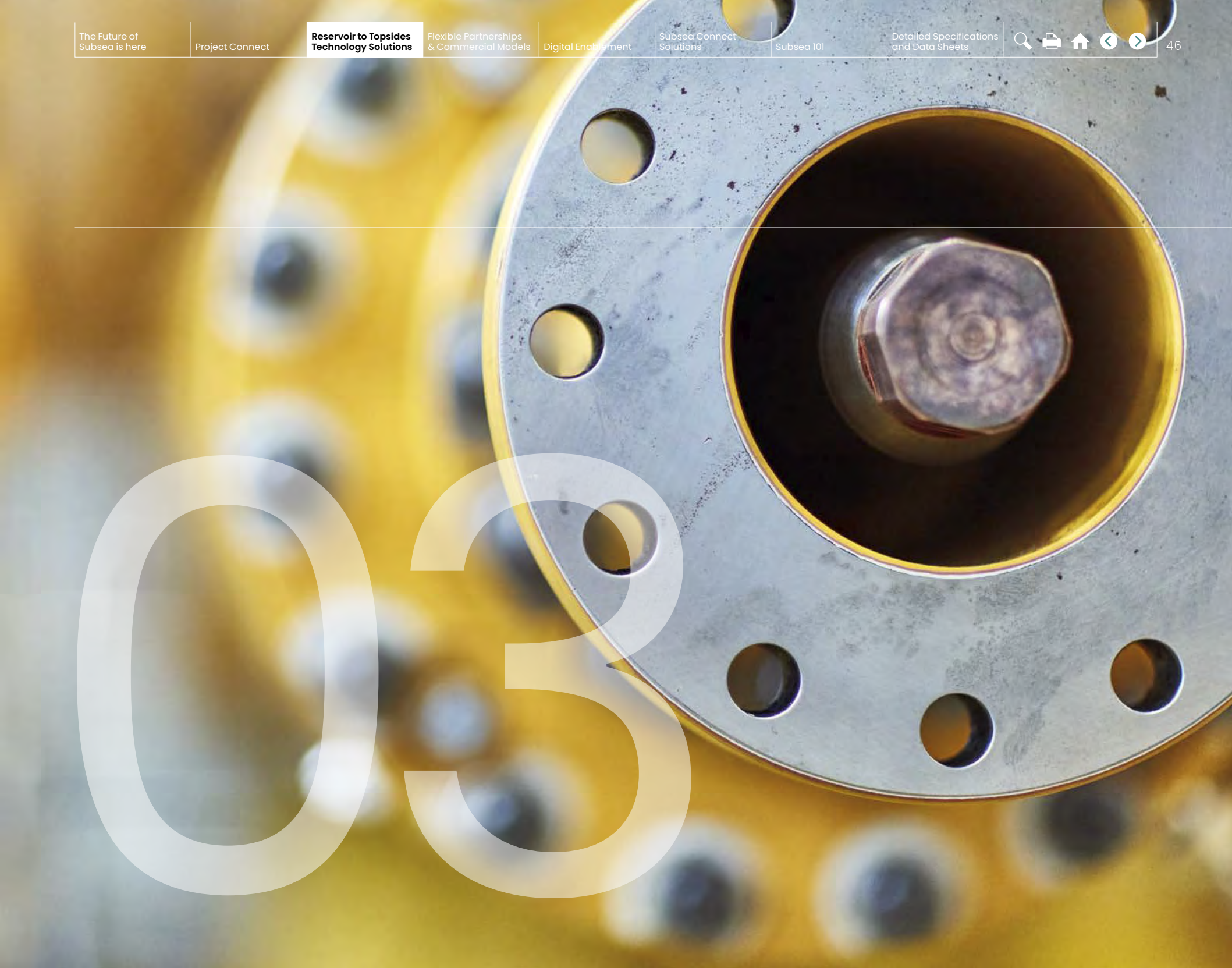
Active power conditioning module, designed to take incoming vessel AC supply and condition this to provide a 60Hz low distortion AC output to the subsea control units. Each module was sized to power the total field (30 wells planned) providing redundancy and security of power supply.

MCS and human machine interfaces software was adapted and modified to capture the enhanced housekeeping data produced by the SemStar5 electronics modules. This provided additional data for analysis to build predictive maintenance routines and for trouble shooting subsea issues.

DHPT instrument cards supplied to monitor the downhole gauge pressure and temperature were identified as obsolete. The new DHPT cards supplied and fitted into the SEMs required an alternative supply voltage.

Baker Hughes' SemStar5 design provided a simple adjustment to cater for either variant of card thereby providing flexibility to install on legacy or new wells.

SemStar5 has been designed to be backwards compatible with legacy Baker Hughes SEMs through virtulisation of the original subsea operating system on the SemStar5 modem's single board computers. The 'SEMulation' software allows SemStar5 to operate alongside the existing legacy modules with no disruption to the topsides hardware or operator interfaces. This has been successfully installed and operating on many control system upgrades globally and provides a cost-effective and fast track method to maintain or expand older control systems without the need for costly infrastructure changes. The SemStar5 has been extensively qualified and proven in the field, with more than 600 units deployed across multiple projects since our first installation in 2011.



03

RESERVOIR TO TOPSIDES TECHNOLOGY SOLUTIONS

The subsea industry has come a long way since its beginnings in the 1960s. The industry has changed extraordinarily since then and today we are designing subsea power and processing modules that would have previously required a platform on the surface.

The one thing that has remained constant is our pioneering innovation that has created practical and efficient solutions for our customers, demonstrating our proven ability to deliver everything required for a subsea system even if we have to develop the underlying technology – just as we have done many times.

RESERVOIR TO TOPSIDES TECHNOLOGY SOLUTIONS

Baker Hughes is the only company with a wide and deep portfolio equipped to optimize subsea developments – from the reservoir to the topsides.

We are uniquely placed to provide both a wide and deep set of capabilities that cut across all E&P segments.

Reservoir optimization and field development – Baker Hughes has over 400 geoscientists globally who are able to provide detailed and localized analysis of regional prospects, fields and developments.

We connect subsurface development options with the best technology solutions on the market today.

We engage early in the process to develop the optimal reservoir and field development plans that maximize value while addressing customer priorities.

On existing developments, we have an established track record of extending field life and maximizing economic recovery. As an example, on a project in Malaysia, our field development team led to a doubling of production in two years and extending the field life by 10 years.

Integrated Well Services

We have developed an integrated lean well construction process that weaves integrated drilling services, integrated well construction, automation and remote operations into a simplified well delivery solution. It redefines the technical limit through integrated well engineering resulting in accelerated drilling campaigns and significant reduction in well costs, and its consequent effect on overall project costs and timelines.

IWS (Integrated Well Services) has several projects around the world; in an example offshore in the North Sea, working with a large E&P operator, we formed a trilateral partnership between Operator, Drilling Contractor and Baker Hughes. We enabled aggressive targets for tangible efficiency gains.

The results from this approach speak for themselves:

- 50% below budgeted costs on the first eight wells drilled
- Wells were delivered eight months ahead of plan
- Technical limit or 'perfect well' target was improved by 25%
- And most importantly, there were no serious injuries or incidents

Aptara™ TOTEX-lite Subsea System

This is one example of our wide and deep portfolio of integrated subsea solutions. Our Aptara™ TOTEX-lite subsea solutions use lightweight, modular technology re-engineered to cut the total cost of ownership in half and designed to be more responsive to changes over the life of the field.

A summary of the benefits it provides:

- Delivers up to 50% lower total cost of ownership for each subsea system
- Innovative and industry-first tree caps incorporate Life-of-field design to deliver unparalleled flexibility
- Modular and structured portfolio
- Compact and up to 50% lighter
- 30% reduction in lead time
- Simpler and easier installation, operation, and maintenance

Topsides Optimization

Production optimization through enhanced topsides, extending asset life with no change in platform footprints to handle 25% more volume at minimal CAPEX. Baker Hughes has proven results here:

- De-bottlenecking, gas handling, and power solutions to extend asset life
- Over 1,400 units upgraded – from gas turbines, centrifugal compressors, reciprocating compressors and more
- Asset life extension
- Improvement in uptime
- Emissions reduction and control


EMAS
NO WELDING
EMAS
EMAS
EMAS

APTARA™ TOTEX-LITE SUBSEA SYSTEMS

Our Aptara™ family of TOTEX-lite products has been born from our life-of-field approach. The Aptara™ name is derived from Latin for “adapt” or “fit”. It signifies the flexibility of this family of products to meet the evolving needs of operators from the time of installation and over the life of field. We have re-engineered the subsea system to make installation, production, and intervention simpler and more efficient – dramatically lowering the total cost of ownership.

Our next-generation technology is smarter, simpler, and more efficient. It is designed to work for you and ensure your subsea system is easier and more economic to install, that it operates smoothly, and is flexible enough to evolve over the life of your field.

Innovative life-of-field approach

Our Aptara™ family of products combines an innovative approach with industry-first patented technologies to deliver subsea systems that have shorter lead times and lower initial CAPEX as well as OPEX savings over the life of your field – making it a TOTEX-lite family. We have taken a radically different life-of-field approach to create a suite of products that is lightweight, compact and optimized to reduce total cost of ownership (TCO).

These individual products are the building blocks of our Aptara™ subsea system. The main products in the Aptara™ family of TOTEX-lite products are:

- Aptara™ lightweight compact tree
- Aptara™ modular compact manifold
- Aptara™ modular compact pump
- Aptara™ composite flexibles
- Aptara™ SFX wellhead solution
- Aptara™ subsea connection systems
  - FLX360 multi-quick connection system
  - HCCS-L Lightweight Horizontal Clamp Connection System

Aptara™ lightweight compact tree

The Aptara™ lightweight compact tree uses unique patented innovative tree caps, allowing it to be configured to suit changing requirements, reducing cost, and increasing value over the life of your field. These tree caps eliminate the need for independent modules and connections, reducing your costs further. At 50% lighter, with a considerably smaller footprint, it can also save you up to 50% in CAPEX and OPEX of the subsea system over the life of your field.

Aptara™ modular compact manifold

The Aptara™ compact block manifold addresses the industry’s need for modular, pre-engineered manifolds that use off-the-shelf components, reducing cycle time, cost and footprint. We have achieved a level of standardization that limits the engineering to the manifold header, structural steel, and foundation, resulting in faster delivery with reduced risks and costs. For the most common configuration, the manifold will be a Make to Order variant with zero product engineering and delivered in 10 months from the award of a contract.

Aptara™ modular compact pump (MCP)

The Aptara™ MCP is the world’s first subsea multi-phase pump without a barrier fluid system which reduces topside footprint by 50% and cuts system costs. The standard pre-qualified 1 MW building blocks enable the Aptara™ MCP to be configured to different field requirements quickly and easily. Our life-of-field approach to design is evident in unique features that reduce the TCO.

The stages are controlled individually by local subsea Variable Speed Drives (VSDs) that allows the pump to react and adapt dynamically to changes in wellstream conditions. This ensures high inherent reliability, as high-risk items such as mechanical seals are not needed. It also effectively eliminates the need to re-bundle the hydraulics during the life of field.

Aptara™ composite flexibles

Baker Hughes' composite riser flexible pipe is a step-change product. It provides a cost-effective solution for ultra-deepwater applications in water depths up to around 10,000 ft (3,048 m). The new product is a hybrid of traditional flexible pipe designs, introducing 21st century materials technology for one specific layer – bringing 30% weight savings without affecting bending radius or compressive load capability.

For risers, this is achieved by reducing hang-off weights and platform burdens, simplifying riser configurations, and minimizing ancillaries and subsea infrastructure while keeping the exposure to new technology to a minimum. The product eliminates riser system complexity, reduces cost and installation time while delivering predictable and stable hydrodynamic performance over the full product lifecycle.

For flowlines and jumpers, we retain the flexibility this product brings with regards to final layouts, accommodating re-spuds and early deployment/wet storing of pipe to accommodate installation windows of opportunity, which may occur off the project critical path. Particularly, for high-sour or high-CO_2 developments, this hybrid composite pipe significantly reduces permeated gas flow rate through the pipe annulus, reducing operational risk and adding cost benefits over the field lifecycle.

Aptara™ SFX wellhead solution

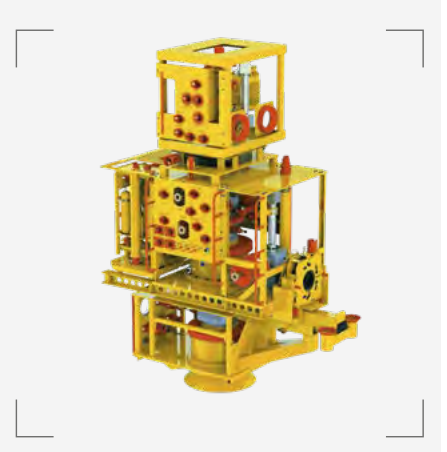
The Aptara™ SFX wellhead solution is focused on improved fatigue resistance to maximize life-of-field options for the operator. The result of our life-of-field approach to design translates into tangible benefits, enabling production enhancement through well intervention activities even in late life and ensuring longevity of field operations, all with a lower risk profile than traditional wellhead systems. The Aptara™ SFX wellhead solution enables you to plan your well activities reliably and with higher confidence for years to come.

Aptara™ subsea connection systems – FLX360 multi-quick connection system

The Aptara™ FLX360 multi-quick connection (MQC) system that enables fast and reliable connections between all elements of the subsea distribution system. It uses a patented locking mechanism that leaves a single moving part of the design on the seabed. The complexity of the connection system is housed within the retrievable and serviceable ROV tooling. Its unique life-of-field design also allows maintenance in situ with no need for disconnection of the connector thereby reducing total cost of ownership. The Aptara™ FLX360 family is extended to also provide reliable and compact connection for steel tube flying leads (STFLs) as well as umbilical termination in a Cobrahead assembly (CHA).

Aptara™ subsea connection systems – Horizontal Clamp Connection System Light (HCCS-L)

Our Aptara™ HCCS-L is a proven horizontal connector suitable for rigid, and flexible jumpers and spools, as well as umbilical termination with use of multi-bore hub technology. The HCCS-L range has been designed to be lighter, smaller and optimized to minimize make-up time, allowing for rapid installation. They come with a pre-mounted stroking tool and require fewer subsea operations, reducing the connection time by more than 30%. Our unique push-type stroking functionality allows full access for cleaning and cap replacement with the pre-mounted stroking tool.

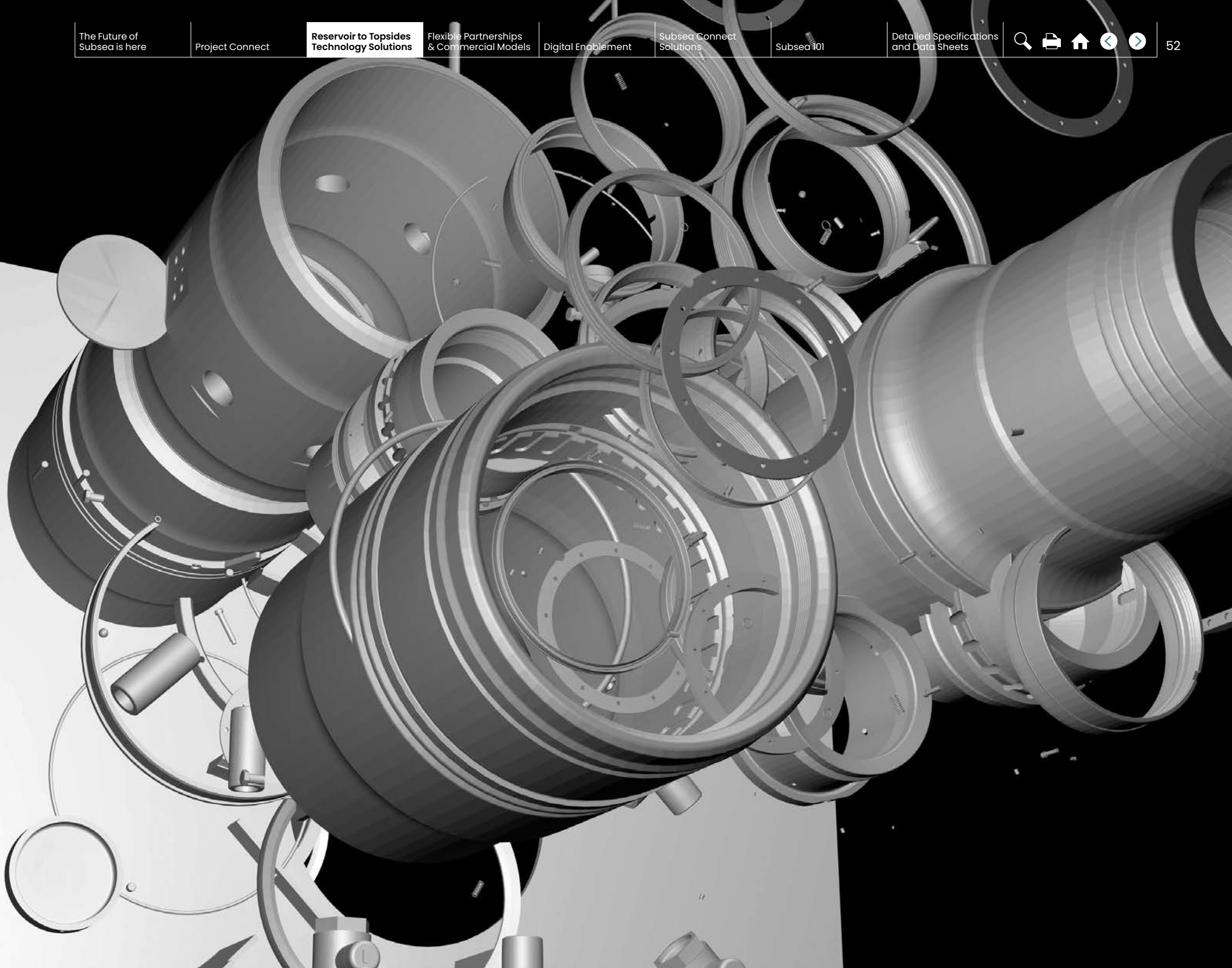


Aptara™ lightweight compact tree

Aptara™ composite flexible

Aptara™ modular compact manifold

Aptara™ modular compact pump (MCP)



SUBSEA WELLHEADS OVERVIEW

With half a century of field-proven experience and more than 5,000 wellhead installations worldwide, our subsea systems set the industry standard. Since its introduction in 1991, operators still rely on the MS-700 in some of the most challenging conditions.

Our new Aptara™ SFX technology takes the core metal sealing technology to another level of reliability and fatigue resistance. We are extending fatigue life through the improved and recently released H-4FX designs. We offer a wide range of premium connections and casing products and continue to develop new solutions like our Ulti-Max family of Gas Tight weld-on casing connectors that will make your operations safer and more productive in increasingly demanding conditions.

Our subsea wellhead and premium weld on connectors are offered as standalone solutions or as an integrated system designed for the robust performance you need, with reliability, efficiency, and versatility that has been proven in the field. Our complete-system approach enables fast, simple and economic installation and running, while our portfolio supports subsea drilling operations at all stages of exploration and production. Lead times for delivery of a subsea wellhead system range between five and 12 months for standard and fully customized solutions respectively.

Baker Hughes' excellence in engineering is typified by our proprietary Metal Sealing (MS) technology, which is one of the industry's most reliable wellhead seals. Our proven technology provides multiple independent metal to metal seals making it significantly more resilient and effective than traditional elastomeric sealing systems, providing a wider range of operating temperatures and improved gas sealing and applied successfully across our portfolio including premium weld on connectors.

Baker Hughes is introducing the next evolution of MS Sealing technology, MS-2. The MS-2 seal incorporates all the advantages of our Legacy MS seal solutions and adds an enhanced single trip integrated lockdown solution to provide assurance for all well applications. This feature provides immediate lockdown up to two million pounds force without the need for a second trip saving rig time. The MS-2 seal is PR2F tested to 20,000 psi per Group 4 requirements including a combined load envelope and is further tested to 200 load cycles ensuring life of field reliability.

We continue to invest in and upgrade market leading solutions. To support operators working in more challenging conditions, we have improved the H-4 profile to provide two to four times more fatigue life. The H-4FX profile is now available, increasing the operating life of the interface and is fully compatible with H-4 style connectors already in the field, which means no change over management for the operator to worry about.

APTARA™SFX WELLHEAD SOLUTION

Our enhanced Standardized Fatigue Resistant Wellhead Solution (SFX) delivers significantly improved fatigue resistance compared to existing systems.

54

MS-800

The MS-800 can reach deeper well depths with a larger production string, which enables larger completion options.

55

MS-700

The MS-700 can be used across a wide range of applications, including TLP/spar tieback, subsea completion and deepwater drilling.

56

ULTI-MAX SPECIALTY CONNECTOR

The Ulti-Max Connector provide Gas Tight performance and meets or exceeds pipe performance capabilities providing confidence in even extreme applications.

57

See Section 8 on page 182 for detailed specifications and data sheets.

SUBSEA WELLHEADS

APTARA™ SFX WELLHEAD SOLUTION

Our enhanced Aptara™ Standardized Fatigue Resistant Wellhead Solution (Aptara™ SFX) takes the field-proven architecture of our MS-700 and MS-800 subsea wellheads to the next level.

The Aptara™ SFX wellhead solution delivers up to 20 times the fatigue resistance of existing systems. With its stress-reducing geometries on extended length forgings, tougher materials (A707 and F22) and a reduced number of welds, the Aptara™ SFX is stronger – providing industry-leading reliability in extreme fatigue conditions. The system delivers this improved performance while maintaining all the familiar system interfaces, tools, and operating procedures that have been proven in fields across the globe. This minimizes risk and improves safety by reducing management of change.

The Aptara™ SFX wellhead solution is focused on improved fatigue resistance to maximize life-of-field options for the operator. The result of our life-of-field approach to design translates into tangible benefits, enabling production enhancement through well intervention activities even in late life and ensuring longevity of field operations, all with a lower risk profile than traditional wellhead systems. The Aptara™ SFX wellhead solution enables you to plan your well activities reliably and with higher confidence for years to come.

Its standardized solution optimizes supply chains, simplifies operations and allows you to extend drilling days in harsh environments, as a result of having lower fatigue damage rates compared to traditional wellheads. The Aptara™ SFX also offers reduced cycle times and we can deliver a Make to Order Aptara™ SFX variant with configured options within 6 months, which eliminates the incremental 6 months of material procurement lead time.

The Aptara™ SFX can be supplied in both, MS-700 and MS-800 configurations and comes with 5 inches of extra sealing surface for compatibility with all completion systems. Available with optimized C1 or automated orbital C class performance welding with tight pipe tolerance providing industry leading girth weld fatigue life performance, the Aptara™ SFX wellhead family can be supplied with fabrication options optimizing the customer's fatigue resistance solution to meet their challenging or extreme global environments and applications.

The comprehensive system includes wellhead, pipe, and casing connectors, all designed to meet or exceed industry standards for materials, quality and fatigue performance. The Aptara™ SFX also comes with improved and standardized inspection protocols for greater safety and reliability.

	Aptara™ SFX Wellhead Solution
Feature	Make to Order
Variant	3 Options
Bending capacity (mm lb-ft)	5.25 or 7
Casing program (inches)	36 x 28 x 22 x 18 x 16 x 14 / 13 x 10 / 9
Casing load (mm lbs)	8
Fatigue loading	Extreme
Materials	– F22 and A707 – DNV C/C1 curve tested welds – DNV B curve tested connector

Typical lead time:

6 months

Our Make to Order Aptara™ SFX wellhead solution can be delivered in 6 months.

SUBSEA WELLHEADS

MS-800

The MS-800 subsea wellhead system was developed in 2007 to allow more flexibility in designing casing programs, using larger drill bits and testing pack-offs to higher pressures.

The MS-800 can reach deeper well depths with a larger production string, which enables larger completion options. The wellhead system gives you the option to run 18-inch and 16-inch casing strings below the mudline, giving you better zonal control of your well casing program. We can deliver an MS-800 in 6 months. The system comes with 8 million lbs of total load capacity, allowing the operator substantial flexibility on casing programs and working pressures up to 20,000 psi.

The MS-800 benefits from true metal-to-metal seals and the system has high-pressure capabilities of 20,000 psi, temperature capabilities up to 350°F (177°C), and bending capacity up to 7 million ft-lbs to maintain high standards of reliability and safe operation.

	MS-800
Feature	Make to Order
Variant	2 Options
Bending capacity (mm lb-ft)	5.25 or 7
Casing program (inches)	36 x 28 x 22 x 18 x 16 x 14 / 13 x 10 / 9
Casing load (mm lbs)	8
Fatigue loading	Normal
Materials	8630 HP / 4130 LP

Typical lead time:

5 months

Our Make to Order MS-800 subsea wellhead system can be delivered in 5 months.

SUBSEA WELLHEADS

MS-700

The MS-700 subsea wellhead system launched in 1991 and continues to be one of the most widely used wellheads in the world. Operators In every global basin have relied upon the MS-700 for some of their most challenging campaigns.

The MS-700 proved its versatility over the years, across a wide range of applications, including TLP/spar tie-back, exploration, subsea completion and deepwater drilling. We can deliver an MS-700 wellhead system, supporting multiple casing configurations from 36 inches through to 7 inches, in around 5 months. The system comes with 7 million lbs of total load capacity, which allows for three casing strings and up to 3 million lbs combined string weight.

Baker Hughes provides the benefits of true metal-to-metal seals with the MS-700 and we supply a single trip running tool to test both the casing hanger and the annulus seal. The system has high-pressure capabilities of 15,000 psi, temperature capabilities up to 350°F (177°C) and bending capacity up to 5.25 million ft-lbs to maintain high standards of reliability and safe operation.

	MS-700
Feature	Make to Order
Variant	2 Options
Bending capacity (mm lb-ft)	5.25
Casing program (inches)	36 x 28 x 20 x 16 x 13 x 9
Casing load (mm lbs)	7
Fatigue loading	Normal
Materials	8630 HP / 4130 LP

Typical lead time:

5 months

Our Make to Order MS-700 subsea wellhead system can be delivered in 5 months.

SUBSEA CONNECTOR

ULTI-MAX SPECIALTY CONNECTOR

With lineage of over 1 million joints installed and counting, our latest weld-on connector, the Ulti-Max™ Family, launched in 2015, is our most rigorously tested solution. It performs in extreme upset conditions with a seawater sealing, while delivering improved rig productivity, through fast make up and casing string installation.

The Ulti-Max GT connector has a gas-tight metal-to-metal internal seal and is available in multiple diameters and thicknesses. It combines all the features of our widely used RL-3M connector with new materials and a more compact, lightweight, and cost-effective design. Baker Hughes also offers a High Fatigue resistant version of the Ulti-Max GT, the Ulti-Max SFX, that meets your Gas Tight and Fatigue requirements.

Designed with flexibility in mind and tailored to specific application needs the Ulti-Max™ GT meets or exceeds all ISO 13679 requirements of tension, compression, bending, internal and external pressure. It also has a single-thread start that optimizes fatigue performance while minimizing the effects of back-out on seal ability and pre-load loss.

Advanced threads and stress reliefs ensure higher fatigue performance. Large self-aligning stab guides provide fast, safe installation in 3.5 turns, and large stress-relief grooves prevent hydraulic locking. Our patented new anti-rotation keys design is easily and safely installed in less than 30 seconds with no special tools for between 49,500 and 62,500 ft-lbs of torque capacity.

	Specialty Connector (Ulti-max GT)	
Feature	Make to Order	Configure to Order
Variant	2 Options	
Production bore size (inches)	20/22	20/22
Wall Thickness (inches)	0.812/1.000	0.438 to 1.500
Tension (kips)	3426 / 5278	up to 7728
Compression (kips)	3426 / 5278	up to 7728
Bending (kip-ft)	1316 / 2209	up to 3092
Burst (psi)	5660 / 7,235	up to 10781
Collapse (psi)	-2820 / -3870	up to -9460
Materials	LCM, 4130	LCM, 4130, A707
Yields (ksi)	70, 80	70, 80

Typical lead time:

5 months

Our Make to Order Ulti-Max Connector Tubular joint can be delivered in 5 months.

SUBSEA TREES OVERVIEW

Baker Hughes completed its first subsea tree system installation in 1962. Since then, we have installed more than 1,400 subsea trees worldwide and are at the forefront of oil and gas field developments.

Our trees are based on standardized, modular designs that drive high manufacturing consistency and delivery speed. With Make to Order lead times of 10 and 14 months, we can help you minimize the time to first oil or gas and maximize the returns on your project. Offering both 5-inch and 7-inch systems, as well as a range of functionality including gas lift, electrical submersible pumps and facilitating control of intelligent completions, Baker Hughes has the tree system to meet your needs in up to 10,000 ft (3,048 m) water depth.

We have a strong legacy in key valve and connector technology, ensuring we deliver trees that offer you the highest levels of reliability and performance. Our latest trees exceed the American Petroleum Institute standard API 17D and demonstrate our commitment to building systems with industry-leading products. For example, our VG300 valve design, which has more than 15,000 valves in operation, has been successfully tested to 1,200 cycles – double the industry standard requirement – demonstrating the reliability and robustness of the design.

APTARA™ LIGHTWEIGHT COMPACT TREE

Designed to reduce initial CAPEX as well as OPEX over the entire life of your field, our Aptara™ lightweight compact tree uses an industry-first design.

~10,000 ft (3,048 m), 10,000 psi, 300°F (149°C)

D-SERIES FOR DEEPWATER

Our D-Series Trees take on the world's most challenging subsea conditions, with structured, modular and cost-effective designs and installation.

~10,000 ft (3,048 m), 15,000 psi, 300°F (149°C)

M-SERIES FOR MEDIUM WATER

Our M-Series Trees are qualified to meet rigorous international standards for subsea products and use field-proven valves and connectors.

~2,500 ft (750 m), 10,000 psi, 300°F (149°C)

S-SERIES FOR SHALLOW WATER

Our light, efficient and reliable shallow water trees are based on an in-depth understanding of the environmental challenges facing operators.

~330 ft (100 m), 6,500 psi, 250°F (121°C)

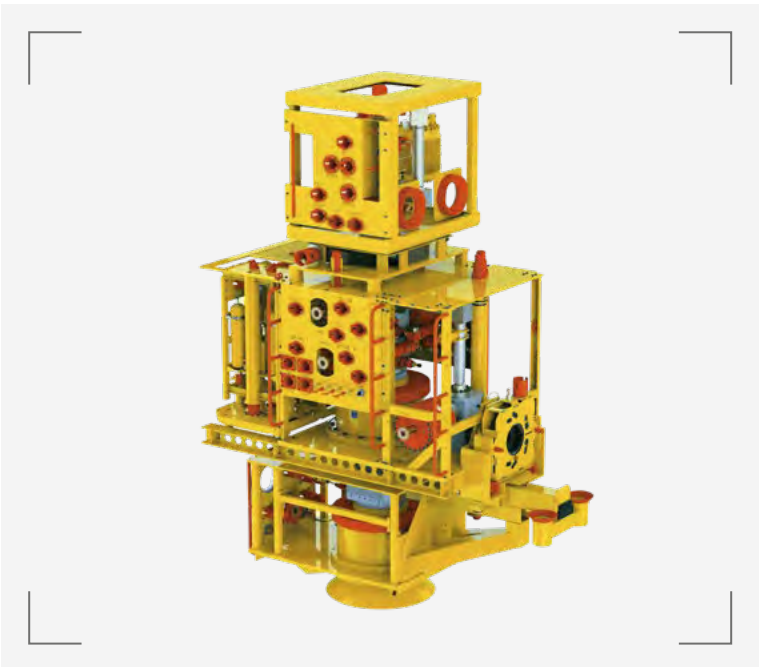
SUBSEA CHOKE VALVES

Our subsea chokes meet the rigorous demands of your wells and ensure your reservoir performs reliably and safely.

See Section 8 on page 182 for detailed specifications and data sheets.

SUBSEA TREES

APTARA™ LIGHTWEIGHT COMPACT TREE



Our revolutionary Aptara™ vertical tree is lightweight and compact and uses our life-of-field approach to reduce not just initial CAPEX but also OPEX over the entire life of your field. This TOTEX-lite approach uses a unique industry-first tree cap design that allows it to be adapted on the seabed to address the changing requirements of your field over its life.

These simpler, lower-cost vertical subsea systems incorporate 4-inch, 5-inch and 7-inch production bores, 10,000 / 15,000 psi pressure ratings and can be run with or without a tubing head spool. The Aptara™ lightweight compact tree can be deployed in up to 10,000 ft (3,048 m) of water.

While our Aptara™ lightweight compact tree is built on mature field-proven technology, its design is driven by our life-of-field approach. It uses an innovative flow path that reduces size and complexity, which supports faster field development, lower field total expenditure (TOTEX) and allows you to realize increased value from your reservoir. The configuration has also been simplified, with a lower valve count requirement that still provides all the functionality you need and complies with all industry standards.

The Aptara™ lightweight compact tree has been designed with the entire lifecycle in mind and our Make to Order variant can be delivered in 10 months. By reducing the number of components, the footprint and weight of the compact tree is reduced by around 50% compared to a traditional deepwater tree. With this reduction in size and complexity, comes a reduction in costs across the entire manufacturing cycle of the tree. Its size and weight offer you flexibility during installation and enable vessel optimization. If you want to flow the well, you can also use a Subsea Test Tree (SSTT) system, either before or after tree installation, as well as a traditional Open Water Completion Workover Riser (CWOR).

The Aptara™ lightweight compact tree includes integrated flow metering, comprising Baker Hughes' Virtual Flow Meter (VFM), downhole flow meter (SureFLO™) and water cut measurements at the tree, providing accurate oil, gas and water flow rate measurements at the wellhead. It also supports enhanced real-time condition monitoring and diagnostics enabling active control and monitoring of subsea equipment integrity.

	Aptara™ Lightweight Compact Tree	
Feature	Make to Order	Configure to Order
Variant	5 Options	
Production bore size (inches)	5⅛ / 7 1/16	
Pressure rating (psi)	10,000	15,000
Temperature rating (operating)	0°F to 300°F (-18°C to 149°C)	
Depth capability	10,000 ft (3,048 m)	10,000 ft (3,048 m)
Tubing head spool	Optional	
Gas lift	Optional	
Downhole function lines	11	
Connection system	Horizontal / Vertical	

Typical lead time:

10 months

Our Make to Order Aptara™ lightweight compact tree variant can be delivered in 10 months.

SUBSEA TREES

APTARA™ LIGHTWEIGHT COMPACT TREE

Our Aptara™ lightweight compact tree system adapts as your needs change through the entire life of your field, with a plug and play capability in the innovative modular tree cap.

The Aptara™ lightweight compact tree allows your tree system to evolve to suit changing reservoir conditions. Its unique patented industry-first design involves an innovative flow path and tree caps that integrate functionality such as High Integrity Pipeline Protection (HIPPS) or add boosting capability to reduce your overall development cost or increase reservoir recovery. The life-of-field cap also facilitates conversion of subsea wells from producer to water injection, adapting your subsea infrastructure to meet your reservoir management needs. Mounting this technology on the tree removes the need for independent modules and connections, reducing your costs further.

The compact tree has a significantly reduced footprint compared with traditional deepwater subsea trees, which means 50% less weight and the potential to reduce TOTEX (CAPEX + OPEX) of the subsea system by more than 50%.

The system is configured for up to 11 downhole functions, including well safety valves, chemical injection, intelligent completions and two electric functions, adding further flexibility and functionality to improve well performance when installed on Tubing Head Spool. The System is configured for up to nine downhole functions when installed directly on Wellhead.

Operations can be optimized with life-of-field tree caps configured for the changing demands of a wells lifetime

HIPPS TREE CAP

The HIPPS tree cap can be added when the pressure is high at the beginning of the field life. This increases your cost efficiency by effectively downrating the subsea pipeline and risers to transient flow pressures. The HIPPS tree cap eliminates the need for the traditional HIPPS module along with all its associated equipment and installation costs. Additionally, as HIPPS is not required beyond the initial phase, the HIPPS tree cap can be easily swapped for a production tree cap and can be used elsewhere.

PRODUCTION TREE CAP

As reservoir pressure falls, or when a HIPPS is not needed, a standard production cap can be installed.

BOOSTING TREE CAP

When boosting is needed in later life of the field, a boosting system can be configured and installed as a tree cap without the need for more equipment on the sea bed. This can increase field output and improve the economics of the field.

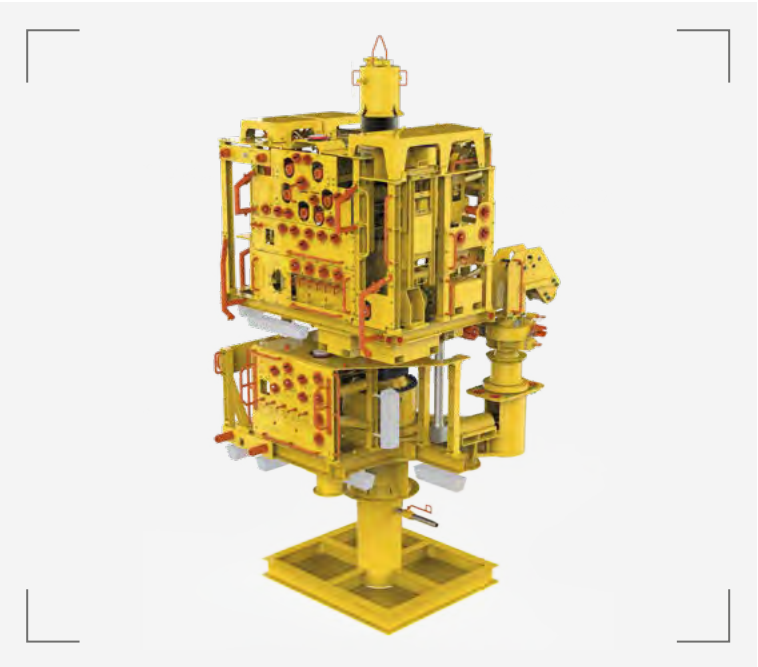
HIPPS tree cap

Production tree cap

Boosting tree cap

SUBSEA TREES

D-SERIES FOR DEEPWATER



	DVXT Structured Product Boundaries	
Feature	Make to Order	Configure to Order
Variant	3 Options	
Prod. Bore Size (inches)	5⅛ or 7 1/16	
Pressure rating	10,000psi	
Temperature Rating (Operating)	0°F to 300°F (-18°C to 149°C)	0°F to 335°F (-18°C to 168°C) for 7
Depth Capability	4,921ft to 6,561ft (1,500M to 2,000m)	10,000ft (3,048m)
Flow Control Module	Yes	No
Gas lift	No	Yes
Downhole function lines	2, 4 or 8	Up to 11
Connection system	Horizontal /Vertical	

Our D-Series Trees incorporate more than 55 years of our design heritage and subsea experience. They take on the world's most challenging subsea conditions, with efficient and cost-effective designs and installation following a structured, modular approach.

Our deepwater D-Series modular short-delivery subsea tree systems are engineered for up to 15,000 psi and 10,000 ft (3,048 m) water depth, with an operating temperature range of 0°F to 300°F (-18°C to 149°C). They feature our DW-HTH4 connector, which provides high capacity and fatigue resistance, as well as the field-proven VG-300 valve product line and Baker Hughes' unrivalled range of controls and connections to complement the system, providing a reliable solution for our customers' field development needs.

The financial viability of deepwater projects can be a challenge, so the minimized lead times we offer are a significant enabler for operators in the oil and gas industry. Our modular approach helps us to increase quality and reduce lead times considerably. The systems can be installed from a vessel or a mobile offshore drilling unit (MODU) in line with a field operator's installation preference.

The systems have an enhanced bending capacity of 5.25 million ft-lb, improving safety and reliability, and can be supplied with an optional retrievable Flow Control Module to improve intervention functionality and minimize life-of-field costs. The D-Series includes both standard production-bore sizing as well as large bore trees for gas developments to allow faster flowrates that improve field economics.

DEEPWATER VERTICAL TREE (DVXT)

Our Deepwater Vertical Tree (DVXT) offers simple installation with functional flexibility.

The DVXT system is a truly flexible structured system that conforms with all operators' installation methodologies. The system can be installed using a simple support vessel and has the flexibility to accommodate either a blowout preventer (BOP) or Open Water Completion Workover Riser (CWOR) system on the tree. Our flexible design also allows for installation on a tubing head spool, or directly onto the wellhead delivering additional CAPEX and OPEX benefits.

The system is configured for up to 11 downhole functions, including well safety valves, chemical injection, intelligent completions and two electric functions, adding further flexibility and functionality to improve well performance when on Tubing Head Spool. The system is configured for up to nine downhole functions when installed direct on Wellhead. By making the Production and Annulus Wing valves integral to the Master Valve Block and removing bolt on arrangements, not only have we removed potential leak paths but we have also reduced the weight of the tree.

Typical lead time:

14 months

Our Make to Order DVXT variants can be delivered in 14 months.

SUBSEA TREES

DEEPWATER HORIZONTAL TREE (DHXT)

Our Deepwater Horizontal Tree (DHXT) can be configured for production or water, gas or alternating injection.

This DHXT tree system's highly flexible design and capability improves both reservoir management and hydrocarbon recovery. It is compact and lightweight, with a flush top plate and extended mandrel for efficient blowout preventer (BOP) operation. And with up to nine hydraulic downhole functions, you can rely on the highest standard of intelligent well control.

The DHXT comes with either 5-inch or 7-inch production bores and the system is configured for up to ten downhole functions, including well safety valves, chemical injection, intelligent completions and two electric functions, adding further flexibility and functionality to improve well performance. In addition, the system benefits from multiple pressure, temperature and sand detection sensors, as well as a variety of features that minimize intervention and maximize the field performance data available.

	5" DHXT Structured Product Boundaries		7" DHXT Structured Product Boundaries	
Feature	Make to Order	Configure to Order	Make to Order	Configure to Order
Variant	Multiple		2 Options	
Prod. Bore Size (inches)	5 1/8		7 1/16	
Pressure rating	10,000psi	15,000psi	10,000psi	
Temperature Rating (Operating)	0°F to 250°F (-18°C to 121°C)	0°F to 300°F (-18°C to 149°C)	0°F to 300°F (-18°C to 149°C)	0°F to 300°F (-18°C to 149°C)
Depth Capability	6,561ft (2,000m)	10,000ft (3,048m)	10,000 ft (3,048 m)	
Flow Control Module	Optional		Yes	No
Gas lift	Optional		No	
Downhole function lines	10	Up to 10	5	
Connection system	Horizontal / Vertical		Horizontal	

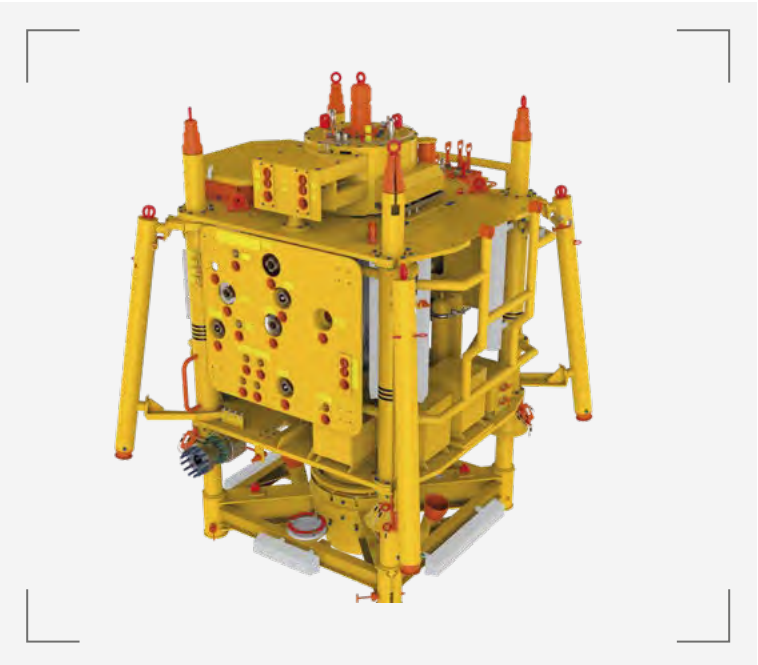
Typical lead time:

12 months

Our Make to Order DHXT variants can be delivered in 12 months.

SUBSEA TREES

M-SERIES FOR MEDIUM WATER



	MVXT Structured Product Boundaries	
Feature	Make to Order	Configure to Order
Variant	2 Options	
Production bore size (inches)	5⅛	7 1/16
Pressure rating (psi)	10,000	
Temperature rating (operating)	0°F to 250°F (-18°C to 121°C)	0°F to 300°F (-18°C to 149°C)
Depth capability	820 ft (250 m)	2,460 ft (750 m)
Electrical submersible pumps	No	
Gas lift	Optional	
Downhole function lines	6	
Connection system	Diver	Horizontal / Vertical
Guidance fishing protection	Flowbase	Guide base NORSOK

Our M-Series trees have served the industry for more than 30 years and are designed for water depths of up to 2,500 ft (750 m), with installation possible from semi-submersible or jack-up drilling rigs. They are qualified to meet the most rigorous international standards for subsea products – API, ISO and NORSOK – and they use standard, field-proven VG300 valves and H4 connectors.

Designed to accommodate guideline drilling and completion techniques, our M-Series subsea tree systems can also be run guideline-less using vessels of convenience, offering the potential to reduce installation costs. They are engineered for 10,000 psi, and an operating temperature range of 0°F to 300°F (-18°C to 149°C).

To date, Baker Hughes has installed more than 700 M-Series Trees in offshore basins around the world. With our proven installation tools, diverless installation and connection to flowlines and umbilicals using our HCCS connection systems, the M-Series accelerates your time to first oil. All our M-Series trees have options for oil, gas, water injection and Electrical submersible pumps applications to enhance reservoir management and hydrocarbon recovery. They are also suitable for template, fisher-friendly and NORSOK protection structures in heavy fishing areas.

The M-Series tree rental tools suite offers an option to minimize CAPEX for small field developments and allow greater flexibility with your planning developments and budgets. The tools can be deployed to any location to meet specific operational needs and provide everything you require for well intervention and maintenance.

MEDIUM WATER VERTICAL TREE (MVXT)

Our Medium Water Vertical Tree (MVXT) is highly compatible with a range of drilling fleets and rigs.

Our guideline MVXT has been used extensively in offshore basins around the world. It provides wide flexibility in field development planning and is designed for both cluster and template applications.

The system is configured for up to six downhole functions, including well safety valves, chemical injection, intelligent completions and two electric functions, adding further flexibility and functionality to improve well performance.

The MVXT can be installed directly onto your completed wellhead to enable batch setting and early completion of the field, minimizing your time to first oil.

Typical lead time:

12 months

Our Make to Order MVXT variants can be delivered in 12 months.

SUBSEA TREES

MEDIUM WATER HORIZONTAL TREE (MHXT)

Our Medium Water Horizontal Tree (MHXT) is compatible with industry-recognized 18¾-inch drilling systems.

Our MHXT is well established in offshore developments around the world. The tree design allows for installation of the tubing hanger directly into the tree master valve block – eliminating the need for an open-water completion riser and reducing your project CAPEX. The tree also provides flexibility for drilling from jack-up rigs, as well as from semi submersibles and drillships.

The MHXT provides flexibility covering both cluster or template configurations, allowing your field architecture to be optimized and helping to minimize costs during initial development. It also simplifies intervention operations through ease of access to the completion when increased downhole activity is required. The tree system is readily suited to the needs of Gas Lift and electrical submersible pumps to address small pool hydrocarbon recovery and improve your development's economics.

The system is configured for up to six downhole functions, including well safety valves, chemical injection, intelligent completions and two electric functions, adding further flexibility and functionality to improve well performance.

MHXT Structured Product Boundaries

Feature	Make to Order	Configure to Order
Variant	2 Options	
Production bore size (inches)	5⅛	7 1/16
Pressure rating (psi)	10,000	
Temperature rating (operating)	0°F to 250°F (-18°C to 121°C)	0°F to 300°F (-18°C to 149°C)
Depth capability	820 ft (250 m)	2,460 ft (750 m)
Electrical submersible pumps	Optional	
Gas lift	Optional	
Downhole function lines	6	
Connection system	Diver	Horizontal / Vertical
Fishing protection	Fisher friendly	Multi-flowbase
Installation	Guidelineless	Guidelineless / Flowbase

Typical lead time:

11 months

Our Make to Order MHXT variants can be delivered in 11 months.

SUBSEA TREES

S-SERIES FOR SHALLOW WATER

Feature	SVXT Structured Product Boundaries: Make to Order	SHXT Structured Product Boundaries: Make to Order	SHXT Structured Product Boundaries: Configure to Order
Variant	2 Options	2 Options	
Production bore size (inches)	5	5⅛	
Pressure rating (psi)	6,500	5,000	
Temperature rating (operating)	0°F to 250°F (-18°C to 121°C)	0°F to 250°F (-18°C to 121°C)	
Depth capability	328 ft (100 m)	262 ft (80 m)	
Wellhead size (inches)	13⅝	13⅝	
Gas lift	Optional	Optional	
Control system	Direct Hydraulic/ Electrohydraulic	Direct Hydraulic	Electrohydraulic
Downhole function lines	3	6	

Monetizing stranded reserves in shallow waters requires an appropriate solution. Baker Hughes is the industry leader in shallow water trees with more than 35% of installations worldwide since 2000. Our light, efficient and reliable designs are based on an in-depth understanding of environmental challenges facing operators – including weather, sub-surface currents, poor visibility, and fishing interaction.

Our S-Series Trees allow you to maximize safety and efficiency for jack-up drilling operations in water depths up to 328 ft (100 m), operating pressures up to 6,500 psi and temperatures between 0°F to 250°F (-18°C to 121°C). Our designs enable deployment using standard offshore jack-up drilling rigs and no need for major modifications.

The S-Series features an innovative barrier design that blends Horizontal and Vertical Tree technology, removing the need for a swab valve through use of Crown Plugs and reducing your CAPEX, while simultaneously helping to reduce the overall height of the system.

Baker Hughes' Smart Tools can further improve installation by performing multiple functions with reduced trips. They can also eliminate the need for diver or remote-vehicle (ROV) assistance by deploying camera technology to the tree and tools. This reduces your dependency on weather conditions, giving greater flexibility for launch scheduling and logistics

SHALLOW WATER VERTICAL TREE (SVXT)

Our Shallow Water Vertical Tree (SVXT) is 20% lighter and 30% shorter than traditional tree-on-mudline systems.

Using the field-proven 13⅝" Wellhead system, our SVXT vertical tree offers a light architecture arrangement with options of mudline conversion. Its optimized modular core block components are fully integrated with Baker Hughes control systems.

It offers fisher-friendly wellhead protection structures and an innovative barrier philosophy that removes the need for a separate tree cap. With a simplified installation process, reduced diver and ROV operational intervention and the option of a gas lift, the SVXT offers you significant cost and operational advantages over a fixed platform or semi-submersible drilled well.

The system is configured for up to three downhole functions, adding further flexibility and functionality to improve well performance.

SHALLOW WATER HORIZONTAL TREE (SHXT)

Our Shallow Water Horizontal Tree (SHXT) is designed to increase tubing size and delivers high performance.

The SHXT integrates the latest technologies and offers lower installation and operating costs. Building on the heritage of our traditional horizontal systems, the SHXT can be run with a high-pressure riser for fast and more efficient installation of the completion.

The system is configured for up to five downhole functions, including well safety valves, chemical injection, intelligent completions and two electric functions, adding further flexibility and functionality.

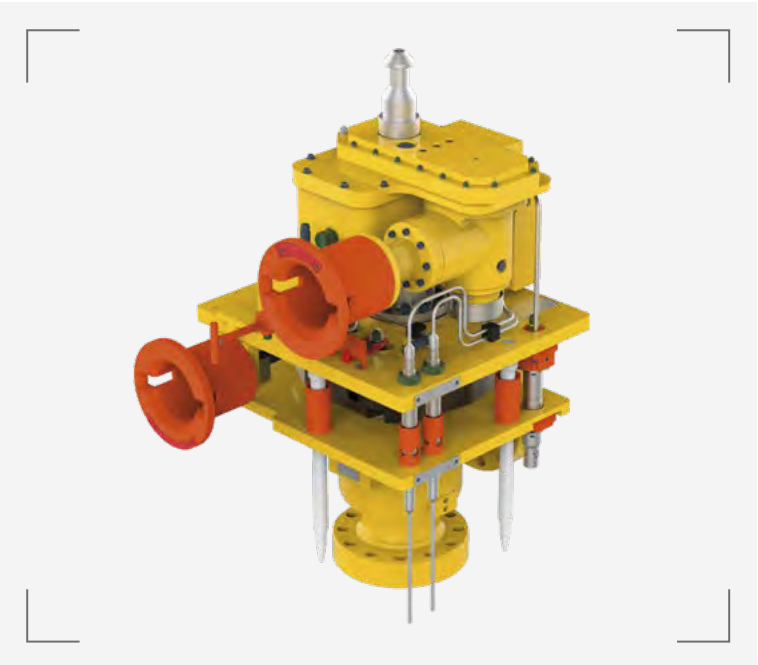
Typical lead time:

11 months

Our Make to Order SVXT / SHXT variants can be delivered in 11 months.

SUBSEA TREES

SUBSEA CHOKE VALVES



With our wealth of experience in the design and manufacture of the equipment required to meet the rigorous demands of wells, including the recent trend towards large bore gas developments, we have the subsea chokes you need to ensure your reservoir performs reliably and safely.

Our latest Hydraulic Stepping Choke has been qualified to API, ISO and NACE standards with endurance testing to twice that required, with more than two million steps performed. Our design allows for both fast actuation timing and superior controllability and stepping resolution, which gives you greater control of the production and injection rates.

To date, we have supplied more than 2,000 subsea choke valves, offering modular configuration options for production, injection, MEG (monoethylene glycol) injection, and gas lift applications, for insert retrievable or non-retrievable operations, and for shallow to deepwater use. Our chokes are available integrated with one of our subsea tree systems, or as a single supply with a lead time of around 7 months.

Comprising a high integrity forged one-piece choke body and using a single-stage High Friction HF-LCV design, our 'plug and cage' trim design has been used successfully on debris/sandy service applications – with multiple trim options that provide the specific range-ability for the application. This proven trim technology controls the flow and the trim design minimizes erosion, vibration and noise within the system. For water injection applications we can offer multi-stage trims to mitigate the onset of cavitation.

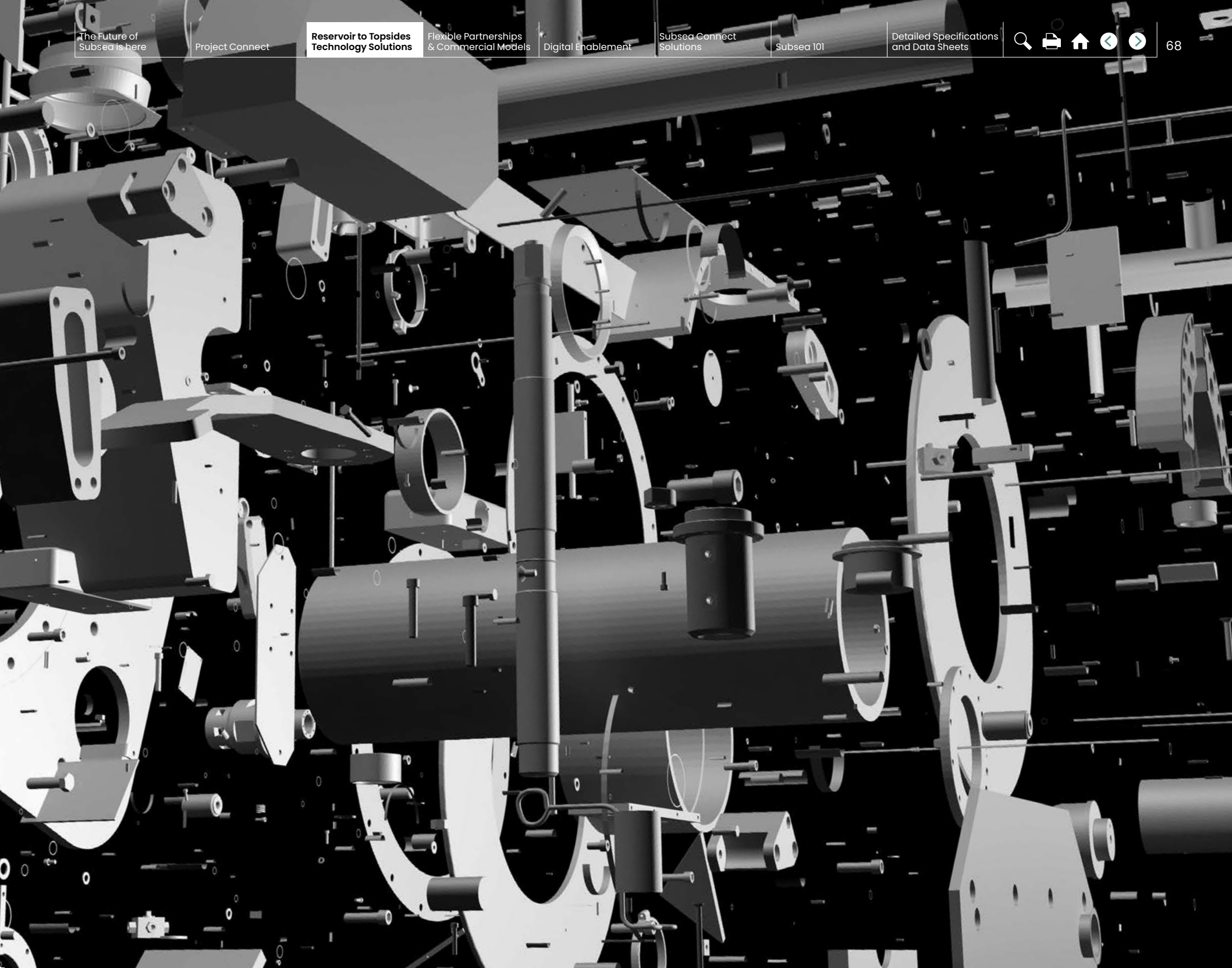
The valve actuator consists of a core gearbox with a proven high-integrity 'ratchet and pawl' design and pulsed/stepped hydraulic cylinders that provide the motive power. The actuator is of the "fail as is" position type, though we provide you with options for either side or top over-ride as part of our modular configuration design.

Our chokes are nominal 2", 5" or 7" sizes and are engineered to operate in water depths up to 10,000 ft (3,048 m), operating pressures of 6,500 psi to 10,000 psi and operating temperatures between -51°F to 300°F (-46°C to 149°C). We use proven materials with premium grade Tungsten Carbides and Corrosion Resistant Alloys for longevity in field life.

Typical lead time:

7 months

Our Make to Order Subsea Choke Valves can be delivered in 7 months.



SUBSEA CONTROL SYSTEMS OVERVIEW

All production availability is underpinned by the reliability of your Subsea Control System. Baker Hughes' control system equipment is designed for reliability, from the unrivaled and industry-leading SemStar5 electronics module, to our Smart distributed flow meter and uniquely and highly-maintainable FLX360.

Our Subsea Control Systems come with dual redundancy throughout, highly effective heat-management and obsolescence-managed components.

Our subsea electronics are all subjected to Highly Accelerated Life Testing (HALT) as part of the design process and during production they are exposed to stringent Environmental Stress Screening (ESS) in the factory. We use purpose-designed Automated Test Equipment to monitor a Subsea Electronics Module throughout ESS, testing it to both the spirit and letter of API 17F. This is how we achieve a result of Mean Time Between Failures (MTBF) that is 10 times better than the Offshore and Onshore Reliability Data Project (OREDA) average – weeding out the causes of possible failure on every unit manufactured.

SEMSTAR5 SUBSEA ELECTRONICS MODULE

SemStar5 is our ultra-reliable fifth-generation subsea electronics module for control systems and draws on 40 years of Baker Hughes' subsea experience.

70

MODPOD SUBSEA CONTROL MODULE

With its configurable and compact design, our ModPod is one of the most advanced, versatile and reliable control system components available.

71

MASTER CONTROL STATION

Our Master Control Station is the unit that brings together the control and monitoring of your Subsea Control System.

72

SUBSEA COMMUNICATIONS AND ROUTING

Our approach to subsea network reliability that has made Baker Hughes a market leader in the provision of complex subsea control networks.

UMBILICAL HEALTH MONITORING

Our Umbilical Monitoring Device (UMD) is specifically designed to monitor the health of an umbilical's electrical conductors continuously.

76

HYDRAULIC POWER GENERATION

While our Hydraulic Power Units are designed to meet your specific requirements, they are engineered and built around standard building blocks.

77

SUBSEA DISTRIBUTION UNIT (SDU)

Our distribution product portfolio enables you to extend the boundaries of subsea production by focusing on simpler, lower cost and optimized solutions.

78

UMBILICAL TERMINATION ASSEMBLY (UTA)

Our UTA products offer a wide range of configuration to meet the most demanding field requirements whilst simplifying installation and operability.

80

MULTIBORE HUB CONNECTION (MHC UTA)

Our MHC-UTA provides Totex savings and simplified seabed infrastructures with direct tie-in of umbilicals to the manifold or SDU.

81

APTARA™ FLX360 MULTI-QUICK CONNECTION SYSTEM

Our FLX360 is an innovative Multi-Quick Connect (MQC) system that enables fast and reliable connections between all elements of the subsea distribution system.

82

See Section 8 on page 182 for detailed specifications and data sheets.

SUBSEA CONTROL SYSTEMS

SEMSTAR5 SUBSEA ELECTRONICS MODULE

	Subsea Electronics Module – SemStar5		
Feature	Make to Order	Make to Order	Make to Order
Variant	1 Option Low Power	1 Option Medium Power	1 Option High Power
Power consumption	< 150 W	< 200 W	< 300 W
Operating environment	23°F to 104°F (-5°C to 40°C) at 9,842 ft (3,000 m) water depth	23°F to 104°F (-5°C to 40°C) at 9,842 ft (3,000 m) water depth	23°F to 104°F (-5°C to 40°C) at 9,842 ft (3,000 m) water depth
DHPTG interface	Baker Hughes, Schlumberger, Well Dynamics	Baker Hughes, Schlumberger, Well Dynamics	Baker Hughes, Schlumberger, Well Dynamics
Communications type	Point-to-point: CAPS DSL CAPS Ethernet Multidrop: CAPS Cooper Modem COPS Copper Modem	Point-to-point: CAPS DSL CAPS Ethernet Multidrop: CAPS Cooper Modem COPS Copper Modem	Point-to-point: CAPS DSL CAPS Ethernet Multidrop: CAPS Cooper Modem COPS Copper Modem
Dimensions – Dia x L (mm)	275 x 912	275 x 912	275 x 1,155
Weight, max	< 286 lbs (130 kg)	<309 lbs (140 kg)	<341 lbs (155 kg)

SemStar5 is our ultra-reliable fifth-generation subsea electronics module for control systems. It has industry-leading reliability, with a mean time between failures (MTBF) of more than 150 years, 10 times the Offshore and Onshore Reliability Data project (OREDA) average.

SemStar5 draws on the design heritage and learning from over 40 years of subsea controls experience. It is modular in construction and highly configurable to meet wide-ranging customer needs from the control and monitoring of trees and manifolds, to SIL2 and SIL3 safety systems, such as Process Shut Down (PSD) and High-Integrity Pipeline Protection System (HIPPS) systems.

The SemStar5 has been extensively qualified and proven in the field, with orders for more than 600 with 225 units already deployed since 2011. It is Technology Readiness Level (TRL) 7 and can be delivered with a typical lead time of seven months.

Reliability extends to our product design, where we specify the use of industrial grade components and all electronic components are de-rated accordingly. Because we know that heat is the greatest threat to the reliability of electronics, SemStar5 has been designed for effective heat-dissipation, through careful choice of materials and thermal modeling. The robustness of the design has also been demonstrated by both accelerated life testing (ALT) and highly-accelerated life testing (HALT), testing the unit in extreme temperatures and vibration conditions to truly understand its performance boundaries and modifying the design and component selection accordingly.

The SemStar5 employs Baker Hughes' high-end networking capability to connect using dynamic, Layer 3 networks. Its software comprises a set of layered components deployed as a single package that executes on each PCB within the unit. This common firmware and hardware used on each functional card facilitates obsolescence management, as the brain on each SemStar5 card can be separated and upgraded without redesign of the cards themselves. We use a cross-industry real time operating system, QNX, for the unit's TCP/IP Ethernet backplane, and external connection to Ethernet enabled devices.

SemStar5 has been designed to be backwards compatible with legacy Baker Hughes SEMs. Our 'SEMulation' software allows SemStar5 to emulate legacy SEMs without disruption to existing topside hardware or operator interfaces, as demonstrated on many successfully upgraded projects. This provides an upgrade path to maintain or expand older systems without the need for costly infrastructure changes.

System redundancy continues into the SemStar5 itself, using a redundant 100 Mbit/s ethernet Backplane and Interbay-comms and a redundant DC power bus to each plug-in module – reducing wiring by 50% and further improving availability of the control system. In situ downloading of software is also permitted to ensure the unit is future proof.

Typical lead time:

7 months

The SemStar5's Make to Order variants can be delivered in 7 months.

SUBSEA CONTROL SYSTEMS

MODPOD SUBSEA CONTROL MODULE

	Subsea Control Module (SCM)	
Feature	Make to Order	Configure to Order
Variant	1 Option	
Temperature rating (storage)	0°F to 122°F (-18°C to 50°C)	
Temperature rating (operating)	23°F to 104°F (-5°C to 40°C)	
Depth capability	6,561 ft (2,000 m)	9,842 ft (3,000 m)
Size – W x D x H (mm)	770 x 770 x 1,550	
Weight in air	6,172 lbs (2,000 kg)	
Weight in water	3,527 lbs (1,600 kg)	
LP working pressure (psi)	5,000	3,000
Number of hydraulic functions	Up to 24	Up to 42
HP working pressure (psi)	10,000	
SCM base connector manufacturer	Siemens Tronic	Teledyne ODI
SCM base connector quantity	Up to 6	
Open/Close Loop	Open	Close
Control Fluids	MTO: – Transaqua HT2 – Oceanic HW443 – Oceanic HW540 (and P) – Oceanic 740R	CTO: Any Water Glycol fluid subject to qualification and compatibility testing

We know that the safe and efficient control of subsea production systems is at the top of our customers' priorities. That's why we have ensured the Baker Hughes Subsea Control Module, 'ModPod', is one of the most technologically advanced, versatile and reliable control system components available.

ModPod is a multiplexed electro-hydraulic Subsea Control Module (SCM), typically used for subsea tree and manifold-mounted applications. It is also used for wider applications such as subsea interventions, workovers, safety-systems and subsea isolation valve (SSIV) control. It ensures the stable and reliable control of subsea valves, while providing the communications and sensor data read-back required to maintain optimal operational efficiency.

The ModPod's modular, configurable design, in conjunction with Baker Hughes' structured engineering and quality processes, enables short cycle times and certainty of schedule. This allows us to deliver Make to Order variants as fast as nine months.

Common ModPod components across all applications also means repeatable build processes, improving reliability at the core of your subsea system. Every manufactured unit is subjected to hyperbaric testing to 9,842 ft (3000 m). Using standard components allows us to volume source them, extending reliability into the supply chain and bringing down the capital cost of this unit in our customers' production systems – a principle that extends to the SemStar5 units within the ModPod.

To date, we have delivered more than 1,000 ModPods to our customers and the SCM has a proven track record across a range of high-functionality applications, hitting production availability targets of over 99%.

The ModPod is API17F, SIIS and IWIS compliant. The standard Make to Order ModPod configuration supports 24 control functions, sufficient for most subsea production applications; however, ModPod variants can be configured to control up to 42 hydraulic functions, enough even for subsea workover control applications. It also offers integral hydraulic filtration and accumulation and hydraulic filtration, which means that separate subsea accumulation modules are not required, reducing the total cost of ownership over the asset life and improving the control system reliability.

Baker Hughes has been designing and manufacturing directional controls valves (DCV) for use in the Mod-Pod Subsea Controls Module (SCM) for over 25 years.

The product has undergone continual development and design validation to meet the ever increasing demands of controls systems from a reliability, availability and safety perspective.

Baker Hughes DCVs are qualified to 10,000psi with a variety of control fluids. Validation work is continuous, and the product line is continuing to evolve to meet the requirements of HPHT (15,000psi and 350F) and 20,000psi field requirements.

Typical lead time:

9 months

While we can offer a fully configured solution, our Make to Order ModPod can be delivered in 9 months.

SUBSEA CONTROL SYSTEMS

MASTER CONTROL STATION

Our Master Control Station (MCS) is the unit that brings together the control and monitoring of your Subsea Control System (SCS). It is designed to operate in conjunction with other topside safety, utility, and management systems.

The MCS enables you to control and monitor your subsea facilities from either the host ICSS/DCS, via TCP/IP, OPC UA/DS or MDIS, or from the unit's local Human Machine Interface (HMI). We can also offer an option where you can use a Remote Operator Work Station, providing full MCS capability from a standalone workstation remote from the MCS itself. This Remote Operator Workstation can be located anywhere with a network link to the MCS, be it in the Central Control Room, or in a remote location away from the host facility.

A Make to Order MCS can be delivered in 10 months, configured for any field or project size. The unit is modular in construction and based around two cabinets for the control of 16 wells, packaged for efficient use of space and minimizing the topside footprint required. The first cabinet houses the host servers and local HMI/Engineering Workstation and routers. The second cabinet contains programmable logic controllers (PLCs) for the handing of and processing of data from the subsea equipment. Fields of greater than 16 wells are accommodated simply by adding more PLC cabinets.

The MCS's HMI allows you to view the status of all the field's subsea devices in one place, monitoring everything from your drill centers and wells, to your manifolds and sensors. It has a layered graphical interface that presents an overview, plus detailed screens that enable you to run diagnostics, as well as capture and record required data. Local area networks also allow the MCS to provide control and data acquisition from other associated equipment, such as the Hydraulic Power Unit (HPU), Electrical Power Unit (EPU) or Uninterruptible Power Supply (UPS).

As an integral element of control system reliability, and therefore a driver for overall system availability, the MCS employs technology you can rely on. This includes robust components proven in Baker Hughes systems over decades, including the Rockwell Allan Bradley Control Logix PLC. The PLC runs software written in ladder logic, using predefined Add-On Instructions (discrete function blocks) that come from Baker Hughes' standard software library, obsolescence-managed offline from project execution, pre-tested and configured to each project application. The MCS's architecture is designed to provide seamless operation, allowing for in-built redundancy, with a hot standby and bump-less transfer between the active and standby system.

Security is also a paramount requirement for any control unit and the MCS is compliant with the cyber security requirement of IEC62443-2-4. The unit's HMI has several operational modes with password protected access privileges. Only the highest privilege enables full device configuration and valve and choke control, the setting of alarm limits and shutdown sequences.

IC-MCS (Industrial Controller – Master Control Station).

Where Programmable Logic Controllers are not a requirement, and when topside space is at a premium, Baker Hughes can offer an IC-MCS.

This technology utilises Beckhoff's TwinCAT 3 eXtended Automated Technology (XAT) operating under Ring 0 (i.e. on a Kernel) of redundant servers. Running 'above' any Operating System (such as Linux or Windows) the Beckhoff system is immune to any operating system error or failure, ensuring there is no impact on the monitoring or control of the Subsea Control System.

The Beckhoff system supports bumpless transfer for duty/standby, and Baker Hughes have successfully tested the control of 30 wells from a single 19" cabinet.

Subsea Gateway

For integrated ICSS/DCS & MCS solutions, Baker Hughes can deliver a subsea gateway. This unit contains SCI (Subsea Communication Interface) servers which provide a communications interface between the Topside system communication and the Baker Hughes subsea equipment for the subsea control system. In this configuration, the subsea facilities can only be controlled and monitored from the host ICSS/DCS on which all logic, shutdowns, sequences and interlocks reside will reside. Communicating to the ICSS/DCS over Modbus TCP/IP or OPC UA/DS, the unit can be delivered MDIS-compliant.

Typical lead time:

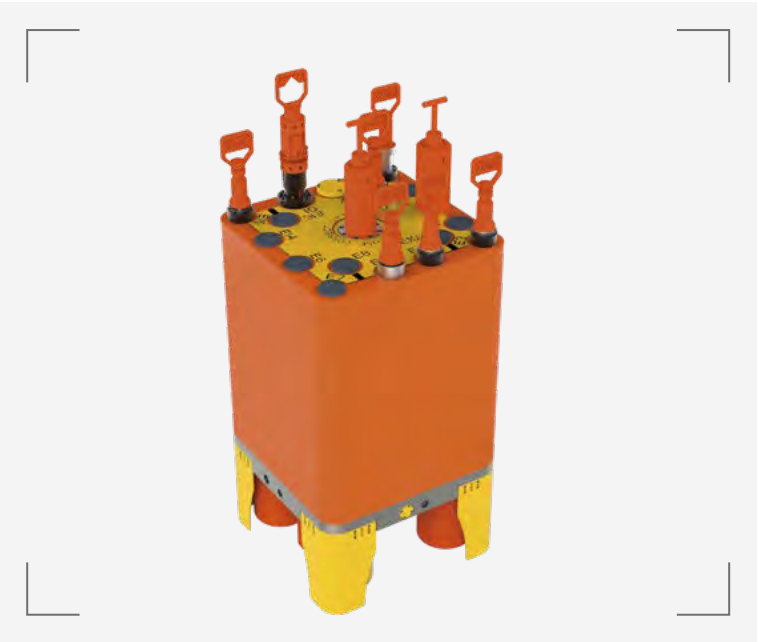
10 months

We can deliver a Master Control System in 10 months, configured to our standard two-cabinet base build to handle up to 16 wells (or more with additional cabinets).


HEATING ONLY
BRITANIA
TL 17 boil
UP 12/8/18
-Waiting NCR
T2949
T2945
T2063
T2062
T2022
T2930
T2939
EMERGENCY
STOP
STATIC SENSITIVE
VENTRIX
PAM
48V DC
0-700V AC
TISU

SUBSEA CONTROL SYSTEMS

SUBSEA COMMUNICATIONS AND ROUTING



	Power Communications Distribution Module (PCDM)		
Feature	Make to Order	Make to Order	Make to Order
Variant	2 Options 6 Slot Manifold	2 Options 8 Slot Manifold	2 Options 10 Slot Manifold
Power consumption including SIIS 2 Power	< 250 W	< 250 W	< 500 W
Input supply	300V – 600V	300V – 600V	300 – 600V
	500V – 1000V	500V – 1000V	
Number of output channels	Up to 6 SHDSL or Ethernet + 1 Ethernet	Up to 6 SHDSL or Ethernet + 2 Ethernet	Up to 11 SHDSL or Ethernet
Power switching	Optional	Optional	Optional
Weight, max	< 2,866 lbs (1,300 kg)	<3,086 lbs (1,400 kg)	<3,417 lbs (1,550 kg)
SIIS2 + power	1 x 30W	1 x 20W	2 x 30W
Communications range	Optical to 120 km	SHDSL Steel Tube 15 km	SHDSL Thermoplastic 30 km
Dimensions – W x D x H (mm)	770 x 770 x 1,841	770 x 770 x 1,841	770 x 770 x 1,841

The availability of modern subsea production systems is largely dependent on the reliability of the control system software and the local area network of modems and devices. We use a three-pronged approach to subsea network reliability that has made Baker Hughes an industry leader in the provision of complex subsea control networks and the development of proven modems that are effective over the longest of Industry offset distances.

Our network specialists start by ensuring fault-tolerance by design. Their standard approach to managing complex subsea communication networks is to use Layer 3, dynamic routing, often equivalent to the number of communication nodes in a large office building.

Secondly, the communication networks are built and tested well before the project extended factory acceptance test (eFAT), ensuring you can 'plug and play' (not 'plug and pray') at what is a crucial stage in your project execution. And of course, our SemStar5 is based on open architecture, which makes adding, upgrading, or swapping of subsea components seamless for life-of-field management and ad-hoc field expansion.

Finally, our modems are extensively tested at the unit and system level, using our on-site vibration beds, thermal chambers and umbilicals of copper quads and twisted pairs. We have even run optical transceivers through six months of Accelerated-Life-Tests to verify vendor selection for subsea use.

SUBSEA CONTROL SYSTEMS

REDUNDANT BUS

Redundant Bus communications are commonly known as multidrop communications, where a master modem is deployed topside and communicates in turn with each subsea unit's modem, which are slaves to the master and a node on the bus.

The number of nodes on the bus is a standard of six; this being an optimum compromise between offset, nodes and topside data refresh rates.

Baker Hughes has supplied Redundant Bus communications since 1993 on numerous projects and it provides a cost-effective communications solution for low offset distances (less than 19 miles/30 km). Throughout that period, Baker Hughes has maintained a communications and power analysis capability, understanding that good system design is at the heart of a reliable control system.

REDUNDANT STAR

Commonly known as point to point networks, Redundant Star communications provide high bandwidth and fast system update rates. They are typically used with optical communications that travel long offset distances (greater than 19 miles/ 30 km) and where complex instruments such as a multi-phase meter or acoustic leak detection form part of the subsea instrument suite.

The Make to Order solution comprises a Master Control Station topside containing routers that permit the use of optical transceivers and Ethernet. This transmits to a subsea receiving unit known as a Power Communications Distribution Module (PCDM).

The PCDM provides up to 10 star outputs and contains a Layer 3 switch that converts optical signals to copper signals for onward transmission to each of the subsea modules in the star. Layer 3 switches allow finer control in the management of the routing of messages through a system. The Layer 3 subsea network topology is hierarchical and aids in the separation and prioritization of subsea messages with full traceability.

Providing multiple active routes, the PCDM can direct packets to their destination via a more deterministic route in link failure modes, making communications systems more robust. It can also increase communications redundancy and availability by 'cross strapping' (routing) between A and B units. This mitigates a distribution failure (umbilical or UTA to PCDM failure) by enabling communications from the failed channel PCDM to be routed to the good channel PCDM, which maintains A and B communications to the units downstream of the PCDMs.

The PCDM provides Optical Communications Input of 100/1000Mbps, depending on offset (Ethernet 10/100Mbps, SHDSL 5.7Mbps – 192kbps) and distribute as an output either Ethernet 10/100Mbps or SHDSL 5.7Mbps – 192kbps.

Typical lead time (PCDM):

10 months

The PCDM can provide up to 10 star outputs and can be delivered in 10 months.

SUBSEA CONTROL SYSTEMS

UMBILICAL HEALTH MONITORING

A subsea production umbilical is a large component of your overall system capital costs and is expected to last the lifetime of your asset. Continuous monitoring of the health of your umbilicals is critical to the smooth functioning of your whole subsea control system. It can provide advance warning if any degradation in the system is expected and allow preventative measures to be put in place in a timely and OPEX-efficient manner.

The Baker Hughes Umbilical Monitoring Device (UMD) is specifically designed to monitor the health of an umbilical's electrical conductors continuously. It measures the insulation resistance between the umbilical electrical conductors and the system ground with high sensitivity, to which the umbilical is connected by applying a DC signal (less than 50 V) in analogue mode, and a pulsed DC signal in digital mode. The Baker Hughes UMD can measure with 1,000 times the sensitivity of a legacy traditional Line Insulation Monitor. The device's high sensitivity is achieved through intelligent signal amplification, a precise online calibration service and DC-offset detection and elimination.

With its sophisticated hardware and advanced software algorithms, the UMD can detect a wide range of leakage conditions in your electrical umbilical cores.

Unlike generic Insulation Resistance (IR) monitoring devices for cross-industry use, the Baker Hughes UMD has a range and accuracy designed specifically for subsea umbilicals: less than 5% error for umbilicals of 10 KΩ to 5 GΩ and less than 20% error for umbilicals of 5 GΩ to 10 GΩ. Leakage capacitance measurements are in the 100 nF to 1 µFT range. This range and accuracy provide more extensive and granular data for the Baker Hughes Digital IR-Monitoring application, which in turn provides continuous and predictive analysis of subsea insulation resistance. This enables timely intervention during planned interventions, rather than ad-hoc resolution of IR-related failures.

The UMD has two alarm settings, Low (L) and Low-Low (LL). These are triggered when the electrical conductor IR falls below the desired thresholds; the parameters of which are easily configured. The signal for the L or LL alarm can be seen through the communications interface and it will also activate a visible LED indicator on the front panel of the unit. Configuration for audible alarms and isolation of power to the primary of the subsea isolation transformer can be enabled.

The UMD can actively function while connected to umbilicals powered up to 1,000 VAC at 50–60 Hz. It has an online earth test circuit that warns if the unit is not adequately grounded. An earth fault allows an earth leakage current to flow through the measuring circuit to calculate IR in analogue mode, or IR and leakage capacitance (CL) in digital mode. Using these parameters, the UMD calculates the exact condition of the umbilical system without affecting your subsea power.

Typical lead time:

10 months

A UMD is provided as part of an Electrical Power Unit (EPU), or Subsea Power and Comms Unit (SPCU), with a lead time of 10 months.

SUBSEA CONTROL SYSTEMS

HYDRAULIC POWER GENERATION

An effective control system requires a stable, redundant supply of clean hydraulic power from the topside Hydraulic Power Units (HPUs). At Baker Hughes, we analyze the requirements of the whole field before specifying, designing and manufacturing a solution that is suitable for all existing requirements and any future expansion cases.

Our Configure to Order HPU is specified with supply and return reservoirs, a transfer pump to fill and recirculate fluid within the unit, electric/pneumatic powered pumps, filters, accumulator banks and other appropriate instrumentation and equipment, such as electric/pneumatic ESD valves, pressure sensors, tank limit switches, pressure safety and relief valves.

While the HPUs we build are designed to meet the specific requirements of your field, they are configured and built around these standard building blocks, enabling us to provide cycle times of 11 months. Equally, we review all client specifications to ensure that the configuration meets their requirements and that any sub components are suitably rated for quality. The standard materials used in our HPUs can also be tailored to meet your unique project requirements for demanding fluids or environments.

We also offer a wide range of field support to our HPUs during the life of a field from initial development through to the workover of a well. This includes ongoing production support, the flushing of equipment to clean the fluid, and pressure testing equipment and components, often at very high pressures.

Manufactured on DNV2.7-3 rated skids, our HPUs meet all local and regional TRS requirements, including ATEX, ASME and PED. Any specific regional legislation is considered carefully during the initial design phase.

	Hydraulic power generation – HPU			
Feature	Make to Order	Make to Order	Make to Order	Configure to Order
Variant	1 Option	1 Option	1 Option	
Region	North Sea	Asia Pacific	Africa / N.America	Field Driven
Temperature rating (storage)	0°F to 122°F (-18°C to 50°C)	0°F to 122°F (-18°C to 50°C)	0°F to 122°F (-18°C to 50°C)	
Temperature rating (operating)	23°F to 104°F (-5°C to 40°C)	23°F to 104°F (-5°C to 40°C)	23°F to 104°F (-5°C to 40°C)	
Size W x D x H (mm)	Up to 9,000 x 3,000 x 3,300	Up to 9,000 x 3,000 x 3,300	Up to 9,000 x 3,000 x 3,300	
Weight in air	Up to 55,115 lbs (25,000 kg) Dry weight	Up to 55,115 lbs (25,000 kg) Dry weight	Up to 55,115 lbs (25,000 kg) Dry weight	
Testing	Std testing	Std testing	Std testing	Std + 3rd party witness
Quality requirements	Std ITP	Std ITP	Std ITP	Customer ITP + 3rd part inspection

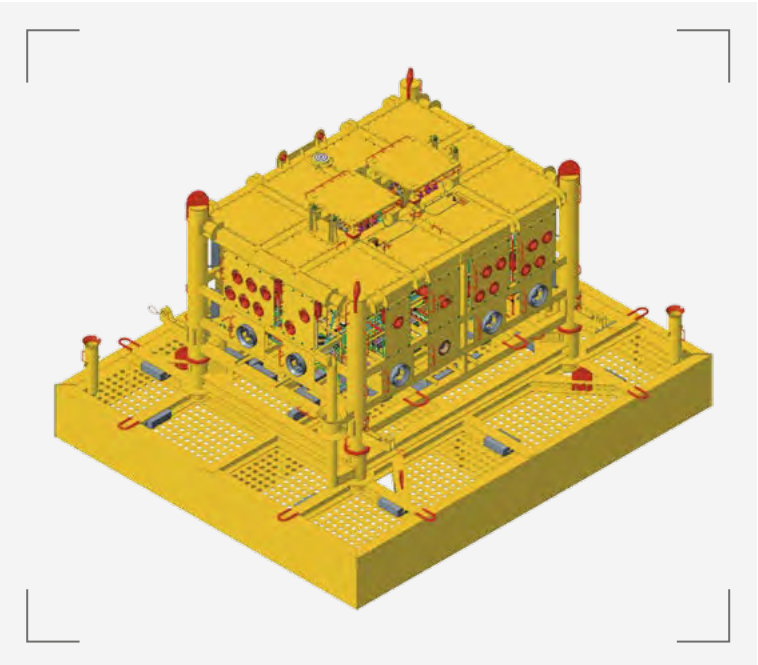
Typical lead time:

10 months

Our Make to Order HPU can be delivered in 10 months, while a fully configured unit would take 11 months.

SUBSEA CONTROL SYSTEMS

SUBSEA DISTRIBUTION UNIT (SDU)



Operating a successful oil and gas production system in a demanding subsea environment requires a complex, yet robust distribution system that will deliver the hydraulic and electrical power, communications and chemicals precisely where and when you need them. Developing such a system demands a broad understanding of your field performance requirements and well conditions.

Our distribution product portfolio enables our customers to extend the boundaries of subsea production by focusing on simpler, lower cost and optimized solutions that put the system at the core. Taking a Total Expenditure (TOTEX) approach, we build fully integrated and highly reliable distribution system equipment to ensure high availability throughout your subsea facilities – from trees and manifolds, to subsea isolation valves (SSIVs), and processing or boosting installations.

The Subsea Distribution Unit (SDU) provide Hydraulic, Chemical, Optical and Electrical distribution to XT, manifolds and UTA through a direct tie-in of the main or infield umbilical using our Aptara™ Horizontal Clamp Connection System Light (HCCS-L) multibore UTA and Aptara™ FLX360 hydraulic flying lead connections which reduces the overall size and weight and saves installation and make up time offshore.

The SDU Module is a retrievable structure independent from the foundation structure and accommodates all the pipe/tube work with related valves and can be configured with hydraulic stab plates (STFL), HCCS-L connections, electrical flying lead connections as well host power and communication distribution modules (PCDM) or electrical distribution unit (EDU) as per your needs in order to optimize your field controls distribution philosophy.

With our fullstream capability, we offer a full range of installation support, including field service engineers, test equipment and tooling where required. Access to our global services means you can also rely on the best possible lead times, typically around 10 months for our Make to Order product offerings. These services are not only available to you during the build and installation process, but also for ongoing support throughout the entire product and field life.

Our industry-leading design teams have the expertise and resources to ensure that your complete subsea distribution system not only benefits from the highest level of engineering optimization and lean manufacturing best practices but is also focused on reducing TOTEX.

Our people bring extensive experience of designing subsea distribution equipment, along with a wealth of knowledge of different installation methods to suit differing water depths and field locations. Their capabilities include in-house development and performance of comprehensive testing programs – such as essential extended factory acceptance testing (EFAT) and site integration tests (SITs) prior to system deployment.

Typical lead time:

10 months

A fully integrated subsea distribution system can be delivered in 10 months.


A3
Baker Hughes
2 HIGH STREET, NAILSEA,
AVON, ENGLAND
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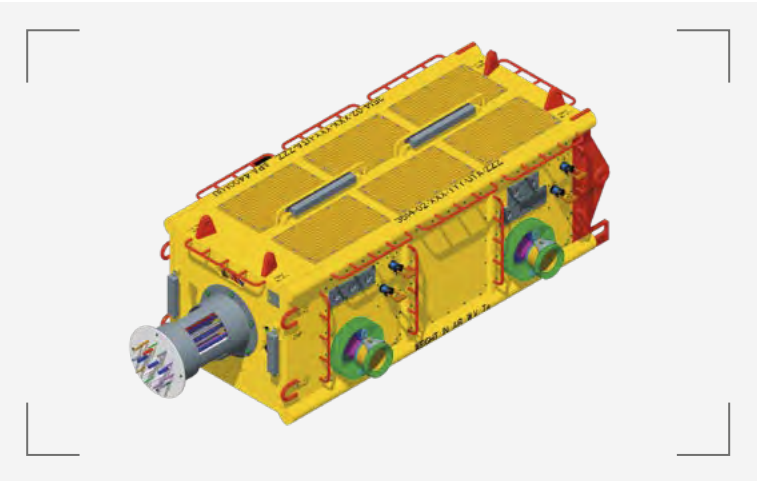
ISSUE
SERIAL No.

SUBSEA CONTROL SYSTEMS

UMBILICAL TERMINATION ASSEMBLY (UTA)



UTA Type D1

	Umbilical Termination Assembly (UTA)		
	UTA Type C1	**UTA Type C2**	**UTA Type D1**
Variant	Make to Order	Make to Order	Make to Order
# Hydraulic MQC connections	Up to 2 outlets	Up to 3 outlets	Up to 6 outlets
# Electrical/Fiber optic connections	Up to 4 outlets (w/ 2 MQC plates)	Up to 18 outlets (w/ 3 MQC plates)	Up to 12 outlets (w/ 6 MQC plates)
Isolation valves	None	Can be provided	Can be provided
Dimension (L X H X W) (mm)	2,945 x 1,087 x 1,383	3,874 x 1,165 x 1,343	3,000 x 1,087 x 1,400
Weight	Approx. 2,000 kg	Approx. 4,500 kg	Approx. 2,000 kg
Umbilical connection (inches)	Typ. 16 flange, class 600	Typ. 20 flange, class 300	Typ. 20 flange, class 300
Payload	Up to 35,000 kg	Up to 65,500 kg	Up to 70,600 kg
Installation	Category C IAW API-17-TR10	Category C IAW API-17-TR10	Category D IAW API-17-TR10
Stab plate	Aptara™ FLX360		
MQC Bore configuration (inches)	Coupler size Up to: 12 x ½ Up to 4 x 1		
Pressure rating	Up to 10,000 psi in all lines		
Depth rating	Up to 3,000m		
Certification	DNV 2.7-3 on request		

The Umbilical Termination Assembly breaks out the SPS services housed within the Umbilical distributing them to the network of subsea structures. Taking as reference the steel tube umbilical (static and dynamic both), the UTA enable break out of the fluid conduits (hydraulic and chemical) as well as the electrical cables and the fibre optical cables. These are then terminated to wet mate, which allows wider distribution of these services to the subsea structures to complete the Subsea Production System (SPS) network by the means of infield flying leads. In this way, the control links of the field are established.

Our structured Umbilical Termination Assemblies are designed to meet the demands of your SPS distribution network and ensure reliable delivery of the field's utilities. We have three Make to Order (MTO) configurations to effectively meet the demands of even the most complex system architecture and layouts.

Our UTA product portfolio enables our customers to extend but also simplify the boundaries of the subsea distribution network with MTO options that work in unison with our wider system offerings to ensure lower cost, simpler execution and leaner cycle times.

With 3 MTO options are designed in compliance to' API-17-TR10 and all have independent DNV 2.7-3 certification for the structures against anticipated load cases for installed as well as installation scenarios. We are able to offer industry leading design against reduced cycle times to ensure umbilical procurement is not impacted by ensuring the primary, secondary and umbilical interface remain unchanged.

All our designs are TRL-7 having been successfully deployed on a range of products from diver accessed fields to deep water developments.

Our Make to Order UTA configurations include the following:

Type C1 is the most compact UTA offering and can accommodate 2-off MQC plates as well as up to 4-off electrical/fiber optic wet mate connectors.

Classified as a UTA Category C in line with API17-TR10, these units typically weigh approximately 3,500 kg.

Type C2 is our medium UTA offering and can accommodate a combination of up to 3-off MQC plates as well as up to 18-off electrical/ fiber optic wet mate connectors. Project specific configurations can also be designed with a number of MQC plates and electrical/ fiber optic connectors and inclusion of ROV operable isolation valves as required. Classified as a UTA Category C in line with API17-TR10, these units typically weigh approximately 4,500 kg.

Type D1 is our largest UTA offering and can accommodate a combination of Up to 6-off MQC plates and Up to 12-off electrical/optical wet mate connectors. Project specific configurations can also be designed with a number of MQC plates and electrical/fiber optic connectors and inclusion of ROV operable isolation valves as required. Classified as a UTA Category D in line with API17-TR10, these units typically weigh 9,000 kg.

SUBSEA CONTROL SYSTEMS

MULTIBORE HUB CONNECTION (MHC UTA)

UTA Type D1

	Multibore Hub Connection UTA (MHC-UTA)
Feature	Make to Order
Variant	3 Options - Type B1, B2 & C1
# Multibore Connection Size	Type B1: 450 MB Type B2: 450-MB Type C1: 450-MB
# Electrical/Fiber optic connections	Type B1: Max. 10 electrical or 8 optical Type B2: Max. 14 electrical or 10 optical Type C1: Max 18 electrical or 8 optical+8 electrical
Dimension (L X H X W) (mm)	MHC UTA Cat. B1: 1,502 x 1,610 x 3,285 MHC UTA Cat. B2: 1,502 x 1,610 x 3,610 MHC UTA Cat. C1: 1,592 x 1,694 x 3,505
Weight (kg)	MHC UTA Cat. B1: 4,700, MHC UTA Cat. B2 5,100, MHC UTA Cat C1: 5,500
Installation	Type B1 & B2 : Category B IAW API-17-TR10 Type C1 : Category C IAW API-17-TR10
Connection System	Aptara™ HCCS-L
Multibore Hub Configuration utilizing SX22 - 1" coupler w/ poppet & SX44- 2" coupler w/ poppet	Multibore 450-V1A | V1B | V1C | V1D : 19x SX22 | 15x SX22 | 11x SX22 | 5x SX22 Multibore 450-V2 : 14x SX22 + 2x SX44 Multibore 450-V3 : 8x SX22 + 6x SX44
Pressure rating (psi)	Up to 10,000 in all lines
Depth rating (m)	Up to 3,000
Depth rating (m)	Up to 3,000
Certification	DNV 2.7-3 on request

The Multibore Hub Connection Umbilical Termination Assembly (MHC UTA) belongs to our Aptara™ HCCS-L connection system family for direct connection of umbilical to the subsea structures such as SDU or Manifold. This provides a totex lite solution compared to a stand alone UTA which typically requires further break out of services, additional mudmat and flying leads and associated installation.

Our Aptara™ HCCS-L enabled MHC UTA provides the following benefits over conventional UTA:

- Compact and light weight product providing reduced installation costs with smaller vessel and ease of load out
- Ease of assembly, handling and installation
- Optimized field layout and fewer subsea structures
- Optimized tooling by commonality with flowline connections to reduce your CAPEX
- Enhanced reliability by possibility of insitue seal inspection or replacement by ROV
- Robust capacity for umbilical installation and tie-in enhancing reliability
- Stroke back and wet parking capability enhancing installation flexibility
- Use of field proven proprietary metal to metal SX sealing coupler with poppets (1" and 2")

The MHC UTA is composed by the "Electrical Compartment" (MHC UTA frame) bolted to the standard Aptara™ HCCS-L Termination. It utilizes multi bore hub technology with metal to metal sealing to connect the hydraulic and chemical lines from the Umbilical to the Manifold/SDU Tubing. The Aptara™ HCCS-L comes with standard landing interfaces for the MHC UTA subsea installation and wet-parking enhancing installation flexibility.

The Electrical Compartment provides the connection for umbilical subsea termination interface (STI), integration and welding access for the hydraulic tubing, houses the cable and termination junction box as well as their associated wet made connectors for the electrical/optical flying leads.

Our Make to Order MHC- UTA configurations includes the following:

Type B1 is the most compact MHC-UTA offering and can accommodate size 450-mulitbore clamp connection as well as up to 10-off electrical or 8-off fiber optic wet mate connectors. Classified as a UTA Category B in line with API17-TR10, these units typically weigh approximately 5,000 kg.

Type B2 is our medium MHC-UTA offering and can accommodate size 450-mulitbore clamp connection as well as Up to 14-off electrical or 10-off fiber optic wet mate connectors. Classified as a UTA Category B in line with API17-TR10, these units typically weigh approximately 5,000 kg.

Type C1 is our largest MHC-UTA offering and can accommodate size 450-mulitbore clamp connection as well as up to 18-off electrical or 8 optic + 8 electrical wet mate connectors.

Classified as a UTA Category C in line with API17-TR10, these units typically weigh approximately 5,500 kg.

SUBSEA CONTROL SYSTEMS

APTARA™ FLX360 MULTI-QUICK CONNECTION SYSTEM

	Aptara™ FLX360 Multi-Quick Connection System
Feature	Make to Order
Temperature rating (operating)	23°F to 104°F (-5°C to 40°C)
Depth capability	9,842 ft (3,000 m)
Coupler size (inches)	Up to: 12 x ½ Up to 4 x 1
Number of lines	Up to 16
Pressure rating	Up to 10,000 psi in all lines
Tubing size (inches)	Up to 1 OD

The FLX360 is an innovative Multi-Quick Connect (MQC) system that enables fast and reliable connections between all elements of the subsea distribution system.

Hydraulic and chemical flying leads are critical components within the subsea system, ensuring reliable delivery of utilities around your subsea field. MQC plates enable the connection of these flying leads to the fixed structures (trees, distribution units, manifolds) through the connection of 'fixed' and 'flying' plates.

The FLX360 is an MQC plate that will meet even the most demanding field applications in terms of depth (qualified to 9,842 ft/ 3,000 m), load capacity (suitable for larger Steel Tube Flying Leads (STFLs) and some umbilicals. It incorporates a unique life-of-field design that allows maintenance in situ with no need for disconnection of the connector, reducing the total cost of ownership.

Originally conceived in 2010, and with over 1,000 MQC plates installed, the API 17F qualified FLX360 system continues to use a patented locking mechanism that leaves only one moving part of the design subsea. The complexity of the connection system (with their associated disadvantages) is housed within the retrievable and serviceable ROV tooling, eliminating screw threads from the system and enabling reliable make up/break out times of approximately 90 seconds.

Typical lead time:

3 months

Our FLX360 MQC System can be delivered in 3 months.

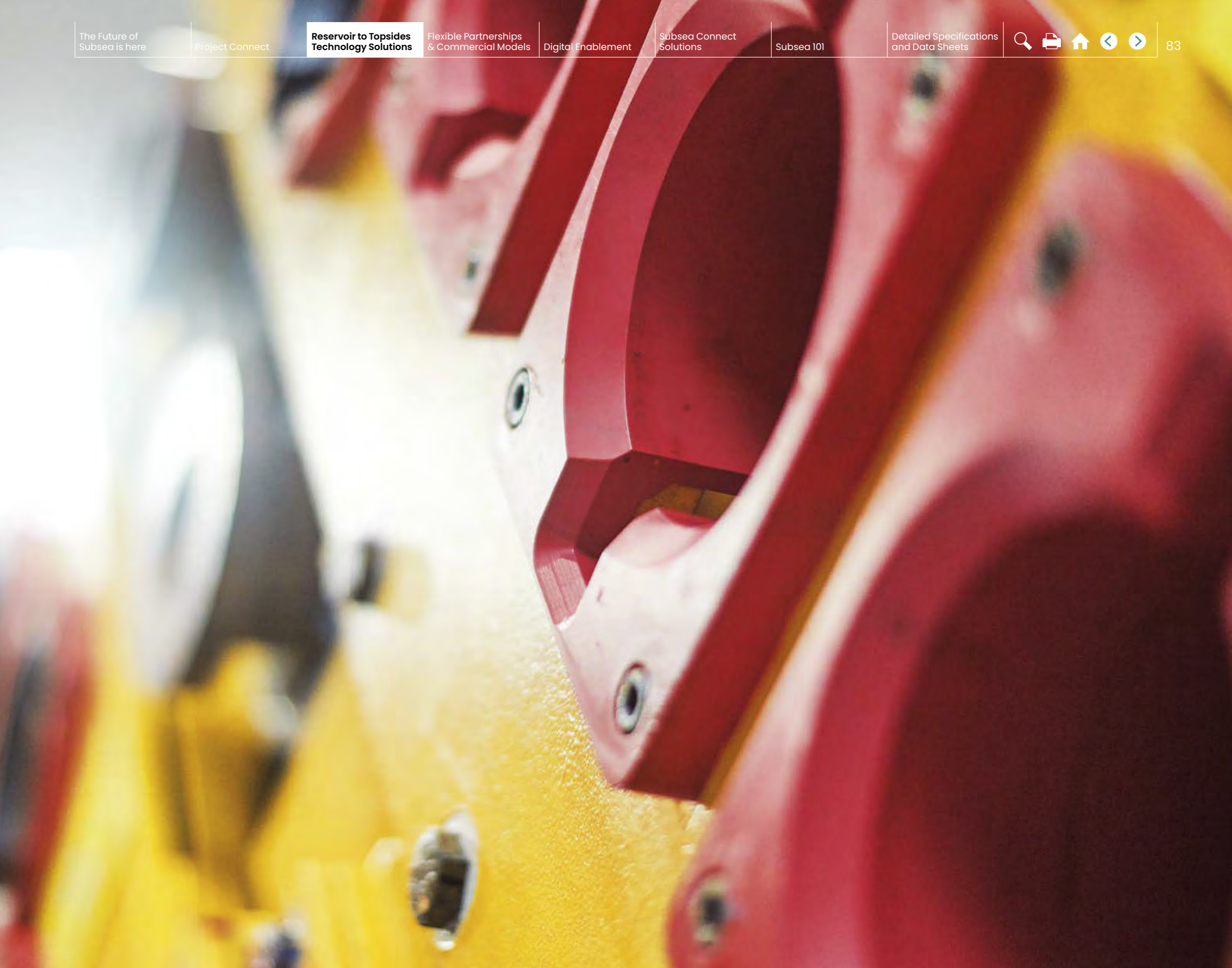
Our suite of FLX360 products will ensure your subsea distribution system performs reliably over the life of the field. The FLX360 product range has undergone continual development and validation to ensure it meets the ever-increasing demands of the subsea system. It has been designed to further reduce CAPEX without any detriment to reliability.

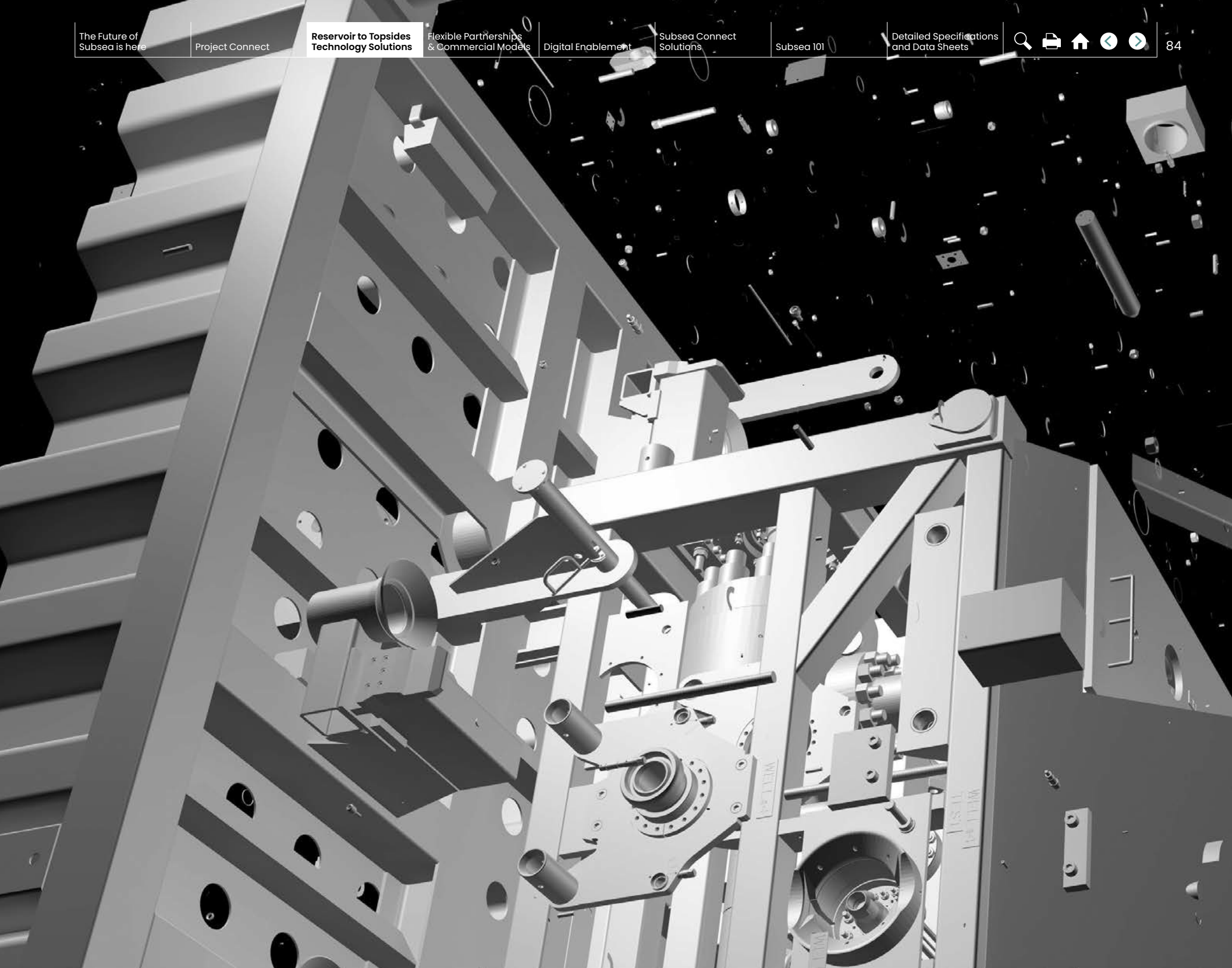
The latest FLX360 MQC plate offers improved calcareous and marine growth management. It uses molybdenum coated components and eliminates excessive close-fitting components as part of the design. The FLX360 also provides 80% more load capacity vs the original design, ensuring its suitability for deepwater STFL applications and some infield umbilicals.

We offer a complementary suite of FLX360 products that includes thermoplastic and steel tube flying lead carrier frames, fixed/ flying plates, parking plates, protective covers and logic plates. Our new simplified tooling package is also qualified to API 17F.

The Aptara™ FLX360 family is extended to include Cobrahead Assembly (CHA) suitable for termination of topside or infield Umbilicals and provides the connection links between the topside services and the subsea installed such as Manifold/SDU/UTA/XT. It enables subsea infrastructure to be reduced relative to a typical UTA connection, as it eliminates the requirement of any additional mudmats or UTA mounting bases and their installations saving cost.

The CHA design extends the FLX360 STFL flying plate with the addition of electrical and/or optical connections.





SUBSEA MANIFOLDS AND PIPELINE PRODUCTS OVERVIEW

Our product portfolio covers everything you need to integrate your subsea production system and ensure safe and efficient fluid transfer from your trees to your risers.

We have the largest installed base of subsea gas projects in the industry. And, with more than 170 manifolds installed, our comprehensive range of cluster and template manifold systems has the proven functional flexibility, scalability, and versatility to adapt to all your field requirements.

All our manifold and pipeline products are built to a modular design that uses standard tried and tested components that will work in a wide variety of configurations. This helps us to compress your schedule and offer reliable, shorter lead times, while minimizing the overall costs and risks.

Our range of products includes cluster and template manifolds, pipeline end manifolds (PLEM), riser bases, pipeline end termination (PLET), manual or remotely operated pig launcher and receivers (PLR), in-line tees (ILT), High-Integrity Pipeline Protection Systems (HIPPS) and subsea isolation valve modules (SSIV). We can also provide flexible or rigid jumpers – both with our industry-leading connection system.

Flexible pipe is highly versatile in meeting the demands of subsea and FPSO-based production. In some environments, it's the only suitable technology for a production system. Flexible pipe systems (FPS) products can be found in every major offshore production basin worldwide and are engineered to withstand the harshest operating conditions. Our systems are currently operating in depths well beyond 2,300m and are being qualified up to 3,000m.

APTARA™ MODULAR COMPACT MANIFOLDS

Our Aptara™ Modular Compact Manifold system addresses the need for modular, pre-engineered manifolds that use off-the-shelf components. Its lower-weight and compact size allows installation from smaller vessels – reducing cost and adding flexibility.

CLUSTER MANIFOLDS

Our Cluster Manifolds cover deep, medium and shallow water applications, using a modular approach to meet your field-specific requirements.

TEMPLATE MANIFOLDS

Our Template Manifolds are designed to ensure the highest reliability and safety across well systems, drilling, controls, installation and workovers.

PIPELINE PRODUCTS AND SOLUTIONS

Our pipeline products and solutions offer long-term reliability and safety with a modular approach that adapts to your field's specific requirements.

FLEXIBLE PIPE SYSTEMS, JUMPERS AND RIGID SPOOLS

Our flexible pipe products, rigid well jumpers, spools and pigging loops optimize your field layout and offer long-term reliability and safety.

See Section 8 on page 182 for detailed specifications and data sheets.

SUBSEA MANIFOLDS AND PIPELINE PRODUCTS

APTARA™ MODULAR COMPACT MANIFOLDS

	Subsea Compact Block Manifold (SCBM)	
Feature	Make to Order	Configure to Order
Variant	2 Options	
Number of slots	6	4
Number of headers	Option 1: 6-slot Dual production Option 2: 6-slot Dual production w/ Gas lift	Option 1: 4-slot Dual production Option 2: 4-slot Dual production w/ Gas lift
Distribution	Standalone SDU	Co-located on Foundation
Connector orientation	Horizontal	Vertical
Pressure rating (psi)	10,000 branch valve block 5,000 Manifold	10,000psi branch valve block 10,000psi Manifold
Temperature rating (°C)	-20°F to 250°F (-29°C to 121°C)	
Water depth rating	9,842ft (3,000m)	
Design life (years)	25	
Prod. header size, NPS (inches)	10	12
Prod. branch size, NPS (inches)	6	
Gas lift header, NPS (inches)	6	4
Gas lift branch, NPS (inches)	2	
Delivery time	10 months	12 months

Baker Hughes is rethinking the future of subsea fields. We are simplifying the complex by launching the new Aptara™ family of TOTEX-lite products. The Aptara™ modular compact manifold is part of this family of light and smart subsea equipment designed to reduce the total cost of ownership over the life of your field.

Our Aptara™ modular compact manifold system has been developed to address the need for modular, pre-engineered manifolds that use off-the-shelf components, reducing cycle time cost and footprint. The new compact block manifold from Baker Hughes has been designed to challenge complexity with simplicity.

The Aptara™ modular compact manifold's core design uses a 4-slot or 6-slot dual header configuration to suit your pipeline requirements and 5-inch or 7-inch branch valve blocks for its branch valve connections, with separate header piping. The manifold branch valves are identical to our Aptara™ lightweight compact tree system valves (e.g. 5-inch trees require 5-inch manifold branch valves), pushing the boundaries of standardization to the next level. This enables large volume purchase of components like valves and forgings, allowing us to hold the stock you need – reducing cost and lead time.

We have achieved a level of standardization that limits the engineering to the manifold header, structural steel, and foundation, resulting in faster delivery with reduced risks and costs. For the most common configuration, the manifold will be Make to Order with zero product engineering and delivered in 10 months from the award of a contract.

Typical lead time:

10-12 months

Our Make to Order Aptara™ modular compact manifold system can be delivered in 10-12 months.

SUBSEA MANIFOLDS AND PIPELINE PRODUCTS

The Aptara™ manifold features a compact design enabled by Aptara™valve block, with reduced pipe work, pipe end preparation, fitting, welding and NDE along with simplified interfaces, and is our response to the industry's need for reduced lead times and total cost. We will have pre-engineered stock of Aptara™valve blocks and gate valves from our 'family range' of 5 1/8" 10,000 psi and 7 1/16" 10,000 psi XT valves, all using existing design and qualified components. The manifold design enables different configurations to be selected to optimize your production. Further, chemical injection valves can be included as required.

The blocks can be readily insulated to provide the necessary thermal properties required to enhance operability, and project specific features such as gas lift can be accommodated in the manifold structure. The manifold and mudmat can be installed in a single lift using smaller and lower-cost vessels.

Where appropriate, pre-assembled and tested blocks (termed 'flat packs') can be shipped to remote fabrication locations for incorporation into the manifold build, assembly and test activity sequence, where facilities may not be as well suited as our XT facility for assembly and testing of the valve blocks.

The Aptara™ modular manifold is complemented by our Aptara™ connection systems, including our latest lightweight and fast horizontal tie-in system, HCCS-L, which is 50% lighter, 30% more compact, has a high capture range and can reduce the connection make-up time by 50%, compared to other conventional connection systems. Another member of the Aptara™ connection system family is the FLX360 stab plate connector. It has a simple latch that allows the ROV to connect flying leads quickly to the surrounding architecture, thus reducing the overall sub-sea hook up time.

Our Make to Order Aptara™ Manifold can be delivered in 10 months and our Configure to Order Variant in 12 months

Aptara™ 4 slot modular compact manifold

SUBSEA MANIFOLDS AND PIPELINE PRODUCTS

CLUSTER MANIFOLDS

	Deepwater Vertical Cluster Manifold (DVCM)	
Feature	Make to Order	Configure to Order
Variant	2 Options	
Number of slots	4	6
Number of headers	Option 1: Dual production Option 2: Dual production with gas-lift	Single prod. + MEG / gas lift + service
Distribution	Standalone SDU	Integrated SDU
Pressure rating (psi)	5,000	7,500 to 10,000
Temperature rating	-20°F to 250°F (-29°C to 121°C)	291°F (144°C)
Water depth rating	6,561 ft (2,000 m)	9,842 ft (3,000 m)
Design life (years)	25	Up to 50
Prod. header size, NPS (inches)	10	8, 12 or 14
Prod. branch size, NPS (inches)	6	8
Gas lift or MEG header, NPS (inches)	4	6
Gas lift or MEG branch, NPS (inches)	2	
Delivery time	12 months	16 months

Offering long-term reliability and safety, our Cluster Manifolds cover deep, medium and shallow water applications. We use a modular approach to ensure we can adapt them to widely varying field-specific requirements, with products ranging from standardized deepwater, shallow-water and injection manifolds, to very large export/gathering manifolds with headers up to 42 inches.

Our Cluster Manifolds are all based on a library of pre-engineered and qualified standard components used as modular building blocks. This gives our portfolio a comprehensive range of functional flexibility and versatility for any subsea field development. It also ensures we can maintain the highest quality and consistency, with lower overall costs and a faster delivery to first oil or gas.

Baker Hughes has an installed base of more than 120 Cluster Manifolds, demonstrating a solid track record in fulfilling the needs of any deepwater oil and gas production system. Lead times typically range between 12 and 16 months, and we offer guideline-less and diverless installation in deepwater, while divers can be used in shallow water.

A skirted mudmat or single/multi-can suction anchor foundation is provided, with the skirt customized to suit soil conditions at your field. We can also supply a gas lift, MEG header and service header, as required, to improve production rates and enhance operability.

Pigging loops facilitate round trip pigging to improve operability for dual flowlines, while a ROV pig launcher or remotely operated pig launcher can be used for single flowline applications.

As standard, all our manifolds come with a design pressure rating of 5,000 psi, 7,500 psi and 10,000 psi to cope with required shut-in pressures. They have a standard temperature rating of 0°F to 250°F (-18°C to 121°C), while higher temperatures can be accommodated depending on your field requirements. Thermal insulation with high thermal cool down performance can be provided, improving availability and flexibility during an unplanned shut down.

DEEPWATER VERTICAL CLUSTER MANIFOLD (DVCM)

Our Make to Order Deepwater Vertical Cluster Manifold (DVCM) has 4 or 6 well slots.

It uses dual production headers, with the option of a gas lift. The DVCM has a standard vertical clamp connection system (VCCS) for flowline and well jumpers with standard seal sizes. It has a production branch size (NPS) of 6 inches and a header of 10 inches, although other size options are available. The DVCM also uses a standalone subsea distribution unit, but an integral distribution solution can be provided.

Our Make to Order DVCM can be delivered in 12 months.

Typical lead time:

12-16 months

Our Make to Order DVCM can be delivered in 12-16 months.

SUBSEA MANIFOLDS AND PIPELINE PRODUCTS

DEEPWATER HORIZONTAL CLUSTER MANIFOLD (DHCM)

Our Make to Order Deepwater Horizontal Cluster Manifold (DHCM) has 4 or 6 well slots.

It uses dual production headers, with the option of a gas lift or MEG header. The DHCM has a standard horizontal clamp connection system (HCCS-L) for flowline and well jumpers with standard seal sizes. It has a production branch size (NPS) of 6 or 8 inches and a header of 12, 14 or 16 inches, although other size options are available. The DHCM also offers integrated subsea distribution with a multi-bore HCCS-L umbilical termination head (MHC UTA). Where needed we can supply thermal insulation provided by our proprietary Heatbank system, which allows for an extended cool down period.

Our Make to Order DHCM can be delivered in 15 months.

INJECTION MANIFOLD (WATER AND GAS)

Our Make to Order Injection Manifold (water and gas) has 2, 4 or 6 well slots.

It uses a single header, with the option of dual headers for a water alternating gas (WAG) injection process. Our Injection Manifold has an injection branch size (NPS) of 6 inches and a header of 8 inches, 10 inches or 12 inches, although other size options are available. It offers ROV-operated valves with no Subsea Control Module (SCM), with a hydraulic option for a WAG injection process. It uses single isolation philosophy, but there is a dual isolation option for WAG, and it has a standard vertical or horizontal clamp connection system for flowline and well jumpers with standard seal sizes.

Our typical Injection Manifolds can be delivered in 12-16 months.

SHALLOW-WATER CLUSTER MANIFOLD

Our standard Shallow-water Cluster Manifold has 4 or 6 well slots.

It uses a single production header, with the option of dual headers, and employs diver operated flange connections for tie-ins. Our Shallow-water Manifold has integrated subsea distribution with a, multi-bore HCCS-L umbilical termination assembly (MHC-UTA) with the option of a diver connected Umbilical Termination Assembly (UTA). It also has an integrated protection structure, to ensure it is fishing-friendly or 'over-trawlable', as per the industry standards ISO 13628-15 and NORSOK U001.

Our typical Shallow-water Manifolds can be delivered in 12-16 months.

GAS EXPORT/GATHERING MANIFOLD

Our Gas Export/Gathering Manifold has multiple headers to suit your field requirements.

Baker Hughes has the largest installed base of customized large-size Gas Export/Gathering Manifolds in the industry. As with our other manifolds, we use of pre-engineered and qualified standard components as modular building blocks. This allows us to deliver highly customized large-size manifolds with lower costs and reduced execution risks to a faster delivery schedule.

Our optimized large-size manifold systems come with as many connection slots as required to suit various field requirements. Their size range (typically from 18 to 42 inches), design pressure and temperature can all be specified to meet your exact project needs. They use a standard horizontal clamp connection system (HCCS), but also our vertical clamp connection system (VCCS)for flowline and well jumpers with standard seal sizes. Integrated subsea distribution can also be provided to suit your field requirements.

Our typical Gas Export/Gathering Manifolds can be delivered in 16-20 months.

	Deepwater Horizontal Cluster Manifold (DHCM)	
Feature	Make to Order	Configure to Order
Variant	2 Options	
Number of slots	4 & 6	8
Number of headers	Option 1: Dual production with gas-lift (oil) Option 2: Dual production with MEG (gas)	Single prod. + MEG / gas lift + service
Distribution	Integrated	Standalone SDU
Pressure rating (psi)	5,000	7,500 to 10,000
Temperature rating	-20°F to 250°F (-29°C to 121°C)	291°F (144°C)
Water depth rating	6,561 ft (2,000 m)	9,842 ft (3,000 m)
Design life (years)	25	Up to 50
Prod. header size, NPS (inches)	10 (oil) or 16 (gas)	12, 14 or 18
Prod. branch size, NPS (inches)	6 (oil) or 8 (gas)	Multibore
Gas lift or MEG header, NPS (inches)	4	6 or 8
Gas lift or MEG branch, NPS (inches)	2	
Delivery time	15 months	16 months

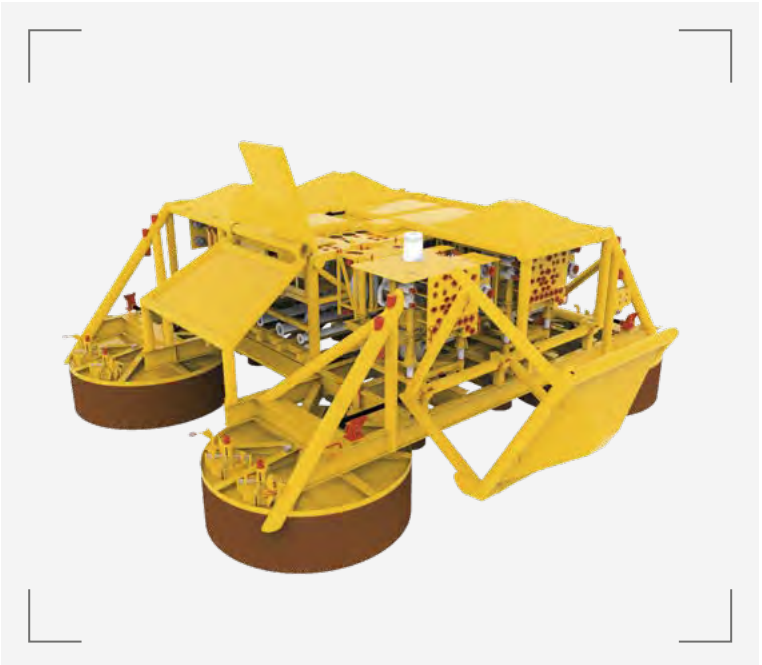
Typical lead time:

12–16 months

for all of our DHCM.

SUBSEA MANIFOLDS AND PIPELINE PRODUCTS

TEMPLATE MANIFOLDS



We take a total-system approach to designing Template Manifolds that will ensure the highest reliability and safety across well systems, drilling, controls, installation and workovers. They are built around the Baker Hughes standard Template Manifold solution, which includes an Integrated Template Structure (ITS), a Template Manifold and a Flow Control Module (FCM).

Like our Cluster Manifolds, our Template Manifolds are based on a library of pre-engineered and qualified standard components used as modular building blocks. They provide functional flexibility and versatility for any subsea field development, while maintaining the highest quality and consistency, with lower overall costs and a faster delivery to first oil or gas.

Baker Hughes has an installed base of more than 45 Template Manifolds, most of which have been delivered in the North Sea where it is required to be fully over-trawlable. Lead times typically range between 12 and 15 months, and our solutions offer you long-term reliability and safety with a modular approach that means we can adapt to your field specific requirements.

INTEGRATED TEMPLATE STRUCTURE (ITS)

Our standard Integrated Template Structure (ITS) is a guideline-less system with 4 or 6 well slots.

With a solid track record in the North Sea, our standard ITS is a reliable choice for any typical oil or gas field service application. It is NORSOK compliant with its fully validated over-trawlable design and integrated protection structure, which has foldable protection hatches to simplify installation.

The ITS's optimized size and weight – around 15-20% lighter than previous designs – also makes installation much easier, and the system comes with a suction control panel for active levelling and include a system for grouting. It has a multi-pile suction anchor foundation that can be tailored to suit soil conditions.

The ITS provides foundation support for your conductor, wellhead, XTs, distribution and manifold, and facilitates access to a blowout preventer (BOP) during drilling, completion and workover interventions. The system also includes ROV access for intervention and operation.

Our Make to Order ITS can be delivered in 12 months

	Template Manifold	
Feature	Make to Order	Configure to Order
Variant	2 Options	
Number of slots	4	6
Number of headers	Option 1: Dual production Option 2: Dual production with gas-lift	Single prod. + injection + service
Protection structure	NORSOK compliant, integrated	NORSOK compliant, integrated
Foundation	4 can suction pile	Made to project
Delivery time	12 months	15 months

Typical lead time:

12–16 months

for all our Template Manifolds.

SUBSEA MANIFOLDS AND PIPELINE PRODUCTS

TEMPLATE MANIFOLD

Our standard Template Manifold is a guideline-less manifold system with 4 or 6 well slots.

It uses dual production headers, with the option of a single header. A gas lift, MEG header and service header can also be provided to enhance operability. The Template Manifold is independently installable and retrievable from the ITS and has a standard horizontal clamp connection system (HCCS-L) for flowline and well jumpers with standard seal sizes, which reduces installation time.

It has a production branch size (NPS) of 6 inches (with an 8-inch option) with combination of controls and hydraulic lines in a multi-bore wing-hub configuration for branches and a header of 10 inches (with options in the range of 12-16 inches). The Template Manifold also uses an integrated subsea distribution unit with a multi-bore HCCS-L Umbilical termination assembly (MHC-UTA) – this reduces the structures needed and therefore CAPEX and INSTALLEX.

The system is designed to cope with higher well growth. Further options include an ROV pig launcher or remotely operated pig launcher for single headers, or a pigging loop (internal or external) for dual headers to enhance operability.

Like our Cluster Manifolds, our Template Manifolds come with design pressure ratings of 5,000 psi, 7,500 psi and 10,000 psi to cope with required shut-in pressures. They have a standard temperature rating of 0°F to 250°F (-18°C to 121°C), while higher temperatures can be accommodated depending on your field requirements. Thermal insulation using our proprietary Heatbank system can be provided with an extended cool down period.

Our typical Template Manifold can be delivered in 12-16 months

FLOW CONTROL MODULE (FCM)

Our Flow Control Module (FCM) channels and controls the flow between tree and manifold.

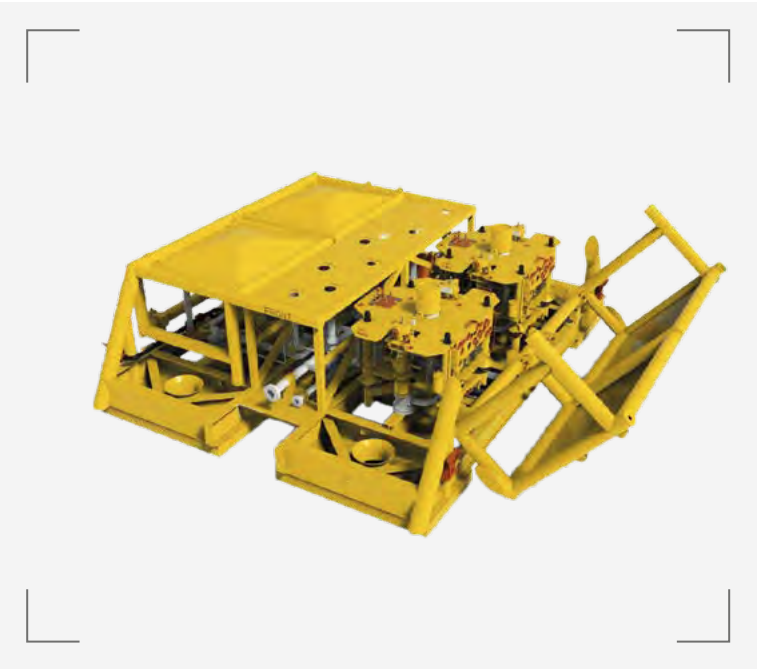
We have extensive experience in delivering the Flow Control Modules that work at the heart of your subsea system to maintain a reliable and accurate rate of flow. Our FCM comes with a dedicated running tool and stroking tool, and houses a choke module, flowmeter and other instrumentation vital to the Template Manifold system.

We offer guideline-less installation of the FCM and the unit is independently retrievable to give you increased reliability and convenience. ROV access is also improved by having a horizontal connection to the manifold and vertical connection to the tree (with the option of both vertical connections). By using multi-bore hubs that handle production, controls and distribution lines, means we can reduce the number of connections and offer a lower installation cost.

We can also provide insulation with our proprietary Heatbank system that gives you an extended cool down period, which can enhance both operability and availability.

Our typical FCM can be delivered in 10-12 months.

SUBSEA MANIFOLDS AND PIPELINE PRODUCTS



SHALLOW-WATER MULTI FLOWBASE (MFB)

Our standard Shallow-water Multi FlowBase (SW MFB) System is a guideline-less system with 2, 4 or 6 well slots.

Baker Hughes have developed a cost optimized solution for shallow water, based on ITS and shallow water Xmas trees and manifolds in the North Sea.

The SW MFB facilitate use a of standard satellite XT into a "template" system, and also easily allows the connection of a step-out well from a well slot in case if this is required. Valves are diver replaceable, and hence there is no need for a retrievable manifold piping module. This represent a huge simplification to the template as tolerance loop is significantly reduced, and fabrication jigs or precision welding will be required. The overall simplification have driven a significant reduction in fabrication complexity total weight reduction by 50% and installation complexity, resulting in lower cost, execution time and installation time.

The MFB provides conductor, wellhead, XTs, distribution and manifold, and facilitates access to a blowout preventer (BOP) during drilling, completion and workover interventions. The system also includes ROV access for intervention and operation.

Our Make to Order FW MFB can be delivered in 10 months

	Shallow Water Multi-flowbase (MFB)	
Feature	Make to Order	Configure to Order
Variant	2 Option	
Number of slots	4	6
Number of headers	Option 1: Single production with gas lift Option 2: Single production with gas lift and water injection	Dual production
Installation	Diverless or Diver assist	
Protection structure	NORSOK compliant, integrated	NORSOK compliant, integrated
Foundation	Mudmat	Suction anchor
Delivery time	12 months	15 months

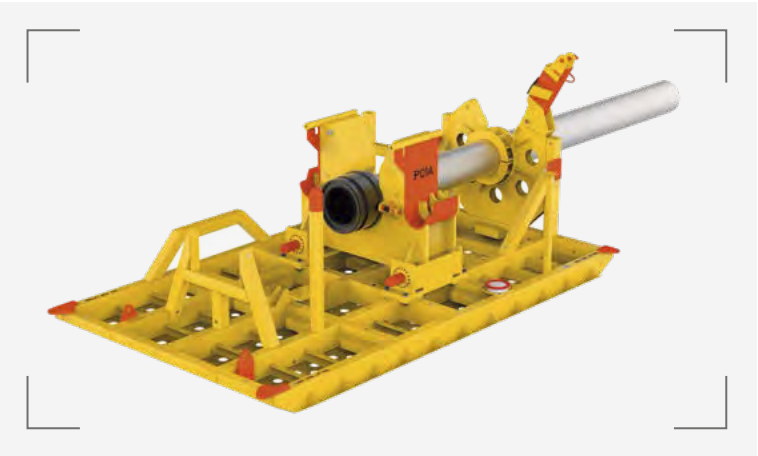
Typical lead time:

12–16 months

for all our Template Manifolds.

SUBSEA MANIFOLDS AND PIPELINE PRODUCTS

PIPELINE PRODUCTS AND SOLUTIONS



Our pipeline products and solutions offer long-term reliability and safety with a modular approach that allows us to adapt them to your field's specific requirements.

We have a longstanding track record for delivering high quality, well-designed pipeline products and solutions such as Pipeline End Termination (PLET), Pipeline End Manifold (PLEM), In-line Tees (ILT), riser bases and Subsea Isolation Valves (SSIV). Our differentiated pipeline products and solutions include an Open-PLET solution, a High Integrity Pipeline Protection System (HIPPS) and remote operated Subsea Pig Launcher and Receiver (PLR).

Our total system approach ensures that we design pipeline products that will achieve the highest standards of reliability and safety, while being much easier to install. This helps us achieve lead times that typically range between 10 and 12 months.

Like our manifolds, our pipeline products are based on a library of pre-engineered and qualified standard components used as modular building blocks. This gives us a portfolio that covers a comprehensive range of products that provide functional flexibility and versatility for any subsea field development. This ensures we can deliver the highest quality and consistency, with lower overall costs and a faster delivery to first oil or gas.

OPEN-PLET

Our Open-PLET solution offers simplicity and robustness to enhance reliability.

Our patented Open-PLET solution allows you to install a separate and independent subsea pipeline and pipeline end termination (PLET) structure. It uses the standard Baker Hughes connection system – HCCS– and simplifies your pipe laying operation due to the elimination of PLET structure work and the associated risks. Your PLET Skid/Structure can therefore be installed on the seabed close to your pipeline.

This all reduces the risk and maximizes safety and reliability during the installation process, reducing your overall cost and installation time.

Typical lead time:

10 months

Our Make to Order Open-PLET can be delivered in 10 months.

HIGH INTEGRITY PIPELINE PROTECTION SYSTEM (HIPPS)

Our High Integrity Pipeline Protection System (HIPPS) is a guideline-less module.

It improves your cost efficiency by effectively downrating the subsea pipeline and risers to transient flow pressures. As well as reducing your necessary CAPEX, this enhances reliability and safety, particularly in the case of a pressure surge through the unit.

HIPPS is easy to install and maintain as it is independently installable and retrievable from foundation. The use of a standard vertical clamp connection system (VCCS) or horizontal clamp connection system (HCCS-L) and intervention tooling allows common tooling with the XT and manifold system.

HIPPS has a standard temperature rating of 0°F to 250°F (-18°C to 121°C), while higher temperatures can be accommodated depending on your field requirements. With a logic solver that is fully compatible with our SemStar5 control system, the unit can be slotted into your field easily. It is also SIL3-rated for safety and comes with a design pressure of 10,000 psi.

Typical lead time:

12 months

Our Make to Order HIPPS module can be delivered in 12 months.

SUBSEA MANIFOLDS AND PIPELINE PRODUCTS

SUBSEA PIG LAUNCHER AND RECEIVER (PLR)

Our Subsea Pig Launcher and Receiver (PLR) has a size range of 4 inches up to 42 inches.

Baker Hughes has a solid track record in delivering Subsea Pig Launcher and Receiver systems offering guideline-less installation, vertical or horizontal configuration and a standard design with 6-off pigs.

Our PLR has a kicker line (either 2 inches or 4 inches) with ROV isolation valves and injection stab. There is also the option to integrate the kicker line as a tandem connection to reduce the number of connections and associated hardware and installation costs. Baker Hughes' new remotely operated PLR is based on our well proven design, which enables pig launching without the need for ROV or vessel intervention, saving significant operational cost.

It is also an enabling technology for long tie-back single flowline field layouts that can result in a significant reduction of your TOTEX. The PLR comes with an acoustic pig detector (APD), which allows you to remotely monitor pig launches. There is also an option for soft-landing a larger size PLR for safer installation.

Typical lead time:

12 months

Our Make to Order PLR can be delivered in 12 months.

REMOTE OPERATED PIG LAUNCHER (ROPL)

Our Remote Operated Pig Launchers have a size range of 4 inches up to 42 inches.

To reduce your CAPEX cost, Baker Hughes has developed a Remote Operated PIG launcher. ROPL facilitate frequent pigging without need for offshore operations, influencing the production or having a large top side compressor station to drive the pig in a loop configuration.

ROPL is designed to hang off the subsea manifold future end allowing the launcher to be implemented at any time of the field life without disturbing the production. The pigs are launched into the flow through the already existing header valves on a production system. Fluid to drive the pig into the production flow is taken from the drill-center service lines via a dual bore configurated connection.

The "heart" in the pig launcher system is the electrical actuated pig selector – a flow diverter that divert the flow to the different kicker lines for pigs preloaded inside the pig launcher barrel. Using low power electrical actuator removes the need for hydraulic lines to the launcher or hydraulic functions on the control system, while the low electrical power required for the flow diverter actuator ensures no impact on the umbilical or subsea control unit.

Typical lead time:

10 months

Our Make to Order ROPL can be delivered in 10 months.

	High Integrity Pipeline Protection System (HIPPS)
Feature	Make to Order
Variant	2 Options
Prod. header size, NPS (inches)	8 or 6
Pressure rating (psi)	10,000 or 5,000
Temperature range	0°F to 250°F (-18°C to 121°C)
Valve close time, sec	<10
SIL rating	SIL3
Delivery time	12 months

	Subsea Pig Launcher and Receiver (PLR)
Feature	Make to Order
Variant	Multiple Options
Pipe size range (inches)	4 – 42
Configuration	Horizontal or vertical
Operation mode	ROV operated or remotely operated (ROPL)
Installation	Pre-installed with the Manifold/PLEM/PLET, re-installable
Pig capacity	Up to 6 pigs
Kicker line	2-inch or 4-inch with ROV isolation valves and injection stab
Configuration	Integrated or separate tandem kicker line connection
Delivery time	12 months

	Remote Operated Pig Launcher (ROPL)
Feature	Make to Order
Variant	Multiple Options
Pipe size range (inches)	10 - 42
Configuration	Horizontal or vertical
Launching mode	Remotely operated via. Topside MCS, Production launch or Service (MEG or gas lift) launch
Operation	Electric actuation (Service launch) or Hydraulic (Production launch)
Installation	Pre-installed with the Manifold/PLEM/PLET, re-installable
Pig capacity	Up to 6 pigs
Kicker line (inches)	2 (Service launch) or 3 (Production launch)
Connector configuration	Dual concentric connection (Service launch) or separate tandem multibore connection (Production launch)
Delivery time	10 months

SUBSEA MANIFOLDS AND PIPELINE PRODUCTS

FLEXIBLE PIPE SYSTEMS, JUMPERS AND RIGID SPOOLS

	Rigid Jumpers and Spools
Feature	Make to Order
Variant	Multiple Options
Pipe size range (inches)	3-42
Orientation	Horizontal or vertical configuration
Bore configuration	Single, dual, multi-bore options
Pipe shapes	Range of 2D and 3D shapes as per field requirements
Thermal insulation	Optional
Installation method	Guideline less
Delivery time	10 months (as kits)

	Flexible Pipe Systems
Feature	Make to Order
Variant	Multiple Options
Pipe Size Range (inches)	2-16
Applications	Risers, Flowlines, Jumpers, Transfer Lines
Thermal Insulation	Optional
Delivery Time	10 months

The design and supply of well jumpers interfacing with XT, manifolds and pipelines are critical to maintaining the safety and reliability of your operations.

We have extensive experience and a proven track record of delivering flexible pipe products through our flexible flowline, riser and jumper portfolio. In addition, we supply rigid well jumpers, spools and pigging loops to optimize your field layout. Our solutions offer long-term reliability and safety, while our modular approach enables us to configure them to your specific field requirements.

Our total system approach ensures that we design pipeline products that will achieve the highest standards of reliability and safety, while being much easier to install. This helps us achieve lead times of around 10 months.

As with all our pipeline products, we use a library of pre-engineered and qualified standard components as modular building blocks, resulting in a versatile portfolio that covers a comprehensive range of subsea field developments. This ensures we can deliver the highest quality and consistency, with lower overall costs and a faster delivery to first oil or gas.

FLEXIBLE PIPE SYSTEMS

Highly adaptable, reliable, and cost-effective pipeline solutions for offshore and subsea projects

Dynamic risers, flowlines, static and dynamic fluid transfer lines, and jumpers are critical to offshore oil and gas production, injection, and export systems. They are subject to extreme temperatures, pressures, physical stresses, and movement while carrying hot, highly pressurized corrosive materials – yet must still ensure reliable connections and optimal product flow. As offshore developments move into deeper waters and even more challenging environments, flexible pipe is a highly versatile fluid transportation solution, often it is the only suitable technology to enable floating production.

Our portfolio of flexible pipe solutions draws on more than 25 years of research and development, material science, and installation experience in some of the harshest conditions the industry offers – particularly in environments where water depth and seabed conditions impose unusual restrictions. Our products are robust, highly flexible, and adaptable to unique project requirements, and offer cost-effective and proven reliability for corrosive reservoirs.

Typical lead time:

10 months

Our Flexible Pipe Systems can be delivered in 10 months.

SUBSEA MANIFOLDS AND PIPELINE PRODUCTS

Baker Hughes unbonded flexible pipes are constructed from multiple layers of helically wound metallic wires and extruded thermoplastic barriers. Each layer is designed to address specific duty requirements, including, for example:

- High temperature
- High pressure
- Corrosivity including CO_2 and H_2S in conveyed fluids
- Dynamic marine environments such as floating production in shallow tidal zones
- Water depths to 3,000m
- Pipe inner diameter from 2 in. to 16 in.
- Required service life
- Flow assurance challenges such as thermal no-touch time
- Robust structure to cater for routing issues such as subsea canyons, or unstable geo-hazards such as mudslides or slopes

In dynamic applications, such as risers and export systems, we optimize designs to accommodate the motion of the production facility. In static environments, our flexible flowlines are ideal for connecting remote wellheads to riser bases and accommodating situations where there is uneven seabed topography or congested seabed architecture.

RIGID JUMPERS AND SPOOLS

Our Rigid Jumpers and Spools can be configured horizontally or vertically, with a piggable design where required.

With decades of experience in delivering well jumpers, we offer a wide size range of 3 inches up to 42 inches to meet your specific field requirements. All our well jumpers come with ancillaries to aid fabrication, testing, load-out and installation.

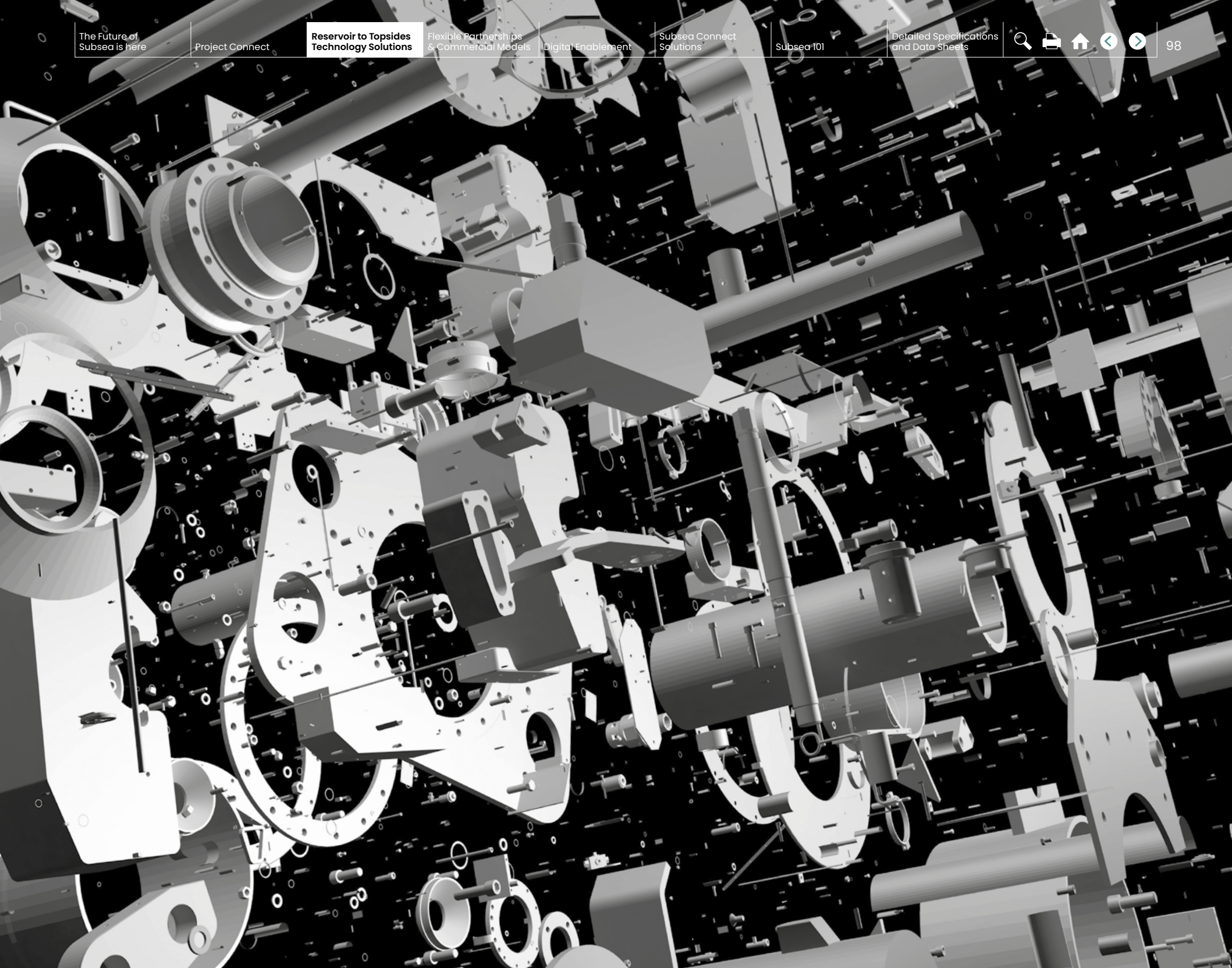
You can choose from single, dual and multi-bore configurations to optimize the field layout and your installation to reduce the total cost. Thermal insulation can also be provided to enhance your operability and improve your hydrate management.

Our Rigid Jumpers and Spools also enhance stability and reliability, as they are designed to withstand vortex-induced vibration (VIV), flow-induced vibration (FIV), settlements and thermal expansions, along with operational loads and accidental seismic conditions.

Typical lead time:

10 months

Our Well Jumpers can be delivered in 10 months.



SUBSEA CONNECTION SYSTEMS OVERVIEW

You can count on the reliability and safety of Baker Hughes' subsea connection systems, even in the most demanding environments.

With more than 2,400 connectors in our installed base worldwide, you can be sure we have the proven connection technology to meet your needs.

More than 20 years' experience has gone into the design of our innovative diverless clamp connection technology. Using standard core components, our clamp technology, hubs and seals all work across multiple alignment structures and bore configurations – improving their reliability and safety, while reducing your overall cost and minimizing downtime.

We supply both horizontal and vertical connections for use in shallow to ultra-deepwaters and offer you our wide system and installation experience, with delivery typically available in 5 months for standard connection sizes. Our industry-leading metal-to-metal GX and SX sealing technology also ensures reliable sealing, even in extreme conditions.

Whatever the configuration of your pipelines, flexibles and umbilicals, we have the subsea connection system you need, fully validated through rigorous qualification testing (industry standards API 6A/17D and 17R and ISO 10423 & 13628-4) to perform in the harshest of environments. We have the widest range of fully-qualified clamp connectors, ranging from 4 inches (300) to 42 inches (M5) pipe size, all designed with robust capacity and with simple ROV tools to minimize installation time.

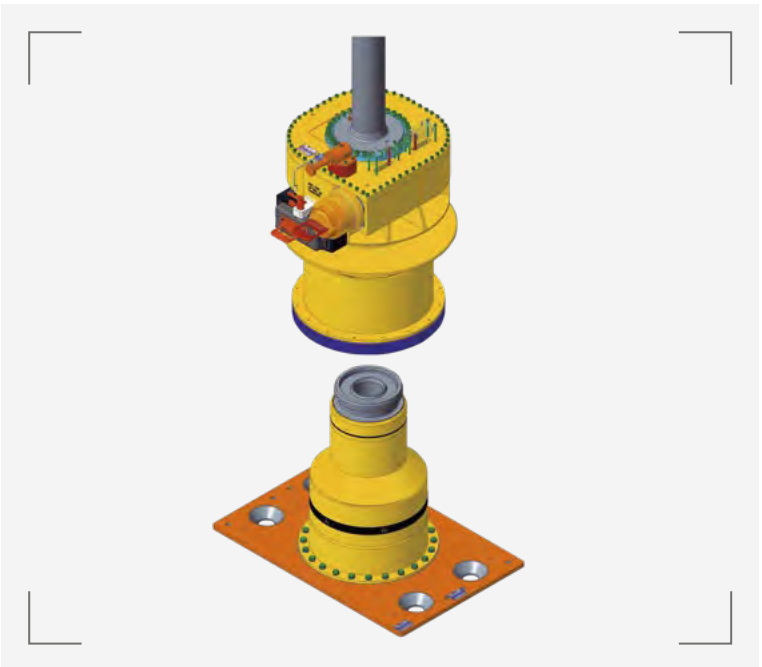
VERTICAL CLAMP CONNECTION SYSTEMS (VCCS)
Our Vertical Clamp Connection System is a proven vertical connector with a robust design and high load capacity to enhance reliability.
100

HORIZONTAL CLAMP CONNECTION SYSTEMS (HCCS)
Our Horizontal Clamp Connection System has a robust design with high load capacity to enhance reliability and is available in various sizes.
101

See Section 8 on page 182 for detailed specifications and data sheets.

SUBSEA CONNECTION SYSTEMS

VERTICAL CLAMP CONNECTION SYSTEMS (VCCS)



	VCCS	
Feature	Make to Order	Configure to Order
Variant	4 Sizes: VCCS 300, 450, 520, 580	1 Size: VCCS 720
Pipe size (inches)	4 - 16	18 - 22
Qualification	API 6A / 17D & API 17R and ISO 10423 & 13628-4	
Design Pressure rating (psi)	MTO 10,000	CTO 15,000
Temperature rating	-46°C to 180°C	
Water depth rating	MTO 3,000m	CTO 3,500m
Design life	Up to 50 years	
Pipe type	Rigid, flexible, pigging loop & PLR	
Bore configuration	Single, dual-concentric	

Our Vertical Clamp Connection System is a proven vertical connector suitable for rigid pipes, flexible pipes with a gooseneck, subsea Pig Launchers and Receivers (PLR), piping loops and control/valve modules. It has a robust design with high load capacity to enhance reliability.

The VCCS uses either standard single bore or dual bore configurations, although there is an option for multi-bores. It accommodates a size range of 3 inches up to 22 inches with standard pre-qualified seal sizes that mean we can offer the lowest cost and a short lead time of five months for MTO sizes. Project-specific seal sizes can also be accommodated, though this will add to the lead time.

In developing the VCCS, our focus has been on optimizing the connector size and weight, as well as the connection make-up-time and efficiency of ROV operations to allow for rapid installation. Its high capture range and installation misalignment tolerances help to reduce installation time and, simply by using gravity through its inbuilt passive soft-landing feature, our VCCS requires no running or stroking tool for connection make-up, reducing vessel time and your offshore installations cost. All VCCS configurations include a back-seal test port.

The VCCS can also integrate a gooseneck for flexibles. In addition a flowmeter can be included if required. VCCS can also be used for PLR applications. Same tooling can be used for all applications providing interchangeability and saving cost.
You can improve reliability by cleaning hubs without retrieving the jumper and seals can be replaced in-situ with the ROV flyable tools, reducing connection time during installation and maintenance.

With a pressure rating up to 15,000 psi and a temperature rating of 350°F (180°C), our VCCS can withstand the harshest environments.
A range of caps for pressure barrier, flooding, protection and testing activities helps you during different stages of operations such as onshore testing, installation, commissioning and future expansion, while we can provide insulation if required to enhance operability of the system VCCS can be provided with insulation.

VCCS tooling can be offered on purchase or rental basis for standard sizes.

Typical lead time:

5 months

Our Make to Order VCCS can be delivered in 5 months.

SUBSEA CONNECTION SYSTEMS

HORIZONTAL CLAMP CONNECTION SYSTEMS (HCCS)

	Aptara™ HCCS-L/HCCS	
Feature	Make to Order	Configure to Order
Variant	3 Sizes: HCCS-L Small, Medium, Large	4 Sizes: HCCS 22, 30, 36, 42
Pipe size (inches)	4 – 18	18 – 42
Qualification	API 6A / 17D & API 17R and ISO 10423 & 13628-4	
Design Pressure rating (psi)	MTO 10,000	CTO 15,000
Temperature rating	-46°C to 180°C	
Water depth rating	MTO 3,000m	CTO 3,500m
Design life	Up to 50 years	
Pipe type	Rigid, flexible, umbilical, pigging loop & PLR	
Bore configuration	Single, dual-concentric & multibore	

Our Horizontal Clamp Connection System is a proven horizontal connector suitable for rigid pipes, flexible pipes, subsea Pig Launchers and Receivers (PLR), piping loops and control/valve modules, as well as umbilical termination with use of multi-bore hub technology. It has a robust design with high load capacity to enhance reliability and is available in various sizes – Aptara™ HCCS-L covers size range of 4" up to 18" while large bore HCCS covers size range from 18" up to 42".

The horizontal clamp connection system uses standard single bore, dual bore, and multi-bore configurations. It accommodates a size range of 3 inches up to 42 inches with standard pre-qualified seal sizes that mean we can offer the lowest cost and a short lead time of five months. Project-specific seal sizes can also be accommodated, though this may add to the lead time.

Our lightweight HCCS-L is part of our Aptara™ family of TOTEX-lite products and the HCCS-L Small (3-6 inches), Medium (8-12 inches) and Large (14-18 inches) have all been developed with a focus on optimizing the connector size and weight, as well as the connection make-uptime and efficiency of ROV operations to allow for rapid installation. They come with a back-seal test port, a pre-mounted stroking tool and require fewer subsea operations, reducing the connection time by over 30%. Our unique push-type stroking functionality allows full access for cleaning and cap replacement with the pre-mounted stroking tool.

Our HCCS-L benefits from the integration of flexible end-fittings into the connector, reducing CAPEX and making the system more compact and reliable.

The HCCS-L also offers umbilical termination with a multi-bore hub configuration, further enhancing reliability and the interchangeability of tooling with other flowline connections. A Pig Launcher Receiver application in manual or remotely operated mode also comes as standard.

The HCCS range consists of HCCS 22 (20-22 inches), HCCS 30 (24-30 inches), HCCS 36 (32-36 inches) and HCCS 42 (38-42 inches) – the largest size in the industry. The whole range enables you to use our proprietary Open-PLET technology, which significantly simplifies your pipeline and PLET installation, reducing installation time, risk and cost while enhancing safety and reliability.

With HCCS clamp transfer feature we are able to recover the clamp with termination.

With a pressure rating up to 15,000 psi and a temperature rating of 356°F (180°C), our HCCS-L/HCCS can withstand the harshest environments. A range of caps for pressure barrier, flooding, protection and testing activities helps you keep the system at peak efficiency, while our proprietary Heatbank insulation provides a high cool-down time, enhancing operability and availability.

Typical lead time:

5 months

Our Make to Order HCCS can be delivered in 5 months.

SUBSEA ELECTRIC SOLUTIONS
OVERVIEW

In line with the industry's ongoing transition from electro-hydraulic to All-Electric systems, Baker Hughes is leading the way with the launch of its first All-Electric subsea production system in 2021.

Subsea electrification offers our customers substantial benefits – the ability to deploy new subsea production systems that have lower CAPEX and OPEX costs, improved reliability and availability, reduced topside footprint, access to assets in deeper water and longer step-outs and elimination of the HSE risk of accidental spillage or release of hydraulic fluid to the environment. Subsea electrification is also an important step towards lowering the carbon footprint of subsea operations.

Our All-Electric technology will be compatible with all our subsea production system variants, including our Aptara™ range of lightweight compact trees and manifolds.

Our capabilities extend to subsurface and include electrical downhole safety valves and electrical ICVs (Inflow Control Valves) from our Intelligent Subsea electrification is also an important step towards lowering the carbon footprint of subsea operations.

Completions group. Our All-Electric system will have the ability to interface with other elements including subsea chemical injection and storage systems (SSCS&I) and to subsea HPUs as an alternative method for controlling the downhole safety valve. Digitalization will play a key role in delivering enhanced reliability and availability and system performance through continuous condition monitoring based on an abundance of data from sensors, control boards and battery management systems embedded in our subsea electric actuators.

Longer term, the next generation of All-Electric subsea production systems will be controlled through autonomous power and communication systems. We are engaging with partners to evaluate the feasibility of using novel wave and tidal power systems together with inherent communication capabilities that will enable the complete elimination of hydraulic and power connections to topside facilities.

But All-Electric is not all in the future. Today we provide electric actuators for brownfield applications to replace faulty hydraulic actuators on manifold structures, high-speed anti-surge actuators for subsea gas compression systems and electric chokes are available as standard on our subsea tree and manifolds. You can learn more about our range of electric actuators later in this section.

ALL-ELECTRIC PRODUCTION SYSTEMS
Our All-Electric Production Systems reduces overall complexity and cost, and allows us to optimize your remaining electric system.

104

ADVANCED INTELLIGENT COMPLETIONS
Our advanced intelligent completions solutions include electric downhole safety valves and electric inflow control valves. These can be used separately or in combination with our subsea solutions to maximize the value of subsea electrification.

105

ELECTRIC ACTUATION
Our electric actuators can use local energy storage or central energy storage with a range of AC and DC power input options.

106

ROTATING ELECTRIC ACTUATORS (REA)
Our portfolio of high power and low power rotating electric actuators cover a wide range of operating and interface requirements.

107

LINEAR ELECTRIC ACTUATORS (LEA)
A premium solution for subsea processing systems, our Linear Electric Actuator offers accuracy better than ±0.15 mm.

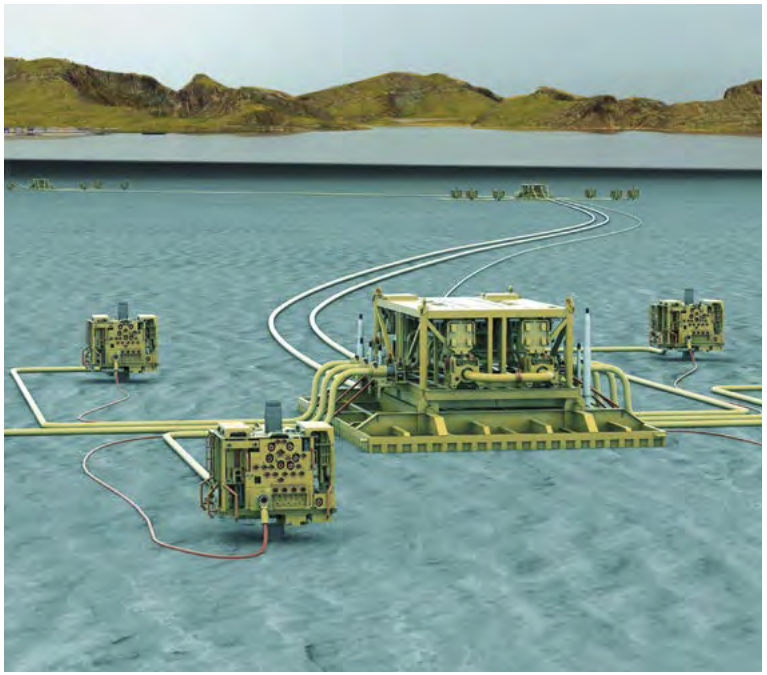
108

ELECTRIC CHOKE
Our electric chokes offer our customers superior motion and positioning control, higher reliability and enhanced condition monitoring capability.

109

SUBSEA ELECTRIC SOLUTIONS

ALL-ELECTRIC PRODUCTION SYSTEMS



Our subsea All-Electric system is based on our state-of-the art technologies and designed to operate at 3,000m water depth. All new components and electrical actuators will be qualified according to API 6A, API 17D and 17F and specifically to the Joint Operators Specification addendum to API17F for All-Electric systems.

Power distribution

From the outset, a decision was made to ensure that our system is compatible with all potential power distribution systems, to provide our customers with maximum flexibility in field architecture design. Power is distributed from a topside or onshore facility as either High-Voltage AC, High-Voltage DC, Low-Voltage AC or DCFO and is converted subsea to 400VDC for infield distribution.

Power & Communications

The power and communications distribution system has been specifically designed for subsea All-Electric and consists of three key modules: an electrical Power and Communication Distribution Module (ePCDM), an electrical Subsea Control Module (eSCM), and an Energy Storage Module (ESM).

Electric Power & Communications Distribution Module (ePCDM) – The ePCDM receives power and communications from the transmission system and distributes it infield to the eSCM and ESM modules. Power is received as either High-Voltage AC, High-Voltage DC, Low-Voltage AC or DCFO and is converted subsea to 400VDC for infield distribution using a step-down transformer and AC/DC convertors to the eSCMs via the ESMs. For DCFO there is no requirement for power conversion since DCFO is distributed at 400VDC.

Optical communications from topside are distributed via an ethernet router to the individual eSCMs as either ethernet or DSL.

Power switching is available in the ePCDM to ensure that individual trees can be separately isolated for intervention.

Energy Storage Module (ESM) – Single or dual redundant ESMs can be mounted on the subsea tree and store energy locally to ensure that we minimize power draw on the overall system and ensure we have sufficient power to operate at long offsets, and/or to operate several trees in parallel. The ESMs are ROV retrievable and include a battery management system (BMS) that is used to control the charging and discharge of the unit and to provide healthcare monitoring.

Electrical Subsea Communications Module (eSCM) – The eSCM modules receive ethernet or DSL communications directly from the ePCDM and 400VDC power distribution from the ESMs. Power and communications are then distributed to the individual electric actuators and to the instrumentation via electrical harnesses.

Electrical Actuators

The main safety critical valves in the system will use spring fail safe close actuators. The 400VDC linear actuators for the gate valves consist of two parts: a rotary electric actuator (REA) and a rotary to linear motion (RLM) where the REA part is ROV retrievable and the RLM remains fixed to the tree body. A 400VDC rotary actuator will be used to function the ball valves on the trees and manifolds.

Typical lead time:

12-24 months

Project dependent.

SUBSEA ELECTRIC SOLUTIONS

ADVANCED INTELLIGENT COMPLETIONS

Maximising the value of subsea electrification requires going beyond the water column and into the subsurface world of Completions.

Completions provide the technology that forms the production (or injection) conduit from reservoir to the tree. This includes a wide variety of technologies including well construction to monitoring to flow control to flow assurance to safety valves to data management and analytics. The requirement for monitoring and control of reservoirs/wellbores is ever increasing with the need to have finer and granular control of the asset.

Implementing the right technology subsurface enables value for the whole production system:

- Removing hydraulics
  - Enables full reduction of umbilical cost
  - Reduce chemical consumption / waste / disposal and the environmental impact
  - Simplify operations
  - Less control lines to handle during installation, reducing the risk, and saving rig time
  - Less feed throughs required through the tubing hanger and tree
  - Faster tool response times for optimizing well performance during production

Electrical Downhole Safety Valve

Safety valves are a critical component of a well's safety and barrier elements and can help save lives and protect property and the environment. Subsurface safety valves have significantly evolved over the last 50 years with applications now requiring pressures up to 25,000psi, setting depths up to 15,000ft, temperatures over 400F and the ability to safely close and shut in well pressure in high rate wells flowing at velocities of over 400 feet per second.

One of our basic philosophies at Baker Hughes is to ensure we provide simple, highly reliable safety valves that always deliver fail-safe closed performance. This will continue with our electric safety valve solutions.

The electric safety valve will provide fail-safe closure operating on field proven power springs for closure in worst-case conditions. Essentially, we will be using existing closure mechanisms provided in over 30,000 safety valves provided in our history. The actuator powering the electric safety valve will deliver reliable low power actuation to open the valve.

We have been operating in harsh deep-water environments for nearly 20 years and the electric safety valve will include the features most critical to reliable performance in these conditions.

Electrical Inflow Control Valves (ICV)

Remotely controlled ICVs are a critical component of an Intelligent Completion providing selective control of various zones/ compartments in the reservoir or wellbore.

Electric ICVs are not new to Baker Hughes. In the early 2000's Baker Hughes designed, manufactured, and installed Electric ICVs in a subsea well offshore Brazil that is still operational today. More recently, Baker Hughes developed our MultiNode electric ICV technology aimed at horizontal, dry tree applications that require many ICVs (Up to 27) to control water breakthrough and have had several installations to date.

Today, we are developing our next generation of Electric ICVs suitable for the harsh conditions of subsea applications. This solution will enable the control of multiple ICVs using a single electric control line whilst using as low power as feasible. The electric ICV is a near-infinitely variable choke that is remotely adjusted with a command from the surface to control the flow in or out of a production zone. This electric completions technology enables applications previously not possible or practical due to limitations of traditional hydraulic intelligent completions.

Digital/Condition monitoring

Our All-Electric system continuously gathers data through sensors used to control and operate the electric actuators and can be designed to capture additional data on demand. Downtime is reduced through predictive maintenance and reduced time for fault finding. The data will be used to better understand the equipment performance and learnings will be taken back into the product development process to ensure even more reliable products over time.

Typical parameters that will be measured include temperature, current, voltage and oil/water content. This enables monitoring of barrier integrity, mechanical wear and battery health. Information is read from direct measurements, and trending of data over time is used to give important information about the system. In addition, partial stroke testing of electric actuators will enable monitoring of valves and actuators which are idle for a period.

SUBSEA ELECTRIC SOLUTIONS

ELECTRIC ACTUATION

Building on more than 15 years of experience, Baker Hughes' market leading portfolio of electric actuators include qualified rotary, quarter turn and linear solutions, with 100 Nm, 600 Nm and 2,700 Nm torque capabilities in single or redundant solutions, making them very adaptable to a range of applications.

Electric actuators combined with a matching power and communications network, are the core element to realizing All-Electric Production Systems. Our actuators benefit from direct drive or from a central energy storage and a range of AC and DC power input options, ranging from 24V (low power) to 400V (high power) solutions.

The actuators can be used for a brownfield retrofit of manual valves or faulty hydraulic valves in Manifolds, Chokes, In-Line Tees, Pipeline End Terminations and Flowline End Terminations, and across All-Electric production systems and Subsea Compression systems.

Typical lead time:

9 months

Our electric actuators can be delivered in 9 months.

SUBSEA ELECTRIC SOLUTIONS

ROTATING ELECTRIC ACTUATORS (REA)

Our existing portfolio of rotating electric actuators has a solid track record and covers a wide range of operating and interface requirements. These include electric chokes, ball valves on manifolds, SURF modules like in-line tees, pipeline end terminations and flowline end terminations, quarter turn valves, retrofitting manual valves, skids, and subsea processing systems – pumps, compressors and water treatment.

Our low power (LP) solutions are adapted to interfacing existing subsea systems through 24 VDC or 48 VDC. The Low Power Rotating Electric Actuators (LP REA) can provide torque of 600 Nm or 2700 Nm depending on load requirements and is directly powered from the subsea control system.

All our rotating electric actuators can be installed through a standard ISO 13628-8 class 4 ROV interface. Our LP REA solutions are at technology readiness levels (TRL) 4-7 and have been installed at many sites, including Dalia and Troll C, while our HP REA solutions are at TRL 4, following extensive qualification activities and submerged system testing for the Ormen Lange Pilot.

Typical lead time:

9 months

Our electric actuators can be delivered in 9 months.

SUBSEA ELECTRIC SOLUTIONS

LINEAR ELECTRIC ACTUATORS (LEA)

In addition to Baker Hughes' standard electric actuator solutions, our portfolio also includes premium solutions for subsea processing systems, including subsea compressor protection, with a Linear Electric Actuator that offers accuracy better than ±0.15 mm.

Our electric actuator for subsea processing systems is designed for continuous and precise operation of the anti-surge valves typically found on subsea gas compressor systems. It has a built-in fail-safe spring package that does not require any internal parts to be operated, other than the output shaft of the actuator. It brings the valve to an open position in case of any failure in the system, ensuring accurate operation and positioning of subsea linear control valves.

The full end-to-end travel of actuator and valve is performed in under two seconds and it is designed with dual-redundancy for all critical systems, including motor, power, communication, and springs. The valve stem area is also protected, flushed and oil-filled by a hot-stab system.

Its specially designed ROV-operated linear stem connection makes subsea retrieval with ROV much easier and enables simple tooling. The actuator also has a built-in, patented electromechanical clutch system that connects and disconnects the valve stem, actuator and spring package enabling valve operation without cycling the fail safe spring package. Reducing risk of mechanical failure for high cycle applications.

Our linear electric actuators are used in a wide range of applications, including tree gate valves (critical and non-critical), manifold gate valves and anti-surge actuation for subsea compressors. We are also currently developing a complete range of linear fail-safe solutions for critical tree valves.

The Linear Anti-Surge Actuator was qualified to 1 million cycles and system tested at the Ormen Lange Pilot, and is currently installed and in operation in the Åsgard Subsea Compression system with a technology readiness level (TRL) 7 rating.

Typical lead time:

9 months

Our linear electric actuators can be delivered in 9 months.

SUBSEA ELECTRIC SOLUTIONS

ELECTRIC CHOKE

An integral part of our All-Electric system evolution, electrically operated chokes are available as an option to conventional hydraulically operated chokes on our tree and manifold systems. Electric Chokes offer our customers superior motion and positioning control, higher reliability and enhanced condition monitoring capability.

The main difference between our hydraulic and Electric Chokes is the control mechanism. Rather than controlling the choke through a conventional electro-hydraulic umbilical, the Electric Choke is controlled by a field-proven and qualified 24V/48V DC REA (Rotating Electric Actuator) which is attached to the choke assembly through an ISO 13628-8 class 4 ROV interface. Our Electric Choke actuators avoid the need for dedicated local energy storage modules by drawing low power directly from the Subsea Electric Module (SEM) located in our standard SemStar5 or Aptara™ controls systems. This also means that they can be easily retrofitted on brownfield electro-hydraulic chokes.

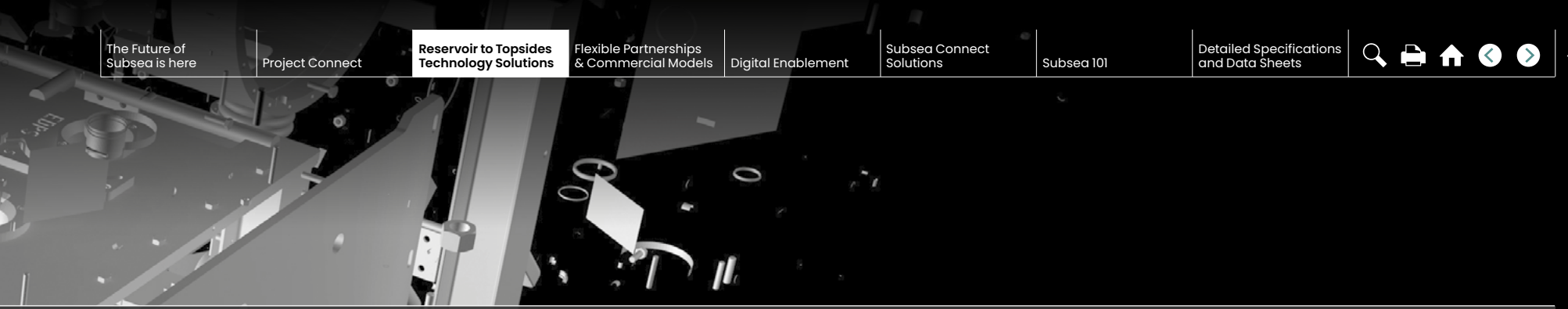
The main choke assemblies on our electric chokes are identical to the hydraulic versions and are available in 2", 5" and 7" sizes and engineered to operate in water depths up to 10,000 ft (3,048 m), operating pressures of 6,500 psi to 10,000 psi and operating temperatures between -51°F to 300°F (-46°C to 149°C).

Our Electric Chokes are available integrated with one of our subsea tree systems,or as a single supply with a lead time of around 7 months.

Typical lead time:

7 months

Our Electric Chokes are available integrated with one of our subsea tree systems, or as a single supply with a lead time of around 7 months.



SUBSEA WELL ACCESS SYSTEMS OVERVIEW

Baker Hughes has a long history of providing safe, efficient, and reliable Well Access services.

In addition to equipment you can purchase outright, we have an extensive portfolio of rental tools and equipment to support operations from installation and commissioning right through to decommissioning. This comprehensive fleet can meet the needs of long and short-term rental contracts, providing well-maintained equipment for subsea contracts.

Our Well Access product portfolio is fully in tune with the challenges you face throughout the lifecycle of a well from installation and commissioning, to production enhancement and ultimately decommissioning, with a focus on reducing your CAPEX and OPEX. And, by making full use of Baker Hughes' full-stream capability, you can be certain of the smooth running of all activities throughout your overall Well Access campaign. We can also provide the downhole tooling and diagnostics you need, while ensuring seamless integration with any drilling activity being undertaken.

We can offer the full solution, through a single contract and execute with the Subsea Connect Interventions Solutions group.

OPEN WATER COMPLETION WORKOVER RISER (CWOR)

Depending upon your field and system requirements, we can offer an Open Water Completion Workover Riser (CWOR) to rent or purchase.

112

INSTALLATION AND WORKOVER CONTROL SYSTEM (IWOCS)

The technology we use is industry-leading and innovative – offering safe, simple, efficient and reliable turnkey-ready IWOCS and intervention products.

113

PRODUCTION ENHANCEMENT - LIGHT WELL INTERVENTION

Our Light Well Intervention systems have the ability to work on any OEM XTs and control the XT functions with our global agnostic IWOCS fleet. We can perform mechanical interventions or fluid stimulation campaigns from a single vessel, with an over-the-side deployment or through a moonpool – allowing more flexibility on vessel selection.

114

SUBSEA TEST TREE (SSTT)

Our long history in supplying SSTT systems enables us to select the most efficient, safe and reliable system to suit your needs.

115

SIMPLIFIED LANDING STRING (SLS)

Our Simplified Landing String is similar to a Subsea Test Tree (SSTT) landing string but without the complexity of well barriers.

116

See Section 8 on page 182 for detailed specifications and data sheets.

SUBSEA WELL ACCESS SYSTEMS

OPEN WATER COMPLETION WORKOVER RISER (CWOR)

Our Open Water Completion Workover Riser (CWOR) provides a conduit from your subsea tree on the seabed to the rig, enabling topside access to the well for all your life-of-field activities. Above the tree, a Well Control Package (WCP) is connected to an Emergency Disconnect Package (EDP), allowing you to isolate the well and disconnect at any time, leaving the well fully contained.

Before we supply an Open Water CWOR, our in-house analysis team will carry out a Global Riser Analysis to select the system most suited to the unique challenges at your location. Lead time for a standard system is around 6 to 24 months and a typical deployment will include a WCP, EDP, stress joint, riser system, swivel, cased wear joint, and tension joint.

To complete your Open Water CWOR system, a surface test tree and lubricator valve will be provided, enabling you to isolate the well at the surface, to facilitate fluids entering and leaving the production bore and to allow access for wireline and coiled tubing tooling to go into the well.

The WCP features redundant emergency barriers that isolate the well during all operating conditions, including the ability to shear and seal wireline or coiled tubing for maximum safety during high flow operations. The barriers are qualified as Safety Heads according to NORSOK D-002. The WCP also features a gate valve as an operational barrier that ensures the emergency barriers are always primed and ready for use.

The EDP features a connector to the WCP that, once the well is isolated, allows the riser system to release from the well, regardless of the angle/location of the riser. This typically complies with API RP 17G (2005). The EDP also features a valve that retains the riser inventory during this disconnect sequence, preventing hydrocarbon escape to the environment.

Depending upon the specifics of the field and your system requirements, you may want to rent rather than purchase a system. We also have regional rental CWOR systems available that could reduce your overall project CAPEX.

	Open Water CWOR System		
Feature	Make to Order	Configure to Order	Configure to Order
Variant	1 Option		
System production size (inches)	7 3/8	5 1/8	6 1/8
System annulus size (inches)	2 nom	2 nom	2 nom
Pressure rating (psi)	10,000	10,000	10,000
Design life	25 years	25 years	25 years
Temperature range	0°F to 250°F (-18°C to 121°C)	0°F to 250°F (-18°C to 121°C)	0°F to 250°F (-18°C to 121°C)
Max water depth	10,000ft (3,048m)	10,000ft (3,048m)	10,000ft (3,048m)
LRP production bore size (inches)	7 3/8	7 3/8	7 3/8
LRP annulus bore size (inches)	2 1/16	2 1/16	2 1/16
EDP production bore size (inches)	7 3/8	7 3/8	7 3/8
EDP annulus bore size (inches)	2 1/16	2 1/16	2 1/16

Typical lead time:

24 months

We can deliver an Open water CWOR in 6 to 24 months, depending on the specification of your system. For rental options, our regional offices can advise on availability.

SUBSEA WELL ACCESS SYSTEMS

INSTALLATION AND WORKOVER CONTROL SYSTEM (IWOCS)

Installation and Workover Control System – IWOCS

Feature	Configure to Order
Separate HPU & MCS Control room in a single 30 feet container	Designed according to ISO 13628-7 & ISO 13628-1
PLC Electronic Control System	Prepared for SIL2 Shutdown (PSD / ESD / EQD) w/Local Shutdown Panels
MCP and RCP with VDU Screen, keyboard and Mouse/Trackball	DnV 2.7-2 Compliant
UPS A/B (220-240VAC, 50 / 60Hz, 16A) Located in non-Ex room	EN50381 "Portable Ventilated Room" Compliant
Up to 44 controlled outputs, LP: 5,000 psi, MP: 10,000 psi, HP: 12,000 psi	IECEx (Zone 1 IIB T3) Compliant System
Separate Dirty Return Tank for contaminated fluid with hydrocarbon detection	DNV 2.7-1 Certified Container / AS 1666 sling
Several layers of redundancy with mechanical or manual back-up	Incorporation of XT supplier SPCU for SCM control
Built-in F&G system, PA and telephone for rig interface	

Our IWOCS is based on field-proven products and services developed by Advantec, a business we acquired in 2015. The technology we use is industry-leading and innovative – offering safe, simple, efficient, and reliable turnkey-ready IWOCS and intervention products.

IWOCS is set up to be a compact unit for the full integration of all required functionality in the installation and workover phases. It is a multifield system that can interface with different OEM systems through one human-machine interface (HMI), providing a fully integrated overview of your operation. Both, direct hydraulic and multiplexed hydraulic control systems are available. A single container incorporates both, the HPU and operator cabin. Alternative solutions are available on request.

Our IWOCS is based on a standardized design and is highly adaptable through software and configuration variants to meet whatever functionality your project requires.

With the full integration of landing string functionality, there are fewer interfaces between companies and vendors, leading to increased efficiency. The functionality and layout of any in-riser SSTT/LS, from any vendor, can be quickly configured insoftware. There is no need for separate HPU/Controls Container from the vendor and the system ensures simplified and safer operations of your LS/SSTT from the HMI Screen.

Our range of rental IWOCS Containers is available in a variety of sizes, functionality and technologies to fit project needs.

- Direct, manual valve operated systems
- Electro-hydraulic (EH) systems for direct control of hydraulic umbilical line pressures to subsea valves and connectors.
- Multiplexed (MUX) EOCS systems for ultra-deep-water applications, including subsea Workover Control Modules (WOCM).
- RWOCS solutions for ultra-deep water (3,000m) application, control skid is placed on the sea bed, controlled by either ROV or EDL downline connection.

Our IWOCS meets the most demanding requirements. The shutdown functions of the systems designed in compliance with SIL2 for 9PSD/ESD/EQD, are initiated from push buttons located on the drilling rig/vessel. The IWOCS containers and skids are all DNV 2.7-1 certified and are supplied with certified lifting slings.

Typical lead time:

12 months

We can deliver a complete system in 9 to 18 months depending upon specification and project timing. For rental options, our regional offices can advise on availability.

SUBSEA WELL ACCESS SYSTEMS

PRODUCTION ENHANCEMENT – LIGHT WELL INTERVENTION

Our Light Well Intervention systems have the ability to work on any OEM XTs and control the XT functions with our global agnostic IWOCS fleet. We can perform mechanical interventions or fluid stimulation campaigns from a single vessel, with an over-the-side deployment or through a moonpool – allowing more flexibility on vessel selection.

We can offer the full solution, through a single contract and execute with our dedicated Production Enhancement Center of Excellence team.

7 inch RLWIS Packages

We have three 7 inch Light Well Intervention packages in our portfolio, primarily for use in riserless applications but can also be used in riser based operations and can be converted with the Well Control Package remaining subsea. In Riserless mode the systems are suitable for a range of slickline, e-line and braided wire applications.

4 inch RLWIS Package

Our 4 1/16 inch 10Kpsi Light Well Intervention Package supports slickline and e-line operations, plug and abandonment, coiled tubing up to 1 3/4 inch OD, through tubing cementing operations, well testing, tree installation and change-out in water depths up to 1,070m (3,500 feet).

3 inch RLWIS

Our 3 1/16 inch 10Kpsi Light Well Intervention Package supports slickline & e-line operations, cutting tubing & casings, zone isolations, shifting sleeves and setting/pulling plugs, well diagnostics & logging, perforating tubing & formation and tree installation & change-out up to water depths of 150m (500 feet).

2 inch Fluid Intervention System

Our 2 inch 10Kpsi Fluid Intervention System can be operated in depths up to 2,000m (6,500 feet) and can be deployed directly on to the subsea tree or with a mud-mat to the sea bed. Live well interventions, well stimulation, scale squeeze, well kill, hydrate remediation and pipeline cleaning can all be supported by this system.

3 inch Fluid Intervention Systems

Our 3 inch 15Kpsi Fluid Intervention System can be operated in water depths up to 3,048m (10,000 feet). This system can be deployed directly on to a subsea tree or to the seabed on a mudmat. Live well interventions, well stimulation, scale squeeze, well kill, hydrate remediation and pipeline cleaning can all be supported by this system.

	Light Well Intervention				
Feature	7.0 inch RLWI	7.1 LWI	7.2 LWI	4.1 inch RLWI	3.1 inch RLWI
Size (inches)	7 1/16	7 3/8	7 3/8	4 1/16	3 1/16
Pressure	10Kpsi	10Kpsi	10Kpsi	10Kpsi	10Kpsi
Temperature	Class – U	Class – U	-9°C to +121°C		
Water Depth	1,600m	3,000m	3,000m	1,070m	150m
PSL	PSL 3	PSL 3G	PSL 3G	PSL 3	
Trim	EE	EE, Sour service	EE, Sour service	EE	EE
Controls	Piloted Hydraulic	Piloted Hydraulic	Piloted Hydraulic	Piloted hydraulic	Piloted Hydraulic
Op Modes	Riserless E-Line & Slickline Riser Based Coil Tubing	Riserless E-Line & Slickline Riser Based Coil Tubing	Riserless E-Line & Slickline Riser Based Coil Tubing	Riserless E-Line & Slickline	Riserless E-Line & Slickline
Design Code	API Spec 16D, 17D, 6A				
Service	NACE MR-0175/ISO15156				

	Light Well Intervention	
Feature	2 inch Fluid Intervention System	3 inch Fluid Intervention System
Size (inches)	2 1/16	3 1/16
Pressure	10Kpsi	15Kpsi
Water Depth	2,000m	3,000m
Controls	ROV operated	ROV operated
Circulation	Dual 2 inch	Dual 2 inch
Deployment	Directly onto asset or on seabed with a mud-mat	Directly onto asset or on seabed with a mud-mat

SUBSEA WELL ACCESS SYSTEMS

SUBSEA TEST TREE (SSTT)

When accessing your well through the blowout preventer (BOP), a Subsea Test Tree (SSTT) landing string is required, providing well isolation and the functionality to disconnect the well.

Our typical SSTT landing string includes an upper string with a surface test tree, swivel, cased wear joint and lubricator valve; a riser system; and a lower string with an annular slick joint, shear sub, SSTT latch, SSTT barrier package, ported slick joint and tubing hanger running tool. As with an Open Water CWOR, our in-house world-class analysis team will carry out a Global Riser Analysis to select the riser pipe system that is most suited to the unique challenges at your location.

Baker Hughes has a long history of supplying SSTT systems, which enables us to select the most efficient, safe and reliable SSTT system to suit your needs. Delivery of an SSTT system takes around six to 12 months and it will typically be supplied in accordance with API RP 17G.

The SSTT's ported slick joint provides a surface on which the pipe rams of the BOP can close to facilitate pressure testing of the hanger seal. Above that, the dual valve package is used during unplanned events, to provide shear and sealing capability of wireline or coiled tubing when there is tooling in the well. Once the well is isolated, the landing string has a disconnect feature to separate the well from the rig. Above this disconnect feature, a valve closes to retain the riser inventory and prevent potentially high-pressure hydrocarbon escape to the environmental riser.

As a contingency measure, the SSTT landing string is also supplied with a shear sub, built to a specific geometry and material grade that can withstand the internal pressure and tension loading, while also being weak enough to be shearable by the BOP shear rams.

Depending upon the specification of your project and exact requirements, these systems can be available to rent or to purchase.

	Subsea Test Tree
Feature	Configure to Order
Water depth (ft)	10,000ft (3,048m)
Production bore size (inches)	7⅜
Design standards	API RP 17G (2005)
Isolate and disconnect time (sec)	10
Conforming standards	SIL-2
Shear systems	Wireline and coiled tubing available

Typical lead time:

6–12 months

We can deliver an SSTT system in 12 months – or as few as 6 months depending upon the specification and project timing. For rental options, our regional offices can advise on availability.

SUBSEA WELL ACCESS SYSTEMS

SIMPLIFIED LANDING STRING (SLS)

Where well testing is not required but full-bore access is required, a Simplified Landing String (SLS) can be provided. It is similar to a Subsea Test Tree (SSTT) landing string but without the complexity of well barriers. Not only does this lower the cost of the SLS but, it also reduces the complexity of the surface control systems and umbilicals – therefore reducing running and retrieval time and lowering your OPEX.

Our typical Simplified Landing String includes an upper string with a circulation head, swivel, cased wear joint and lubricator valve, a riser system, and a lower string with a crossover joint, shear sub, ported slick joint and tubing hanger running tool. As with an Open Water CWOR, our in-house world-class analysis team will carry out a Global Riser Analysis to select the riser system that is most suited to the unique challenges at your location.

Baker Hughes has extensive experience in supplying efficient, safe, and reliable SLS systems. Delivery takes around 6 to 12 months and the system will typically be supplied in accordance with API RP 17G. We will configure the lower string in the SLS to interface with your project-specific blowout preventer (BOP) and, like the SSTT, the SLS comes with a ported slick joint that provides a surface on which the pipe rams of the BOP can close to facilitate pressure testing of the hanger seal.

As a contingency measure, the SLS is also supplied with a shear sub, built to a specific geometry and material grade that can withstand the internal pressure and tension loading, while also being weak enough to be shearable by the BOP shear rams.

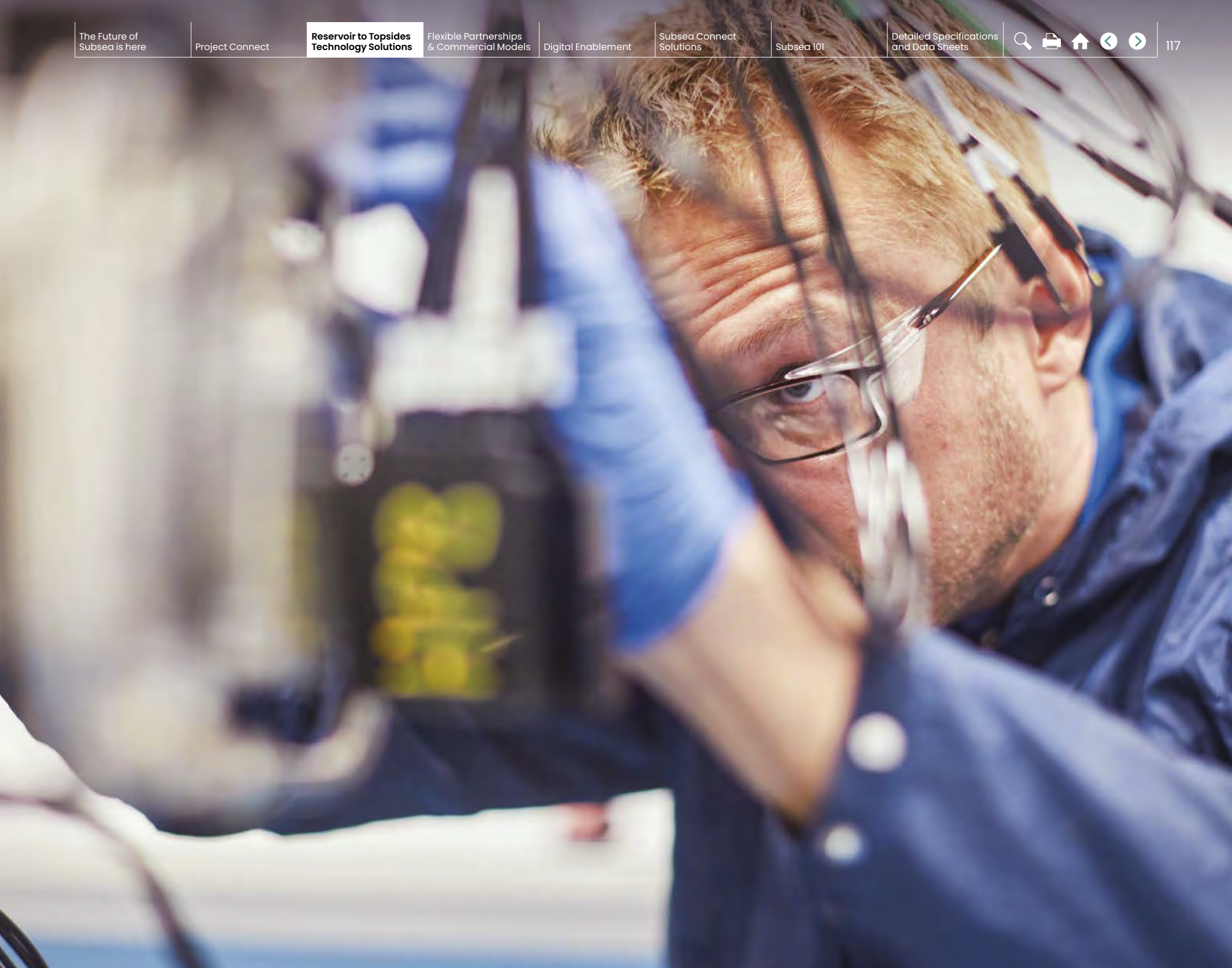
Depending upon the specification of your project and exact requirements, these systems can be available to rent or to purchase.

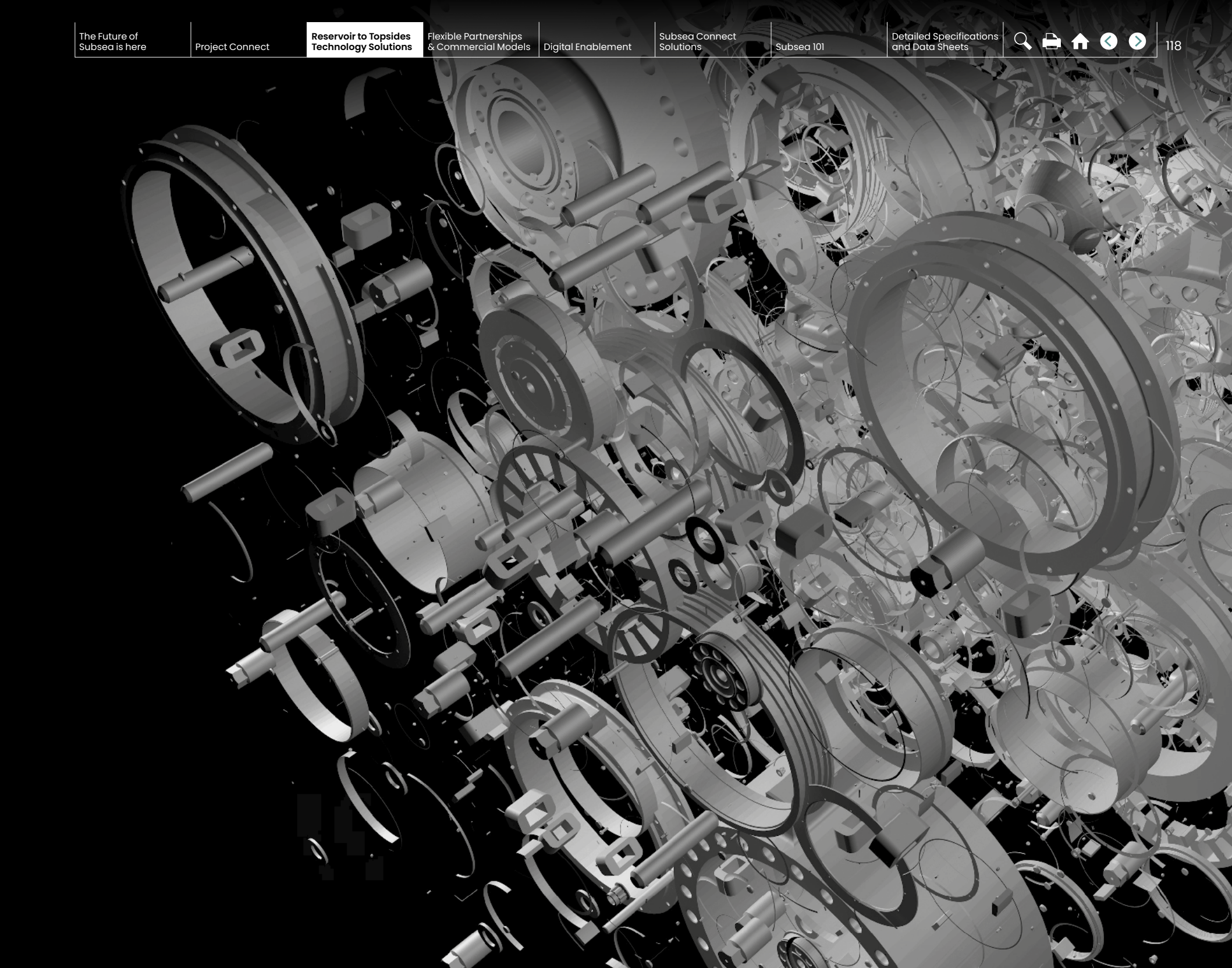
	Simplified Landing String
Feature	Configure to Order
Operating pressure (psi)	10,000
Water depth (ft)	10,000
Production bore size (inches)	7⅜
Sealing system	Ported and annular slick joints
XT tooling	THRT, THROT, THOJ, hydraulic latch connector
Shear coupling	Shear sub
Design standards	API RP 17G (2005)

Typical lead time:

6–12 months

We can deliver an SLS system in around 6 to 12 months.





SUBSEA POWER AND PROCESSING SYSTEMS OVERVIEW

With our broad expertise and capabilities in subsea boosting, compression, separation, seawater treatment and injection, and high-voltage subsea power systems, we can help you increase recovery rates, access stranded assets and reduce your overall production costs.

From barrier-fluidless boosting to subsea sulphate removal, our processing systems are designed to increase the efficiency of your subsea operations, while reducing the impact on your topside footprint and weight. Our designs bring processing closer to the well in an efficient manner and also reduce your carbon footprint compared to conventional subsea and topside solutions.

Baker Hughes is a global leader in subsea processing, with the technologies and expertise that means we can simplify your system design, minimize its environmental impact, and reduce your life-of-field costs. We can reduce your system costs, time and risk, all while allowing even the most complex subsea projects to be tackled in the safest and most reliable way.

SUBSEA BOOSTING

Our Aptara™ Modular Compact Pump is a completely integrated, All-Electric boosting system that can accelerate and improve oil recovery in both, new and mature wells.

120

SUBSEA COMPRESSION

Our subsea gas compression is now qualified technology and widely accepted by the industry to significantly improve the economics of mature gas fields.

Subsea Compression 122
Blue-C™ Compressor 123
Dry-gas Systems 123
Wet-gas Systems 123

SUBSEA SEPARATION

Our subsea separation solution can de-bottleneck your topside production facilities, allowing you the potential to increase production and reduce your related CAPEX.

Gravity Separators 124
Compact Separators 124

SEAWATER TREATMENT AND INJECTION

Our seawater treatment system allows seawater to be treated and injected subsea, eliminating the need for heavy, high-pressure risers and flowlines.

125

SUBSEA POWER

We can supply fully integrated AC power solutions for all types of applications – from the simplest single-load scenario to long step-out systems with high-power loads.

126

SUBSEA BOOSTING

THE APTARA™ MCP RANGE OF SUBSEA BOOSTING SYSTEMS

The Aptara™ Modular Compact Pump (MCP) is a completely new and leading-edge technology platform for subsea pumps that represents a world first for rotating equipment. It has been designed to provide the flexibility to handle an unrivalled range of fluids and applications – from multi-phase boosting to water injection to CO_2 injection – simply by changing the internal hydraulics of the pump from helico-axial for multiphase boosting, to centrifugal for water and CO_2 injection. The motor stage sizes and Variable Speed Drive (VSD) units are identical across all variants of the pump, emphasizing the flexibility and structured nature of the MCP design.

The innovative architecture of the Aptara™ MCP makes it compact and its modular construction means that we can offer pre-qualified designs for a wide range of pump sizes.

Our life-of-field approach to design is evident in the Aptara™ MCP's unique features that reduce total cost of ownership. The stages are controlled individually by local Variable Speed Drives (VSDs) that allow the pump to react and adapt dynamically to changes in fluid conditions. It also provides inherent redundancy, as the pump can operate with one or more non-operational stages if required.

The MCP breaks convention by using no barrier fluid – significantly reducing topside footprint by 50%+ and lowering overall system cost. Unlike a conventional subsea pump, which uses one high-voltage motor to drive a long shaft connected to a series of impellers, the MCP has a unique architecture with integrated motor impellers that rotate around a static shaft. This eliminates potential rotodynamic issues whereas in a conventional pump, the motor is connected to the same shaft that drives the impellers, which limits the numbers of stages that can be stacked.

Each integrated motor, or "stage" is clad with permanent magnets and generates 250kW of drive power. The stages are stacked to provide a range of power densities – from 1MW with 4-stages to 6MW with 24-stages, and more if that's what you require. Because each stage experiences a relatively low load, the pump can operate without a barrier fluid, and instead uses specialized synthetic diamond bearings that are cooled by the process fluid. The hermetically sealed motor also ensures high inherent reliability, as high-risk items such as mechanical seals are not needed. The standard pre-qualified building blocks enable the Aptara™ MCP to be configured to a range of different field requirements.

With Subsea VSDs and no need for a barrier fluid system, all that is required to link the electric pump system to topside is a simple and light power umbilical. This can reduce your topside footprint by more than 50% and CAPEX by more than 25%, making Aptara™ MCP an ideal solution for brownfield modifications and long step-outs with topside space and weight constraints.

The Aptara™ MCP also helps you manage your EHS priorities and lower your carbon footprint. The absence of a barrier-fluid system eliminates the risk of accidental release of fluid into the environment and our fluid-less design removes the need to transport barrier fluid to your platform or FPSO.

APTARA™ MULTIPHASE MCP

The Aptara™ Multiphase MCP can accelerate and improve your oil recovery in both, new and mature wells by adding energy to multiphase wellstreams and by lowering wellhead pressure. It can unlock and enable access to your assets, even in the most challenging subsea conditions, such as long tie-backs, lower-pressure reservoirs or wells with difficult flow assurance. The Aptara™ Multiphase MCP will be fully tested and qualified by 2021.

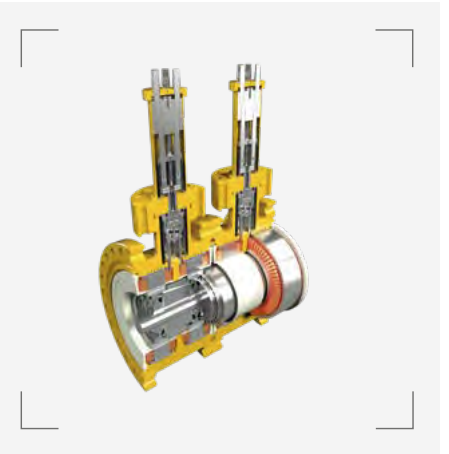
APTARA™ CO_2 INJECTION MCP

The Aptara™ CO_2 Injection MCP is specifically designed for the pre-salt fields in Brazil which have a very high CO_2 content. A key advantage in this application over more conventional subsea pumps is the significant reduction in space and weight on the FPSO.

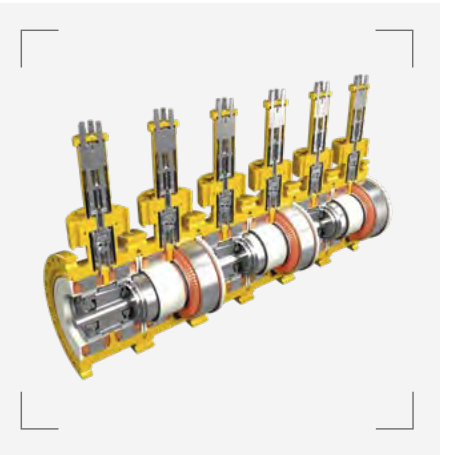
The MCP will be used to inject CO_2 in its supercritical phase (where the CO_2 gas essentially performs like a fluid) into the reservoir following subsea separation from the wellstream. The pump will use Baker Hughes proprietary single-phase centrifugal impellers that have been field proven in topside CO_2 injection pumps. All other elements of the boosting system are identical to the Multiphase MCP.

APTARA™ SINGLE-PHASE MCP

The Multiphase MCP can be used also for water injection applications, but will have a lower efficiency compared to a dedicated single-phase pump. The goal is therefore to develop a single-phase version of the MCP, changing the impellers from helicoaxial to centrifugal impellers, while keeping all other elements of the boosting system identical to the Multiphase MCP. The Single-phase MCP can be used for water injection as a standalone system or in combination with our Seawater treatment system and for low GVF (Gas Volume Fraction) wellstream boosting or upstream from a subsea separation system.



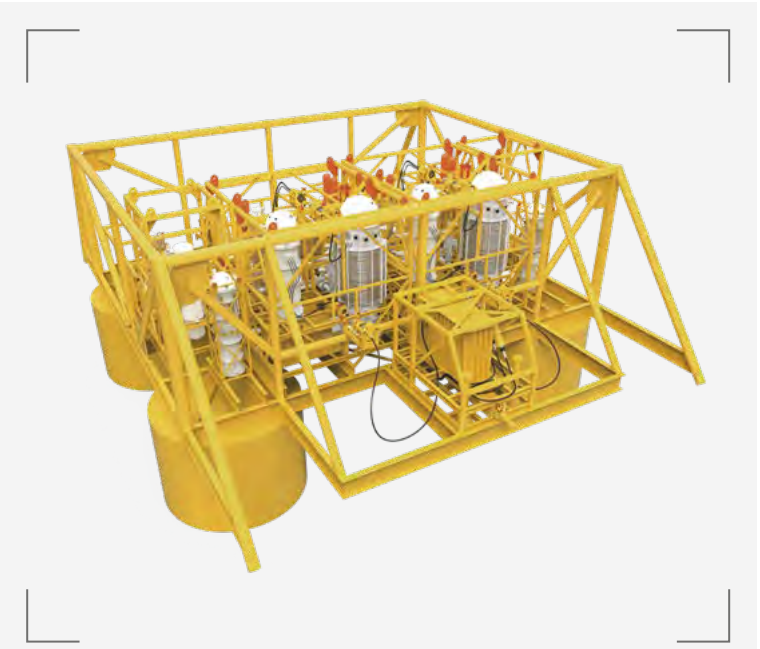
4 stage configuration



12 stage configuration

Note: Other configurations also available

SUBSEA COMPRESSION



Baker Hughes' subsea gas compression is designed and developed with industry partners to significantly improve the economics of mature gas fields. We have extensive experience in designing subsea compression systems for both, dry-gas and wet-gas applications, with power from topside or from subsea power distribution systems.

Reservoir pressures decrease as gas is produced, until the pressure may be insufficient to maintain the flow. Traditionally, production has been optimized by either reducing arrival pressure onshore or compressing the gas on a platform. Now we can place compression systems on the seafloor, eliminating the need for costly topside facilities and reducing your overall HSE concerns.

Baker Hughes in able to provide a fully-integrated subsea compression system, complete with a subsea power distribution. Our subsea compression systems use Blue-C™ centrifugal compressors from Baker Hughes and the system is placed as close to the wellhead as possible to provide the most efficient compression.

While all subsea compression systems require a reliable high-voltage power supply, the choice of power supply topology depends on the step-out distance and the number and power requirements of the loads. The step-out distance also determines where you need to place the variable speed drives (VSDs) that control the subsea compressors – either topside, on a floating structure, or subsea – and we can accommodate any of these design configurations.

We have considerable in-house expertise in the design of high-voltage subsea power systems. We worked with the Ormen Lange license to qualify the world's first subsea power distribution system with subsea variable speed drives (VSDs), subsea switchgear (SWG) and subsea uninterruptable power supplies (UPSs). This was done in an integrated system string test together with Baker Hughes's Blue-C™ Compressor, using an MGV1 electrical motor, at Shell's Nyhamna facility in Norway in 2015.

BLUE-C™ COMPRESSOR

Our Blue-C™ Compressor is a high-speed centrifugal compressor designed for subsea applications.

Our Blue-C™ Compressor is at the heart of both our subsea dry-gas and wet-gas compression systems. It comes with a choice of an MGV0, MGV1 or MGV2 high-speed induction motor that means the compressor can operate at a broad range of power levels from 4 MW to 20 MW to best meet your reservoir conditions. As the world's first centrifugal compressor qualified to handle up to 5% Liquid Volume Fraction (LVF), the Blue-C™ Compressor can support true wet-gas performance for both, subsea and topside compression. Compression systems based on the Blue-C™ Compressor can be tailored to cover almost any operating conditions, providing you with the optimal combination of differential Pressure (delta P) and flow.

DRY-GAS SYSTEMS

Our Dry-gas Systems can use active coolers to help reduce the size and weight.

Due to the inherent design of dry-gas systems, they tend to be larger, heavier and more costly than wet-gas systems as they require additional equipment including a scrubber or separation unit where the liquid phase is separated from the gas. The dry gas is then channeled to the compressor, while the liquid is boosted with a pump. The gas and liquid are then transported through separate or combined pipelines to a floating facility or back to shore.

Baker Hughes has extensive experience of designing systems with active coolers instead of passive coolers, which results in an overall reduction in system size and weight.

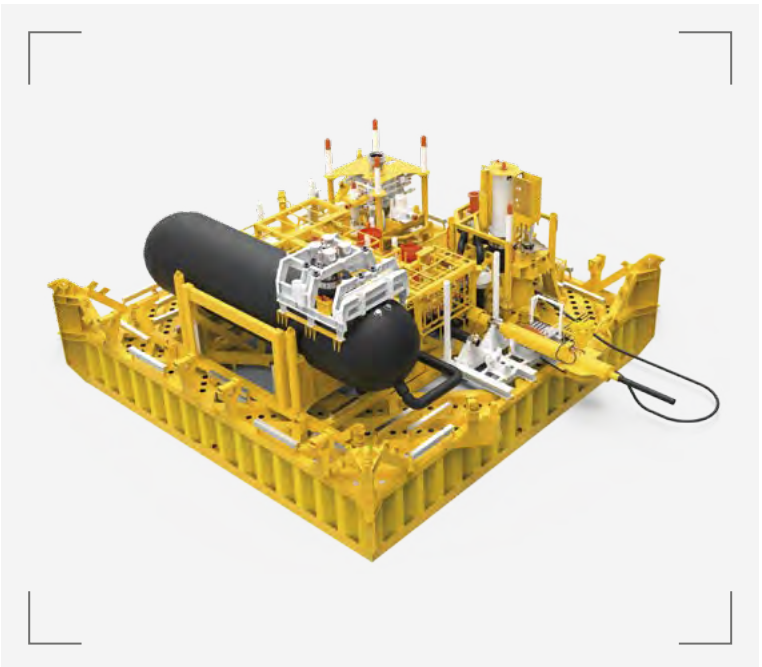
WET-GAS SYSTEMS

Our Wet-gas Systems can handle up to 5% LVF for both subsea and topside applications.

Our wet-gas compression systems use a simpler compression system than other industry solutions; it eliminates the need for the scrubber, condensate pump and pump control system. The result is a reduction in size and weight of up to 40% and the potential for a 30% reduction in your total CAPEX compared to a conventional dry-gas system.

The fundamental requirement of a wet-gas system is that the compressor must be capable of handling gas with up to 5% LVF. Unique to Baker Hughes, we have wet-tolerant impellers that help do this, with special materials and coatings, and modifications made to the impeller geometry and compressor flowpath. These innovative impellers have been qualified at Equinor's K-Lab facility in Norway for use in the Blue-C™ Compressor.

SUBSEA SEPARATION



When compared to topside separation, subsea separation offers better conditions to avoid flow assurance issues like the formation of emulsions and hydrates. Handling of production fluids can be done closer to the production wells and more efficiently at higher pressures. Baker Hughes' solution can de-bottleneck your topside production facilities by freeing up storage and transport capacity, allowing you the potential to increase production and reduce your related CAPEX.

Production systems typically have complex multi-phase flow streams where oil, gas, water or particles like sand may be combined. Our subsea separation systems combine technologies that can handle gas-liquid, liquid-liquid or solids separation (or a combination of them) for flow management. They also condition the flow for further boosting, transportation or reinjection while reducing the risk of flow assurance issues during production.

Baker Hughes has the required expertise and experience to design and supply the optimal subsea separation system for you. Our field-proven technology and experience includes Equinor's Troll C, the world's longest-running subsea separation and reinjection system – operating since 2001 and enabling significant increases in the field's oil production.

Our building-block approach includes an open-interface that allows us to partner with suppliers of complementary technology to ensure we design a robust and simple solution that meets your field requirements. We can also provide a reliable full system design where separation is integrated with our subsea boosting and compression solutions for transportation and/or reinjection.

GRAVITY SEPARATORS

Our Gravity Separators are robust and simple.

They can achieve three-phase separation (gas, water and oil) and are designed with sand handling capabilities. Our semi-compact gravity separators are an improvement on traditional gravity separators and can offer robust system solutions for deepwater applications, where they can be combined with internal separation enhancing devices and bulk separation equipment for gas, water and/or sand handling.

COMPACT SEPARATORS

Our Compact Separators are designed to handle high-pressure environments.

In ultra-deepwater applications, conventional gravity separators have limitations, due to the high-pressure environment. In these conditions, smaller-diameter vessels used in compact separation become more attractive. While gravity settling and coalescence are the dominant mechanisms in conventional gravity separators, compact separation solutions enhance coalescence of the different phases by other means, typically centrifugal forces or turbulence. In-line, pipe-type and cyclonic separation devices all form part of our compact separation solutions.

SEAWATER TREATMENT AND INJECTION

Water injection is a widely used technique to support pressure to the reservoir and enhance oil recovery. With abundant seawater available offshore, it is ideal for injection applications, but needs to be treated first. Traditionally, seawater has been treated in large-scale, heavy topside processing plants. Baker Hughes' seawater treatment system allows seawater to be treated and injected subsea, eliminating the need for heavy, high-pressure risers and flowlines, and offer more than a 90% reduction in the weight of topside equipment.

Seawater treatment involves the removal of solids that can cause blockages or fracture the formation, as well as sulphates and other divalent ions, which can cause scaling and souring when interacting with either formation water or sulphate-reducing bacteria in the reservoir.

Our subsea seawater treatment systems are based on a modular concept that can be tailored to provide exactly the level of water quality and injection capacity you need, including standard raw seawater treatment, sulphate removal and desalination. The systems are also All-Electric, so only require a power cable to run them, and use strategically positioned subsea water injection pumps to inject the treated water around the reservoir – optimizing water flooding and improving oil recovery.

All our seawater treatment systems are designed to be highly reliable and the system uses many of the technologies present in typical topside facilities, including Ultra-filtration (UF) and Nano-filtration (NF) membranes. The UF and NF membranes are run at low flux to extend their life, and we avoid the regular use of the aggressive chemicals that are normally needed to clean them and recover their performance.

The UF membranes are back-washed regularly with Sodium Hypochlorite, which is produced subsea in an electro-chlorinator unit, ensuring that the membrane modules only need to be retrieved once every five years for maintenance.

In standard raw seawater treatment, the water is filtered to remove any solids or microorganisms using a coarse filter that removes particles down to 30 microns. The water can then be treated using UV radiation, an alternative to chemical disinfection, to kill bacteria, prevent biofouling and reduce the risk of microbiologically-induced corrosion in the injection system.

Baker Hughes' approach to subsea sulphate removal is a refinement of raw seawater treatment that involves a three-step process before the water reaches the required quality for pumping into the injection well. The first step is essentially the standard raw seawater treatment, but this treated water then passes through a series of UF membranes where particles and even bacteria down to a nominal size of 0.02 microns are removed. In the third and final step, the water passes through a series of NF membranes that remove sulphates and other divalent ions, with a small boosting pump compensating for the pressure drop between the NF and UF membranes.

An additional module with reverse-osmosis membranes can be added to the sulphate removal system to remove salt from the seawater and enable tuneable salinity for injection, providing the potential to slightly increase recovery by removing more residual oil from the reservoir. This module is placed in parallel with the NF module and the rest of the process is virtually the same used for sulphate removal.

SUBSEA POWER

MECON DM 145/700

MECOM WM 36/500

A reliable power supply is critical for all types of subsea processing activities – even more so if your project faces challenges such as long tie-backs, multiple loads, deepwater, harsh conditions or operation in sensitive areas. Baker Hughes can supply fully integrated AC power solutions for all types of applications – from the simplest single-load scenario to long step-out systems in deepwater with multiple, high-power loads.

As a pioneer of subsea power, we designed and qualified the world's first subsea power transmission, supply and distribution system for Shell's Ormen Lange Pilot in Norway. Today, the systems we design are integrated using our unique portfolio of high voltage connection systems. Baker Hughes' MECON electric connectors are available up to 145kV and 1800A, covering the full range of power requirements used in subsea processing systems.

Our power systems include everything from topside drive systems and integrated HV subsea connection systems, to multi-port switchgears and standalone circuit breakers. We provide subsea variable speed drive solutions, 5-20 MVA subsea transformer modules and the controls and monitoring you need. Our field-proven systems are designed for maximum installation efficiency and long-term operating reliability – and they can be tailored to meet your specific project needs.

145kV dry-mate connection systems
To transfer electrical power from onshore or offshore hosts down to the subsea equipment, our 145kV dry-mate connection system can provide multi-megawatt transfer over more than 100 kilometers. It is currently the only high-power connection system in the market fully qualified for operation above 100kV, and is qualified for 700A and down to 3,609 ft (1,100 m). The solution is currently in operation and classified as TRL 7.

36kV dry and wet-mate connection systems
Our 36kV connection systems are the most efficient transmission solution for medium tie-back distances in the multi-megawatt range that are required for subsea processing. The 36kV systems are also used together with subsea switchgears and variable speed drives (VSD) to provide full distribution systems where multiple loads are fed through a single cable to reduce cost. These systems come in both, dry-mated and wet-mated configurations and are fully qualified up to 700A and down to 10,000ft (3,048 m). The dry-mate system is currently in operation and classified as TRL 7 and the wet-mate system is TRL 4.

12kV supply systems
Baker Hughes has market leading technology for supplying power into subsea compressors, pumps and auxiliary systems, including qualified wet-mate connections at 12kV and 1800A, which is sufficient to feed the biggest compressors in the market.

Typical lead time:

9 months

Typical lead time for high-voltage power connectors is 9 months.

04

FLEXIBLE PARTNERSHIPS & COMMERCIAL MODELS

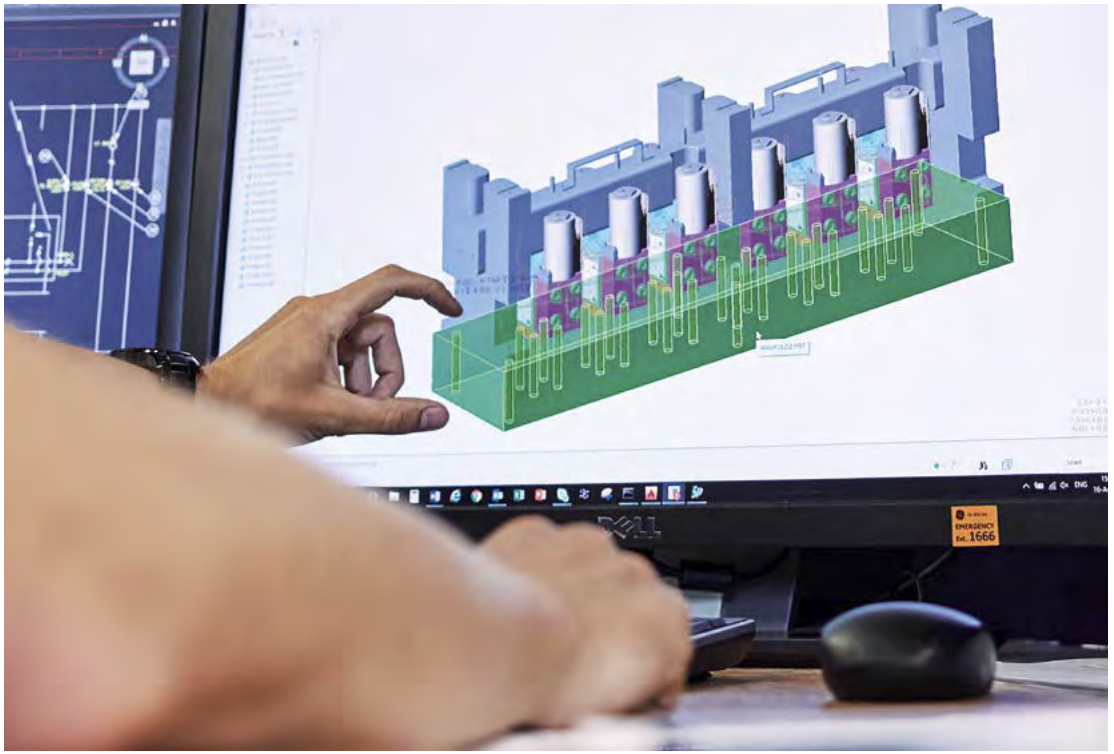
In recognition of the varied requirements of individual projects and regions, we have developed suitable partnerships as well as innovative commercial models that help unlock the value in subsea projects.

We recognize that the demands of each project are different and often partnering to deliver a broader and more integrated solution can unlock value. We do not have a single prescriptive response, rather we use our established frameworks with a range of global partners to select the best option, based on the unique demands of the project, according to technical strengths, regional coverage and capabilities. We can also take an adaptive approach looking to find new partnerships where these are the best fit for the project scope or local environment.

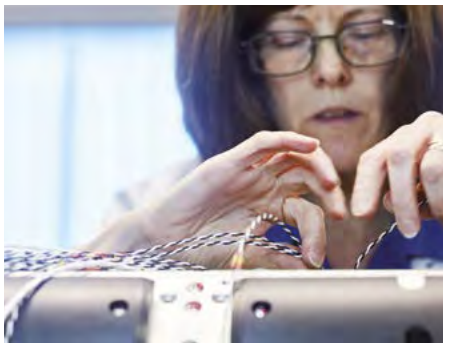
Baker Hughes continues to lead the way in innovative commercial models. We have various models that balance risk and reward to ensure that our priorities are aligned with yours. These are designed on the basis of our TOTEX-lite philosophy and to ensure an accelerated schedule to project completion, often extending through the life of the field. We're changing our approach, moving away from traditional contracts to deliver in alliances, consortia and under integrated contracts. These commercial models enable us to remove ambiguities and additional layers of cost and uncertainty, and align the participants to the same objectives. We have also introduced performance-based contracts where our compensation is linked to schedule, performance, uptime or production rates. An example is the contract we have with Diamond Offshore where the BOP stack on the rig is paid for based on availability. If it's not available, we don't get paid.

CASE STUDIES

No other company brings together capabilities across the full value chain of oil and gas activities – from upstream to midstream to downstream.



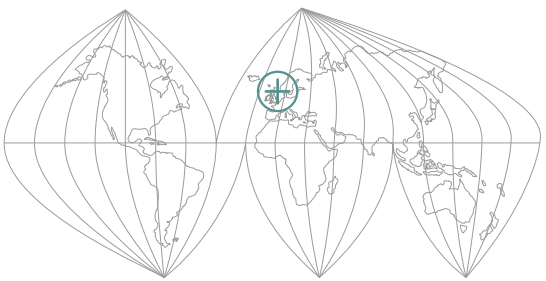
Our wide and deep portfolio of products and services enables us to create new sources of value, improving productivity and project economics through integrated equipment and service offerings. We are also leaders in state-of-the-art software, advanced analytics, controls and sensing, and asset performance management – helping us to share risk, reduce costs and increase productivity at a wide range of projects around the globe.



CASE STUDY

SUBSEA CONNECT HELPS BUZZARD FLY HIGHER

For the Buzzard Phase II project in the UK North Sea, Baker Hughes is working with CNOOC International in a new outcome-focused framework where we bring drilling, completions, subsea production systems and SURF together, delivering as an integrated alliance team to develop new reserves and bring additional production on stream.



The Challenge

The Buzzard Phase II project in the North Sea was conceived against a background of tight economics and a historical track record of delay and project overspend that encouraged new thinking between the operator CNOOC International and its major suppliers.

Taking a different approach, the project is delivered by an integrated project team in which Baker Hughes comes together with the operator, drilling contractor, SURF contractor and others to provide oil field equipment and services under a performance-based commercial model, fostering an environment of trust and collaboration, where all parties are aligned to achieve project success.

Buzzard Phase II features an additional six subsea wells which are tied back to existing assets where platform topsides and subsea infrastructure are modified and expanded to accommodate the new production.

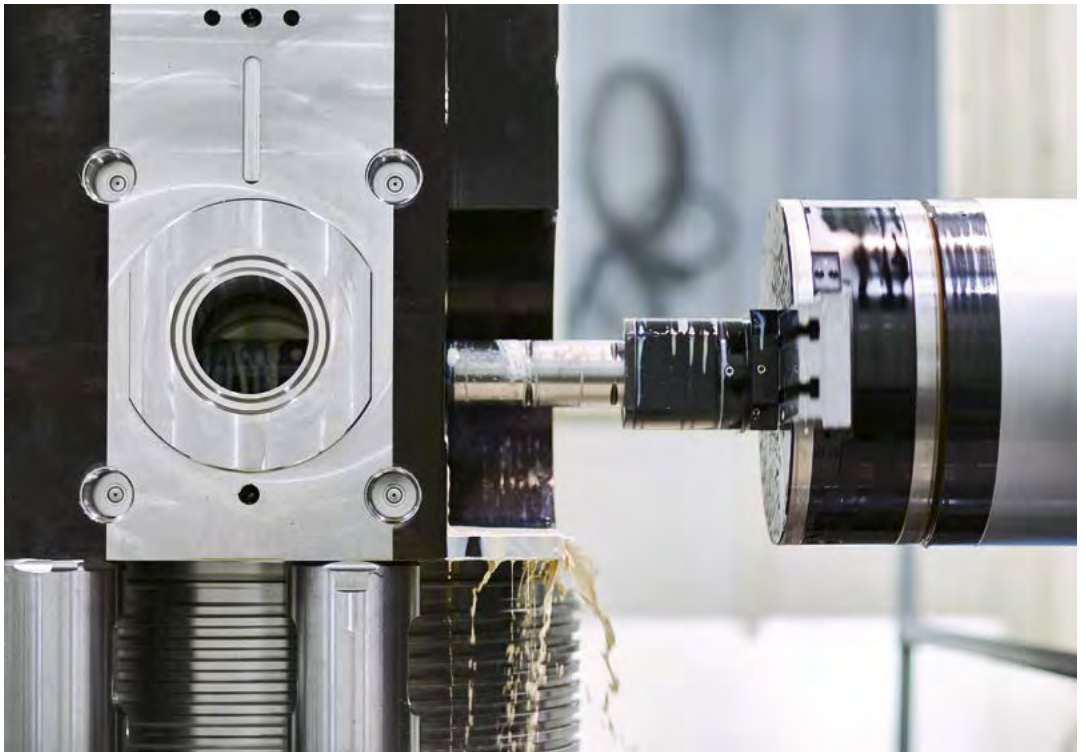
Working in an alliance lets Baker Hughes do a complex programme spanning well design, drilling, completions and subsea equipment supply in conjunction with subsea construction and brownfield expansion activities, doing so in a way which manages interfaces, mitigates risks and aligns programme deliverables with the aim of installing and commissioning phase II with minimal impact to ongoing operations.

The Solution

In line with our Subsea Connect vision, we supply structured and modular solutions based on existing, proven technologies and standardization: a strategy designed to save both, time and money while decreasing risk and increasing certainty.

Baker Hughes provides an extensive scope, from well design, drilling, completions, wireline and tubular running through to subsea system design and supply allowing unique opportunities to standardize, optimize and deliver in an integrated manner from the reservoir to the topside.

The Subsea tree system selected for Buzzard is our Make to Order MHXT, which is already familiar to CNOOC International and many global customers, while MS700 well-heads were supplied from an existing off-the-shelf system and subsea controls feature our standardized SemStar5 technology. The use of pre-configured, structured products brings certainty in the engineering, procurement, manufacturing and installation phases.



The Benefits

The alliance approach, with Baker Hughes providing field services and equipment, overcomes the typical cost, delay and risk associated with the traditional contracting model. Our participation alongside partners recognizes the need for lowering development costs in a sustainable manner, ultimately aiming to yield lower costs per barrel.

We are committed to supporting our customer in improving the economics of the field, achieving efficiencies across the supply chain and establishing a new way of working in the North Sea. Alongside our partners, we applied our Subsea Connect vision – primarily the pillars of Project Connect and Reservoir to Topside Technology Solutions – to provide certainty to the operator through a combined commitment to one common objective.

Buzzard Phase II is aligned with the Oil & Gas UK Vision 2035 objectives, which outline next-generation outcomes for the industry: provide direction, instill confidence, inspire transformation, drive collaboration, create competitive advantage, secure investment and drive value.

Enabling technology
5 x Hybrid MS700 (Low Pressure Housing)/SG-1 (High Pressure Housing) + Conductors
1 x Hybrid MS700 (Low Pressure Housing)/SG-5 (High Pressure Housing) + Conductors
6 x MHXT
6 x Control System – SCM Sem Star 5

> The real win is to overcome the challenges of cost and schedule to produce first oil on time and on budget.

6x
Hybrid MS700 wellheads

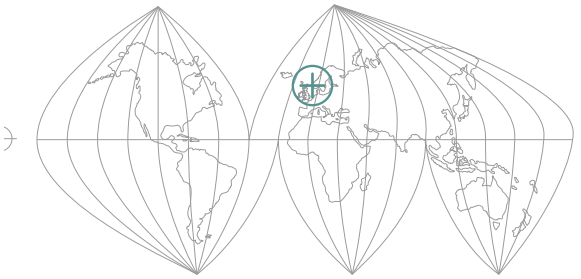
6x
MHXT

6x
SCM SemStar5

CASE STUDY

NEW CHAPTER FOR BAKER HUGHES' NORWEGIAN SUCCESS STORY

A consortium execution model between Baker Hughes, installation partner and our client will help to meet a timely first oil commitment for the landmark expansion of a vintage Norwegian field, while simultaneously boosting efficiencies and minimizing risks.



The Challenge

Our client is growing an established field on the Norwegian Continental Shelf with a system of 17 new wells and five Multi Flow Base template manifolds feeding back to an upgraded FPSO.

The operator, a newly formed partnership, is targeting first oil from the project in late 2021 as part of an ongoing expansion plan at the vintage harsh environment development in 130m water depths. The integrated SPS-SURF project is due to be completed in mid-2022.

17

New wells to feed into the upgraded Jotun FPSO

The Solution

Baker Hughes teamed up with a SURF partner to provide a collaborative SPS and a SURF solution on an EPCI basis. Key to success was a flexible execution model that was tailored to the needs of our customer.

We will supply proven equipment including trees and manifolds that will minimize required engineering. Our project solution enables the re-use of existing installation tools owned by the operator which has minimized the project's TOTEX.

A Norway-based build solution and an execution team co-located in Stavanger will cement existing relationships between the Baker Hughes consortium alliance and the client team with whom we are already very familiar and have a well-established and successful working relationship.

Our joint project management team will further facilitate close collaboration and provide ready access for ad-hoc meetings, project follow-up, witnessing and discussions.

The Benefits

Our alliance approach to contracting for the SPS-SURF package provided certainty over reporting and lines of accountability based on management of interfaces and associated risks. Delays will be reduced and gaps avoided through the integrated contract structure.

Furthermore, early engagement with the client ensures that continuity and the valuable lessons of risk identification, management and mitigation are not lost between the FEED, tender and execution stages of the expansion.

Finally, our "One Team" approach is part of making the client our number one priority and putting the project first, building on the existing relationships between all parties and committing to an expansion that is delivered on time, within budget and incident free.

Enabling technology

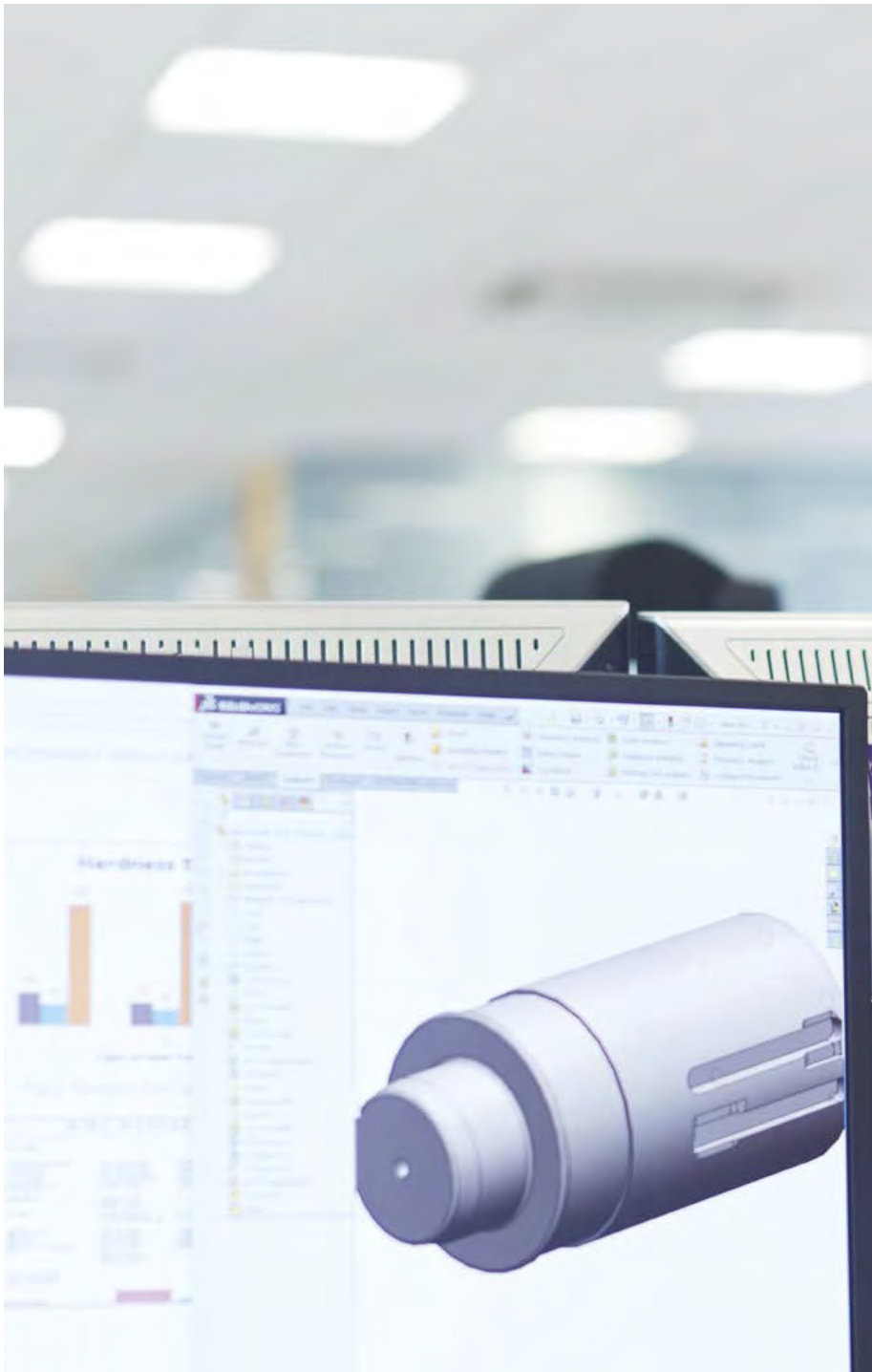
MVXT to Medium Water Vertical Tree
Multi-Flowbase Template Manifold

> We offered the right mix of standardization and bespoke engineering solutions, that maximized value while delivering against our client's priorities.

CASE STUDY

HIGH-TEMP EXPERTISE KEEPS THE LNG FLOWING

Baker Hughes is providing a reliable high-temperature product and delivery solution to a customer in the Asia Pacific region as part of ongoing efforts to build one of the world's most complex LNG developments, a mega-project in the Browse Basin off Australia.



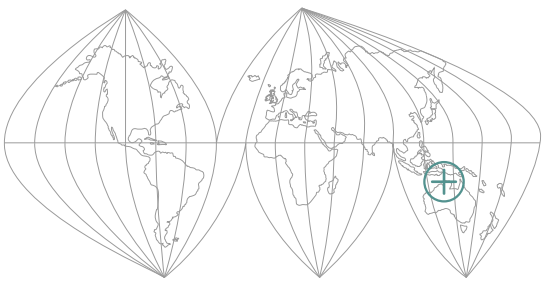
The Challenge

Our customer has three mega-projects rolled into one, including the world's largest offshore facilities located off the north coast of Western Australia, the longest subsea gas export pipeline in the southern hemisphere, and onshore LNG processing facilities near Darwin.

The landmark development's onshore facilities feature two LNG trains that need to be constantly fed with gas, as well as LPG and condensate plants, storage tanks, utilities and a materials off-loading facility and jetty.

Moving from Phase 1 into Phase 2a dictated an economic and technical solution that would meet "super-critical" availability and delivery commitments as initial production reaches an anticipated plateau. Constraints in the field off north-west Australia include high temperatures in a location remote from existing service options.

Offshore infrastructure in the basin includes the world's largest semi-submersible platform to support hydrocarbon processing systems, utilities and living quarters. An FPSO also features for offshore processing.



The Solution

Our subsea equipment solution for this deepwater oil development project relied on the use of modular product designs that were backwards compatible with the existing infrastructure. The scope of supply included seven deepwater horizontal trees (three for injection, four for production), nine subsea control modules (SCMs), topside and subsea controls distribution equipment, and vertical connections systems.

The design incorporated a first-of-its-kind "scale-squeeze" system to treat scale build-up in the production lines. A sampling system with 3-inch manual valves was also integrated into the horizontal trees to test the effectiveness of this innovation.

To address the unique logistical and testing challenges of the project, Baker Hughes adopted an integrated approach, with collaboration from our regional teams based in Aberdeen and Nailsea in the UK, and Sandvika in Norway. Local services based in Sonils and Cabinda, Angola, led the final testing and installation, and provided ongoing support throughout the project, while EPC project management was run out of the UK. Manufacturing also took place in the UK, as well as in Brazil.

Baker Hughes' global team coordinated closely with all these groups to ensure a smooth operation and the installation of the seven subsea tree systems and tooling was all achieved within a seven-month period from December 2014 to July 2015.

> The first-of-its-kind 'scale-squeeze' system treats scale build-up in the production lines.

The Benefits

Our subsea design delivered significant TOTEX (CAPEX plus OPEX) savings by enabling our customer to build on their existing subsea infrastructure from surrounding fields and by reducing well intervention costs through product design innovations. First oil from the field was achieved on schedule, with an average production rate of 40,000 barrels of oil (BOE) per day.

The integrated scale-squeeze system removed the need for an "injection" choke insert and eliminated the risk of damage to the choke's internal sealing surfaces. It also added a "piggyback" connection (for contingency) and is equipped with a hinged hatch, which protects the connection system from dropped objects. The system enabled connections to be installed without shutting down production and minimized the volume of seawater that had to be removed after intervention, further reducing non-productive time.

Integration of the sampling system into the trees also contributed to cost savings by eliminating the need to install a separate sampling structure and foundation. Sampling can now be done at the well before fluid enters the flowline system without shutting down production. Information and data from the samples can then be used to evaluate scale build-up between squeeze operations and more accurately calibrate multi-phase flow measurement.

ENABLING TECHNOLOGIES

DVXT – Our deepwater vertical tree is engineered for up to 10,000 psi and 10,000 ft (3,048 m) water depths and enables greater intervention flexibility, improving well performance at lower costs. Each of the primary tree system elements are interchangeable and provide, where design and practicality allow, backward compatibility with the equipment used in the original project. Our made-to order DVXT variant can be delivered in 14 months.

SemStars5™ – SemStars5 is our ultra-reliable fifth-generation subsea electronics module for production control systems and draws on 40 years of Baker Hughes' subsea experience. The SemStars5's Make to Order variants can be delivered in seven months.

Baker Hughes' MS-700 – The MS-700 can be used across a wide range of applications, including TLP/spar tieback, subsea completion and deepwater drilling. The system comes with 7 million lbs of total load capacity, which allows for three casing strings and up to 3 million lbs combined string weight. We can deliver an MS-700 wellhead system, supporting multiple casing configurations from 36 inches through to 7 inches, in around five months.

> Our execution plan in cooperation with our partners will control installed costs and minimize operational risks.

The Solution

Baker Hughes designed and is supplying a highly competitive, optimized subsea solution that meets the customer's economic and technical objectives. Equipment includes support for 10 additional wells based on large-bore, high-temperature products from our Aptara™ range, the only such hardware on the market. Also included is our flexible pipe solution.

We built on our extensive Phase 1 knowledge of the project alongside a regional delivery model that was very attractive to the developer, including fabrication at McDermott and proximate service provision.

Baker Hughes further offered an integrated execution model in partnership with an established SURF approach which we believe results in a commercial structure that is hard to beat.

The Benefits

Baker Hughes delivered a fit for purpose solution for Phase 2a that optimized economics, assured delivery and availability and minimized risk. We are further supplying best in class support services based on in-country infrastructure and extensive subsea know-how.

Our efforts will provide certainty in mission-critical LNG supply contract commitments and help to protect and enhance the financial and reputational standing of our client. Furthermore, our solution approach is designed to meet the challenges of a lower price environment through cost savings.

The combination of Baker Hughes in SPS and McDermott on SURF provided our customer with a one-two punch of proven expertise and collaboration that will help the mega-project hit internal targets and meet external commitments.

Enabling technology
DWHC MS-700 Wellhead Systems
DVXT Deep Water Vertical XT
Aptara™ HCCS-L Medium Connection System
FLX360 (Mark 1) Connections
SemStar5 Control System
10km of 8" production and 10km of 2.5" gas lift flexible flowline jumpers including terminations and bend restrictors
MCS functionality to remove HIPPS from HMI following decommissioning

165°C

Temperature of the well fluid as it passes through the Phase 2a subsea trees.

05

DIGITAL ENABLEMENT

Digital has a central place in the future of subsea developments. We incorporate digital technologies in both our internal processes and the solutions we develop and deploy for our customers.

Internally, Digital Enablement manifests itself in our Brilliant Factory program that streamlines our manufacturing and fulfilment process. This has resulted in more efficient processes and faster fulfilment. Additionally, we have made major investments in newer manufacturing technologies like 3D printing (additive manufacturing) that allow us to improve the design and manufacturing processes and unlock efficiencies that would not have been possible with traditional methods.

Digital Enablement is an increasingly important part of our customer solutions. These fall into two broad categories:

- Field development and optimization delivered through development and planning insights – integrating reservoir intelligence with well planning, drilling information and geo-mechanical modelling to ensure optimal reservoir drainage and field development
- Production enhancement and asset performance management involve an open, scaleable multi-cloud platform, with tailored software solutions. We have solutions that enhance equipment performance and deliver system health checks for field optimization. We use the latest technology to drive obsolescence management and analysis and prevent equipment failure through predictive analytics and failure modelling

Our engageDrilling and engageSubsea platforms provide real-time remote monitoring and analytics that drive equipment uptime and increase productivity.

DIGITAL ENABLEMENT

engageSubsea

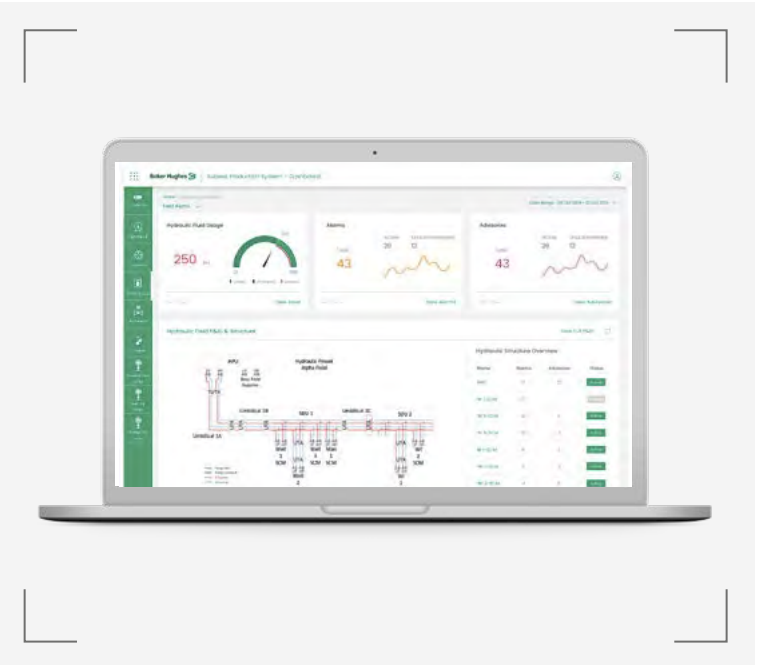
engageSubsea is a real-time modular remote monitoring platform for proactive asset management and instant troubleshooting which can be deployed at any stage of field life.

- Reduced downtime, with virtual experts able to identify and resolve issues from any location
- Instant digital access to documentation and financial statuses, including work order management
- Ability to support comprehensive monitoring of a facility's integrity and performance
- Trend diagnostics, event prediction and recommendations for intervention and maintenance
- Live inventory management overview with tracking of past, present and future maintenance and recertification events
- Proactive obsolescence alerting with upgrade or last time purchase advice
- Advice from flow assurance specialists on flow regularity and production optimization

engageSubsea gives you the ability to tie together your assets at a global level, significantly reducing regionalized inventory holding by 50% on a typical five-well field. Its ability to group work orders together can cut offshore transportation and personnel requirements by over 60% when supported by virtual experts.

The modular nature of engageSubsea means additional digital production optimization solutions such as subsea Equipment Integrity Management (Equip IM) and Flow Assurance Management (Flow AM) can be integrated to enhance your digital asset lifecycle management even further.

- 50% reduction in inventory
- Spares optimization
- Maintenance management
- Real time inventory & work order management



50%

reduction in inventory

DIGITAL ENABLEMENT

engageSubsea includes Equipment Integrity Management (Equip IM) and Flow Assurance Management (Flow AM) to make your operational decision-making more intelligent and help you optimize subsea production.

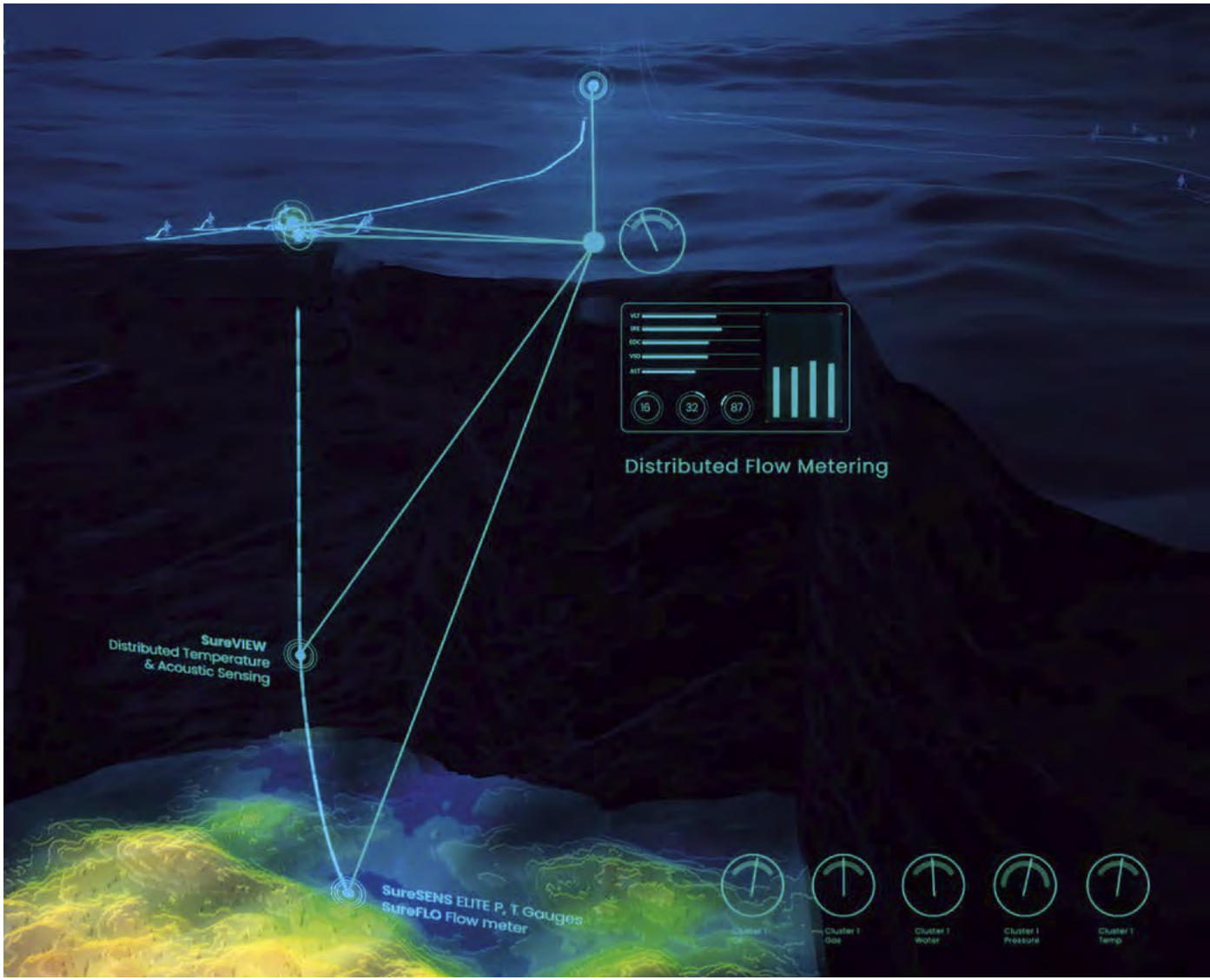
Baker Hughes' digital solutions combine advanced hardware, intelligent software and trusted services to help you mitigate risk, improve safety and operate with a reduced CO_2 footprint. A more connected view of your operations also improves uptime and efficient operations while reducing cost.

Hardware – Precise sensing and measurement technologies deliver critical data for monitoring, diagnostics and analytics, providing critical data to support operations and protect your equipment.

Software – Advanced analytics solutions deliver improvements in safety, reliability, and performance of assets through analysis of real-time and historical data from the subsea production system, providing system-level insights to support key operational decisions.

Support – Baker Hughes' subsea services are designed to support equipment lifecycle management and respond swiftly to your operational needs, including budgeting and planning of maintenance activities. These services also connect insights from subsea analytics with Baker Hughes domain experts to support equipment troubleshooting and provide recommendations for performance optimization.

Lead times on all these solutions depend on the configuration and sensor inputs you need but can be as low as 4 to 10 months.



DIGITAL ENABLEMENT

EQUIPMENT INTEGRITY MANAGEMENT

Baker Hughes' subsea Equipment Integrity Management (Equip IM) is a single platform for proactive monitoring and analysis of real-time operations of equipment from your well, production system and risers enabling a range of diagnostics and prognostic capabilities through our powerful digital analytics engine.

Equip IM delivers an improved understanding of equipment status and remaining useful life. It enables an intelligent view of subsea data to support your team in making the best decisions on when and how to maintain equipment to maximize availability and uptime.

Built on an industry-leading analytics platform supporting advanced analytics and artificial intelligence (AI), Equip IM aggregates subsea data and provides you with early warnings on maintenance needs, early system degradation or impending equipment failure. Smarter maintenance planning can be enabled to support life of field by allowing you to set alarms to cover a comprehensive range of configurable thresholds, rules, and performance deviations.

Equip IM's intuitive way of interpreting production data from the whole system can result in smarter decisions in consolidating, deferring or advancing different operations so that resources are optimized, and the downtime of unexpected operations is reduced. Equip IM can help your organization give you a more intelligent view of the remaining life of components and the overall health of your system on one asset or a portfolio of assets.

Baker Hughes has more than 30 years' experience delivering custom Equipment Integrity Management solutions for subsea – from the well, production system to risers. Baker Hughes has unrivalled access to the latest digital analytics and AI technology through the Baker Hughes Digital organization and its various industry partners, such as c3.ai.

Application Modules

The Equip IM solution builds its intelligence from the data of multiple sensors from production system, well and risers. Baker Hughes customizes sensor solutions and analytics from configurable modules to monitor all aspects of your subsea system.

Equip IM leverages sensor inputs and uses an advanced analytics engine to provides intuitive and sophisticated data visualization of all subsea systems independently. Separate application modules are available to support detailed analysis of historical instrument data, operational trends, and forecasted performance based on real-time inputs. Monitoring is available through a single web interface accessible both, offshore and onshore which to facilitate collaboration and training of operations personnel.

Typical lead time:

5 months

Our subsea Equip IM system is normally delivered as part of the subsea production system but can also be supplied as a standalone application within 5 months.

DIGITAL ENABLEMENT

Equip IM has a number of application modules specifically designed to monitor the following sub-systems intelligently:

	Naxys – Acoustic and Electromagnetic Monitoring Solutions	
Equip IM Application Modules	Baker Hughes Sensor solutions	Data & analytic outputs to determine:
Variant	Naxys A5	Naxys A10 & A10E
Controls Equipment Health	Baker Hughes SemStar5 subsea electronics as well as legacy Baker Hughes subsea electronic modules	– status and availability of subsea instrumentation and major controls equipment units including Subsea Control Modules (SCMs), Power Communication and Distribution Modules (PCDMs), and Master Control Station (MCS) among other equipment – equipment Remaining Useful Life (RUL) – equipment service history and intervention needs
Electrical Health	Baker Hughes' Umbilical Monitoring Device (UMD) and Subsea Line Insulation Monitor (PLIM)	– health of controls electrical system and Subsea Electronic Modules – health of electrical conductors within the subsea umbilical distribution system, including insulation and capacitance leakage – trends to enact proactive measures before a complete failure occurs
Communications Health	Baker Hughes Topside and subsea modems, switches and routers	– status and availability of subsea communications infrastructure – health of devices, routing, traffic, and applications within the communications network – network availability and improved understanding of failure conditions and loss of redundancy – decay or attenuation within communications infrastructure
Hydraulic Health	Baker Hughes Druck and/or Presens	– status and availability of hydraulic control system – hydraulic fluid usage and calculated leakage – hydraulic pressures, flows and pump performance – subsea accumulator performance
Actuator Health (hydraulic)	Baker Hughes Druck and/or Presens	– valve operation performance and anomaly detection through analysis of valve profiles – opening and closing times for each operation, as well as pressure and/or flow transients in supply and return systems – historical records of valve operations and actuator profiles – analysis & comparison of multiple valve profiles
SPS Actuator Health (electric)	Baker Hughes IFOKUS electrical actuators	– detailed positioning and operational data
Choke Health	Sensor agnostic	– choke position status and actuator operational performance – flow regime, pressure and/or temperature anomalies and cavitation risks – variations on choke flow performance indicating potential degradation through erosion
Hydrocarbon leak detection	Baker Hughes Naxys acoustic and electromagnetic monitoring	– acoustic speed tracking (pump RPM) – electric VSD frequency monitoring – slip ratio estimation – monitoring of harmonics – resonant frequencies detection – vibration levels trending – detection of pump imbalance, electrical ground faults and failure – pump operation verification and early detection of changes and failures
Equipment Vibration		
Processing equipment Monitoring		
Well Health	Baker Hughes SureSENS™ QPT ELITE permanent downhole gauges Baker Hughes SureVIEW™ DTS and DAS systems	– static and dynamic pressures and temperatures at selected locations within the well – production performance – reservoir characteristics and optimal production rates based on dynamic pressure data – fibre optic data based on distributed acoustic sensing (DAS) and distributed temperature sensing (DTS) to identify contra-flow, thief zones, and leak detection – active monitoring of well during start up, production, and shut downs
Risers Health	Baker Hughes SPIRE	– real-time information time and location of outer sheath breach, and location of annular water
	Baker Hughes MAPS	– information on unloaded tensile wires
	Baker Hughes Riser Distributed Temperature Sensing (DTS)	– understanding of pipe temperature profile including under ancillary equipment
Sand Erosion	Various sensors across SPS and well	– erosion rate at choke galleries, pipe bends and fittings – cumulative erosion effects

DIGITAL ENABLEMENT

SPS – NAXYS ACOUSTIC & ELECTROMAGNETIC MONITORING SOLUTIONS

Baker Hughes' Naxys system uses acoustic and electric sensor arrays for the non-intrusive monitoring of an entire subsea installation. Its applications range from acoustic leak detection to advanced acoustic and electric monitoring of subsea machinery and processes.

We are the industry-leader in acoustic and electromagnetic monitoring technology, with hundreds of installations on more than 30 subsea fields since 2005, with many on the Norwegian continental shelf. Our technology enhances your condition-monitoring capabilities and is critical to detecting leaks in your system. It also enables you to monitor your subsea pumps and compressors, as well as fluid induced vibration, which can be a challenge on long-offset applications due to the high velocities involved.

With our proven track record and unique capability, we can deliver a standalone Naxys system in around eight months, though combining the order with other Baker Hughes subsea production system hardware is likely to be a cost-effective option. Tighter integration with our subsea systems analytics will also provide differentiated capabilities for condition monitoring.

Effective leak detection depends on the differential pressure across leakage, the gas-oil ratio, the distance to leakage, water depth, obstructions and background noise. Typical detection thresholds for wide area coverage in a subsea installation and surrounding infrastructure (up to 1,640 ft/500 m) require a Signal to Noise Ratio greater than 6 dB at the sensor location.

Depending on your system architecture, we might recommend a smaller Naxys A5 unit be used on each tree or the 'bird cage' Naxys A10 on a central location.

The monitoring system includes acoustic speed tracking (pump RPM), electric VSD frequency monitoring, slip ratio estimation, monitoring of harmonics, resonant frequencies detection and vibration levels trending. It also supports your maintenance cycle and ongoing efficient operation by offering pump imbalance detection, the detection of electrical ground faults and failure, pump operation verification and early detection of changes and failures.

Typical lead time:

10 months

Our Make to Order Naxys acoustic and electromagnetic monitoring solution can be delivered in 8 months.

DIGITAL ENABLEMENT

WELL – SURESENS QPT ELITE DOWNHOLE GAUGES

Our SureSENS™ QPT ELITE permanent downhole gauges measure static and dynamic pressures and temperatures at selected locations within the well. They offer best-in-class capability and represent a step change in reliability and accuracy. The gauges have an industry-leading pressure resolution of 0.0001 psi, enabling more accurate reservoir modeling and flow measurement, and it is possible to install up to 32 gauges on the same cable.

Baker Hughes is the industry leader in downhole gauge and monitoring technology with proven track record dating back to the 1960s and thousands of SureSENS™ gauges installed in all varieties of applications globally. They are AWES and IWIS compliant, with fully qualified downhole and subsea technology.

The static pressure information recorded can be used to determine production performance, calculate reserves, and provide input to reservoir simulations, while the dynamic pressure data can help determine reservoir characteristics and optimize production rates.

Typical lead time:

5 months

We can deliver a SureSENS™ QPT ELITE permanent downhole gauge in 5 months.

WELL – SUREVIEW DISTRIBUTED TEMPERATURE SENSING (DTS) AND DISTRIBUTED ACOUSTIC SENSING (DAS)

Our SureVIEW™ DTS and DAS systems are both industry-leading fiber optic systems comprising interrogators and downhole technology. Independently tested by a major IOC, they handle fiber optic well monitoring in a reliable, accurate and cost-effective solution that is designed to meet any well monitoring need by providing customized, actionable intelligence in a variety of downhole environments.

With hundreds of permanent DTS installations in high-pressure/high-temperature (HPHT) environments globally, we have extensive experience with fiber optic well monitoring and can operate DTS and DAS using the same downhole fiber. Our marinized subsea DTS interrogator is also fully qualified to subsea control standards IWIS and ISO 13628-6.

The systems support the identification of contra-flow, thief zones and leak detection, giving you intelligent control of your reservoir. They enable injection profiling and water-flood optimization, to help maintain reservoir pressure, and provide gas cap detection, gas lift monitoring and hydrate monitoring.

Typical lead time:

5 months

A Make to Order SureVIEW optical system can be delivered in 5 months.

DIGITAL ENABLEMENT

RISER SPIRE – REAL-TIME SHEATH BREACH DETECTION SYSTEM

SPIRE is a real-time riser outer sheath breach and flooded anulus detection system. During pipe manufacture the pipe is SPIRE enabled by electrically isolating an existing load carrying tensile wire.

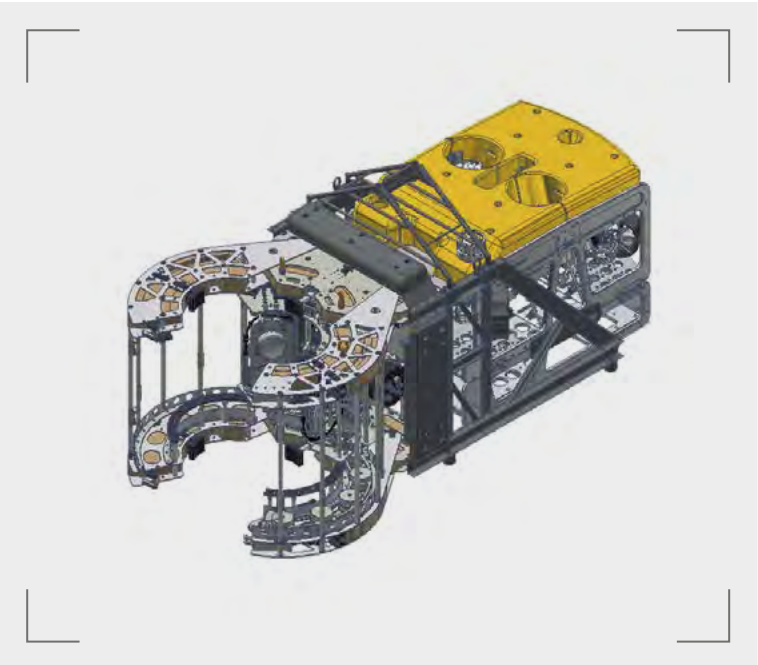
At the client request we can provide and install the controller instrument and detector to monitor for sheath breach. Benefits include; real-time information time and location of breach, and location of annular water, detection reliability, very small equipment footprint, deployable as either a monitoring system or as an inspection service and has a current tested range of 3.64km through a five sectioned pipe comprising of flowline to riser.

Typical lead time:

5 months

(Dependent on pipe lead time)

DIGITAL ENABLEMENT



RISER MAPS – DETECTION OF UNLOADED TENSILE WIRES IN RISER

Riser MAPS is a powerful, rugged and proven technology that gives stress data on wires. It can detect unloaded wires even under ancillary equipment (up to end termination and under bend stiffener) +/-15m reach. It offers unloaded wire detection resolution to individual wires with both, inner and outer wires being analysed.

Riser MAPS monitors tensile wire integrity continuously and provides real-time readings. It is installed outside the riser's outer sheath. Hence it poses no risk to riser integrity and can be installed on new risers or on existing risers in situ.

Typical lead time:

5 months

DIGITAL ENABLEMENT

FLOW ASSURANCE MANAGEMENT (FLOW AM)

Baker Hughes' subsea Flow Assurance Management (Flow AM) solution is based on a simpler and lower cost system for enabling production data from each well in the subsea production system. This system aggregates data from the entire subsea production system, including wells and risers, and provides an accurate view of your flows and phase fractions throughout the network to support your operation decisions.

Production engineers who actively monitor subsea production data for potential flow assurance risks (such as hydrates, wax and erosion) can benefit from FlowAM's data aggregation, visualisation and analytics insights for the entire subsea production network through a single intuitive user interface.

For technical authorities and project leads recommending flow metering strategies, Flow AM offers attractive solutions for production allocation that support small subsea infrastructures and can achieve your accuracy requirements with reduced cost and lead times.

Baker Hughes' Flow AM solution supports effective decision making and provides greater intelligence, accuracy and description of subsea flowing conditions by integration of flow metering solutions from the production system, wells and risers through advanced analytics.

SPS – VIRTUAL FLOW METER (VFM)

Our Subsea Virtual Flow Meter (VFM) is a digital analytics tool that provides oil, gas and water flow rate estimation for single phase or multi-phase production flows, as well as flow estimation for water-injection, gas-lift or chemical-injection networks. It uses robust physics-based flow models, optimized within a Bayesian probabilistic framework, to provide clear, accurate and flexible analysis of all flows and individual instrument measurements.

Working with the latest industry-standard correlations, our VFM offers true visibility of your subsea production system, helping you to control and maintain a balanced and efficient network. With its high accuracy and the flexibility to expand, our VFM can be used to complement your physical multi-phase flow meters — or to replace them entirely.

We can supply a Make to Order VFM in around four months, and it uses typical instrumentation from the subsea gathering network, including downhole pressure and temperature sensors on each tree; wellhead pressure and temperature sensors, for both upstream and downstream production, and/or gas lift choke valves; pressure and temperature sensors within the subsea networks (such as manifold headers); and topside/arrival pressure, temperature, and flow measurements if available.

DIGITAL ENABLEMENT

Field-wide models are considered within the VFM and include wells, chokes, manifolds, venturis and flowlines. We use a modular approach to represent your subsea production field architecture – interconnecting different component models and assuming mass continuity of the fluids. By considering your entire subsea production system, the VFM employs a data-fusion approach that also allows 'graceful degradation' of the estimation accuracy should one or more sensors be lost.

	Flow Assurance Management (Flow AM)	
Flow AM Application Modules	Baker Hughes Sensor solutions	Data and analytic outputs to determine:
Flow Meter	Baker Hughes Virtual Flow Meter (VFM)	– oil, gas and water flow rate estimation for all wells – single-phase flow rate estimation for water and/or gas injection wells, gas lift applications, or chemical injection applications – flow regime and operating conditions at any point within the production network (including virtual pressure, temperature and flow estimates)
	Baker Hughes Distributed Flow Meter (DFM) – enhanced VFM solution that includes a water fraction meter and venturi meters for each well	– water properties fluctuations such as salinity – same as other outputs as the VFM with improved accuracy, particularly on water fraction detection and quantification;
Well Flow Meter	Baker Hughes Downhole Flow Meters: SureFLO™ 298 SureFLO™ 298EX	– high accuracy downhole flow measurements of two phases with standard or divergent venturi device
Risers	Baker Hughes Riser DTS	– understanding of pipe temperature profile including under ancillary equipment during start up, operational and shutdown conditions
Hydrate	Analytics application based on Baker Hughes Virtual Flow Meter (VFM) sensors	– hydrate formation conditions in gas, oil, condensates under normal operation, shutdown, startup – minimum inhibitor dose required to prevent hydrate formation at a given pressure
Wax	Analytics application based on Baker Hughes Virtual Flow Meter (VFM) sensors	– wax formation conditions during production operations using compositional modeling of gas, oil and wax phases; considers oil with suspended wax particles and allows quantitative analysis of wax precipitation
Sand production	Sensor agnostic (Baker Hughes Sensors in development)	– sand production rate and at each well
Chemical Injection	Analytics application	– chemical injection flow rate requirements for each well – Active monitoring of production condition as well as start ups and shut downs

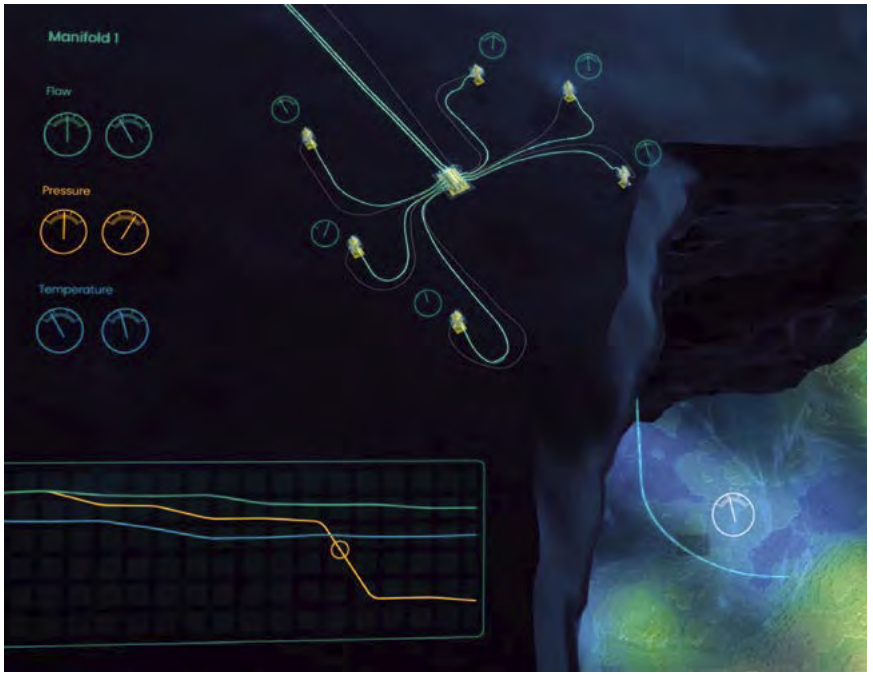
Typical lead time:

4 months

A Make to Order VFM can be delivered in around 4 months.

DIGITAL ENABLEMENT

FLOW ASSURANCE MANAGEMENT (FLOW AM)



SPS – DISTRIBUTED FLOW METER (DFM)

Our Distributed Flow Metering Solution combines distributed physical measurements and virtual flow metering technology to handle complex production applications and enhance accuracy and insights across the gathering network. It integrates our subsea Virtual Flow Meter (VFM) with venturi meters and a water fraction meter at the tree, enabling comparable multi-phase flow metering accuracy but with a simplified set up.

The solution relies on Baker Hughes' proven digital capabilities in software development and integrated analytics, along with our strong knowledge across intelligent subsea production systems. The concept of our Distributed Flow Metering Solution was proven using more than three years' data from a North Sea application. We have considerable experience of delivering the required instrumentation and system integration and can activate this innovative solution within a 12-month lead time.

Our VFM provides a system/network view of flows across your production network and can even allow automatic reconciliation of topside measurements if they are available. It uses typical subsea instrumentation and can be considered on both, green and brown fields. Complementing this technology with discrete instruments for water fraction and salinity measurement improves accuracy for detection of water breakthrough.

Bringing this together, the Distributed Flow Metering Solution enables you to remove complex subsea flow meters, such as a Wet Gas Flow Meter (WGFM) or Multi-Phase Flow Meter (MPFM) and to reduce the weight of and simplify the tree structure by eliminating the need for a Flow Control Module.

Typical lead time:

12 months

WELL – DOWNHOLE FLOW METERING SOLUTIONS (SUREFLO™)

We introduced the first downhole flow measurement system in the industry in 1993 and have more than 25 years of experience using standard downhole venturi and quartz electronic gauges. As a result, our SureFLO family of downhole flow meters have been engineered to measure a wide range of well applications and fluid properties. They provide a complete suite of downhole information that comprises flow rate, surface gas flow rates, water cut, gas breakout indicator and real-time pressure and temperature measurements, and are available with a lead time of around five months.

Our SureFLO 298 flowmeter can achieve the high-accuracy flow measurement of 98% required for production allocation. The flowmeter features a customized venturi design that can handle a variety of production rates and fluid properties. Using a wireline retrievable venturi sleeve and high-accuracy quartz gauges, the SureFLO 298 also provides the highest available measurement accuracy and has been approved by the Bureau of Ocean Energy Management, Regulation and Enforcement (BOEMRE) for well allocation purposes in the Gulf of Mexico.

Our SureFLO 298EX flowmeter is the industry's first full-bore access downhole electronic flowmeter and incorporates our proprietary, high resolution quartz gauges. With unrestricted access, it enables full production and can achieve a high-accuracy measurement of 98%. The specialized design of the SureFLO 298EX system means you can measure flow without having an internal diameter restriction in the wellbore.

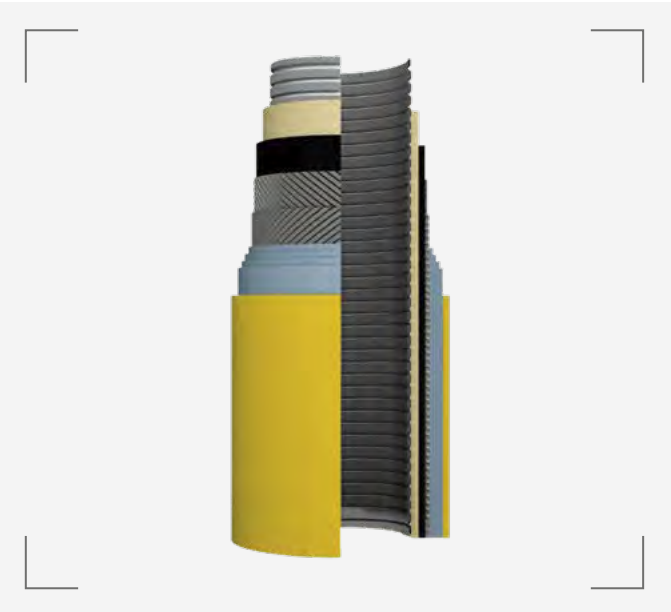
SureFLO downhole flow meters can be used in both, liquid and gas environments across producer or injector wells. By adding permanent pressure and a temperature gauge above or below the SureFLO 298 carrier, a measurement of the produced fluid fraction can also be made.

Typical lead time:

5 months

A make to order SureFLO 298 or 298EX can be delivered in 5 months.

DIGITAL ENABLEMENT



RISER DTS – DISTRIBUTED TEMPERATURE SENSING

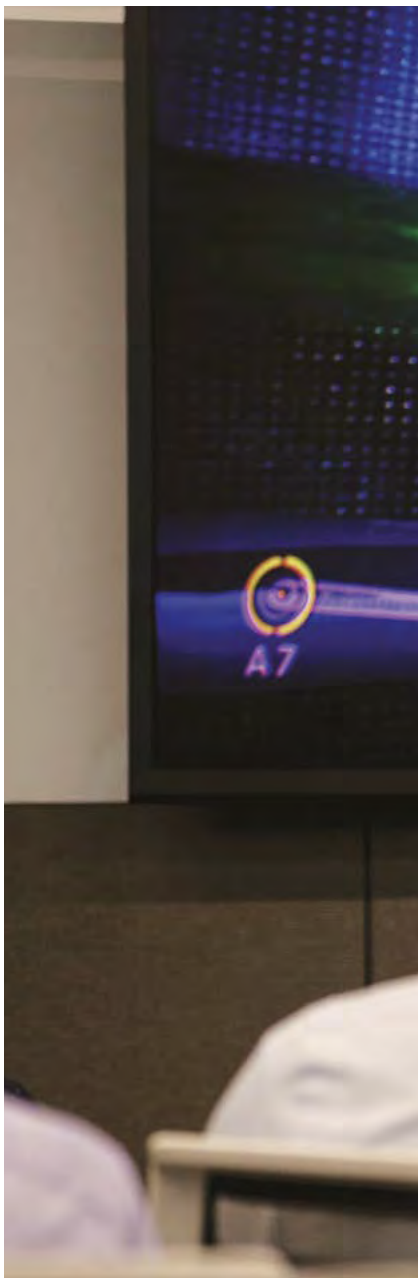
Baker Hughes' Riser Distributed Temperature Sensing (DTS) systems are industry-leading fiber optic systems comprising interrogators and pipes enabled by embedding optical fibre technology within the tensile wire layer of the pipe.

This reliable and sturdy technology gives real time pipe system temperature profiling to indicate flow assurance problems (hydrate formation, waxing) and, understanding of pipe temperature profile including under ancillary equipment. It can monitor pipe during "cool down" periods and can, in certain circumstances, indicate system disturbances, buoyancy movement/ bend stiffener damage.

Typical lead time:

5 months

(Dependent on pipe lead time)




B6
B5
B4
A4
A3

06

SUBSEA CONNECT SOLUTIONS

Subsea Connect Solutions are outcome-based solutions that we have created to address specific customer needs and problems. These solutions provide a seamless approach that brings together the entire Baker Hughes portfolio from the reservoir to the top side. This minimizes interfaces and the associated inefficiencies delivering real value.

Across Baker Hughes, we work together with our customers on the evaluation, creation, development, and commercialization of outcome-based solutions that take advantage of our unique portfolio that extends from the reservoir to the top side.

SUBSEA CONNECT SOLUTIONS

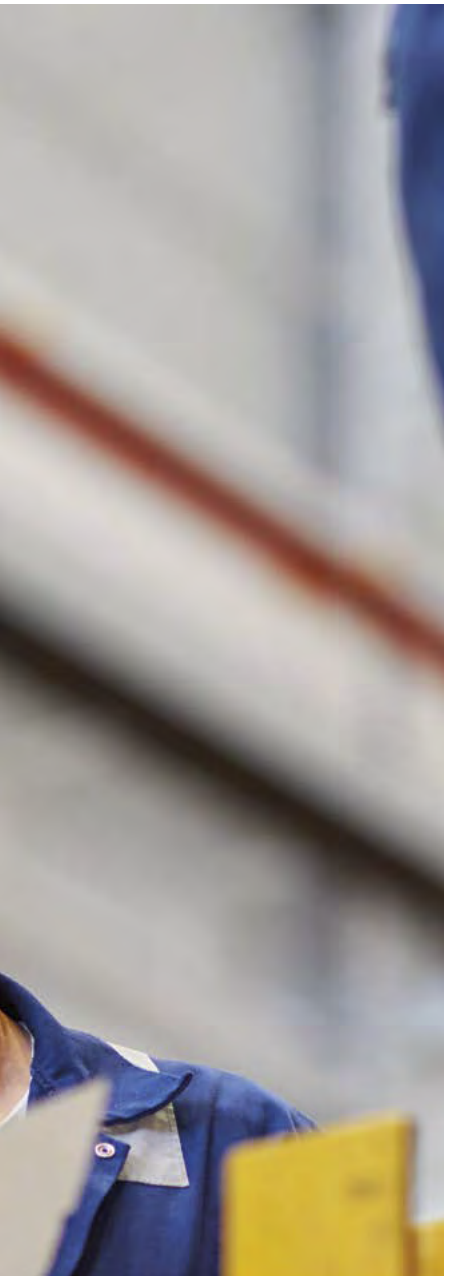
SEAMLESS TIEBACKS

Our Seamless Tieback solutions are designed to improve project economics dramatically by providing pre-designed, pre-configured and pre-engineered systems. These solutions cover the full scope from reservoir engineering, integrated well services, well construction, completions, SPS, SURF and tieback to an existing host. With a lead time that is slashed by up to 40% these solutions reduce time to first oil/gas, reduce payback time and boost returns.

Challenges facing mature basins

In well-developed basins like the UK's North Sea and the Gulf of Mexico in the US, it is common to come across prospects or fields that typically hold less than 50 million barrels of oil equivalent reserves. These volumes are often insufficient to justify investment in dedicated processing facilities, but favour instead, solutions that leverage the maturity of the regions, by utilising existing processing facilities on adjacent developments, with spare capacity.

Whilst this 'tie-back' solution is a largely established model, the economics of such fields often remain marginal. Operators and investors hence continue to challenge the industry to develop more innovative systems, that serve to better meet their economic outcome needs.



Subsea Connect's Seamless Tieback Solutions

Through our increasingly early and collaborative partnerships, Baker Hughes fully understand the priorities of our customers and their investors in this arena. We are hence delighted to announce that in applying our Subsea Connect philosophies we have now developed off-the-shelf, system solutions, that requires minimal bespoke design, benefit from standard, stocked products and consequently can be installed in less than a year from order. These 'turnkey' tie back system solutions are truly unrivalled, providing fast, reliable and simply, the most economically compelling outcomes for our customers.

Our systems are 10Kpsi rated and cater to both, medium/shallow water and deep-water applications. They support up to 4 wells in each instance, at step out distances of up to 15km to the host facility. The functionality of the systems fully caters to the widest range of operating envelopes, and has been designed to address the vast majority of all developments in these environments.

By featuring a comprehensive array of monitoring, control, and chemical injection capability, we are able to standardise on many of the traditionally bespoke elements, limiting the project design effort to simply configuring the system to the specific field layout requirements

But we don't stop there: As a true application of our Subsea Connect Model, our solution potentially offers even greater value, by challenging the traditional boundaries and fully leveraging Baker Hughes' breadth of capability, to provide truly seamless reservoir to topsides solutions.

It is a fact, for instance, that our Integrated Well Services solutions have a proven track record of slashing drilling and completion times by up to 50% over conventional models, and so looking to a fully integrated subsurface – subsea solution is tangible, and can only serve to deliver even greater value to our customers – across the complete scope of the project, not just the subsea scope!

An important element of the Subsea Connect philosophy is our decision to align our interest with those of our customers. To reinforce our commitment to our partnerships with customers we offer outcome-based commercial models – with further options for financing to qualifying candidates.

In summary, our Seamless Tieback Solutions are game-changing – they are faster, more economic and more robust than anything else on the market today and are fully underpinned in certainty of outcome, by the four pillars of Subsea Connect.

> We go beyond any other solution by fully leveraging Baker Hughes' breadth of capability, to provide truly seamless solution across the complete scope of the project, not just subsea!

SUBSEA CONNECT SOLUTIONS

INTERVENTION SOLUTIONS

Our Subsea Connect Intervention Solutions are designed to deliver up to 50% cost out reduction and 50% increase in productivity by leveraging our best in class technology, talent and project management expertise. We are able to achieve this by integrating individual products, services and technologies into a single seamless solution that is focused on the best possible outcome for our customers.

> Baker Hughes can leverage its global workforce and services bases to mobilize an LWI solution in about 20% of the time of a traditional riser.

We harness our 40+ years of product and technology leadership in the subsea industry to design and deliver a differentiated service offering in subsea well intervention. Baker Hughes has a strong track record of supplying riser based intervention systems, sometimes referred to as Completion Work Over Risers (CWORs) and Intervention Work Over Control Systems (IWOCS). The evolution in technology allows us to package this traditionally rig based capability into mono-hull Light Well Intervention Solutions or Services (LWIS). This is a relatively new addition to the Baker Hughes services portfolio. In a brief period of time Baker Hughes has acquired a comprehensive portfolio of technology and technical expertise that translates into around 30% of the overall market capacity. Our value proposition is simple: 'Any well, any service and any commercial model.'

Our Subsea Connect Intervention Solutions are a truly integrated offering that enable us to deliver unparalleled value to our customers. By bringing along Baker Hughes' proven track record in adjacent services such as reservoir, well services, well access, best-in-class service facilities, personnel, and project management and digital tools, we deliver a totally different economic return model to our customers.

First, we pull together the best technology solutions to connect to the well and work inside the well, supported by a large multi-disciplined workforce and shop support infrastructure around the globe. With a track record of over 100 agonistic wells (meaning not only Baker Hughes trees, well heads, completions but those supplied by other OEMs too) we have credibly demonstrated our ability to work with any equipment.

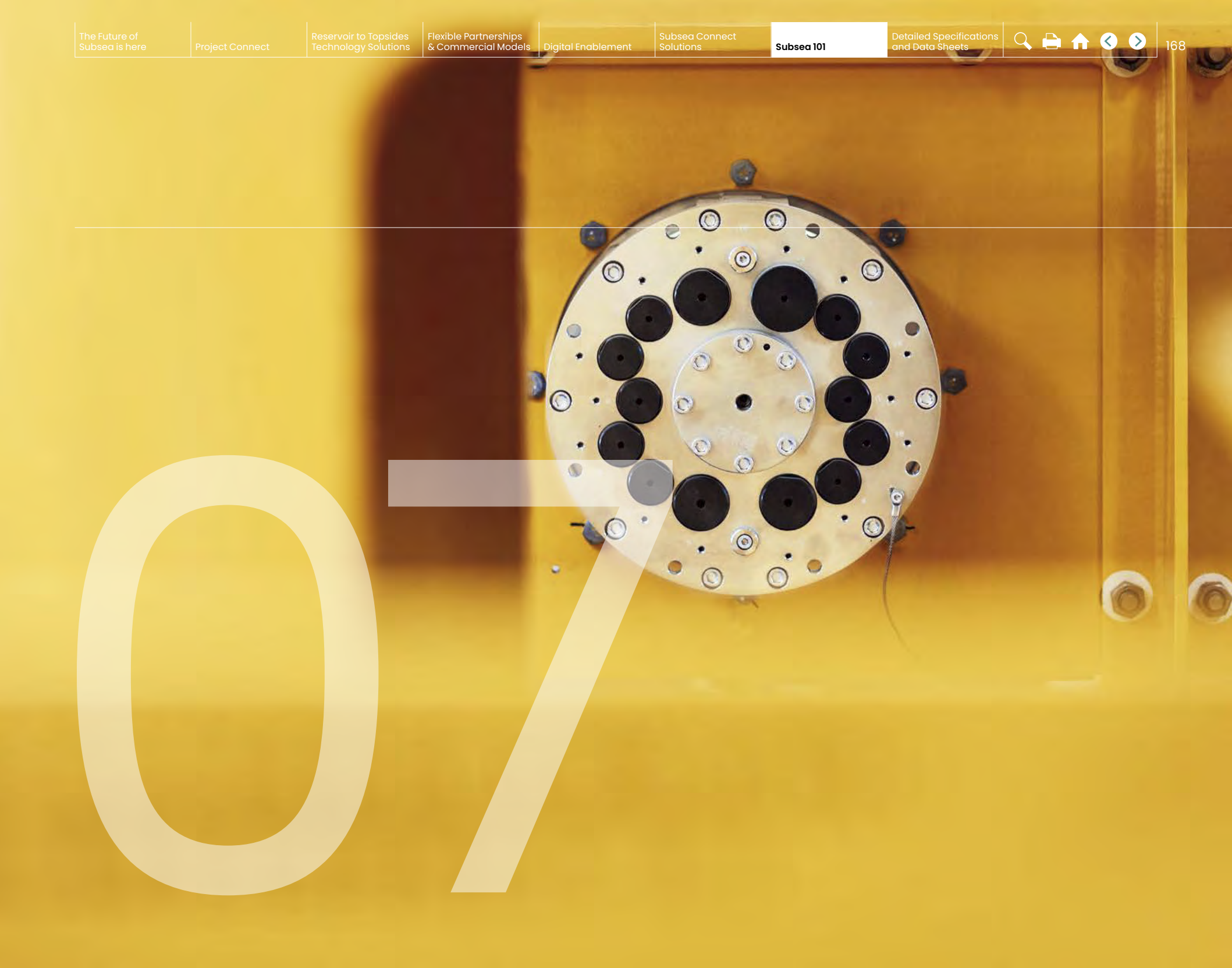
Next, we ensure we have the optimal partners based on location and application. Then, we plan the operation/campaign, ensuring we configure or engineer all services to provide a seamless "one-stop-shop" solution that addresses our customer's priorities.

Finally, where appropriate, we bring in innovative commercial models that ensure full alignment of all concerned parties.

To illustrate the above, if we take for instance, a well in 3,048 metres (10,000 ft) water depth, around 100 miles offshore and consider the planning, mobilisation, transit and site readiness, Baker Hughes can mobilize a solution in around 20% of the time of a traditional riser to service. Additionally, we have a proven track record of safe and fast operations. This productivity saving, along with a large globally mobile work force deployed through our global infrastructure, ensures we can deliver real and measurable value to our customers e.g., increased production, extended life of field, payback time of cost of operation.

Our focus remains on applying our unique portfolio, extending from the reservoir to the top side, to drive real and measurable value to our customers – a truly new way of subsea well interventions.


DCITV-C
EMPTY LIFT ONLY



07

SUBSEA 101

Selecting the optimal products for your system needs is complex. We have frameworks to guide your subsea design.

This section describes the rationale behind the effective selection of a subsea control system.

SUBSEA 101

The purpose of this section is to help define the rationale behind the effective selection of subsea control system architectures and technologies. We will consider the various options and choices to be made and then look at how these can be applied across a series of four scenarios.

Find more Subsea 101 case studies online

Similar papers cover equipment selection criteria in different geographies, water depths and customer challenges.

www.bakerhughes.com/subsea-101

Overview

The effective selection of control system architectures and technologies can have a significant positive bearing on subsea production system economics, through reduced subsea hardware and associated installation, maintenance and intervention.

Step-out distances, field-size and phasing of production, data refresh rates, subsea instrumentation and topside/downhole interfaces all have an impact on the product and technology choices to be made in the control system. This is overlaid with the need for high production availability over the life of the asset, with the provision for cost-efficient future field-expansion and non-disruptive obsolescence management of the equipment and electronics.

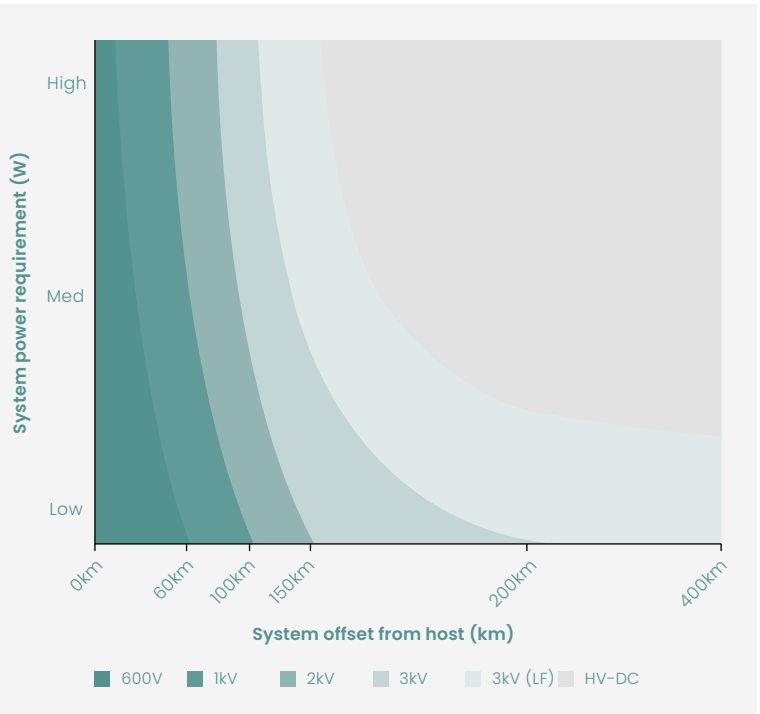
Good early engagement between an experienced and capable controls equipment vendor and the asset operator is imperative in balancing capital outlay for the asset with life-of-field requirements, which may be as long as 50 years. This needs to be underpinned with a choice of well-defined, make-to-order, low cost and cycle products, the repeatability of which underpins control system reliability and operational excellence. Furthermore, experienced control system vendor capability in power, communications and, crucially, network analysis will help to support good decision-making in field development – from the initial concept right through to the final field upgrade.

This section considers the technical and commercial considerations made when selecting the optimal control system for any given application and the relative impacts of the above on asset capital outlay and life-of-field costs, along with production availability and control system performance.

Critical factors

We now consider the five critical factors facing any operator when it comes to determining control system architecture and network topologies. They are namely: field power demands; electrical physical constraints; data refresh rates; topside control systems; and subsea instrumentation interface protocols.

Figure 1: Baker Hughes system operating voltages



1. Field power demands

The critical factors in offshore electrical distribution networks are offset distances and field power-consumption requirements. The chart in Figure 1 provides an overview of Baker Hughes' system operating voltages, with respect to system power requirements and offset distance.

We'll look at how we leverage these power and voltage options in the four field scenarios addressed on the following pages.

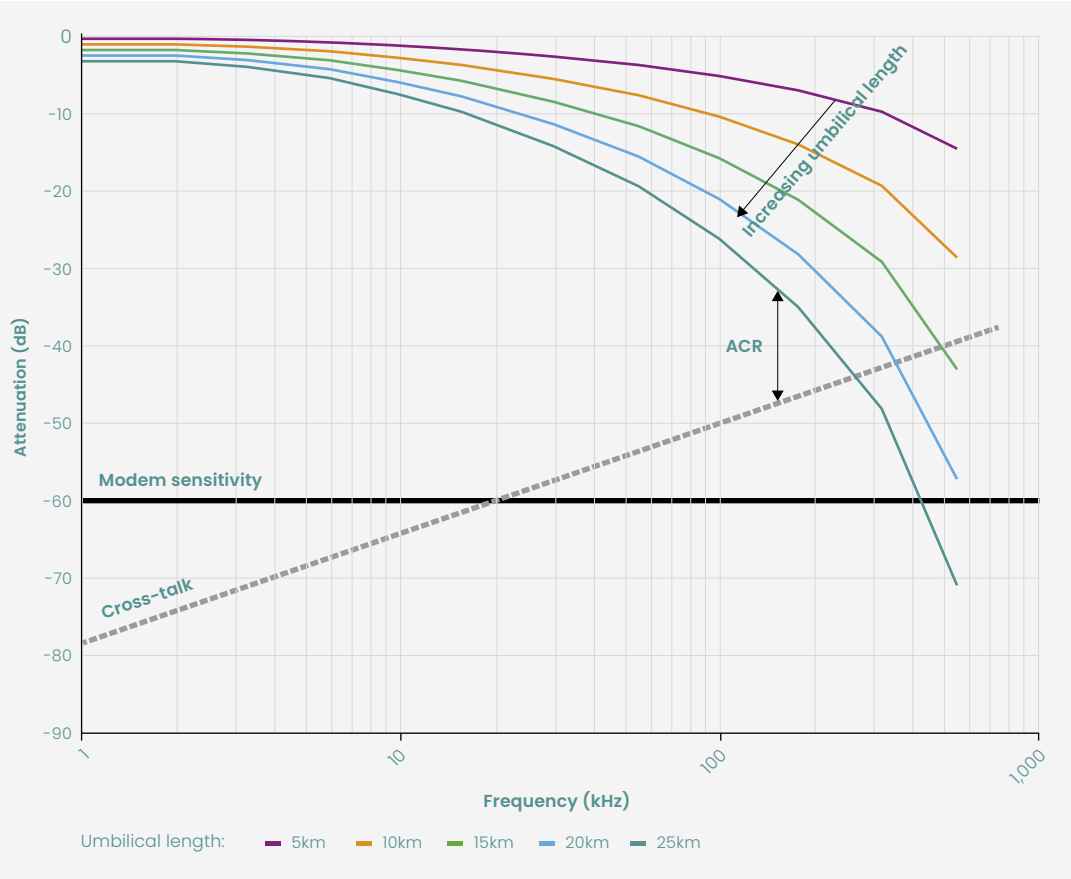
2. Electrical physical constraints

Subsea control systems are affected by power losses through the electrical-distribution system and, if copper-based, the degradation of communication signals from the topside to the asset. As the umbilical length (offset) increases, the maximum achievable data-rate decreases for copper-based communications. This is so because the higher frequency-carrier required for these data-rates is subject to higher attenuation. This is illustrated in Figure 2.

- **Cross-talk** Cross-talk is the leakage of communications from a first line into a second line, where it is seen as noise, decreasing the signal to noise ratio (SNR) of the transmission on that line. Communication cores within an umbilical are typically twisted-quads, which are designed to reduce electrical noise pickup on the signal wires from cross talk; however, cables are not usually screened from cross-talk as this leads to higher attenuation of the communications signal. The separation and materials between cores, the capacitance, and the resistive and inductive load will also impact communications performance.
- **Umbilical parameters** A reduction in the cross-sectional area of copper cores will reduce the umbilical overall cost, but it will also reduce the communication throughput and/or communication distance. Cable parameters can vary substantially between different umbilicals. The presence of steel hydraulic tubes and cable screens can increase attenuation of the signals and affect the communication distance and data-rates. Umbilicals may also contain 3-phase High Voltage cables for subsea pumps, where the higher harmonic frequencies of the power source may interfere with the communications frequencies.

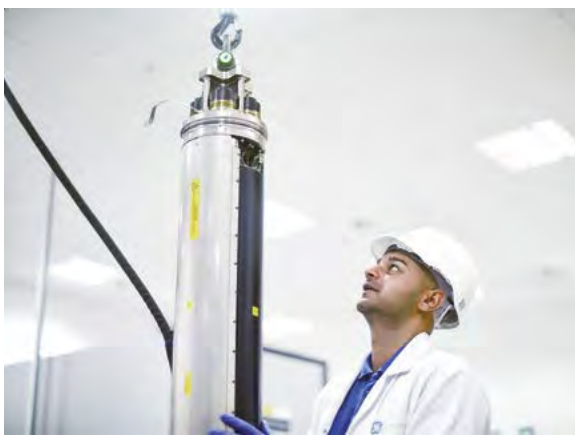
The electrical analysis of the field considers all these aspects in balancing equipment cost with field performance (data refresh rates). We use detailed analysis tools, developed with modem developers, to determine suitability of the system and to define optimum transmit and receive levels. The analysis establishes that satisfactory system performance can be achieved for the worst-case maximum load conditions assuming worst-case umbilical characteristics. The analysis capability can also be used for umbilical selection, design and optimization.

Figure 2: Cross-talk plotted against offset



The minimum load case confirms that the voltages supplied to all the cables, connectors and subsea equipment do not exceed maximum limits, by analysing the drill center with the shortest offset when minimal equipment is installed and at idle load.

For fibre optics, the analysis simulates and confirms that for each link to each well there is an adequate link sensitivity margin whilst maintaining sufficient link overload margin. Analysis will also define the requirement for attenuation to protect the sensitive fiber optic transceivers.



3. Data refresh rates

We provide a suite of communications solutions to cover a range of refresh rates and offset distances, as shown in Figure 3. This ensures that a suitable communications medium can be selected for the application, whether that is communicating to the field, or communications within the field.

4. Topside control systems

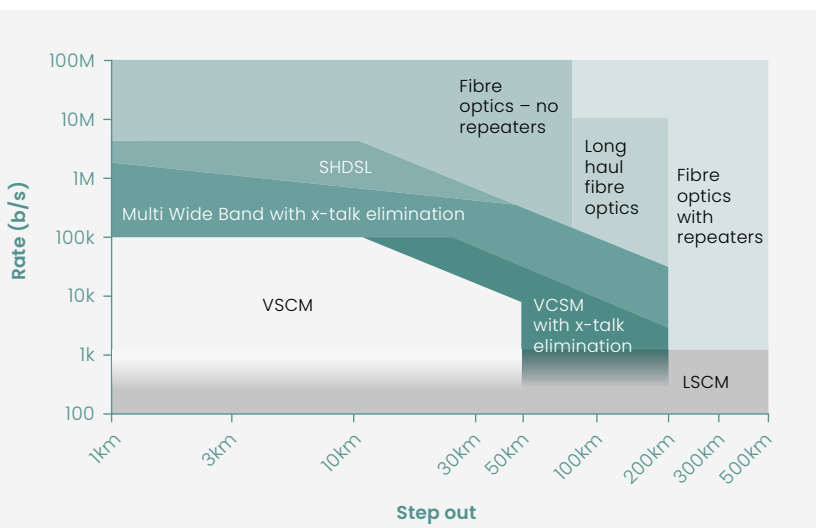
Topside control systems typically fall into three categories, usually chosen depending on customer preference/experience and any topside real-estate constraints. Our most commonly requested topside solution and standard offering is to deliver a standalone MCS which communicates with and controls the subsea equipment, and which is connected to the ICSS/DCS through an agreed interface (typically Modbus TCP/IP, OPC UA or MDIS).

Through this interface, the MCS will hand-off any/all required data to the ICSS/DCS and will respond to commands from the ICSS/DCS to control elements of the subsea system.

We also have experience of providing fully integrated topside systems. In this configuration, all controls logic (including shutdowns, interlocks, alarms) is performed by the DCS. Here, we provide a 'subsea gateway' that converts topside communication into proprietary communication protocols for subsea communication and adds prioritization and timestamping headers to the messages.

A third configuration is a standalone MCS together with an ICSS 'node'. In this configuration, we are responsible for the development, testing and integration between the MCS and the subsea node of the ICSS. This ICSS node is integrated into the remaining ICSS nodes on the platform using the ICSS supplier's proprietary hardware/software interfaces. The advantage of this configuration is that it reduces integration testing from the commissioning scope.

Figure 3: Baker Hughes communications toolbox



> Baker Hughes has previously integrated control systems with all major ICSS/DCS suppliers, including Yokogawa, Kongsberg, Honeywell, ABB and Siemens.

5. Subsea instrumentation interface protocols

In terms of protocol interfaces to subsea instrumentation and devices, we work to the following industry standard interfaces provided by SemStar5.

- **SIIS L1** Although used increasingly less frequently in greenfield applications, SIIS (Subsea Instrumentation Interface Standardization) Level 1 encompasses 4-20mA instrumentation. SemStar5 has highly accurate, individually calibrated 4-20mA inputs in both 2 and 4 wire configurations. Each channel is individually protected against over current for additional protection against channel failure.
- **SIIS L2** All CANbus SIIS Level 2 devices utilise the CANOpen protocol in accordance with CiA 443 profile. To communicate to the devices from Topside, Baker Hughes uses a CANopen Gateway which forms part of the CAN process running on each Sensor Support Module (SSM) or Fieldbus Support Module (FSM) within the SemStar5. This gateway conforms to the CiA 309 specification and provides a low-level access to and control of device to which the SEM connects. It is primarily provided for maintenance tasks and provides direct access to objects in the CANopen interface of the devices connected.
- **SIIS L3** SemStar5 supports multiple SIIS Level 3 Ethernet interfaces with Low, Medium and High-Power requirements. At the 'physical layer', the Ethernet links to the instrument come with a default of 100Base-TX Full Duplex.

Functional Assessments

The following scenarios consider for different, but typical greenfield and brownfield developments and walk you through the functional and commercial assessments that are required to identify the most appropriate control system.

Scenario 1: Small 'greenfield' development, short-medium offset

The cash-flow constraints and the required rapid return on investment often associated with small greenfield developments, necessitate minimal capital outlay on subsea and topside equipment, along with low operational expenditure.

In these circumstances, decisions relating to controls equipment and system architecture can have a proportionally larger impact on the financial viability of the investment. Therefore, control system design for small field developments is usually focused on minimising the need for subsea controls equipment and connections.

These smaller fields are typically low or low-medium well-count assets, at short offsets from the shore or a platform, often less than 20Km. This means communications may be super-imposed onto the umbilical power cores, in a Comms-On-Power (COPS) configuration, thus leveraging existing copper in the umbilical and keeping umbilical costs to a minimum.

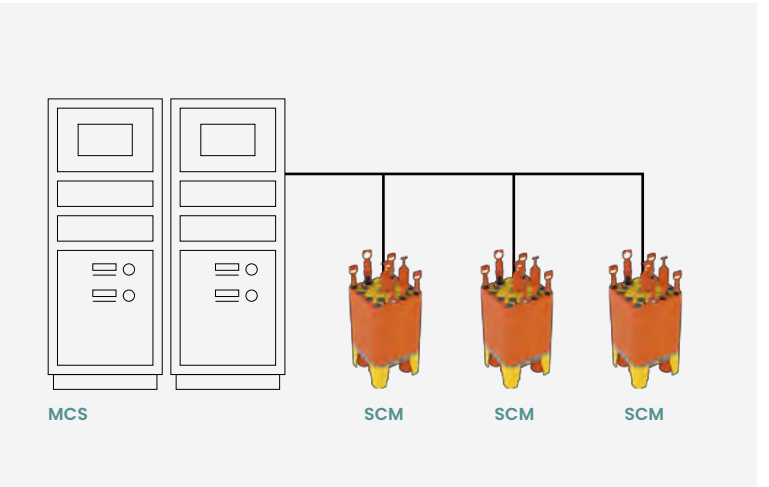
Furthermore, COPS network is distributed to the wells over a redundant Multidrop (MD) bussed network. Here, a master modem is located in the topside controls equipment and communicates with slave modems, or network 'nodes' in the subsea equipment at each well. This configuration type is illustrated in Figure 4.

Baker Hughes has supplied Redundant Bus communications since 1993. We have standardized the maximum number of nodes on the bus to six; this being an optimum compromise between offset, number of nodes, and topside data refresh rates. Most of the cost-efficiency comes from the minimal use of subsea electrical wet-mates connectors and the absence of subsea fiber optic wet-mate connectors.

Subsea heavy-power consumers are also kept to a minimum in order to keep the field voltage down. This helps minimize the size of the copper-core in the umbilical, which is another significant cost-driver. In a Baker Hughes system, no subsea transformer is required for either a 600V or 1000V system.

If the initial greenfield project is the first phase for a larger project and control system provision is required for future expansion, then the same cost-constraints exist, but we must ensure a balance is reached between initial cost outlay and future costs. This is explored further in scenario 3.

Figure 4: Multi-drop communications



Scenario 2: Large 'greenfield' development, medium-long offset

In larger, longer offset systems, efficient power management becomes much more of a focus for the control system design. In addition to a large well count, these systems typically have heavy-power consuming subsea instruments for monitoring and managing flow-assurance over a long-distance.

To mitigate power losses in longer umbilical, transmission voltage in the topside power equipment is stepped up, and then stepped-down again in the subsea field to ensure subsea electrical wet-mate connection costs are kept to a minimum.

Likewise, fiber optic communications are the preference for medium to long offset control systems to mitigate any degradation of communication signals from the topside to the asset. Fiber optic communications are converted subsea to copper-based communications using the Power & Communications Distributions Module (PCDM). This ensures costly subsea fiber optic wet-mate connectors are minimized and improves the overall availability of the control system.

The PCDM also routes the communications subsea. Subsea-routing has become key to many subsea field developments and Baker Hughes' track record in subsea-routing for long-offset assets has underpinned the next generation of subsea communications development through SemStar5. Commonly known as point-to-point networks, 'Redundant Star' communications provide high bandwidth and faster update rates for complex, high bandwidth-preferred instruments such as a Multi-Phase Meters and Acoustic Leak Detectors where higher bandwidth offers a greater level of resolution.

This configuration type is illustrated in Figure 5.

In addition to enabling efficient subsea physical connectivity, the PCDM is a tool in cost-effective and availability-sensitive network design. In general, the control system design will seek to minimize subsea components to simplify subsea data management over such a large topology, thus reducing capital outlay and the risk of networks difficulties during operations.

The PCDM contains a Layer 3 managed switch that converts optical signals to copper signals for onward transmission to each of the subsea modules in the star. Layer 3 switches allow finer control in data-routing through a system. The Layer 3 subsea network topology is hierarchical and aids in the separation and prioritization of subsea messages with good traceability.

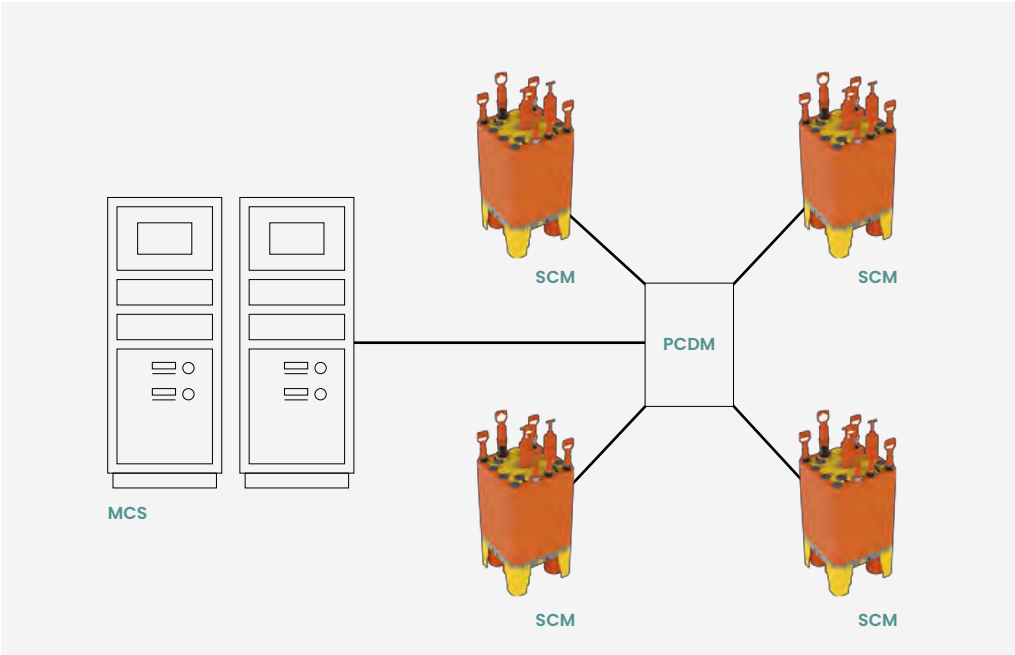
Providing multiple active routes and finer control, the PCDM can direct packets to their destination via a more deterministic route in link failure modes. It can also increase communications redundancy and availability by 'cross strapping' between A and B units. In the event of distribution failure (umbilical or UTA to PCDM), this enables communications from the good channel PCDM to be routed to the failed channel PCDM, and maintains A and B communications to the units downstream of the PCDMs.

Scenario 3: Upgrade and expansion of existing control systems

In a severely cost-conscious environment, phased subsea field-development is highly desirable. As such, in recent years, Operators have tended to typically develop a small, low-capital initial phase of a project, perhaps 2-6 wells in size, before expanding the field into latter, larger phases.

In this scenario, the SPS Control System must be architecturally designed for a low-cost first phase that will facilitate positive cash flow without obstructing the project technically or commercially in the future. This differs from the ad-hoc expansion more often seen in brownfield field expansion.

Figure 5: Point-to-point communications (only one power/communication channel is shown)



The main driver of the total-installed-cost (TIC) of a small first phase is the diameter and type of the composite umbilical. So it makes sense to keep the umbilical capital outlay to a minimum. A second umbilical might be laid for later phases, but it's obviously preferable to lay only one main dynamic umbilical for a field, particularly when required for long-offset or in deep water.

Control system expansion
To ensure umbilical costs are kept to a minimum, Operators and Subsea Equipment Vendors need to collaborate to optimize the expansion capacity of each element of the SPS:

- **Expandable power systems** One way is to minimize the copper power cores in the umbilical is to utilise any 'spare' cores as the field expands, potentially at the cost of system redundancy and reliability (although not necessarily availability). With the MTBF of our electronic-based subsea equipment proven to be +150yrs, there's a case for dialling down the levels of redundancy and reversing the aversion to single-point failure.

If power-switching/power-isolation between the SCMs is required, it can be done from switches in the topside control cabinets to limited wells for the initial phase, later replaced and expanded with subsea switching modules, such as within the PCDMs; thereby, freeing-up copper cores in the umbilical for power delivery in the latter phases.

In terms of power capacity, adding subsea power nodes to an existing umbilical should not be a problem. It may require a larger UPS during power expansion, should the topside capital constraints create limits on the first phase, and, of course, additional topside real-estate will need to be planned in advance for extra MCS/UPS cabinets, batteries, and other equipment.

- **Expandable hydraulic services** System hydraulic pressure drop as subsea process valves are opened is easily manageable subsea, as our SCMs have in-situ accumulation, as shown in Figure 6; so, with each deployed SCM further accumulation is added to the field.

Where hydraulic pressure drop is a concern, for example when requiring simultaneous operation of chokes over a large expanded field, battery-powered electric actuators such as the Ifokus LP-REAs provide on-demand Choke actuation, while drawing only 1 Amp at 48 W to recharge (after 3 full Choke cycles) when the demand has passed.

The Hydraulic Power Unit (HPU) might be sized for the initial phase, with extra fluid reservoirs plumbed-in only when needed on latter phases. The pumps may not even need to be replaced, providing that a longer pressurisation period is acceptable for the field – often a function of equipment remediation limitations.

Regarding subsea hydraulic distribution, here the Baker Hughes UMSIRE-compliant Compact UTA would be sufficient to break out the umbilical for the first phase. For later phases, the same UTA can be linked into a Subsea Distribution Unit (SDU) or landed out on a larger structure, such as a manifold.

- **Expandable subsea communications networks** In a composite umbilical, adding optical fibre in between the tubing will not increase the overall composite size; here we are simply swapping filler material with fibre bundles. It is therefore commercially feasible to have fiber all the way from the topside to the SCMs for the first few wells, thereby initially avoiding the need for subsea routing.

As the field is expanded and the cost of proliferating subsea fiber optic wet-mate connectors becomes prohibitive, the Optical Flying Leads could be re-routed by ROV to Baker Hughes PCDMs, which in turn would route via SHDSL modem technology to the new wells. The modular 'any card, any slot' capability of SemStar5, means both optical and DSL modems would be fitted at low cost to all SEMs to ensure SCM commonality across the phases. Any internal SEM routing between the modems is simply dealt with by the 'SemStar5 Ethernet Backplane'.

The alternative is simply to use Comms-on-Power or 'COPS' multi-dropped communications to the SCMs, where the communications signal is super-imposed on the umbilical power cores. We would use modern Quadrature Amplitude Modulation (QAM) techniques to maximize the offset and bandwidth to the subsea nodes.

- **Expandable software** Our SCADA systems are based on drag-and-drop, pre-tested GE Cimplicity software. This makes adding wells to a first phase an iterative task with simple regression testing. The HMI can also be readily expanded, again through drag-and-drop icons and software.

  Our standard approach of using unlimited Layer 3 routed networks for subsea communications means system nodes (SEM cards, subsea routers, instruments, etc.) can be infinitely added without any of the risks associated with large unwieldly Layer 2 routed networks. We also use dynamic networks as standard, essentially 'plug-and-play' network expansion, rather than using static networks, which would require a network specialist offshore to reconfigure the IP-networks as the field is expanded.

In summary: through cost-focused control system design, experienced analysis, excellent network practices, and modular expandable system components, there is no reason that the first phase of a field development should carry any of the burden or cost of future field expansion.

Figure 6: Baker Hughes Modpod, with standard in-situ Accumulator

Subsea Control Module (SCM)

Control System Upgrades

When considering the life-of-field costs of any control system it is essential to plan for the inevitable obsolescence of the subsea and topsides hardware; in particular, the control system electronics. Proactive obsolescence management will help to ensure that topside and subsea equipment can be upgraded with minimal disruption to ongoing production operations.

The evolution of subsea electronics over the past 30 or more years shows the scale of obsolescence management required to keep fields producing and the importance of backwards compatibility. The SemStar5 is backwards compatible with all prior SEM variants and Figure 7 shows three options for upgrading an existing Baker Hughes control system, where technology and backwards compatibility can be used to minimize expense and disruption.

Option 1 is the most disruptive and costly, but cleanest upgrade, solving obsolescence subsea and topside simply by swapping out both subsea and topside equipment. In Option 2, only the subsea equipment is upgraded, including the SCM. In Option 3, just the SEM is upgraded in a refurbished legacy SCM.

Options 2 and 3 are often deployed in a phased implementation, eventually upgrading all the subsea SCMs and SEMs. For both these options 'SEMulation' is utilized, where the new SemStar5s emulate the legacy SEMs they replace, using existing protocols to talk with the MCS. This means the operator will see no change from the MCS, despite having mitigated obsolescence in the subsea equipment.

Scenario 4: Tiebacks into a non-Baker Hughes system

Many fields are limited by their original expansion case, where perhaps latter extensions and tiebacks were unanticipated. The challenge for these unanticipated phases is how to expand the field beyond original expectations with minimum capital outlay and little or no disruption to ongoing production.

The optimum solution often means utilising existing asset infrastructure, such as the topsides and subsea equipment and often the same umbilical. However, the Original Equipment Manufacturer (OEM) for the early phases may well have used proprietary protocols for communication to the subsea hardware, making this challenge particularly difficult; there is no 'plug & play' option here.

This is where Baker Hughes technology such as 'concurrent' or 'dual-band' communications may help, to add non-OEM topsides and subsea equipment, without the need for the capital and installation costs of a new field umbilical. In this scenario the original field umbilical is utilised to host the new equipment power and communications for the field expansion, without disrupting power and communications to the OEM equipment. Optimal use is made of any existing umbilical cores. If any spare cores in the umbilicals are used to host the new power and communications, which is known as 'concurrent communications', there is little risk of affecting the existing system. If umbilical cores are shared between the new and old equipment, by transmitting at sufficiently separate frequencies, in what is known as 'dual-band communications', then communications filtration will be required to ensure communication frequencies do not overlap and cause disruption.

Figure 7: Options for upgrading obsolete Topside and Subsea Electronics

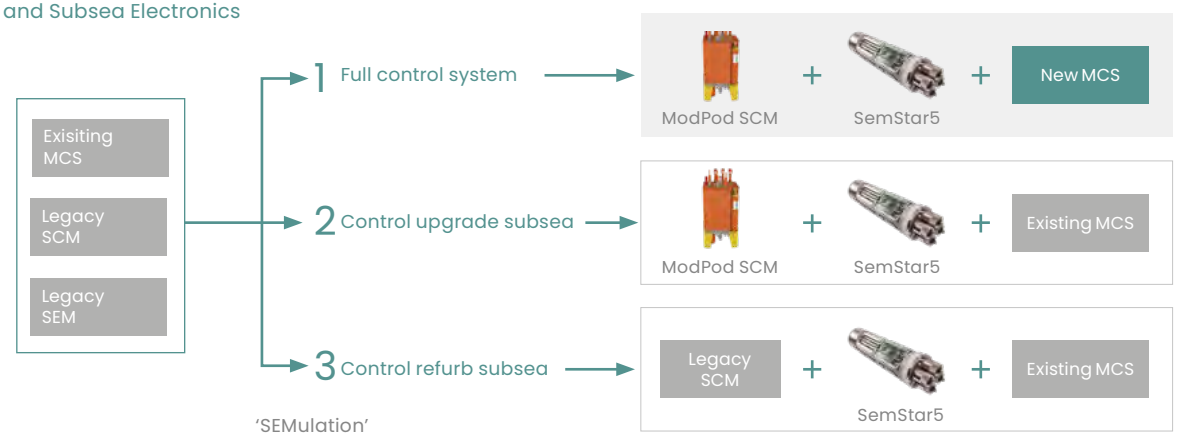
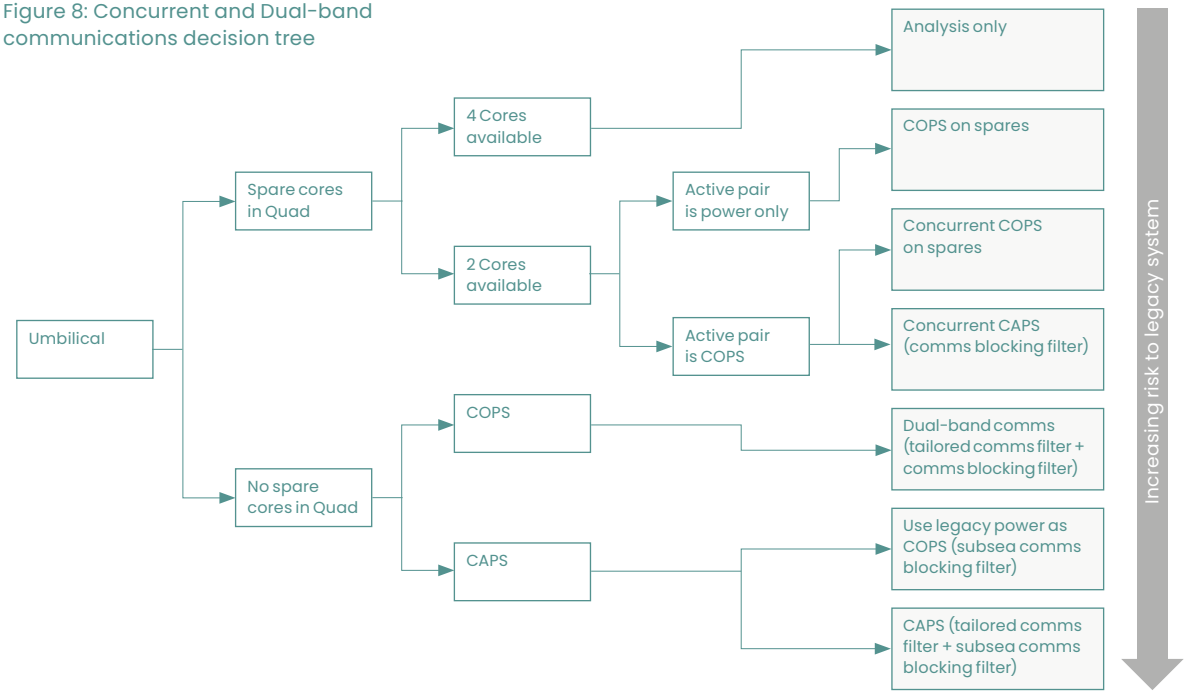


Figure 8: Concurrent and Dual-band communications decision tree



The decision tree, shown in Figure 8, shows how the level of risk of disrupting the existing system increases as more sharing of cores is required within the umbilical. This is mitigated by increased levels of topside and subsea communications filtration, as seen in the decision tree.

Once we have carefully analysed the existing frequencies on the umbilical, we use a multi-band, Quadrature Amplitude Modulation (QAM) modem in these applications to provide a specific communications frequency. Done correctly, this can save $millions in expanding existing assets.

In conclusion

At Baker Hughes, a combination of early and ongoing engagement; experienced systems engineering capability; and products designed for low TOTEX and high availability ensures that our Subsea Control Systems are commercially and technically optimized throughout the life of the asset.

400

More than 400 Baker Hughes Subsea Electronic Modules (SEMs) in active production were deployed pre-2000. Total Baker Hughes SEMs deployed by 2020 will by 1500+.

08

DETAILED SPECIFICATIONS AND DATA SHEETS

We have re-engineered our portfolio to develop structured products that fall into three categories:

Make to Order (fully engineered to meet typical requirements resulting in faster lead times and lower costs)

Configure to Order (configured using standard components and sub-assemblies requiring minimal additional engineering hours)

Engineer to Order (engineered solutions to address applications that fall outside our regular boundaries and options)

Subsea Systems

Subsea Wellheads

With half a century of field-proven experience and more than 5,000 wellhead installations worldwide, our subsea systems set the industry standard.

	MS-700	MS-800	Aptara™ SFX Wellhead Solution
Feature	Make to Order	Make to Order	Make to Order
Variant	2 Options	2 Options	3 Options
Structural			
Mandrel size (inches)	27	27 / 30	27 / 30
Bending capacity (lbs-ft)	5.25 mm	5.25 / 7 mm	5.25 / 7 mm
Casing program (inches)	36 x 28 x 20 x 16 x 13 x 9	36 x 28 x 22 x 18 x 16 x 14 / 13 x 10/9	36 x 28 x 22 x 18 x 16 x 14 / 13 x 10/9
Casing load (lbs)	7 mm	8 mm	8 mm
Hanger positions	3	3	3
Pressure, temperature and lockdown			
Pressure rating (psi)	20,000 above; 7,500 below	20,000 above; 7,500 below	20,000 above; 7,500 below
Temperature	35°F to 350°F (2° C to 177° C)	35°F to 350°F (2° C to 177° C)	35°F to 350°F (2° C to 177° C)
Lockdown per seal (kips)	750	750	750
Fatigue			
Fatigue loading	Normal	Normal	Extreme
Materials	8630 HP / 4130 LP	8630 HP / 4130 LP	F22 and A707 DNV C curve tested welds DNV C curve tested connector
Below mudline hangers (maximum)	16-inch 5,000 psi @ 725 kips	18-inch 5,000 psi @ 500 kips 16-inch 10,000 psi @ 2,000 kips	18-inch 5,000 psi @ 500 kips 16-inch 10,000 psi @ 2,000 kips
Options			Available in MS-700 variant

Subsea Systems

Subsea Wellheads

With half a century of field-proven experience and more than 5,000 wellhead installations worldwide, our subsea systems set the industry standard.

Ulti-Max GT

Feature	Make to Order																	
Diameter x wall thickness (inches)	20 x 0.438		20 x 0.500		20 x 0.625		20 x 0.812[C]		22 x 0.750		22 x 0.812		22 x 0.875		22 x 1.000		22 x 1.500	
Connector material (ksi)	70	80	70	80	70	80	80	95	70	80	70	80	70	80	70	80	70	80
Compatible pipe grades	X56, X65, X70	X80	X56, X65, X70	X80	X56, X65, X70	X80	X56, X60	X65, X70	X56, X65, X70	X80	X56, X65, X70	X80	X56, X65, X70	X80	X56, X65, X70	X80	X56, X65, X70	X80
Tension (kip)[A]	1,884	2,153	2,144	2,450	2,663	3,043	2,937	3,426	3,505	4,006	3,784	4,324	4,065	4,646	4,618	5,278	6,762	7,728
Compression (kip)[B]	1,884	2,153	2,144	2,450	2,663	3,043	2,937	3,426	3,505	4,006	3,784	4,324	4,065	4,646	4,618	5,278	6,762	7,728
Bending (kip-ft)[A]	752	859	850	971	1,042	1,191	1,128	1,316	1,501	1,715	1,611	1,841	1,721	1,967	1,933	2,209	2,706	3,092
Internal pressure (psi)[A]	3,062	3,500	3,494	3,994	4,364	4,988	4,852	5,660	4,759	5,439	5,149	5,885	5,546	6,338	6,330	7,235	9,433	10,780
Collapse pressure (pis)[A]	-520	-520	-770	-770	-1,520	-1,520	-2,590	-2,820	-1,920	-1,980	-2,310	-2,430	-2,700	-2,880	-3,690	-3,870	-8,520	-9,460
Anti-rotation capacity (ft-lbs)[D]	49,500	56,500	49,500	56,500	49,500	56,500	56,500	62,500	55,000	62,500	55,000	62,500	55,000	62,500	55,000	62,500	TBD	
Max. OD/Min. ID (in)	21.88/18.62						21.88/18.25				24.182/19.88						TBD	
Pin/Box length (in)	9.32/9.24										12.19/12.19						TBD	
Make-up loss (in)	6.86										8.66						TBD	
Weight (lb)	291										477						TBD	

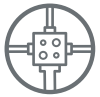
A Capacity values are calculated at yield per API 5C3

B Compression capacities are calculated at buckling

C For this size only, the connector yield strength is higher than the pipe to meet pipe capacity (a design that meets pipe capacity with same yield strength is currently in development)

D Assumes 3 anti-rotation keys installed

Subsea Systems



Subsea Trees

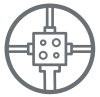
Baker Hughes completed its first subsea tree system installation in 1962. Since then, we have installed more than 1,400 subsea trees worldwide and are at the forefront of oil and gas field developments.

Aptara™ Lightweight Compact Tree

Feature	Make to Order					Configure to Order
Variant	Option 1	Option 2	Option 3	Option 4	Option 5	
Production bore size (inches)	5 1/8	5 1/8	5 1/8	7 1/16	7 1/16	
Annulus bore size (inches)	2 1/16	2 1/16	2 1/16	2 1/16	2 1/16	
Pressure rating (psi)	10,000	10,000	10,000	10,000	10,000	15,000
ISO 10423 PSL	PSL 3G	PSL 3G	PSL 3G	PSL 3G	PSL 3G	
Temperature rating (storage)	0°F to 122°F (-18°C to 50°C)	0°F to 122°F (-18°C to 50°C)	0°F to 122°F (-18°C to 50°C)	0°F to 122°F (-18°C to 50°C)	0°F to 122°F (-18°C to 50°C)	
Temperature rating (operating)	0°F to 300°F (-18°C to 149°C)	0°F to 300°F (-18°C to 149°C)	0°F to 250°F (-18°C to 121°C)	0°F to 300°F (-18°C to 149°C)	0°F to 250°F (-18°C to 121°C)	
Temperature rating downstream choke	-50°F to 300°F (-46°C to 149°C)	-50°F to 300°F (-46°C to 149°C)	-50°F to 250°F (-46°C to 121°C)	-50°F to 300°F (-46°C to 149°C)	-50°F to 250°F (-46°C to 121°C)	-51°F to 300°F (-46°C to 149°C)
Depth capability	Up to 10,000 ft (3,048 m)	Up to 10,000 ft (3,048 m)	Up to 10,000 ft (3,048 m)	Up to 7,217 ft (2,200 m)	Up to 7,217 ft (2,200 m)	6,561 ft (2,000 m)
FAT	API 17D	API 17D	API 17D	API 17D	API 17D	S561
Trim level	HH x EE	HH x EE	HH x EE	HH x EE	HH x EE	
Insulation	No	No	No	No	No	Yes
Tubing head spool	Yes	Yes	No	Yes	No	
Tubing hanger size (inches)	13 5/8	18 3/4	18 3/4	18 3/4	18 3/4	
Electrical downhole functions	2	2	2	2	2	1 off DHPT can be swapped for Optical Feed Thru System.
Hydraulic downhole functions	7	9	7	9	7	
Production isolation valve	No	No	No	No	No	Yes / Manual
Gas lift	No	No	No	No	No	Yes
Production choke configuration	Fixed – Cap Retrievable	Fixed – Cap Retrievable	Fixed – Cap Retrievable	Fixed – Cap Retrievable	Fixed – Cap Retrievable	
Chemical metering	Yes	Yes	Yes	Yes	Yes	-
Tubing hanger	5-inch nom	5-inch nom	5-inch nom	7-inch nom	7-inch nom	
Tubing thread	5 1/2-inch – 27# Vam Top	5 1/2-inch – 27# Vam Top	5 1/2-inch – 27# Vam Top	7 1/16-inch – 32# Vam Top	7 1/16-inch – 32# Vam Top	X-Over pup
Hydraulic working pressure – LP (psi)	5,000	5,000	5,000	5,000	5,000	

Table continues >

Subsea Systems



Subsea Trees

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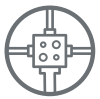
Aptara™ Lightweight Compact Tree (continued)

Feature	Make to Order					Configure to Order
Variant	Option 1	Option 2	Option 3	Option 4	Option 5	
Hydraulic working pressure – HP (psi)	10,000	10,000	10,000	10,000	10,000	
Top connection	720 HD HUB	720 HD HUB	720 HD HUB	720 HD HUB	720 HD HUB	
Bottom connection (XT & THS)	HT-H4 connector	HT-H4 connector	HT-H4 connector	HT-H4 connector	HT-H4 connector	DWHT-H4 Connector
Controls provider	Baker Hughes	Baker Hughes	Baker Hughes	Baker Hughes	Baker Hughes	
Choke provider	Baker Hughes	Baker Hughes	Baker Hughes	Baker Hughes	Baker Hughes	
Flowline connection system	Horizontal	Horizontal	Horizontal	Horizontal	Horizontal	Vertical

Subsea Systems



Subsea Trees

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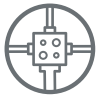
D – Series Summary

	5" DHXT Structured Product Boundaries		7" DHXT Structured Product Boundaries		DVXT Structured Product Boundaries	
Feature	Make to Order	Configure to Order	Make to Order	Configure to Order	Make to Order	Configure to Order
Variant	Multiple		2 options		3 Options	
Prod. Bore Size (inches)	5 1/8		7 1/16		5 1/8 / 7 1/16	
Ann. Bore Size (inches)	2 1/16		2 1/16		2 1/16	
Pressure rating	10,000psi	15,000psi	10,000psi		10,000psi	
API PSL	PSL3	PSL3G	PSL3	PSL3G	PSL3	PSL3G
Temperature Rating (Storage)	0°F to 122°F (-18°C to 50°C)		0°°F to 122°F (-18°C to 50°C)		0°F to 122°F (-18°C to 50°C)	
Temperature Rating (Operating)	0°F to 250°F (-18°C to 121°C)	0°F to 300°F (-18°C to 149°C)	0°F to 250°F (-18°C to 121°C)	0°F to 300°F (-18°C to 149°C)	0°F to 300°F (-18°C to 149°C)	0°F to 335°F (-18°C to 168°C) for 7
Temperature Rating Downstream Choke	-51°F to 250°F (-46°C to 121°C)	0°F to 300°F (-18°C to 149°C)	-51°F to 250°F (-46°C to 121°C)	-51°F to 300°F (-46°C to 149°C)	-31°F to 300°F (-35°C to 149°C)	-51°F to 335°F (-46°C to 168°C) for 7
Insulation	Optional	Optional	No	Yes	No	Yes
Depth Capability	6,561ft (2,000m)	10,000ft (3,048m)	10,000ft (3,048m)	10,000ft (3,048m)	4,921ft (1,500m)	10,000ft (3,048m)
FAT	IOGP S561	API 17D	API17D	IOGP S561	API17D	IOGP S561
Trim level	HH x EE		HH x EE		HH x EE	
Flow Control Module	Optional		Yes	No	Yes	No
Tubing Head Spool	N/A		N/A		Yes	No
Electrical downhole functions	2	Up to 2	1	Up to 2	1	Up to 2
Hydraulic/ Chemical downhole functions	8	Up to 8	4	Up to 8	1, 3, 7	Up to 9
Chemical metering	Optional		No	Yes	Optional	Yes
Electrical Submersible Pumps	No		No		No	
Gas Lift System	Optional		No		No	Yes
Sand Detector	Optional		Yes	No	Optional	Yes
Choke type	Production	Injection[A]	Production	Production, Injection[A]	Production	Production, Injection[A]
Prod Choke CV	Cv185 / Cv250		Cv400	Cv750	Cv205 or Cv750	Cv250
Prod Choke Configuration	ROV Insert retrievable or FCM retrievable		FCM Retrievable	ROV insert retrievable	ROV Insert retrievable or FCM Retrievable	FCM Retrievable
Flowmeter	None	WGFM, MPFM, SPFM	None	WGFM, MPFM, SPFM	None	WGFM, MPFM, SPFM

Table continues >

Subsea Systems



Subsea Trees

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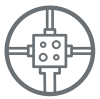
D – Series Summary (continued)

	5" DHXT Structured Product Boundaries		7" DHXT Structured Product Boundaries		DVXT Structured Product Boundaries	
Feature	Make to Order	Configure to Order	Make to Order	Configure to Order	Make to Order	Configure to Order
Variant	Multiple		2 options		3 Options	
Wellhead Connector Secondary Lock	Yes		Yes		Yes	
Wellhead Connector secondary Unlock	Yes		Yes		Yes	
Drill Through capability	Optional		Optional		N/A	N/A
Tubing Hanger (inches)	5 Nom or 7 Nom with 5 outlet		7 Nom (6-¼ outlet)		5 or 7	
Working Pressure - LP	5,000psi		5,000psi		5,000psi	
Working Pressure - HP	10,000psi		10,000psi		10,000psi	
Top Connection (inches)	18¾, 10k, H4, Extended Mandrel		18¾, 10k, H4, Extended Mandrel		18¾, 10k, H4, Extended Mandrel	
Bottom connection	DWHT-H4 connector		DWHT-H4 connector		DWHT-H4 connector	
Wellhead Size (inches)	36		36		36	
Controls type	Electro-hydraulic		Electro-hydraulic		Electro-hydraulic	
Controls provider	Baker Hughes		Baker Hughes		Baker Hughes	
Choke provider	Baker Hughes		Baker Hughes		Baker Hughes	Baker Hughes
Flowline connection system	Vertical / Horizontal	Horizontal, Mono / Dual	Horizontal, Multi-bore	Horizontal, Mono / Dual / Multi - bore	Vertical or Horizontal	Horizontal, Mono / Dual / Multi - bore

Subsea Systems



Subsea Trees

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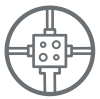
DVXT Structured Product Boundaries

Feature		Make to Order		Configure to Order
Variant	Option 1	Option 2	Option 3	
Production bore size (inches)	5 1/8	7 1/16	7 1/16	
Annulus bore size (inches)	2 1/16	2 1/16	2 1/16	
Pressure rating (psi)	10,000	10,000	10,000	
ISO 10423 PSL	PSL 3G	PSL 3G	PSL 3G	PSL 3
Temperature rating (storage)	0°F to 122°F (-18°C to 50°C)	0°F to 122°F (-18°C to 50°C)	0°F to 122°F (-18°C to 50°C)	
Temperature rating (operating)	0°F to 250°F (-18°C to 121°C)	0°F to 335°F (-18°C to 168°C)	0°F to 335°F (-18°C to 168°C)	
Temperature rating downstream choke	-51°F to 250°F (-46°C to 121°C)	-31°F to 300°F (-35°C to 149°C)	-31°F to 300°F (-35°C to 149°C)	-50°F to 300°F (-46°C to 149°C)
Insulation	No	No	No	Yes
Depth capability	6,561 ft (2,000 m)	4,921 ft (1,500 m)	4,921 ft (1,500 m)	10,000 ft (3,048 m)
FAT	API17D	API17D	API17D	S561
Trim level	HH x EE	HH x EE	HH x EE	
Flow Control Module	Yes	Yes	Yes	No
Tubing head spool	Yes	Yes	Yes	No
Electrical downhole functions	1	1	1	2
Hydraulic/chemical downhole functions	7	1	3	9
Chemical metering	No	Yes	Yes	Yes
ESP	No	No	No	
Gas lift	No	No	No	Yes
Sand detector (non intrusive) downstream of choke	No	Yes	Yes	Yes
Choke type	Production[A]	Production[A]	Production[A]	
Production choke CV	CV205	CV750	CV750	CV250
Production choke configuration	ROV insert retrievable	Fixed on FCM	Fixed on FCM	FCM retrievable
Wellhead connector secondary unlock	Yes	Yes	Yes	
Wellhead connector secondary lock	Yes	Yes	Yes	
Hyd, working pressure / hydraulic working pressure – LP (psi)	5,000	5,000	5,000	
Hyd, working pressure / hydraulic working pressure – HP (psi)	10,000	10,000	10,000	
Top connection	18 3/4-inch / 10k / H4 / extended mandrel	18 3/4-inch / 10k / H4 / extended mandrel	18 3/4-inch / 10k / H4 / extended mandrel	
Bottom connection	DWHT-H4 connector	DWHT-H4 connector	DWHT-H4 connector	
Controls provider	Baker Hughes	Baker Hughes	Baker Hughes	
Flowline connection system	Vertical / monobore	Horizontal / multibore	Horizontal / multibore	Horizontal / concentric / dual / multi

[A] Injection Make to Order trees available

Subsea Systems



Subsea Trees

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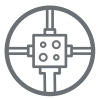
7-inch Production DHXT Structured Product Boundaries

Feature	Make to Order		Configure to Order
Variant	Option 1	Option 2	
Prod. Bore Size (inches)	7 1/16	7 1/16	
Ann. Bore Size (inches)	2 1/16	2 1/16	
Pressure rating (psi)	10,000	10,000	
API PSL	PSL3G	PSL3G	PSL3
Temperature Rating (Operating)	0°F to 250°F (-18°C to 121°C)	0°F to 250°F (-18°C to 121°C)	0°F to 300°F (-18°C to 149°C)
Temperature Rating Downstream Choke	-51°F to 250°F (-46°C to 121°C)	-20°F to 250°F (-29°C to 121°C)	-51°F to 300°F (-46°C to 149°C)
Insulation	No	No	Yes
Depth Capability	10,000ft (3,048m)	10,000ft (3,048m)	
FAT	API17D	API17D	IOGP S561
Trim level	HH x EE	HH x EE	
Flow Control Module	Yes	Yes	No
Electrical downhole functions	1	1	Up to 2
Hydraulic/ Chemical downhole functions	4	4	Up to 8
Chemical metering	No	Yes	Yes
Gas Lift System	No	No	
Sand Detector	Yes	Yes	No
Choke Type	Production	Production	Injection A
Prod Choke CV	Cv400	Cv400	Cv750
Prod Choke Configuration	FCM Retrievable	FCM Retrievable	ROV insert retrievable
Flowmeter	None	WGFM	WGFM, MPFM, SPFM
Wellhead Connector Secondary lock	Yes	Yes	
Wellhead Connector Secondary Unlock	Yes	Yes	
Drill Through capability	Optional	Yes	
Tubing Hanger (inches)	7 Nom (6-1/4 outlet)	5 Nom	
Tubing Hanger Sealing	Metal to Metal	Metal to Metal	
Working Pressure - LP	5,000psi	5,000psi	
Working Pressure - HP	10,000psi	10,000psi	
Top Connection (inches)	18-3/4, 10k, H4, Extended Mandrel	18-3/4 10k, H4, Extended Mandrel	
Bottom Connection	DWHT-H4 connector	DWHT-H4 connector	
Wellhead Size (inches)	36	36	
Controls Type	Electro-hydraulic	Electro-hydraulic	
Controls provider	Baker Hughes	Baker Hughes	
Choke provider	Baker Hughes	Baker Hughes	
Flowline connection system	Horizontal, Multi-bore	Horizontal, Mono-bore	Horizontal, Dual-bore

Subsea Systems



Subsea Trees

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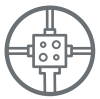
5-inch DHXT Structured Product Boundaries

Feature	Make to Order Production Trees	Configure to Order
Variant	Maximum functionality	
Prod. Bore Size (inches)	5 1/8	
Ann. Bore Size (inches)	2 1/16	
Pressure rating (psi)	10,000	15,000
API PSL	PSL 3	PSL3G
Temperature Rating (Storage)	0°F to 122°F (-18°C to 50°C)	
Temperature Rating (Operating)	0°F to 250°F (-18°C to 121°C)	0°F to 300°F (-18°C to 149°C)
Temperature Rating Downstream Choke	-51°F to 250°F (-46°C to 121°C)	-51°F to 300°F (-18°C to 149°C)
Insulation	No	Yes
Depth Capability	Up to 6,561ft (2,000m)	10,000ft (3,048m)
FAT	IOGP S561	API 17D
Trim level	HH x EE	
Flow Control Module	Optional	
Electrical downhole functions	2	Less than 2
Hydraulic/ Chemical downhole functions	8	Less than 8
Chemical metering	Optional	
Electrical Submersible Pumps	No	
Gas Lift System	Optional	
Sand Detector	Optional	
Choke Type	Production	Injection A
Prod Choke CV	Cv185	Cv250
Prod Choke Configuration	ROV Insert retrievable or FCM retrievable	
Flowmeter	None	WGFM, MPFM, SPFM
Wellhead Connector Secondary lock	Yes	
Wellhead Connector Secondary Unlock	Yes	
Drill Through capability	Optional	
Tubing Hanger (inches)	5 Nom or 7 Nom with 5 outlet	

Table continues ›

Subsea Systems



Subsea Trees

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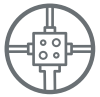
5-inch DHXT Structured Product Boundaries (continued)

Feature	Make to Order Production Trees	Configure to Order
Variant		
Tubing Hanger Sealing	Metal to Metal	
Working Pressure - LP (psi)	5,000	
Working Pressure - HP (psi)	10,000	
Top Connection (inches)	$18^{3}/_{4}$, 10k, H4, Extended Mandrel	
Bottom Connection	DWHT-H4 connector	
Wellhead Size (inches)	36	
Controls	Baker Hughes	
Choke provider	Baker Hughes	
Flowline connection system	Vertical/ Horizontal Mono-bore/ Dual-bore	

Subsea Systems



Subsea Trees

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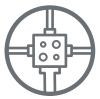
M – SERIES SUMMARY

	MHXT Structured Product Boundaries		MVXT Structured Product Boundaries	
Feature	Make to Order	Configure to Order	Make to Order	Configure to Order
Variant	2 Options		2 Options	
Production bore size (inches)	5⅛		5⅛	7 1/16
Annulus bore size (inches)	2 1/16		2 1/16	
Pressure rating (psi)	10,000		10,000	
Temperature rating (storage)	0°F to 122°F (-18°C to 50°C)		0°F to 122°F (-18°C to 50°C)	
Temperature rating (operating)	0°F to 250°F (-18°C to 121°C)	0°F to 300°F (-18°C to 149°C)	0°F to 250°F (-18°C to 121°C)	0°F to 300°F (-18°C to 149°C)
Temperature rating downstream choke	0°F to 250°F (-18°C to 121°C)	-50°F to 300°F (-46°C to 149°C)	0°F to 250°F (-18°C to 121°C)	-50°F to 300°F (-46°C to 149°C)
Insulation	No	Yes	No	Yes
Depth capability	820 ft (250 m) Diver	2,460 ft (750 m) ROV	820 ft (250 m) Diver	2,460 ft (750 m) ROV
FAT	API17D	S561	API 17D	S561
Trim level	HH x EE		HH x EE	
Flow Control Module	N/A	Yes	N/A	
Tubing head spool	N/A		No	
Electrical downhole functions	1		1	
Hydraulic/chemical downhole functions	5		5	
Chemical metering	No	Yes	No	Yes
Electrical submersible pumps	Optional		No	
Gas lift	Optional		Yes	
Sand detector	No	Yes	No	Yes
Choke type	Production[A] / Gas lift	Production[A]	Production[A]	
Production choke CV	CV185 / CV65	CV250	CV185	CV250
Production choke configuration	ROV release		ROV insert	
Fishing protection	Yes	None	Yes	None
Wellhead connector secondary lock	Yes	Yes	Yes	Yes
Wellhead connector secondary unlock	Yes		Yes	
Drill through capability	No	Yes	N/A	N/A
Tubing hanger	5-inch nominal	7-inch nominal 5-inch outlet	5-inch / 7-inch	

Table continues >

Subsea Systems



Subsea Trees

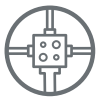
Baker Hughes completed its first subsea tree system installation in 1962. Since then, we have installed more than 1,400 subsea trees worldwide and are at the forefront of oil and gas field developments.

M – SERIES SUMMARY (CONTINUED)

	MHXT Structured Product Boundaries		MVXT Structured Product Boundaries	
Feature	Make to Order	Configure to Order	Make to Order	Configure to Order
Variant	2 Options		2 Options	
Hydraulic working pressure – HP (psi)	10,000		10,000	
Hydraulic working pressure – LP (psi)	3,000	5,000	5,000 (CTO)	
Top connection (inches)	18¾ / 10k / H4		18¾ 10k H4 mandrel	
Bottom connection	HT-H4 connector		MD H-4 connector	
Wellhead size (inches)	30	36	30	36
Controls type	Electro-Hydraulic		Electro-Hydraulic	
Controls provider	Baker Hughes		Baker Hughes	
Choke provider	Baker Hughes		Baker Hughes	
Fishing protection	Fisher friendly	None	None	NORSOK
Guidance	No	Flowbase	Flowbase	Guide base
Electrical Submersible Pump (ESP)	Yes		No	Yes
Flowline connection system	Diver flange	Remote horizontal / template	Diver flange	Horizontal / template

[A] Injection Make to Order trees available

Subsea Systems



Subsea Trees

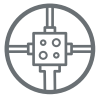
Baker Hughes completed its first subsea tree system installation in 1962. Since then, we have installed more than 1,400 subsea trees worldwide and are at the forefront of oil and gas field developments.

MHXT Structured Product Boundaries

Feature	Make to Order Production Trees		Configure to Order
Variant	Option 1	Option 2	
Production bore size (inches)	5 1/8	5 1/8	
Annulus bore size (inches)	2 1/16	2 1/16	
Pressure rating (psi)	10,000	10,000	
ISO 10423 PSL	PSL 3		PSL3G
Temperature rating (storage)	0°F to 122°F (-18°C to 50°C)	0°F to 122°F (-18°C to 50°C)	
Temperature rating (operating)	0°F to 250°F (-18°C to 121°C)	0°F to 250°F (-18°C to 121°C)	0°F to 300°F (-18°C to 149°C)
Temperature rating downstream choke	0°F to 250°F (-18°C to 121°C)	0°F to 250°F (-18°C to 121°C)	-50°F to 300°F (-46°C to 149°C)
Insulation	No	No	Yes
Depth capability	820 ft (250 m) Diver	820 ft (250 m) Diver	2,460 ft (750 m) Diver
FAT	API17D	API17D	S561
Trim level	HH x EE	HH x EE	
Electrical downhole functions	2	2	
Hydraulic/chemical downhole functions	5	5	7 (7 1/16 only)
Chemical metering	No	No	
Electrical submersible pumps	No	Yes	Yes
Gas lift	Yes	No	
Choke type	Production[A]	Production[A]	Gas lift
Prod choke CV	CV185	CV185	CV250
Production choke configuration	ROV Insert Retrievable	ROV Insert Retrievable	Diver release
Fishing protection	No	Friendly	NORSOK
Wellhead connector secondary lock	Yes	No	Yes
Wellhead connector secondary unlock	Yes	Yes	
Drill through capability	No	No	Yes
Tubing hanger	5-inch nominal	5-inch nominal	7-inch nominal 5-inch outlet
Hydraulic working pressure – LP (psi)	3,000	3,000	5,000
Hydraulic working pressure – HP (psi)	10,000	10,000	
Top connection (inches)	18 3/4 / 10k / H4	18 3/4 / 10k / H4	18 3/4 / 10k / H4 mandrel
Bottom connection	MD HT-H4 connector	HT-H4 connector	DWHT-H4
Wellhead size (inches)	30	36	

Table continues ›

Subsea Systems



Subsea Trees

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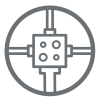
MHXT Structured Product Boundaries (continued)

Feature	Make to Order Production Trees		Configure to Order
Variant	Option 1	Option 2	
Controls provider	Baker Hughes	Baker Hughes	Direct/3rd party
Choke provider	Baker Hughes	Baker Hughes	
Well type	Satellite	Satellite	Template
Flowline connection system	Diver Flange	Diver Flange	Remote Horizontal

[A] Injection Make to Order trees available

Subsea Systems



Subsea Trees

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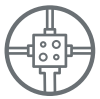
S – SERIES SUMMARY

	SHXT Structured Product Boundaries		SVXT Structured Product Boundaries	
Feature	Make to Order	Configure to Order	Make to Order	Configure to Order
Variant	2 Options		2 Options	
Production bore size (inches)	5 1/8		5	
Annulus bore size (inches)	2 1/16		2 1/16	
Pressure rating (psi)	5,000		6,500	
Temperature rating (storage)	0°F to 122°F (-18°C to 50°C)		0°F to 122°F (-18°C to 50°C)	
Temperature rating (operating)	0°F to 250°F (-18°C to 121°C)		0°F to 250°F (-18°C to 121°C)	
Temperature rating downstream choke	0°F to 250°F (-18°C to 121°C)		0°F to 250°F (-18°C to 121°C)	
Insulation	None		None	
Depth capability	262 ft (80 m)		328 ft (100 m)	
FAT	API17D	S561	API17D	S561
Trim level	HH x EE		HH x EE	
Flow control module	N/A	N/A	N/A	N/A
Tubing head spool	N/A	N/A	N/A	N/A
Electrical downhole functions	1		1	
Hydraulic/chemical downhole functions	5		2	
Chemical metering	No		No	
Electrical submersible pumps	No	No	No	No
Gas lift	No	Yes	Optional	
Sand detector	No		No	
Choke type	Production[A]		Production[A]	
Production choke CV	CV185		CV185	CV250
Production choke configuration	ROV insert retrievable		Diver insert retrievable	
Fishing protection	No	Yes	No	Yes
Tubing hanger (inches)	5 nom		5 nom	
Hydraulic working pressure – LP (psi)	3,000		3,000	
Hydraulic working pressure – HP (psi)	7,500		7,500	
Top connection (inches)	13 5/8 Hub		13 5/8 Hub	
Bottom connection (inches)	13 5/8 CH-8		13 5/8 CH-8	

Table continues ›

Subsea Systems



Subsea Trees

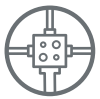
Baker Hughes completed its first subsea tree system installation in 1962. Since then, we have installed more than 1,400 subsea trees worldwide and are at the forefront of oil and gas field developments.

S – SERIES SUMMARY (CONTINUED)

	SHXT Structured Product Boundaries		SVXT Structured Product Boundaries	
Feature	Make to Order	Configure to Order	Make to Order	Configure to Order
Variant	2 Options		2 Options	
Wellhead size (inches)	13⅝		13⅝	
Controls type	Electro-hydraulic	Direct hydraulic	Electro-hydraulic	Direct hydraulic
Controls provider	Baker Hughes		Baker Hughes	
Choke provider	Baker Hughes		Baker Hughes	
Flowline connection system	Diver		Diver	

[A] Injection Make to Order trees available

Subsea Systems



Subsea Trees

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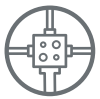
SVXT Structured Product Boundaries

Feature	Make to Order		Configure to Order
Variant	Option 1	Option 2	
Production bore size (inches)	5	5	
Annulus bore size (inches)	2 1/16	2 1/16	
Pressure rating (psi)	6,500	6,500	
ISO 10423 PSL	3	3	3G
Temperature rating (storage)	0°F to 122°F (-18°C to 50°C)	0°F to 122°F (-18°C to 50°C)	
Temperature rating (operating)	0°F to 250°F (-18°C to 121°C)	0°F to 250°F (-18°C to 121°C)	
Temperature rating downstream choke	-50°F to 250°F (-46°C to 121°C)	-50°F to 250°F (-46°C to 121°C)	
Insulation	No	No	
Depth capability	328 ft (100 m)	328 ft (100 m)	
FAT	API17D	API17D	S561
Trim level	HH x EE	HH x EE	
Electrical downhole functions	1-off	1-off	
Hydraulic/chemical downhole functions	2-off	2-off	
Gas lift	No	Yes	
Choke type	Production[A]	Production[A]	
Production choke CV	CV185	CV185	
Production choke configuration	Diver insert retrievable	Diver insert retrievable	
Fishing friendly protection	Yes	Yes	
Hydraulic working pressure – LP (psi)	3,000	3,000	
Hydraulic working pressure – HP (psi)	7,500	7,500	
Top connection (inches)	13 5/8 Hub	13 5/8 Hub	
Bottom connection (inches)	13 5/8 CH-8	13 5/8 CH-8	
Wellhead size (inches)	13 5/8	13 5/8	
Controls type	Electro-hydraulic	Electro-hydraulic	Direct Hydraulic
Controls provider	Baker Hughes	Baker Hughes	
Choke provider	Baker Hughes	Baker Hughes	
Flowline connection system	Diver Flange	Diver Flange	

[A] Injection Make to Order trees available

Subsea Systems



Subsea Trees

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SHXT Structured Product Boundaries

Feature	Make to Order		Configure to Order
Variant	Option 1	Option 2	
Production bore size (inches)	5⅛	5⅛	
Annulus bore size (inches)	2 1/16	2 1/16	
Pressure rating (psi)	5,000	5,000	
ISO 10423 PSL	3	3	3G
Temperature rating (storage)	0°F to 122F (-18°C to 50°C)	0°F to 122F (-18°C to 50°C)	
Temperature rating (operating)	0°F to 250°F (-18°C to 121°C)	0°F to 250°F (-18°C to 121°C)	
Temperature rating downstream choke	0°F to 250°F (-18°C to 121°C)	0°F to 250°F (-18°C to 121°C)	
Insulation	None	None	
Depth capability	328 ft (100 m)	328 ft (100 m)	
FAT	API17D	API17D	S561
Trim level	HH x EE	HH x EE	
Electrical downhole functions	1-off	1-off	
Hydraulic / chemical downhole functions	1-off	1-off	5
Gas lift	No	Yes	
Choke type	Production[A]	Production[A]	
Production choke CV	CV185	CV185	
Production choke configuration	Diver insert retrievable	Diver insert retrievable	
Fishing friendly protection	N/A	N/A	Yes
Tubing hanger (inches)	5	5	
Hydraulic working pressure – LP (psi)	3,000	3,000	
Hydraulic working pressure – HP (psi)	7,500	7,500	
Top connection (inches)	13 5/8 Hub	13 5/8 Hub	
Bottom connection (inches)	13 5/8 CH-4	13 5/8 CH-4	
Wellhead size (inches)	13 5/8	13 5/8	
Controls type	Direct Hydraulic	Direct Hydraulic	Electro-Hydraulic
Choke provider	Baker Hughes	Baker Hughes	
Flowline connection system	Diver Flange	Diver Flange	

[A] Injection Make to Order trees available

Subsea Systems

Subsea Control Systems

All of Baker Hughes' control system equipment is designed for reliability, from our uniquely-latched FLX360 hydraulic Stabplates, to our ultra-reliable electronics module, the SemStar5.

Subsea Electronics Module – SemStar5

Feature	Make to Order	Make to Order	Make to Order
Variant	1 Option Low Power	1 Option Medium Power	1 Option High Power
Power consumption	< 150 W	< 200 W	< 300 W
Operating environment	23°F to 284°F (-5°C to 40°C) at 9,842 ft (3,000 m) water depth	23°F to 284°F (-5°C to 40°C) at 9,842 ft (3,000 m) water depth	23°F to 284°F (-5°C to 40°C) at 9,842 ft (3,000 m) water depth
DHPTG interface	Baker Hughes / Schulmberger / Well Dynamics	Baker Hughes / Schulmberger / Well Dynamics	Baker Hughes / Schulmberger / Well Dynamics
Communications type	Standard: 2-wire CAPS DSLOptions: 5-wire CAPS Ethernet, 2-wire COPS APCM	Standard: 2-wire CAPS DSLOptions: 5-wire CAPS Ethernet, 2-wire COPS APCM	Standard: 2-wire CAPS DSLOptions: 5-wire CAPS Ethernet, 2-wire COPS APCM
DCV Drives (M = momentary / C = continuous)	Up to 28 (M)	Up to 26 (M) Up to 2 (M / C)	Up to 24 (M) Up to 4 (M / C)
SIIS L1 interfaces	Up to 4 off 2-wire	Up to 2 off 4-wire Up to 2 off 2-wire	Up to 2 off 4-wire Up to 2 off 2-wire
SIIS L2 interfaces	2 off	5 off	8 off
SIIS L3 interfaces	1 off	2 off	3 off
SCM flowmeters	4 off	5 off	5 off
SEM pressure vessel	Bucketless (sea water wetted)	Bucketless (sea water wetted)	Bucketless (sea water wetted)
Dimensions – dia x L/mm	275 x 912	275 x 912	275 x 1,155
Weight/max	< 286 lbs (130 kg)	<309 lbs (140 kg)	<341 lbs (155 kg)

Subsea Systems

Subsea Control Systems

All of Baker Hughes' control system equipment is designed for reliability, from our uniquely-latched FLX360 hydraulic Stabplates, to our ultra-reliable electronics module, the SemStar5.

ModPod – Subsea Control Module (SCM)

Feature	Make to Order	Configure to Order	Configure to Order	Configure to Order
Variant	Option 1	Option 2	Option 3	Option 4
Temperature rating (storage)	0°F to 122°F (-18°C to 50°C)	0°F to 122°F (-18°C to 50°C)	0°F to 122°F (-18°C to 50°C)	0°F to 122°F (-18°C to 50°C)
Temperature rating (operating)	23°F to 104°F (-5°C to 40°C)	23°F to 104°F (-5°C to 40°C)	23°F to 104°F (-5°C to 40°C)	23°F to 104°F (-5°C to 40°C)
Depth capability	6,561 ft (2,000 m)	9,842 ft (3,000 m)		
Size – W x D x H (mm)	770 x 770 x 1,550			
Weight in air	4,409 lbs (2,000 kg)			
Weight in water	3,527 lbs (1,600 kg)			
Testing	Std Testing (Std FAT/ Hyperbaric and SRT)			
Quality requirements	Baker Hughes VGS applied	Client specs		
Lockdown interface	Podlock	Podlock	Podlock	Podlock
Material restrictions	PMI to VGS			
Podlock	-201 podlock	-201 podlock	-210	-210
4 piece skirt	Open	Enclosed		
Project pressure units	Bar			
Cleanliness requirement	SAE AS 4059 Class 6B-F	SAE AS 4059 Class 6B-F	SAE AS 4059 Class 6B-F	SAE AS 4059 Class 6B-F
System fluid: non-environmental (Grade A – D)	Castrol Transaqua HT2	Oceanic HW443	Oceanic HW540	Oceanic HW540P
System fluid: environmental (Grade E)	Oceanic HW540E			
Test fluid	Castrol Transaqua HT2	Oceanic HW443		
Hunting T-O series coupler	Delrin poppet seal	Peek poppet seal		
DCV version	Mark 2.0	Mark 2.1		
DCV type	Bi-stable	Mono-stable		
Supply arrangement	Dual hydraulic supplies			
Flow meters	No flow meters	4-20mA flow meters	CANbus flow meters	
Number of hydraulic functions	Up to 18	Up to 42	Up to 42	Up to 42
Supply accumulators	2 LP bladder type	1 LP and 1 HP bladder type	2 LP piston type	1 LP and 1 HP piston type
Pressure transducers	Single element type	Dual element type		
HP SCSSV return vent arrangement	Vents directly to sea	Vents via the SCMMB		
IWC return vent arrangement	Vents directly to sea	Vents via the SCMMB		
Return line override connections	None	Return line override connections		

Table continues >

Subsea Systems

Subsea Control Systems

All of Baker Hughes' control system equipment is designed for reliability, from our uniquely-latched FLX360 hydraulic Stabplates, to our ultra-reliable electronics module, the SemStar5.

ModPod – Subsea Control Module (SCM) (continued)

Feature	Make to Order	Configure to Order	Configure to Order	Configure to Order
Variant	Option 1	Option 2	Option 3	Option 4
Function line flow controllers (FLFCs)	None	Fit to each LP function line as required		
Flow restrictors	None	Fit to each function line as required		
LP working pressure (psi)	5,000	Up to 5,000	Up to 5,000	Up to 5,000
HP working pressure (psi)	10,000	Up to 10,000	Up to 10,000	Up to 10,000
SCM base connector manufacturer	Siemens Tronic	Teledyne ODI		
SCM base connector quantity	Up to 6			
Number of ways	4	7	12	
SCM cover connector manufacturer	Siemens Tronic	Teledyne ODI		
SCM cover connector quantity	Up to 6 (overall)			
Number of ways	4	7	12	
Number of SEMs	2	1		
Installation tooling	RCR tool			
Warning and instruction language requirements	English			
Documentation	Generic Baker Hughes documents and drawings	Project specific format and content		
SCM markings	Front indication only / single color RAL 2004			
TRS requirements	UK and EU only	Australian	US	

Subsea Systems

Subsea Control Systems

All of Baker Hughes' control system equipment is designed for reliability, from our uniquely-latched FLX360 hydraulic Stabplates, to our ultra-reliable electronics module, the SemStar5.

Subsea Communications and Routing – Power Communications Distribution Module

Feature	Make to Order	Make to Order	Make to Order
Variant	2 Options 6 Slot Manifold	2 Options 8 Slot Manifold	2 Options 10 Slot Manifold
Power consumption including SIIS 2 Power	< 250 W	< 250 W	< 500 W
Input supply	300 V – 600 V	300 V – 600 V	300 V – 600 V
	500 V – 1,000 V	500 V – 1,000 V	
Number of output channels	Up to 6 SHDSL / Ethernet + 1 Ethernet	Up to 6 SHDSL / Ethernet + 2 Ethernet	Up to 11 SHDSL / Ethernet
Power switching	Optional	Optional	Optional
Weight/max	< 2,860 lbs (1,300 kg)	<3,080 lbs (1,400 kg)	<3,410 lbs (1,550 kg)
SIIS2 + power	1 x 30 W	1 x 20 W	2 x 30 W
Feature	**Options**	**Options**	**Options**
Communications range	Optical to 74 mi (120 km)	SHDSL Steel Tube 15 km	SHDSL Thermoplastic
Operating environment	23°F to 104°F (-5°C to 40°C) at 9,842 ft (3,000 m) water depth	23°F to 104°F (-5°C to 40°C) at 9,842 ft (3,000 m) water depth	23°F to 104°F (-5°C to 40°C) at 9,842 ft (3,000 m) water depth
Input communications	SHDSL / Optical	SHDSL / Optical	SHDSL / Optical
Output to infield units	CAPS Ethernet / SHDSL+ 300 to 600VAC	CAPS Ethernet / SHDSL+ 300 to 600VAC	CAPS Ethernet / SHDSL+ 300 to 600VAC
Ethernet range	<70 m	<70 m	<70 m
SHDSL range	Up to 9 mi (15 km) Steel Tubed Umbilical / 19 mi (30 km) Thermoplastic*	Up to 9 mi (15 km) Steel Tubed Umbilical / 19 mi (30 km) Thermoplastic*	Up to 9 mi (15 km) Steel Tubed Umbilical / 19 mi (30 km) Thermoplastic*
SHDSL bandwidth	To 192 kbps up to 5.7 Mbps	To 192 kbps up to 5.7 Mbps	To 192 kbps up to 5.7 Mbps
Dimensions – W x D x H (mm)	770 x 770 x 1,841	770 x 770 x 1,841	770 x 770 x 1,841

* Depending on umbilical properties

Subsea Systems

Subsea Control Systems

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Subsea Distribution System – Subsea Power Distribution and Management – Subsea Transformer Module

Feature	Make to Order	Configure to Order	Configure to Order
Variant	1 Option		
Primary: single phase multip-tap winding rating	20 kVA 50 / 60 Hz 1kV / 1.7 kV & 3 kV		
Primary: 3 phase winding rating		30 kVA 50 / 60 Hz 1.7 kV	30 kVA 50 / 60 Hz 3 kV
Secondary: single phase windings No & Rating	6 off 6 kVA 600 V	6 off 6 kVA 600 V	6 off 6 kVA 600 V
HV input power connector	3 / 4 way male tronic / ODI	3 / 4 way male tronic / ODI	3 / 4 way male tronic / ODI
LV output power connector	12 way female tronic / ODI	12 way female tronic / ODI	12 way female tronic / ODI
CP connector	7 way female tronic / ODI	7 way female tronic / ODI	7 way female tronic / ODI
Water ingress monitor	Yes	Yes	Yes
Galvanic insulation between windings (IR)	>1G ohm	>1G ohm	>1G ohm
Depth rating	9,842 ft (3,000 m)	9,842 ft (3,000 m)	9,842 ft (3,000 m)
Temperature rating	Op 23°F to 104°F (-5°C to 40°C) Store 0°F to 122°F (-18°C to 50°C)	Op 23°F to 104°F (-5°C to 40°C) Store 0°F to 122°F (-18°C to 50°C)	Op 23°F to 104°F (-5°C to 40°C) Store 0°F to 122°F (-18°C to 50°C)
Color	Orange (RAL2004)	Orange (RAL2004)	Orange (RAL2004)
Dimensions (h x w x d) (mm)	1,550 x 770 x 770	1,550 x 770 x 770	1,550 x 770 x 770
Lifting mandrel	ISO13628-8 Type A	ISO13628-8 Type A	ISO13628-8 Type A
Mass/max	4,400 lbs (2,000 kg)	4,400 lbs (2,000 kg)	4,400 lbs (2,000 kg)

Subsea Systems

Subsea Control Systems

All of Baker Hughes' control system equipment is designed for reliability, from our uniquely-latched FLX360 hydraulic Stabplates, to our ultra-reliable electronics module, the SemStar5.

Hydraulic Power Generation – Hydraulic Power Unit – HPU

Feature	Make to Order	Make to Order	Make to Order	Configure to Order
Variant	1 Option	1 Option	1 Option	
Region	North Sea	Asia Pacific	Africa / N. America	Field Driven
Temperature rating (storage)	0°F to 122°F (-18°C to 50°C)	0°F to 122°F (-18°C to 50°C)	0°F to 122°F (-18°C to 50°C)	
Temperature rating (operating)	23°F to 104°F (-5°C to 40°C)	23°F to 104°F (-5°C to 40°C)	23°F to 104°F (-5°C to 40°C)	
Depth capability	Topside on shore only	Topside on shore only	Topside on shore only	
Size W x D x H (mm)	Up to 9,000 x 3,000 x 3,300	Up to 9,000 x 3,000 x 3,300	Up to 9,000 x 3,000 x 3,300	
Weight in air	Up to 55,115 lbs (25,000 kg) Dry weight	Up to 55,115 lbs (25,000 kg) Dry weight	Up to 55,115 lbs (25,000 kg) Dry weight	
Weight in water	N/A	N/A	N/A	
Testing	Std testing	Std testing	Std testing	Std + 3rd party witness
Quality requirements	Std ITP	Std ITP	Std ITP	Customer ITP + 3rd party inspection
Structural skid design	Base Skid / Frame Construction Structure iaw DNV 2.7-3 Slings iaw DNV 2.7-1	Base Skid / Frame Construction Structure iaw DNV 2.7-3 Slings iaw DNV 2.7-1		
Skid material	Coated Carbon Steel	316L Stainless Steel	316L Stainless Steel	
Hazardous area rating	Zone 1	Zone 1	Zone 1	
Ingress protection	IP 66 / pump motors to be IP 56	IP 66 / pump motors to be IP 56	IP 66 / pump motors to be IP 56	
Noise level	<90 dB at 1 m	<90 dB at 1 m	<90 dB at 1 m	
Protection	N/A	N/A	N/A	
Material restrictions	No PMI	No PMI	No PMI	PMI
Working pressures (psi)	LP: 5,000 / HP: 10,000	LP: 5,000 / HP: 10,000	LP: 5,000 / HP: 10,000	Field Driven
Cleanliness requirement	SAE AS 4059E Class 6 (B-F)	SAE AS 4059E Class 6 (B-F)	SAE AS 4059E Class 6 (B-F)	
Tubing material	AISI 316-316L	AISI 316-316L	AISI 316-316L	
Reservoirs	Separate supply and return reservoirs manufactured as one unit	Separate supply and return reservoirs manufactured as one unit	Separate supply and return reservoirs manufactured as one unit	
Level monitoring	Sight level gauges c/w isolation valves, integral check valves and drain connection. Remote: Level transmitters, removable without draining, ESD outputs,	Sight level gauges c/w isolation valves, integral check valves and drain connection. Remote: Level transmitters, removable without draining, ESD outputs,	Sight level gauges c/w isolation valves, integral check valves and drain connection. Remote: Level transmitters, removable without draining, ESD outputs,	
Accumulation	Bladder and piston (up to 54 L)	Bladder and piston (up to 54 L)	Bladder and piston (up to 54 L)	
Pumps	2off LP / 2off HP / 1off Re-circulating	2off LP / 2off HP / 1off Re-circulating	2off LP / 2off HP / 1off Re-circulating	

Table continues ›

Subsea Systems

Subsea Control Systems

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Hydraulic Power Generation – Hydraulic Power Unit – HPU (continued)

Feature	Make to Order	Make to Order	Make to Order	Configure to Order
Variant	1 Option	1 Option	1 Option	
Region	North Sea	Asia Pacific	Africa / N. America	Field Driven
Instrumentation (local gauges)	All externally mounted including: Individual pump outputs, Common pump output headers, Output headers, ESD outputs, Fluid side of accumulators, Accumulator pre charge	All externally mounted including: Individual pump outputs, Common pump output headers, Output headers, ESD outputs, Fluid side of accumulators, Accumulator pre charge	All externally mounted including: Individual pump outputs, Common pump output headers, Output headers, ESD outputs, Fluid side of accumulators, Accumulator pre charge	
Instrumentation (remote)	4-20 mA Pressure transmitters including	4-20 mA Pressure transmitters including	4-20 mA Pressure transmitters including	
Hydraulic output	4 x LP A / 4 x LP B / 4 x HP A / 4 x HP B	4 x LP A / 4 x LP B / 4 x HP A / 4 x HP B	4 x LP A / 4 x LP B / 4 x HP A / 4 x HP B	
Hydraulic system	Open Loop (ESD vent to tank)	Open Loop (ESD vent to tank)	Open Loop (ESD vent to tank)	Closed loop
Local control panel	Yes	No	No	
LP tubing size (inches)	1/2	1/2	1/2	
HP tubing size (inches)	3/8	3/8	3/8	
LP fittings	LP: NPT	LP: NPT / Gyrolok	LP: NPT / Gyrolok	
HP fittings	HP: Cone and threaded	HP: Cone and threaded	HP: Cone and threaded	

Subsea Systems

Subsea Control Systems

All of Baker Hughes' control system equipment is designed for reliability, from our uniquely-latched FLX360 hydraulic Stabplates, to our ultra-reliable electronics module, the SemStar5.

Aptara™ FLX360 Multi-Quick Connection System

Feature	Make to Order	Configure to Order	Configure to Order
Variant	1 Option		
Temperature rating (storage)	0°F to 122°F (-18°C to 50°C)		
Temperature rating (operating)	23°F to 104°F (-5°C to 40°C)		
Depth capability	9,842 ft (3,000 m)		
Size – W x D x H (mm)	600 x 600 x 400 (fixed plate) 451 x 395 x 520 (flying plate)		
Weight in air	Fixed plate: 308 lbs (140 kg) Flying plate: 220 lbs (100 kg)		
Weight in water	Fixed plate: 243 lbs (110 kg) Flying plate: 174 lbs (79 kg)		
Testing	Std Testing	Std + SRT	Std + 3rd party witness
Quality requirements	Standard ITP	Customer ITP	Customer ITP + 3rd party inspection
Acid injection system	Included		
Anode material			
Material restrictions	No PMI	Positive Material Identification (PMI)	
Tubing material	316L / 3.1 certification level	Inconel 625 / SuperDuplex / 6Mo	Inconel 625 / SuperDuplex / 6Mo
Project pressure units	Bar		
Cleanliness requirement	SAE AS 4059 Class 6B-F		
Coupler size	Up to : 12 x ½-inch		
	Up to : 4 x 1-inch		
Number of lines	Up to 16		
Pressure rating	Up to 690 bar in all lines		
Tubing size	Up to 1-inch OD		
Tube tail type	316L / 3.1 certification level	Inconel 625 / SuperDuplex / 6Mo	Inconel 625 / SuperDuplex / 6Mo
Tooling	FLX360 Tool		
Linear offset	100 mm – all directions		
Angular misalignment	±25 degrees		
Rotational misalignment	±20 degrees		
Mate and de-mate timing	<3 minutes		
Documentation	Std Doc Pack		
Tooling markings	Locked / unlocked indication		
Third party design DVR	Not supplied	Third party option	

Subsea Systems

Subsea Manifolds and Pipeline Products

Our product portfolio covers everything you need to integrate your subsea production system and ensure safe and efficient fluid transfer from your trees to your risers.

Aptara™ Modular Compact Manifold

Feature	Make to Order	Configure to Order
Variant	2 Options	
Connector orientation	Horizontal	Vertical
Number of slots	6	4
Number of headers	Option 1: 6-slot Dual production	Option 1: 4-slot Dual production
	Option 2: 6-slot Dual production w/ Gas lift	Option 2: 4-slot Dual production w/ Gas lift
Distribution	Standalone SDU	Co-located on Foundation
Pigging	Round trip with external pigging loop	External PLR (ROV or remotely operated ROPL)
Standards	ISO 10423, ISO 13628, (API spec. 6A, 17D & RP 17P, 17R) ISO 19900 & 19902	RP 17P, 17R) ISO 19900 & 19902
	ASME B31.8, ASME B31.3 & DNV RP-F112	
TRL rating	7 for core components	
Pressure rating (psi)	10,000psi branch valve block 5,000psi Manifold	10,000psi branch valve block 10,000psi Manifold
Temperature rating	-20°F to 250°F (-29°C to 121°C)	
Water depth rating	6,561 ft (2,000 m)	
Design life (years)	25	Up to 50
Prod. header size / NPS (inches)	10	12
Prod. branch size / NPS (inches)	6	-
Gas lift / MEG header / NPS (inches)	6	4
Gas lift / MEG branch / NPS (inches)	2	
Material class	Production: Block - LAS fully clad HH / Piping - Super Duplex Gas lift: Super Duplex	Production: Block - LAS fully clad HH / Piping - Clad carbon steel Gas lift: Super Duplex
Dropped object	5kJ point load (Ø100mm)	
Barrier philosophy	Dual isolation for prod. Single isolation for gas lift	Single isolation for prod. Single isolation for gas lift
Bore configuration	Single bore	Dual bore concentric
Piggable ID variation	Within ±5%	
Levelling	±3° passive	
Foundation type	Mudmat	Suction anchor
Wet-parking of well Jumpers and flowlines	Provided on foundation mounted landing beam (to allow manifold module retrieval independently of foundation)	None
Cross over between headers	Not included	included with ROV or Hyd valve

Table continues >

Subsea Systems

Subsea Manifolds and Pipeline Products

Our product portfolio covers everything you need to integrate your subsea production system and ensure safe and efficient fluid transfer from your trees to your risers.

Aptara™ Modular Compact Manifold (continued)

Feature	Make to Order	Configure to Order
Variant	3 Options	
Piggable bend radius	5D	
Landing speed (m/s)	0.5	
Lifting	4-point lifting with slings	
Insulation	If required, high performance thermal insulation systems	
Jumper type	Flexibles	Rigids
Connection system	HCCS-L	VCCS
Caps	Low-pressure/deployment caps	High-pressure caps
Stab plates	FLX360	
Header valve	Ball valve, ROV (Fail As-is), Upstream side	Hydraulic fail safe close (FSC), Upstream side
Branch valve	Gate valve, hydraulic fail safe close (FSC) to header inlets and ROV isolation	Gate valve, hydraulic fail safe close (FSC) to header inlets and ROV isolation
CIMVs	Not included	1-off on each header
Hyd. compensation	Closed loop	
Subsea Control Module (Retrievable)	1x dedicated SCM	2x dedicated SCM or XT controlled
PT sensor	2x (one off on each header)	
Acoustic sand detector	2x (one off on each header non-intrusive clamp on)	
Pig detector	1x (on pigging loop non-intrusive clamp on)	2x (one off on each header non-intrusive clamp on)
Retrievable control units	None	PCDM's or EDU's co-located on foundation

Subsea Systems

Subsea Manifolds and Pipeline Products

Our product portfolio covers everything you need to integrate your subsea production system and ensure safe and efficient fluid transfer from your trees to your risers.

Deepwater Vertical Cluster Manifold – DVCM

Feature	Make to Order	Configure to Order
Variant	2 Options	
Connector orientation	Vertical	
Number of slots	4	6
Number of headers	Option 1: Dual production Option 2: Dual production with gas-lift	Single / dual prod. + MEG / gas lift
Distribution	Standalone SDU	Integrated SDU
Pigging	Round trip with external pigging loop	External PLR (ROV or remotely operated ROPL)
Standards	ISO 10423 / ISO 13628 / (API spec. 6A / 17D and RP 17P / 17R) ISO 19900 and 19902	ISO 10423 / ISO 13628 / (API spec. 6A / 17D and RP 17P / 17R) ISO 19900 and 19902
	ASME B31.8 / ASME B31.3 and DNV RP-F112	
TRL rating	7	
Pressure rating (psi)	5,000	7,500 to 10,000
Temperature rating	-20°F to 250°F (-29°C to 121°C)	291°F (144°C)
Water depth rating	6,561 ft (2,000 m)	9,842 ft (3,000 m)
Design life (years)	25	Up to 50
Prod. header size, NPS (inches)	10	8 / 12 / 14
Prod. branch size, NPS (inches)	6	8
Gas lift or MEG header, NPS (inches)	4	6
Gas lift or MEG branch, NPS (inches)	2	
Material class	FF	HH / EE
Dropped object	5 kJ point load (Ø100 mm)	Up to 20 kJ
Barrier philosophy	Dual isolation for prod.	Custom
Bore configuration	Single bore	Dual bore concentric (for GL / MEG)
Piggable ID variation	Within ±5%	Within ±5%
Levelling	±3° passive (with center column)	Active with ROV hyd. jacks
Foundation type	Single anchor suction pile	Skirted mudmat
Wet-parking	Not included	Separate skids
Flowmeter	Not included	Provided through each branch, outlet to main header
Piggable bend radius	3D	5D
Landing speed (m/s)	0.5	
Lifting	4-point lifting with slings	Lifting frame

Table continues ›

Subsea Systems

Subsea Manifolds and Pipeline Products

Our product portfolio covers everything you need to integrate your subsea production system and ensure safe and efficient fluid transfer from your trees to your risers.

Deepwater Vertical Cluster Manifold – DVCM (continued)

Feature	Make to Order	Configure to Order
Variant	2 Options	
Insulation	If applicable, high performance thermal insulation system can be provided	If applicable, high performance thermal insulation system can be provided
Jumper type	Rigid	Flexibles with gooseneck
Connection system	VCCS 300 and 450	450 dual bore concentric
Caps	Low-pressure / deployment caps	High-pressure caps
Stab plates	FLX360	
Header valve	Ball valve / ROV	Hydraulic fail safe open (FSO)
Branch valve	Gate valve, hydraulic fail safe close (FSC) to header inlets and ROV isolation	Gate valve, hydraulic fail safe close (FSC) to header inlets and ROV isolation
CIMVs	Not included	Optional
Hyd. compensation	Closed loop & locally on each actuator	Common sea-chest with accumulators
Control system	1x SCM	2x SCM
PT sensor	2x (one off on each header)	As required
Acoustic sand detector	2x (one off on each header non-intrusive clamp on)	As required
Pig detector	2x (one off on each header non-intrusive clamp on)	As required
Retrievable control units	Not included	2x retrievable PCDMs / EDUs

Subsea Systems

Subsea Manifolds and Pipeline Products

Our product portfolio covers everything you need to integrate your subsea production system and ensure safe and efficient fluid transfer from your trees to your risers.

Deepwater Horizontal Cluster Manifold – DHCM

Feature	Make to Order	Configure to Order
Variant	2 Options	
Connector orientation	Horizontal	Horizontal
Number of slots	4 & 6	8
Number of headers	Option 1: Dual production with gas-lift (oil) Option 2: Dual production with MEG (gas)	Single prod. + MEG / gas lift + service
Distribution	Integrated SDU	Standalone SDU
Pigging	Round trip with external pigging loop	External PLR (ROV or remotely operated ROPL)
Standards	ISO 10423 / ISO 13628 / (API spec. 6A / 17D and RP 17P / 17R) ISO 19900 and 19902	ISO 10423 / ISO 13628 / (API spec. 6A / 17D and RP 17P / 17R) ISO 19900 and 19902
	ASME B31.8 / ASME B31.3 and DNV RP-F112	ASME B31.8 / ASME B31.3 and DNV RP-F112
TRL rating	7	7
Pressure rating (psi)	5,000	7,500 to 10,000
Temperature rating	-20°F to 250°F (-29°C to 121°C)	291°F (144°C)
Water depth rating	6,561 ft (2,000 m)	9,842 ft (3,000 m)
Design life (years)	25	Up to 50
Prod. header size, NPS (inches)	10 (oil) / 16 (gas)	12 / 14 / 18
Prod. branch size, NPS (inches)	6 (oil) / 8 (gas)	Multibore
Gas lift or MEG header, NPS (inches)		4 / 6
Gas lift or MEG branch, NPS (inches)		2
Material class	FF	HH / EE
Dropped object	5kJ point load (Ø100 mm)	Up to 20KJ
Barrier philosophy	Dual isolation for prod.	Custom
Bore configuration	Single bore	Dual bore concentric / multi-bore
Piggable ID variation	With in ±5%	Within ±5%
Levelling	±3° passive	Active with ROV hyd. jacks
Foundation type	Mudmat	Multi pile suction anchor
Wetparking	Provided on foundation mounted landing beams	Provided on foundation mounted landing beams
Flowmeter	Not included	Provided through each branch, outlet to main header
Piggable bend radius	3D	5D
Landing speed (m/s)	0.5	0.5
Lifting	4-point lifting with slings	4-point lifting with slings

Table continues ›

Subsea Systems

Subsea Manifolds and Pipeline Products

Our product portfolio covers everything you need to integrate your subsea production system and ensure safe and efficient fluid transfer from your trees to your risers.

Deepwater Horizontal Cluster Manifold – DHCM (continued)

Feature	Make to Order	Configure to Order
Variant	2 Options	
Insulation	If required, high performance thermal insulation systems	If required, high performance thermal insulation systems
Jumper type	Rigid	Flexibles with integrated connector
Connection system	HCCS-L Small / Medium and Large	HCCS-L Small / Medium and Large
Caps	Low-pressure / deployment caps	High-pressure caps
Stab plates	FLX360	
Header valve	Ball valve / ROV	Hydraulic fail safe open (FSO)
Branch valve	Gate valve, hydraulic fail safe close (FSC) to header inlets and ROV isolation	Gate valve, hydraulic fail safe close (FSC) to header inlets and ROV isolation
CIMVs	Not included	Can be provided
Hyd. compensation	Closed loop & locally on each actuator	Common sea-chest with accumulators
Control system	1x SCM	2x SCM
PT sensor	2x (one off on each header)	As required
Acoustic sand detector	2x (one off on each header non-intrusive clamp on)	As required
Pig detector	2x (one off on each header non-intrusive clamp on)	As required
Retrievable control units	2x retrievable PCDMs / EDUs	On Standalone SDU

Subsea Systems

Subsea Manifolds and Pipeline Products

Our product portfolio covers everything you need to integrate your subsea production system and ensure safe and efficient fluid transfer from your trees to your risers.

Shallow Water Multi-flowbase (MFB)

Feature	Make to Order	Configure to Order
Variant	2 Options	
Connector orientation	Horizontal	
Number of slots	4	6
Number of headers	Option 1: Single production with gas lift Option 2: Single production with gas lift and water injection	Dual production
Distribution	Standalone UTA/Flying leads	
Pigging	Round trip with external pigging loop	External PLR (ROV or remotely operated ROPL)
Standards	ISO 10423, ISO 13628, (API spec. 6A, 17D & RP 17P, 17R) ISO 19900 & 19902	
	ASME B31.8, ASME B31.3 & DNV RP-F112	
TRL rating	7 core components	
Pressure rating (psi)	5,000	As required
Temperature rating	-20°F to 250°F (-29°C to 121°C)	As required
Water depth rating	Diver depth	
Design life (years)	25	Up to 50
Prod. header size, NPS (inches)	10	8, 12 or 14
Prod. branch size, NPS (inches)	6	
Gas lift or MEG header, NPS (inches)	4 or 6	8
Gas lift or MEG branch, NPS (inches)	2	
Material class	FF	HH or EE
Dropped object	Per NORSOK/ISO Multi-well structure	
Barrier philosophy	Single isolation	Dual isolation
Bore configuration	Single bore	
Piggable ID variation	Within ±5%	Within ±5%
Levelling	±3° passive	
Protection structure	NORSOK compliant, integrated	Skirted mudmat
Manifold Retrievability	Fixed pipe-work, diver replaceable valve with flange ends	
WHLR System	Provided	
Foundation	Mudmat	Mudmat with piling or suction can
Wetparking for flowlines	Provided on foundation mounted landing beams	
Flowmeter	–	Can be accommodated

Table continues >

Subsea Systems

Subsea Manifolds and Pipeline Products

Our product portfolio covers everything you need to integrate your subsea production system and ensure safe and efficient fluid transfer from your trees to your risers.

Shallow Water Multi-flowbase (MFB) (continued)

Feature	Make to Order	Configure to Order
Variant	2 Options	
Piggable bend radius	3D	5D
Landing speed (m/s)	0.5	
Lifting	4-point lifting with slings	
Insulation	If required, high performance thermal insulation systems	
Connection system+	Diver Flanges or Diverless HCCS-L	ICARUS
Caps	Low-pressure/deployment caps	High-pressure caps
Stab plates	FLX360	
Header valve	Ball valve, ROV	Hydraulic fail safe open (FSO)
Branch valve	Gate valve, ROV	Gate valve - Hydraulic
CIMVs	Not included	Optional
hyd. compensation	Closed loop & locally on each actuator	Common sea-chest with accumulators
Control system	–	Dedicated SCM
PT sensor	1 off on each header	As required
Acoustic sand detector	1 off on each header, non-intrusive clamp on	As required
Pig detector	1 off on each header, non-intrusive clamp on	As required
Retrievable control units	Retrievable UTA, Flying leads, (PCDM/EDU if required)	

Subsea Systems

Subsea Manifolds and Pipeline Products

Our product portfolio covers everything you need to integrate your subsea production system and ensure safe and efficient fluid transfer from your trees to your risers.

Template Manifold

Feature	Make to Order	Configure to Order
Variant	2 Options	
Connector orientation	Horizontal	
Number of slots	4	6
No. of headers	Dual production	Single / dual prod. + MEG / gas lift (& service)
Distribution	Integrated SDU	Standalone SDU
Pigging	Round trip with external pigging loop	External PLR (ROV or remotely operated ROPL)
Standards	ISO 10423 / ISO 13628, (API spec. 6A / 17D & RP 17P / 17R) ISO 19900 & 19902	
	ASME B31.8 / ASME B31.3 & DNV RP-F112	
TRL rating	7	
Pressure rating (psi)	5,000	7,500 to 10,000
Temperature rating	-20°F to 250°F (-29°C to 121°C)	291°F (144°C)
Water depth rating	1,640 ft (500 m)	1,640 ft (500 m)
Design life (years)	25	Up to 50
Prod. header size / NPS (inches)	10	8, 12 / 14
Prod. branch size / NPS (inches)	6 + service + controls in a multibore	
Gas lift / MEG header / NPS (inches)	4 / 6	8
Gas lift / MEG branch / NPS (inches)	2	
Material class	FF	HH / EE
Dropped object	5kJ point load (Ø100mm)	Up to 20kJ
Barrier philosophy	Dual isolation for prod.	Single isolation for injection
Bore configuration	Production + service + controls	
Piggable ID variation	Within ±5%	Within ±5%
Levelling	±3° active by ROV suction control feature	
Protection structure	NORSOK compliant, integrated	Separately installed
Foundation	4 can suction pile	Multi-suction pile
Wetparking for flowlines	Provided on foundation mounted landing beams	Provided on foundation mounted landing beams
Flowmeter	Dedicated on XT	Manifold mounted
Piggable bend radius	3D	5D

Table continues ›

Subsea Systems

Subsea Manifolds and Pipeline Products

Our product portfolio covers everything you need to integrate your subsea production system and ensure safe and efficient fluid transfer from your trees to your risers.

Template Manifold (continued)

Feature	Make to Order	Configure to Order
Variant	3 Options	
Landing speed (m/s)	0.5	0.5
Lifting	4-point lifting with slings	4-point lifting with slings
Insulation	If required, high performance thermal insulation systems	If required, high performance thermal insulation systems
Connection system	HCCS-L Small / Medium & Large	HCCS-L Small / Medium & Large
Caps	Low-pressure / deployment caps	High-pressure caps
Stab plates	FLX360	3rd party
Header valve	Ball valve / ROV	Hydraulic fail safe open (FSO)
Branch valve	Gate valve, hydraulic fail safe close (FSC) to header inlets and ROV isolation	Gate valve, hydraulic fail safe close (FSC) to header inlets and ROV isolation
CIMVs	Not included	Optional
Hyd. compensation	Closed loop & locally on each actuator	Common sea-chest with accumulators
Control system	1x SCM	As required
PT sensor	1 off on each header	As required
Acoustic sand detector	1 off on each header, non-intrusive clamp on	As required
Pig detector	1 off on each header, non-intrusive clamp on	As required
Retrievable control units	2x retrievable PCDMs / EDUs	As required

Subsea Systems

Subsea Manifolds and Pipeline Products

Our product portfolio covers everything you need to integrate your subsea production system and ensure safe and efficient fluid transfer from your trees to your risers.

Pipeline Products and Solutions – High Integrity Pipeline Protection System (HIPPS)

Feature	Make to Order
Variant	3 Options
Prod. header size / NPS (inches)	8 / 6
Design pressure (psi)	10,000 / 5,000
Temperature range	0°F to 250°F (-18°C to 121°C)
Valve close time/sec	<10
Material class	FF / EE
Dropped object	5kJ point load (Ø100mm)
Barrier philosophy	Dual isolation for production
Bore configuration	Single bore
Piggable ID variation	Within ±5%
Levelling	±3° passive
Foundation type	Mudmat
Wetparking	Provided on foundation mounted landing beams
Landing speed (m/s)	0.5
Lifting	4-point lifting with slings
Insulation	If required, high performance thermal insulation systems
Jumper type	Rigid
Connection system	HCCS-L Small, Medium & Large
HIPPS valve	Gate valve, hydraulic operated FSC
Hyd. compensation	Closed loop & locally on each actuator
Control system	1x dedicated SCM
PT sensor	4 off on header
Voting scheme	2004 / 2003
SIL rating	SIL3
Delivery time	12 months

Subsea Systems

Subsea Connection Systems

You can count on the reliability and safety of Baker Hughes' subsea clamp connection systems, even in the most demanding environments.

Connection Systems

	VCCS	Aptara™ HCCS-L	HCCS
Functional specifications			
Pipe size (inches)	4 - 22	HCCS-L: 4 - 18	HCCS: 18 - 42
Qualification	API 6A/17D & API 17R		
TRL rating	7	7	7
Design Pressure rating	GX seal rating: 15,000 psi for ID <=275mm 10,000 psi for ID>275mm		
Temperature rating	-51F to 356F (-46C to 180C)		
Water depth rating	Depth rating: 11,482ft (3,500m) for Up to 18 9,843ft (3,000m) for Up to 22	Depth rating: 11,482ft (3,500m) for Up to 18	Depth rating: 9,843ft (3,000m) for Up to 228,202ft (2,500m) for Up to 42
Design life	20 - 50 yrs (limited by cathodic protection of parent structure)	20 - 50 yrs (limited by cathodic protection of parent structure)	20 - 50 yrs (limited by cathodic protection of parent structure)
Load capacity	See respective load charts	See respective load charts	See respective load charts
Bore configuration	Single bore, dual bore	Single bore, dual bore, multibore	Single bore
Hub cleaning	ROV flyable cleaning tools for male & female hub	ROV flyable cleaning tools for male & female hub (except M2 & M5)	ROV flyable cleaning tools for male & female hub (except M2 & M5)
Black seal test arrangement	Provided on outboard hub	Provided on inboard hub	Provided on inboard hub
Connection tools	Seal surface cleaning tool; torque tool and hotstab	Seal surface cleaning tool; stroking tool; torque tool and hotstab	Seal surface cleaning tool; Seal replacement tool, stroking tool; torque tool and hotstab
Caps	HP caps; test caps; LP cap; flooding cap; protection caps	HP caps; test caps; LP cap; flooding cap; protection caps	
Wet parking	On separate parking skids, if needed	On foundation or tubing head spool (if required)	
Clamp position	Outboard mounted		
Options	VCCS	HCCS-L	HCCS
Bore configuration	Dual-concentric or multibore	Dual-concentric or multibore	
Insulation	Can be provided with extended cool down time	Proprietary heatbank with extended cool down time	
Seal replacement	ROV flyable seal replacement tool with stroking tool	ROV flyable seal replacement tool	–
Flexible	Gooseneck can be provided or complete jumper	Integrated end-fitting on hub with full 360° swivel, installation tool	–
Flowmeter	Option to mount on the gooseneck or jumper	Option to mount on termination	–
Umbilical termination	NA	With multiborehub, compact electrical termination – ref. MHC UTA	–
Pig launcher	Option to integrate PLR	Option to integrate PLR on termination	Option to integrate PLR on termination
Open-PLET	NA	–	Proprietary PLET deployment system to simplify PLET installation for independent installation of PLET and pipeline
Contingency tools	Stroking tool; seal replacement tool; basket and clamp cutting tool	Seal replacement tool, basket and clamp cutting tool	Clamp cutting tool
Metrology interface		Can be provided on caps	

Subsea Systems

Subsea Connection Systems

You can count on the reliability and safety of Baker Hughes' subsea clamp connection systems, even in the most demanding environments.

Vertical Clamp Connection System (VCCS) Standard Sizes

System Size	Pipe Size, NPS (inches)	Standard Seal Size, ID mm
VCCS 300	4	100
	6	140
VCCS 450	6	140
	8	185
	8 + 2 dual bore (concentric)	C175 A250-275
	10	235
	12	275
VCCS 520	12	275
	14	320
VCCS 580	16	365
	18	400
VCCS 720	18	400
	22	505

Vertical Clamp Connection System (VCCS) Tooling

Standard Tooling	Optional Tooling
Torque tool and calibration unit	Stroking tool
Inboard hub cleaning tool	Outboard hub cleaning tool
ROV hot stab	Seal replacement tool
	Tooling basket
	Inspection tool
	Gooseneck lifting adaptor

Subsea Systems

Subsea Connection Systems

You can count on the reliability and safety of Baker Hughes' subsea clamp connection systems, even in the most demanding environments.

Horizontal Clamp Connection Systems (HCCS) Standard Sizes

System Size	Clamp Size	Pipe Size, NPS (inches)	Standard Seal Size, ID mm
HCCS-L small	300	4 or less	100
		6	140
HCCS-L medium	450	8	185
		8 + 2 dual bore (concentric)	C175 A250-275
		10	235
		12	275
		Multibore 450-V1A | V1B | V1C | V1D	19x SX22 | 15x SX22 | 11x SX22 | 5x SX22
		Multibore 450-V2	14x SX22 + 2x SX44
		Multibore 450-V3	8x SX22 + 6x SX44
HCCS-L large	520	14	320
		Multibore 520-V1	12x SX22 + 6x SX44
	580	16	365
		18	400
HCCS 22	720	18	400
		22	505
HCCS 30	940	20 or 22	600
		24 or 26	680
HCCS 36	M2	32 to 36	870
HCCS 42	M5	38 to 42	1020

Horizontal Clamp Connection Systems (HCCS-L/HCCS) Tooling

Standard Tooling	Optional Tooling
Stroking tool	Seal replacement tool (HCCS-L)
Torque tool and calibration unit	Inspection tool
Inboard / outboard hub cleaning tool	Flowline lifting tool (FLT)
ROV hot stab	Cap replacement tool (HCCS sizes)
Tooling basket	Connection override tooling package
Installation guidepost	
Seal replacement tool (HCCS)	

Subsea Systems

Subsea Well Access Systems

Baker Hughes has a long history of providing safe, efficient and reliable Well Access services. In addition to equipment you can purchase outright, we have an extensive portfolio of rental tools and equipment to support operations from installation and commissioning right through to decommissioning. This comprehensive fleet can meet the needs of long and short-term rental contracts, providing well-maintained equipment for subsea contracts.

Open Water Completion Workover Riser System – CWOR

Feature	Make to Order	Configure to Order	Configure to Order
Variant	Option 1		
System production size (inches)	7⅜	5⅛	6⅛
System annulus size (inches)	2 nom	2 nom	2 nom
Pressure rating (psi)	10,000	10,000	10,000
Design life	25 years	25 years	25 years
Temperature range	0°F to 250°F (-18°C to 121°C)	0°F to 250°F (-18°C to 121°C)	0°F to 250°F (-18°C to 121°C)
Max water depth	9,842 ft (3,000 m)	9,842 ft (3,000 m)	9,842 ft (3,000 m)
Test and qualified	API RP 17G	API RP 17G	API RP 17G
Trim level	E-E with H_2S trim	E-E with H_2S trim	E-E with H_2S trim
Quality requirements	Standard ITP	Standard ITP	Standard ITP
Product service level	PSL 3G	PSL 3	
BSEE compatible	Yes		
BSEE certified	No	Yes	
Autoshear	Yes	No	
Deadman	Yes	No	
Safety integrity level scope	SIL-2 of controls system only	Not applicable	Full SIL-2
Safety integrity level coverage	SIL-2 of ESD, EQD and Deadman, Autoshear	SIL-2 of ESD / EQD	Full SIL-2
LRP & EDP production bore size (inches)	7⅜		
LRP & EDP annulus bore size (inches)	2 1/16		
LRP barrier No.1 sealing direction	Seal from below	non-sealing	
LRP barrier No.1 function	Safety Head	Grip / seal	Grip
LRP barrier No.2 sealing direction	Seal from below	Bi-directional	Not required
LRP barrier No.2 function	Safety Head	Gate	Shear and Seal Gate
LRP barrier No.3 sealing direction	Bi-directional	Seal from above	
LRP barrier No.3 function	Gate	Shear and Seal Gate	
EDP RV sealing direction	Bi-directional	Seal from above	
EDP RV function	Gate	Shear and Seal Gate	
Stress joint	Yes		
Stress joint production bore (inches)	7⅜		
Riser safety joint	Not required	Simple frangible bolts	Telescopic pressure balanced
Production riser type	Mono-bore	Dual bore	

Table continues ›

Subsea Systems

Subsea Well Access Systems

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Open Water Completion Workover Riser System – CWOR (continued)

Feature	Make to Order	Configure to Order	Configure to Order
Variant	Option 1		
Annulus type	Flexible Hose	Coiled Tubing	Dual bore riser
Lubricator valve	Yes	No	
Lubricator Valve Production bore (inches)	7 3/8	6 3/8	
Dual Lubricator Valve	No	Yes	
Lubricator Valve dual use with Open water and In-riser	No	Yes	
Lubricator valve sealing direction	Bi-directional	From above only	
Lubricator Valve pump through	Yes	No	
Lubricator Valve Chemical injection	Yes		
Tension Joint	Yes	No	
Cased Wear Joint	Yes	No	
Swivel	Yes	No	
Surface Test Tree	Yes	No	
STT production bore (inches)	7 3/8 (mono-bore)		
Controls system	Electro-hydraulic (Multi-plex)	Direct Hydraulic	
WOCM location	EDP – retrievable	Not applicable	
Cleanliness requirement	SAE AS 4059 Class 6B-E		
Control fluid	HT-2	Alternative considered	
Working pressure – LP	3,000	5,000	
Working pressure – HP	10,000		
Material	316/316L	625	6Mo
LRP lower interface	Clamp		
LRP lower connector	Included	Not part of scope	
EDP connector high angle release	Yes	No	
EDP upper interface	Hydraulic	Manual	
Riser	Casing Riser	Drill Pipe Riser	
STT upper wireline interface adapter (inches)	11 1/2 4-ACME OTIS Quick Union	Alternative considered	Not part of scope
STT lower Interface (inches)	13 5/8 flange		
STT KW interface	Clamp	Alternative considered	
STT PW interface	Clamp	Alternative considered	
Warning and instruction language requirements	English	Project specific	

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Installation and Workover Control System – IWOCS

Feature	Configure to Order			
Variant				
Physical properties typical				
Dimensions – L x W x H (mm)	9,144 x 2,550 x 3,150			
Weight	Max Unit Gross weight 55,115 lbs (25,000 kg)			
Temperature rating	Operating: 14°F to 104°F (-10°C to 40°C); Storage: -4° F to 122° F (– 20°C to 50˚C); Relative humidity: 20% to 80%			
Required utilities				
Power	Rig Three Phase – Motors	440 VAC 63A 50/60 Hz – Max +/- 10%		
	Single Phase – UPS	230 VAC 16C A 50/60 Hz Max +/- 10%		
	Rig Single Phase – WOCS	230 VAC 16C A 50/60 Hz Max +/- 10%		
Air	Instrument air	6-8 Bar		
Water supply (A/C)	Chilled water	10-30 L/min @ 5-8°C max 3 bar		
Unit features				
Frame works				
Design standard	DnV 2.7-1			
Handling	4 leg lifting sling, tugger, ISO corners on each side of base frame, skid mounted forklift pockets			
Access	Entrance door to the MCP room through air lock. Door to the HPU room from inside the MCP room.			
Hydraulic output	**Qty**		**Regulated pressure**	
Low pressure	According to hyd schematic		0-5,000 psi	
Medium pressure	According to hyd schematic		0-10,000 psi	
High pressure	According to hyd schematic		0-12,500 psi (15,000 psi)	
Test lines	2 (typical)		0-12,500 psi / 0-5,000 psi	
Return lines (psi)	1		3,000 psi (M.W.P.)	
Pumps / motors (typical configuration)				
Low pressure / flushing	Supply pressure	690 Bar		
	Drive type	Electric	Qty	2
	Motor rating	15 kW	Flow Rates	10.0 L/min
High pressure	Supply pressure	863 Bar		
	Drive type	Electric	Qty	2
	Motor rating	15 kW	Flow Rates	5.0 L/min

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Installation and Workover Control System – IWOCS (continued)

Feature	Configure to Order			
Variant				
Circulation / filling (including filling lance)	Supply pressure	10 Bar		
	Drive type	Electric	Qty	1
	Motor rating	1.5 kW	Flow Rates	30.0 L/min
Reservoirs				
Volumes	Supply	1,000 L	1,000 L	1,000 L
	Return	1,000 L	1,000 L	1,000 L
	Dirty Return	500 L (ext res.)	500 L (ext res.)	500 L (ext res.)
Accumulators (Scalable to project requirements)				
Design standards	ASME VIII, Division 1 / PED			
Low pressure	Type:	Piston		
	M.W.P:	690 bar		
High pressure	Type:	Piston		
	M.W.P:	871 bar		
Instrumentation / Control				
Instrumentation				
General	Transmitter data input to control logic and on screen display.			
Pressure transducers	Locations	Downstream of pumps, filters, regulators and at hydraulics outputs		
	Signal Output	4 – 20 mA	Accuracy	± 0.25% scale range
Flow meter	Locations	1 off System Supply Flowmeter is installed upstream Pressure Regulator distribution for verification of volume for LP functions. 1 off HP Flowmeter is installed upstream Pressure Regulator for verification of volumes for the HP functions 1 off Subsea Return & 1 off System Return flowmeter with by-pass installed downstream Return Filter for verification of return volume		
	Type	Turbine Flow meters, with totalizer	Turbine Flow meters, with totalizer	Turbine Flow meters, with totalizer
	Signal Output	4 – 20 mA	Accuracy	± 0.25% scale range
Level transducers	Locations	Reservoirs	Reservoirs	Reservoirs
	Signal Output	4 – 20 mA	Accuracy	± 0.25% scale range
Pressure gauges	Locations	Various Locations within system	Various Locations within system	Various Locations within system
	Type	Bourdon	Accuracy	± 1% scale range

Table continues ›

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Installation and Workover Control System – IWOCS (continued)

Feature	Configure to Order			
Variant				
Gas detector	Location	Dirty Return Tank (External tank)	Dirty Return Tank (External tank)	Dirty Return Tank (External tank)
	Type	Sieger Optima Plus 0-100%LEL Methane, IR point gas detector		
	Signal Output	4 – 20 mA	Accuracy	± 1% scale range
Flame detector	Type	2 ch. Loop Powered Fire / Smoke Detector	2 ch. Loop Powered Fire / Smoke Detector	2 ch. Loop Powered Fire / Smoke Detector
Programmable Logic Controller (Scalable to project requirements)				
General	The PLC contains a central rack with processor module, interface modules and 3 expansion racks, Safety and Non-safety digital input / output modules and analogue input modules. The PLC controls at all times all the pumps and DCV valves initiated from VDU screens on the operator stations, manual start and stop of pumps is controlled from the motor starter panel located in the HPU. The PLC also monitors all HPU instruments such as pressure transmitters and status indicators on the input / output modules.			
Manufacturer	Siemens	Siemens	Type	Simatic CPU
Local Control – HPU				
The HPU has the following local control and monitoring functions:	Local Pump Control Panel for System pumps and Circulation pump Regulator panels (Note that the most commonly used main regulators are installed in the MCR) Manual operation of all solenoid valves Manual valves for selected hydraulic outlet lines Pressure gauges on all hydraulic outlet lines Level gauges on reservoirs Accumulator panel Flushing panel Isolation valves and crossover loops for system service and maintenance. Emergency Stop push button on all electrical motors Push button for forced start on System Pumps Local clogging indicator on filters Manual hydraulic fluid cleanliness system (sample points)			
HMI Interface				
	Operator stations function as HMI and provide a graphical interface to the process, i.e. mimic pictures to control the processes. There are 2 Local Control Panels (LCP) and 1 remote control Station. The LCP consist of a double (redundant) PC system for interfacing to two separate VDUs in the MCP. The same information is available at both VDUs. Operator can choose which screen to operate from for control and visualization of the WOCS.			

Table continues ›

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Installation and Workover Control System – IWOCS (continued)

Feature	Configure to Order		
Variant			
Main Interfaces			
Hydraulic Connections (Scalable to project requirements)			
Workover umbilical MQC plate:	7 way stabplate	LP Hotline Outlet:	2 off
LV umbilical MQC plate:	5 way stabplate	HP Hotline Outlet:	2 off
SFT MQC plate:	8 way stabplate	Filling point Hydr.Fluid:	1 off
Fluid to dirty return tank	1 off		
Electrical Connections			
Rig utilities	Jumpers terminated in Ex junction box		
UPS	Jumpers terminated in Ex junction box		
MCS comms	Jumpers terminated in Ex junction box (Electrical connectors for subsea power and optical comms)		
Materials			
Structure			
Frameworks	Structural Steel		
Components			
Reservoir	AISI 304 Stainless Steel		
Accumulators	17-4 PH – Martensitic Stainless Steel		
Valves and hardware	316 Stainless Steel		
Tubing	316 Stainless Steel		
Testing and Certification			
Testing			
Function test	ISO 13628-7		
Load testing	DnV 2.7-1 / DnV 2.7-3		
Ventilation / purging	EN 50381		
Certifications			
Components	CE Marked		
Electrical equipment	IECEx		
Non-electrical equipment	ATEX		
Lifting	DnV 2.7-1		

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Oilfield Equipment Headquarters
2630 The Quadrant
Aztec West
Bristol
BS32 4GQ
United Kingdom

Asia Pacific
2 Benoi Road
Singapore, SG 629876
Singapore

Europe
Stoneywood House
Dyce
Aberdeen
AB21 9LA
United Kingdom

Latin America
Avenida Republica do Chile
330 Ventura Corporate
Towers
West Tower B
Rio de Janeiro, RJ 20031-170
Brazil

Middle East, North Africa, Turkey and India
Po Box 567
Technopark
Dubai
United Arab Emirates

North America
3300 N. Sam Houston
Parkway East, Houston
TX 77032-3411
US

Russia and CIS
Presnenskaya Naberezhnaya
10 Naberezhnaya Tower
Moscow, MOW 123112
Russia

Sub-Saharan Africa
Bishop Aboyade Cole
Street No. 927/928
Mansard Place
PO Box 54255
Victoria Island
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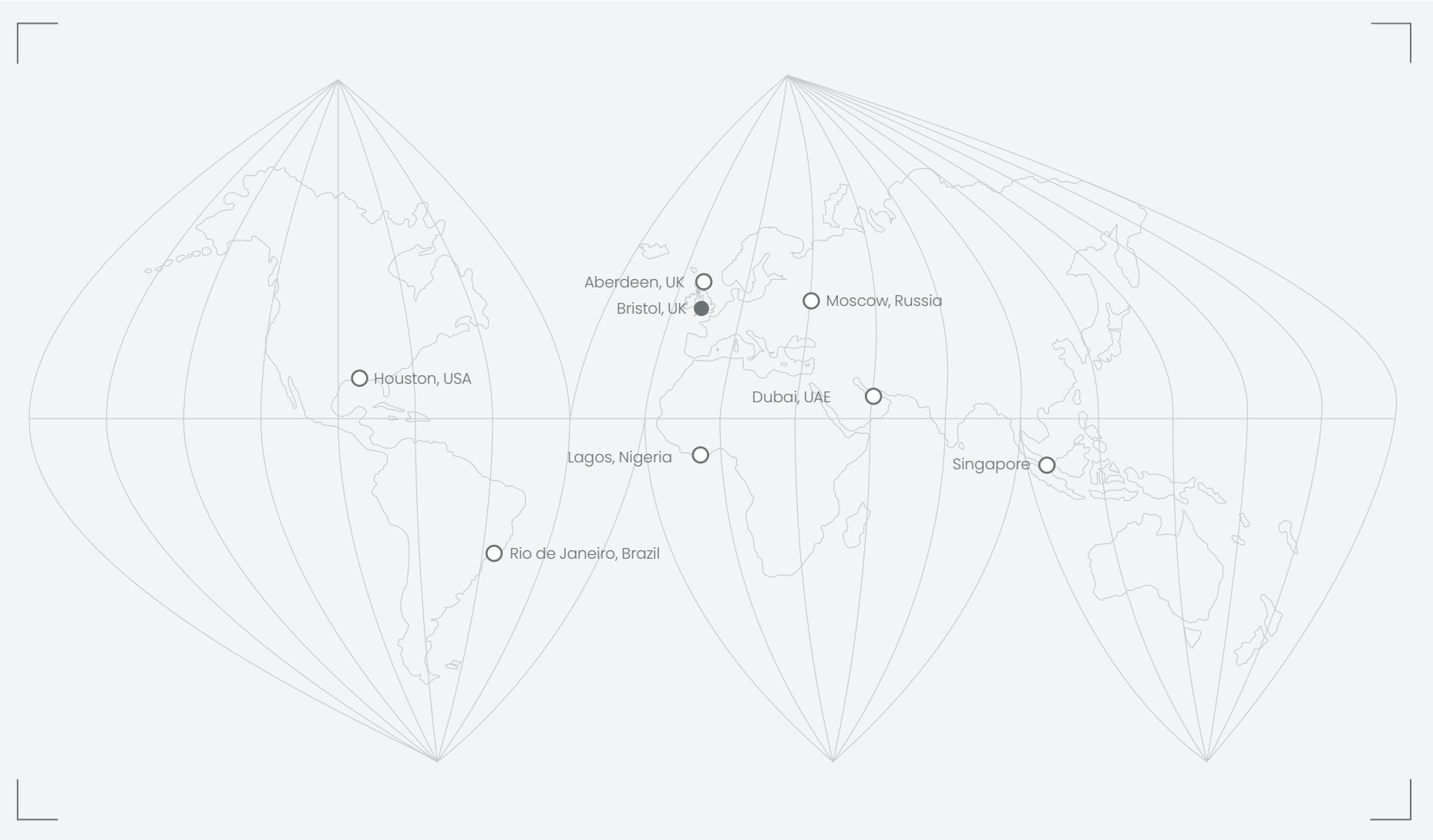
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