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OFFSHORE OIL AND GAS DEVELOPMENT ACTIVITIES AND CHALLENGES

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Abstract

During the last fifteen years the demand for oil and gas has increased by over 30%, thereby providing the need to develop reservoirs located in either harsh environments or in regions not easily accessible. New frontiers for the development of "stranded gas" have also emerged as a result of sustained commodity prices. Exploration and development of deepwater oil and gas reserves is not without its challenges, ranging from engineering design issues such as hydrostatic collapse, and on bottom vortex induced vibration, to flow management concerns associated with hydrate formation and wax deposition. More recently dynamic riser service requirements have become an issue because of reservoir souring caused by water flooding. In particular the use of corrosion fatigue testing is being used to re-validate life-of-service fatigue models for steel catenary riser systems. With the move to deeper water the installation challenges associated with subsea equipment, infield flowlines and export pipeline systems are becoming more problematic. Increased installation requirements have resulted in the upgrading of offshore vessels as well as the introduction of strain based design criteria.

Oil and Gas Industry Update

The growth within the oil and gas industry is directly related to global economics. An assessment of key indicators has shown that:

- A slower rate of growth was experienced in late 2004 and 2005.
- Europe continues to underperform but the USA and Japan are growing at sustainable rates.
- In 2005, Gross Domestic Product (GDP) of China and India grew at rates of 9% and 7%, respectively.

Additional to the key factors sighted above, the overall global GDP for 2005 also increased but at a reduced rate of change. Economic projections suggest the GDP will remain stable for 2006; with a slight increase in 2007.

With a sustained economic growth the oil and gas supply and demand will likely show the following:

- Overall energy consumption to increase by 2% per annum.

- World oil demand to be in excess of 100 million barrels per day (mmbpd) by the year 2025.

- The USA and developing economies will account for over 64% of the increase in energy demand.

With the transportation sector remaining the major factor in oil consumption, natural gas is forecast to grow by at least 2% per annum driven by power generation and industrial uses.

In meeting the increase in energy consumption the offshore arena will supply at least 30% of all oil production. Regional consumption and production statistics are shown graphically in Figure 1. As indicated the areas showing the largest increase will be the emerging Asian economies led by China and India. The mature market economies of the USA, Japan and Europe will also show increased demand but on a smaller scale. From the supply side, the OPEC cartel will continue to provide a solid foundation with additional production being forecast from West Africa, Brazil, Russia, the Asia Pacific Rim and North America.

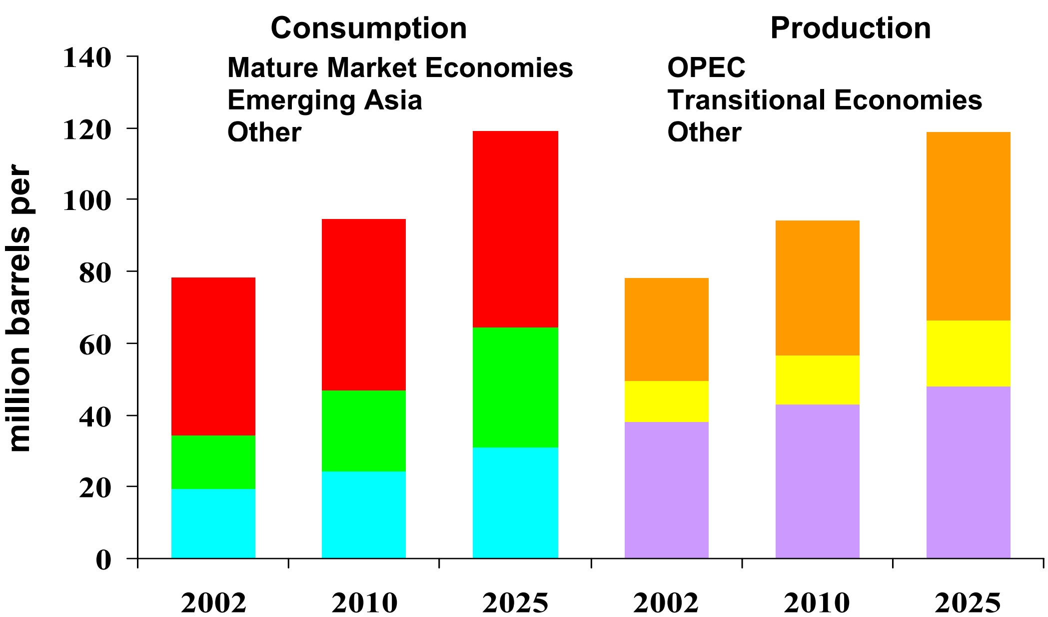

Figure 1. Regional Consumption and Production Statistics

Because of the supply and demand dynamics, commodity prices for oil are projected to increase in the near term, with a "breakpoint" (price adjustment period) being reached in the next two or three years. Similar to oil, annual gas consumption is expected to increase at record levels, reaching over 150 trillion cubic feet by 2025.

Traditional supply sources for natural gas will continue to be the Middle East, Russia and West Africa, with support from Asia and the Americas.

Figure 2 depicts a sequence of events that influences the importance of the offshore arena. As shown, once demand has surpassed conventional supply, the increase in commodity pricing will activate an increase level of deepwater offshore activity where the potential for large field discoveries is the greatest.

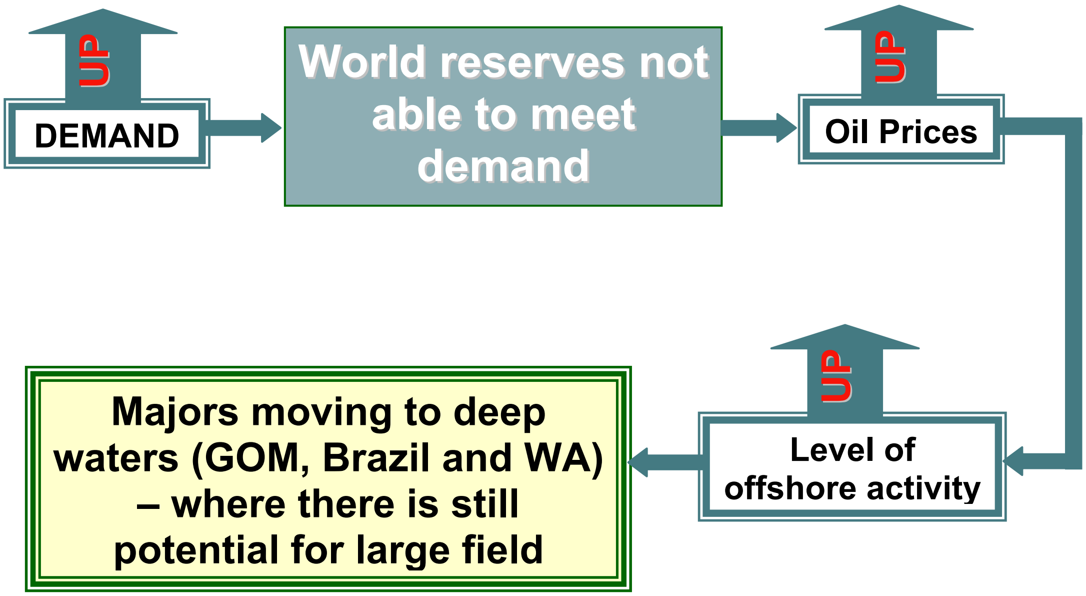

Figure 2. Deepwater Offshore Activity

Deepwater Opportunities

With the world economics in place and the need to meet industry and consumer demands defined, the opportunities for deepwater exploration and development will continue to flourish. Specifically, industry analysts have indicated the following scenario for continued growth in the deepwater arena:

- Deepwater oil production will grow by at least 300% over the next decade.
- Deepwater oil production accounts for almost 3% of the total world production.
- Deepwater production will peak at more than 8 million bbl/day by 2016.

Wood Mackenzie has presented the yet-to-find deepwater oil and gas reserves, as shown in Figure 3. As indicated the undiscovered resources are estimated to be in excess of 180 billion barrel oil equivalent (BOE), with proven reservoirs of approximately 70 billion BOE. Using the 180 billion BOE estimate, Figure 4 shows the seven major areas that will dominate the deepwater discoveries.

Based on a full cycle internal rate of return, Figure 4 considers not only the yet-to-find reserves but also the best financial opportunity for deepwater production.

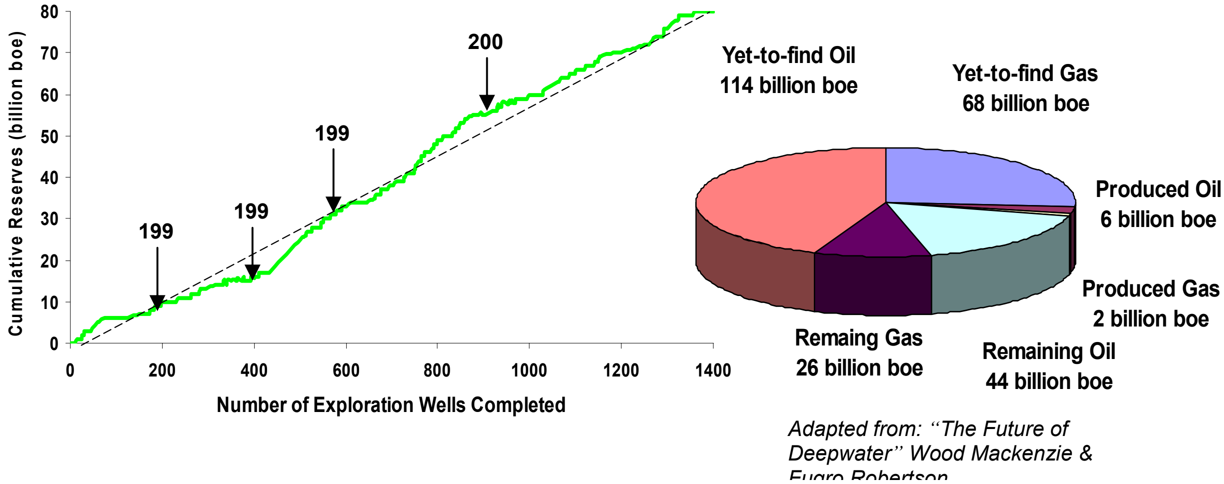

Figure 3. Yet to find deepwater reserves

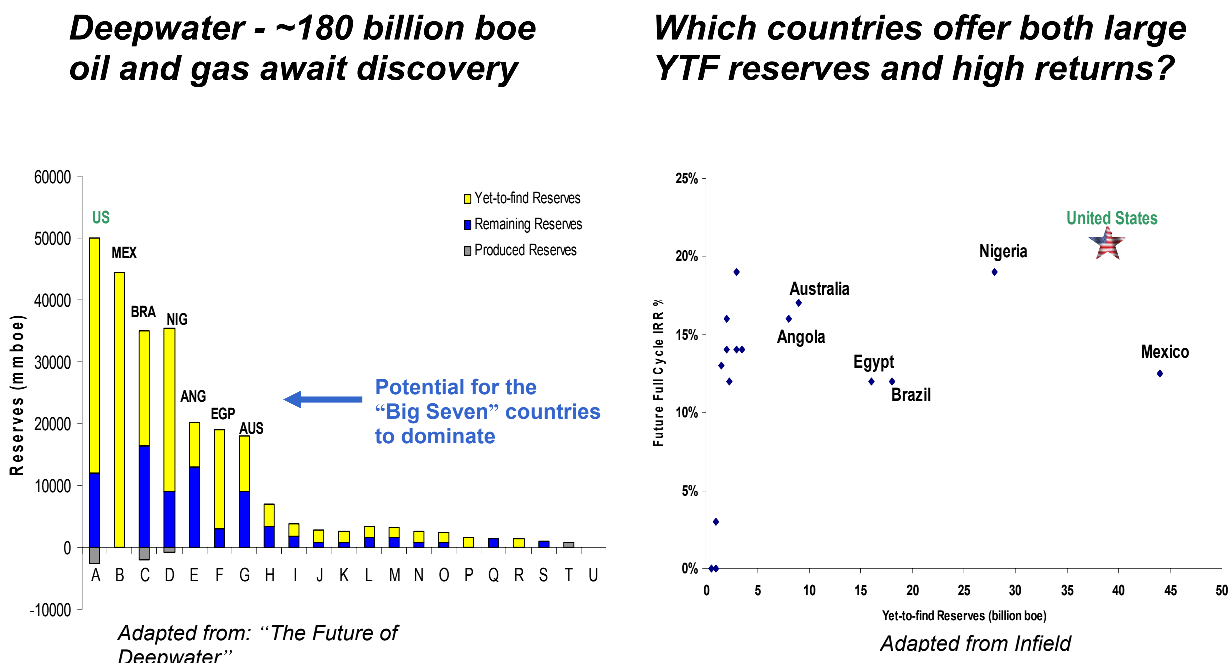

Figure 4. Financial opportunity

Deepwater Technology Challenges

Deepwater production will face many technical challenges including, but not limited to:

- Ultra deepwater – over 10,000 ft (3000 m).
- Remote fields – long offsets.
- Complex sea floor topography and harsh metocean conditions.
- High pressure/high temperature reservoirs.
- Variable produced fluid compositions.

Deepwater Production Systems

Producing oil and gas in ultra deepwater has pushed the limits of proven technology both from the standpoint of floating production systems and subsea equipment, including riser, flowlines and export pipeline systems. The prevailing limitation of various offshore production systems is shown in Figure 5, with dry tree units such as compliant towers, tension leg platforms (TLP) and spars being used in water depths of almost 6,000 ft. (1853 m). Wet tree systems, typically associated with floating production, storage and off loading (FPSO) and semi-submergible floating production systems (FPS) are used in water depths of over 8,000 ft (2400 m).

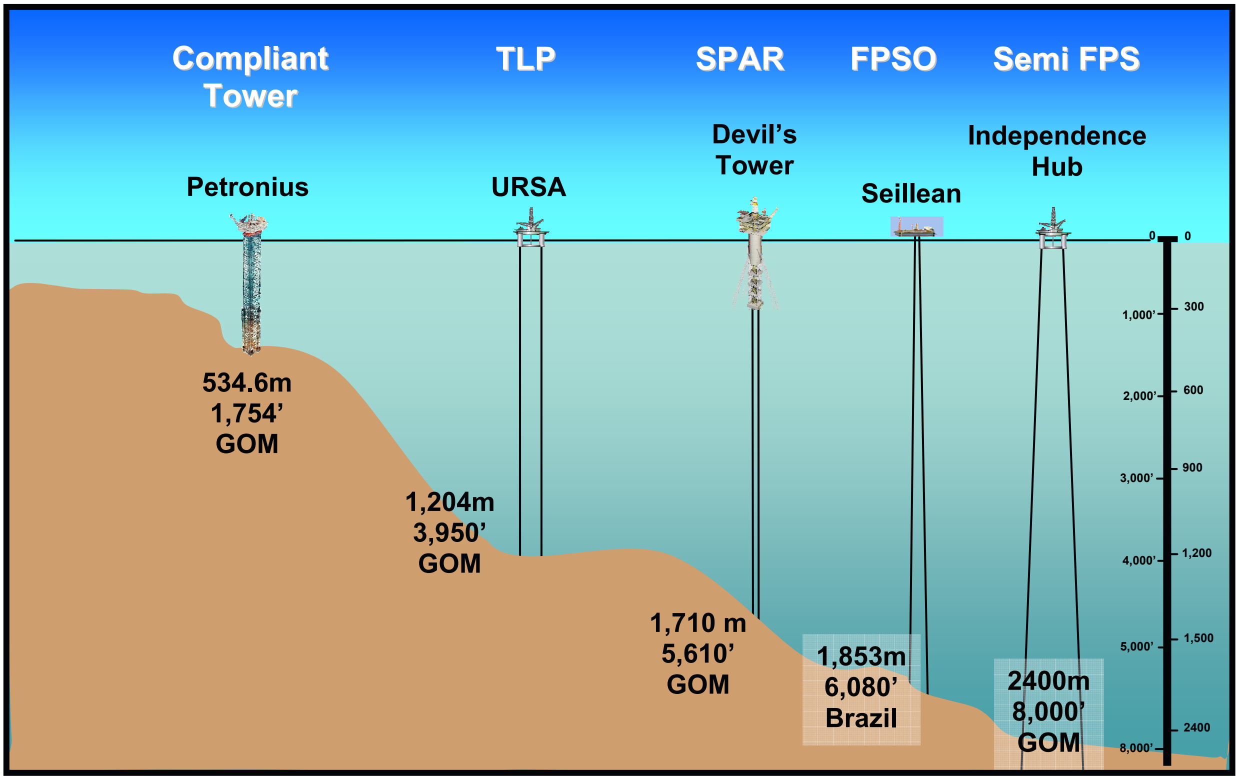

Figure 5. Offshore production systems

The advantages of the dry tree and wet tree concepts are presented as follows:

Dry Tree Solutions	Wet Tree Solutions
- Single well center	- Multiple drill centers
- Lower operating cost and life cycle cost	- Lower capital cost
- Minimum well intervention cost and downtime	- Minimized drilling costs
- Reduce flow assurance risk	- Improved project schedule
- Potential for higher recovery	- Increased field development flexibility
	- Maximized economics for small developments

The reliability of deepwater production systems has been attributed to a better understanding of riser and mooring technology. For ultra deepwater production units a number of riser systems have been deployed, including top-tensioned risers, steel catenary risers and flexible pipe risers. Additional to these systems, free standing riser configurations have been used and are under further development. Figure 6 shows the various deepwater riser systems either being deployed or under consideration.

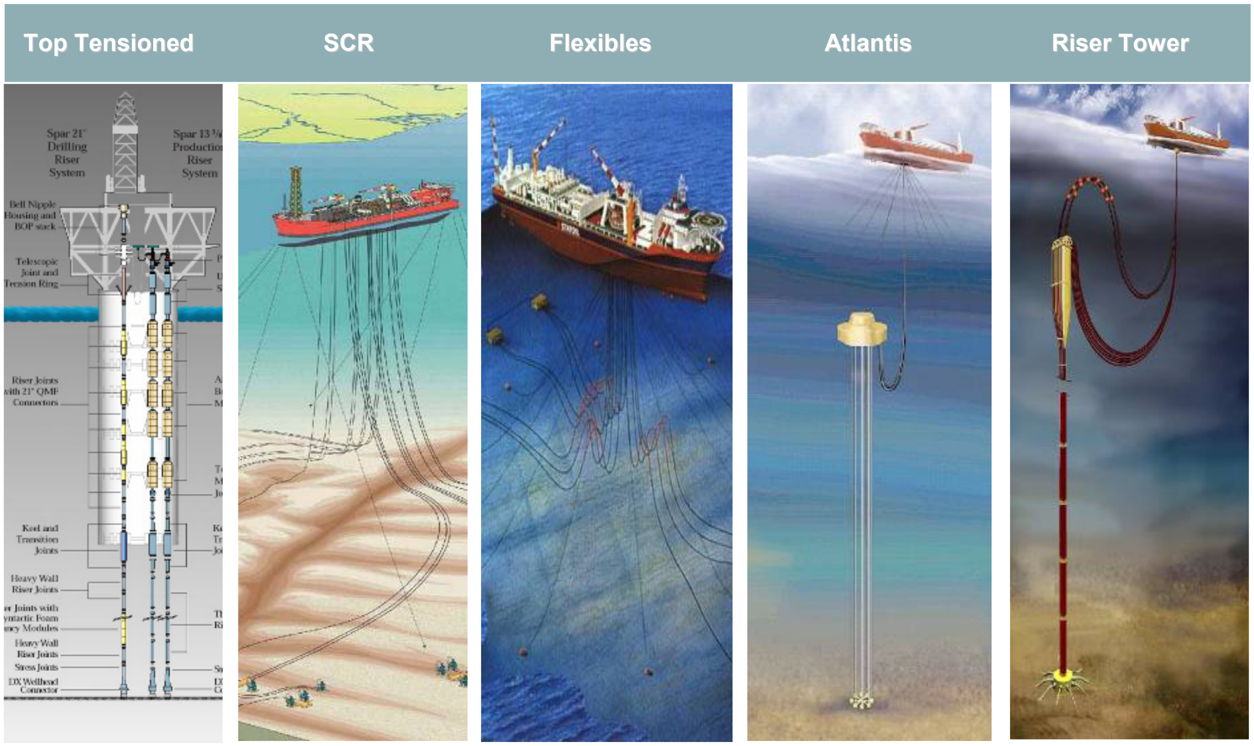

Figure 6. Various deepwater riser systems

Similar to deepwater risers, deepwater mooring systems have evolved with rigid pipe being used with threaded, or mechanical couplings, or welded end to end, similar to pipeline construction. Installation alternatives for the rigid tendons have included vertical running from the TLP or horizontal tow-out and upending. These advances in riser and mooring technology have facilitated the use of ultra deepwater production systems.

Deepwater Flowlines and Pipelines

The challenge associated with deepwater flowlines and pipelines lies not only in the engineering and design, but also with the limitations being faced during installation. Conventional S-Lay installation vessels have recently been upgraded for deepwater requirements with tensioning capacity of 1000 tons. S-Lay installation of pipelines up to 20-inch diameter is possible in 8000 ft. (2400mm) water depth. For smaller diameters, 4-inch to 18-inch, Reel-Lay vessels are often used. The high departure angle results in lower tension loads, although some residual torsion effects can be encountered.

Additional to the upgraded S-Lay and Reel-Lay methods, J-Lay has been widely used to install pipeline in diameters of up to 32-inch. Similar to Reel-Lay, J-Lay has a high departure angle thereby resulting in lower tension loads. Pipeline towing has also been used for deepwater construction, wherein relatively short lengths of multiple lines need to be installed.

Remote Field Locations

Seabed to shore has risen to the forefront as a viable alternative to the installation of surface production equipment. Figure 7 highlights the project specifics of the Orman Lange Field Development, offshore Norway. As shown the first phase of the project will consist of 16 subsea wells and two subsea manifolds producing almost 50 million cubic meters of gas per day.

Located some 70 miles offshore, in a water depth up to 3600 ft. (1200 m) the second phase of the project will require the installation of a subsea compression module.

Orman Lange Field Layout - Seabed to Shore

Field locations: Offshore Norway
Distance to shore: 120 km
Sea Depth: 800-1,200 m
Subsea Wells: 16
Subsea Manifolds: 2
Maximum Production: 49.36M m³/day

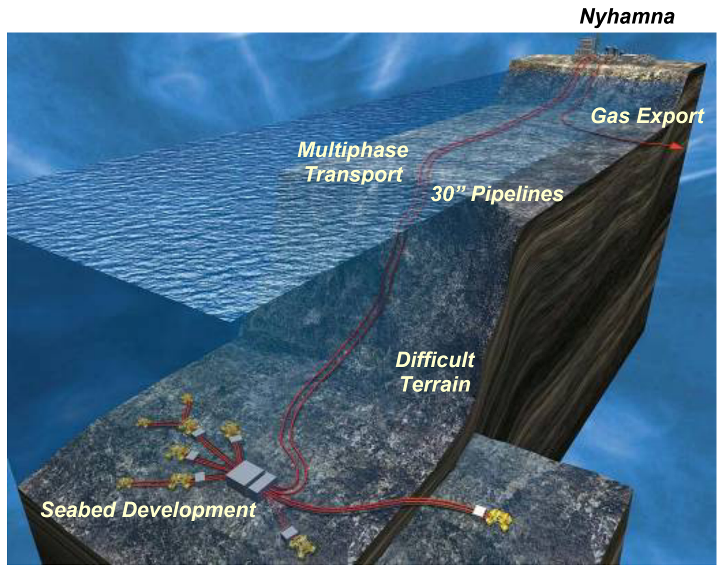

Figure 7. Orman Lange Field Layout

The use of longer tie-backs and remote field subsea to shore technology is evident by the projects noted in Figure 8.

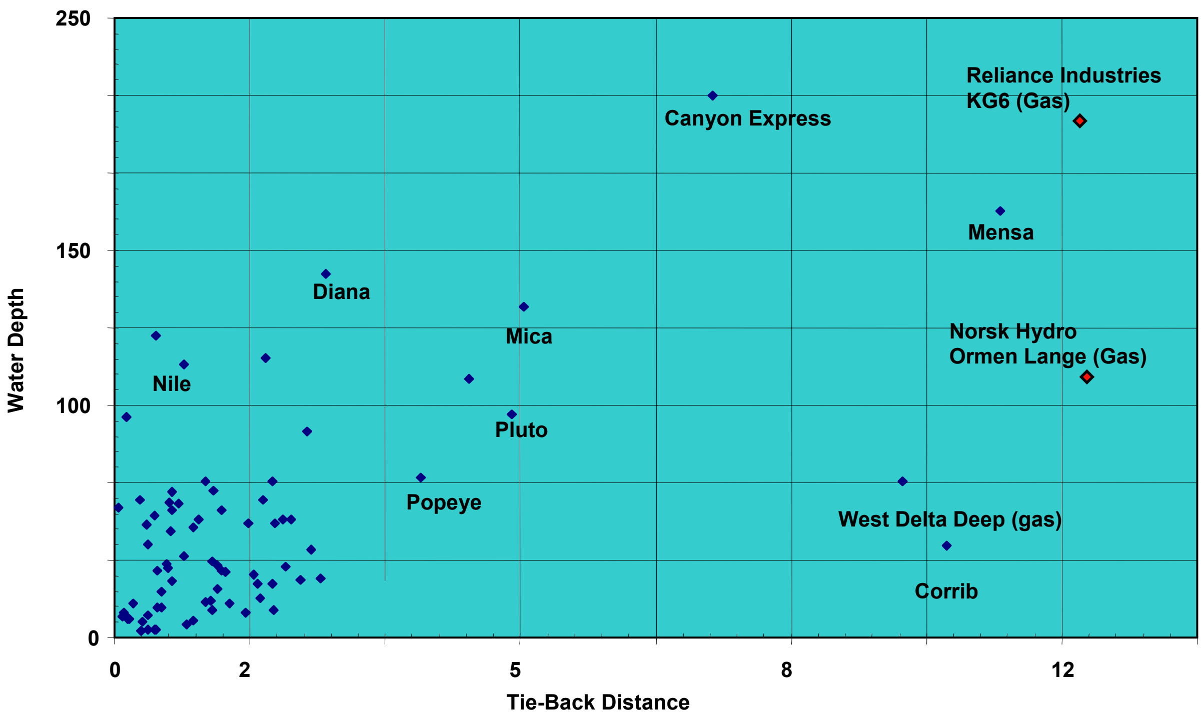

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Figure 8. Projects

Complex Topography/Metocean Conditions

Recent experiences in the Gulf of Mexico have shown the importance of understanding sea floor topography and metocean conditions that can impact the security and performance of subsea assets. Specifically, complex sea floor topographies that must be addressed are:

- Large changes in elevation
- Seabed undulations that cause free spans
- Unstable soil conditions

For the metocean conditions the occurrence of loop currents, storm surges and sea bottom currents can affect the operation of both the pipeline and riser systems. The recent hurricane activity in the Gulf of Mexico (2005) accounted for the shut in of over 1 million barrels of oil per day.

High Pressure/High Temperature

The exploitation of deepwater oil and gas reservoirs has resulted in the need to develop designs and materials compatible with high pressures and high temperatures (HP/HT). With respect to infield flowlines and tie-back pipeline systems the challenges associated with HP/HT are:

- Excessive expansion
- Pressure and temperature cycling
- High stress and strain
- Compatibility of integrated hardware and equipment

As shown in Figure 9, the number of offshore HP/HT developments continues to increase with operating pressures approaching 1400 bar (20,500 PSI) and temperatures up to 220°C (428°F). Engineering design considerations for HP/HT flowlines and pipelines will normally include either strain based or limit state requirements that are predicated on nonlinear material response. Structural mechanical modeling is often used to predict performance behavior associated with burst, collapse, wrinkling, ratcheting, fracture and fatigue.

Produced Fluids

Two of the major hurdles associated with deepwater produced fluids are flow assurance issues and corrosion damage.

Concerning flow assurance, hydrate and wax formation are the major concern because of the low seabed temperatures. Mitigation is normally focused on insulation in the form of pipe-in-pipe configurations or the use of various inhibitors or additives that will alter the fluid behavior.

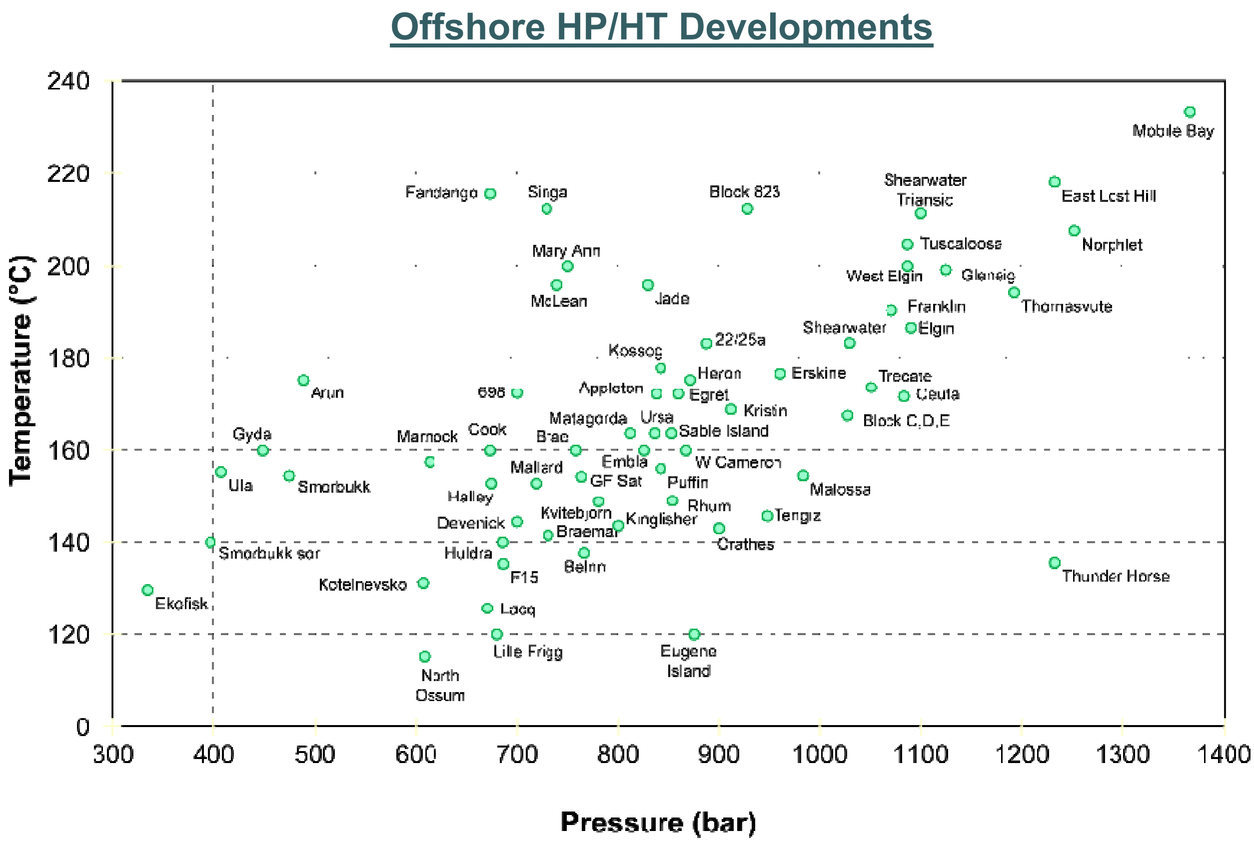

Figure 9. Offshore HP/HT Developments

In addition to hydrate and waxing problems, scale formation and salt deposition can also be an issue. Again, chemical additives and periodic cleaning, if possible, have been found to be effective means of mitigation. To a lesser extent, emulsion and slugging can occur, thereby resulting in reduced flow efficiency. Computational models are often used to simulate potential flow management problems, with operating parameters and fluid properties being used to predict flow regimes and upset conditions. Mitigation may include chemical additives, stricter control of operating parameters or a change in the basic design of the delivery system.

Aside from the flow assurance issues, the make up of the produced fluids can also impact the service performance of the riser and pipeline system. The presence of CO_2 and/or H_2S can result in damage mechanisms such as sulfide stress cracking, hydrogen induced cracking and corrosion fatigue. With the need to provide pressure maintenance a number of reservoirs are being subjected to enhanced recovery using a water flood program. Normally the raw seawater will be chemically treated to safeguard against microbial contamination. However as a safeguard it is assumed that most production fluid using a water flood interface are expected to have some degree of "souring". Assessment of pipeline and riser performance in low concentrating of H_2S has shown dramatic reduction in the life expectancy. Special care in material selection, manufacturing and fabrication is required to ensure the best performance.

Influence of Emerging Technologies

For some time the oil and gas industry has faced "strategic inflection points", where conventional technology no longer meets the challenges. Figure 10 illustrates the relationship between emerging and enabling technology. Enabling technology becomes a mandate once it has been established that an extension of conventional or existing technology is not feasible or the incremental benefit within a given time frame is inadequate.

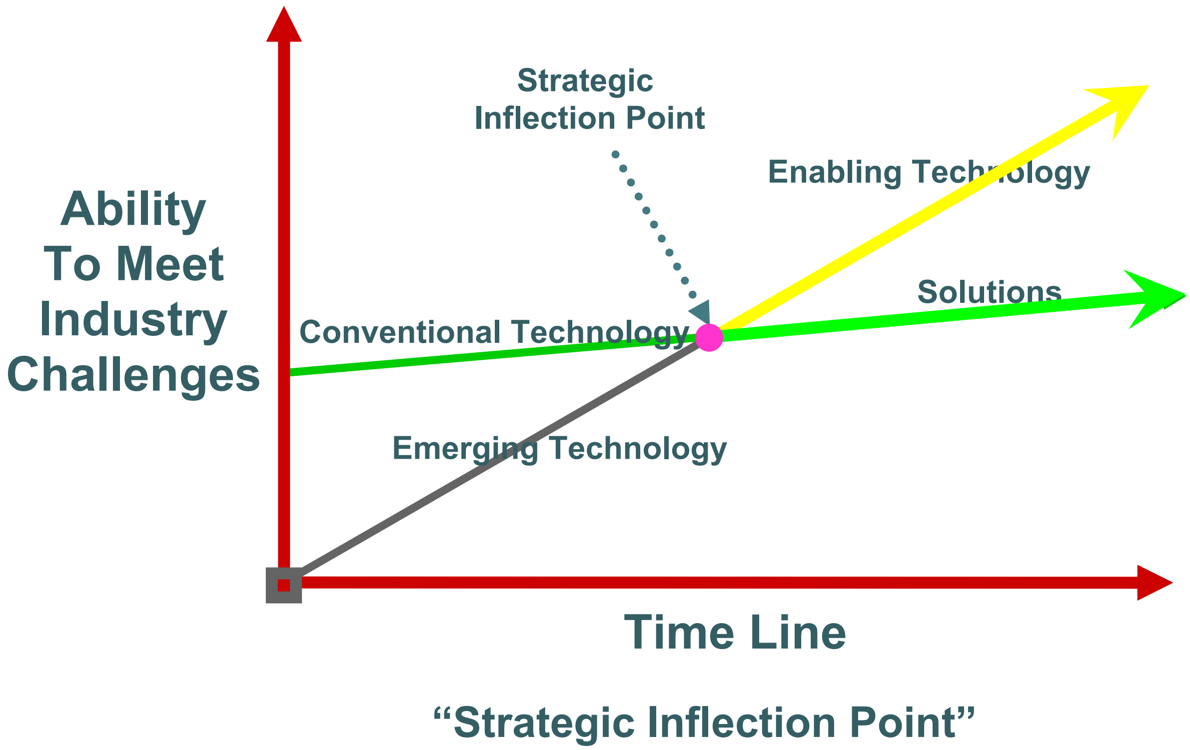

Figure 10. Emerging and enabling technology

Examples of emerging and enabling technologies can be found with floating production system designs, deepwater tether configurations and oil and gas handling equipment. Figure 11 exemplifies the ultra deepwater tether (tendon) concepts and material applications whereas Figure 12 is an example of a complete new approach to subsea oil and gas processing.

Figure 11. Carbon fiber tether and tendon

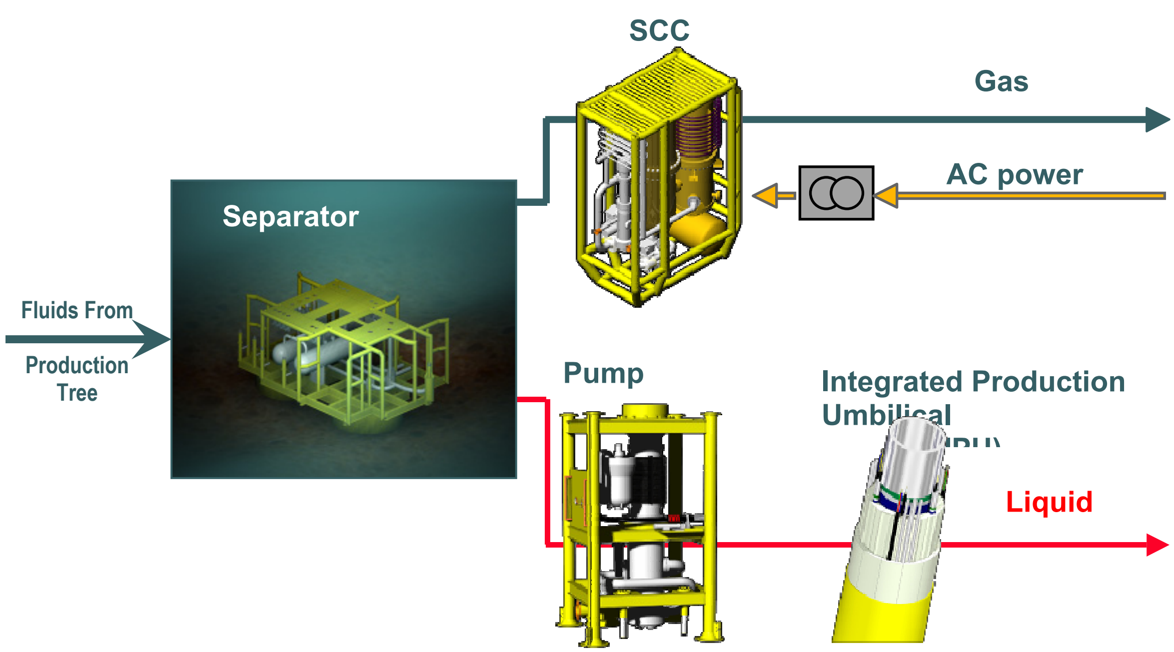

Figure 12. New approach

Summary

In reviewing the extent of offshore development activities and reflecting on the challenges facing deepwater production the following summary can be made:

- Increasing energy demands will continue to require rapid exploitation of offshore oil and gas reservoirs.

- The need to reduce cost, improve recovery and increase overall economic performance will drive the deepwater technology.

- The deepwater challenges continue to reside in reservoir performance, produced fluid characteristics, overall system flexibility and operational performance.

- "Strategic inflection points" have been identified wherein emerging technologies will transform to enabling technologies.

- Considering the challenges facing the oil and gas industry it is clear that material technology will play a vital role in the development of cost effective and reliable deepwater production systems.